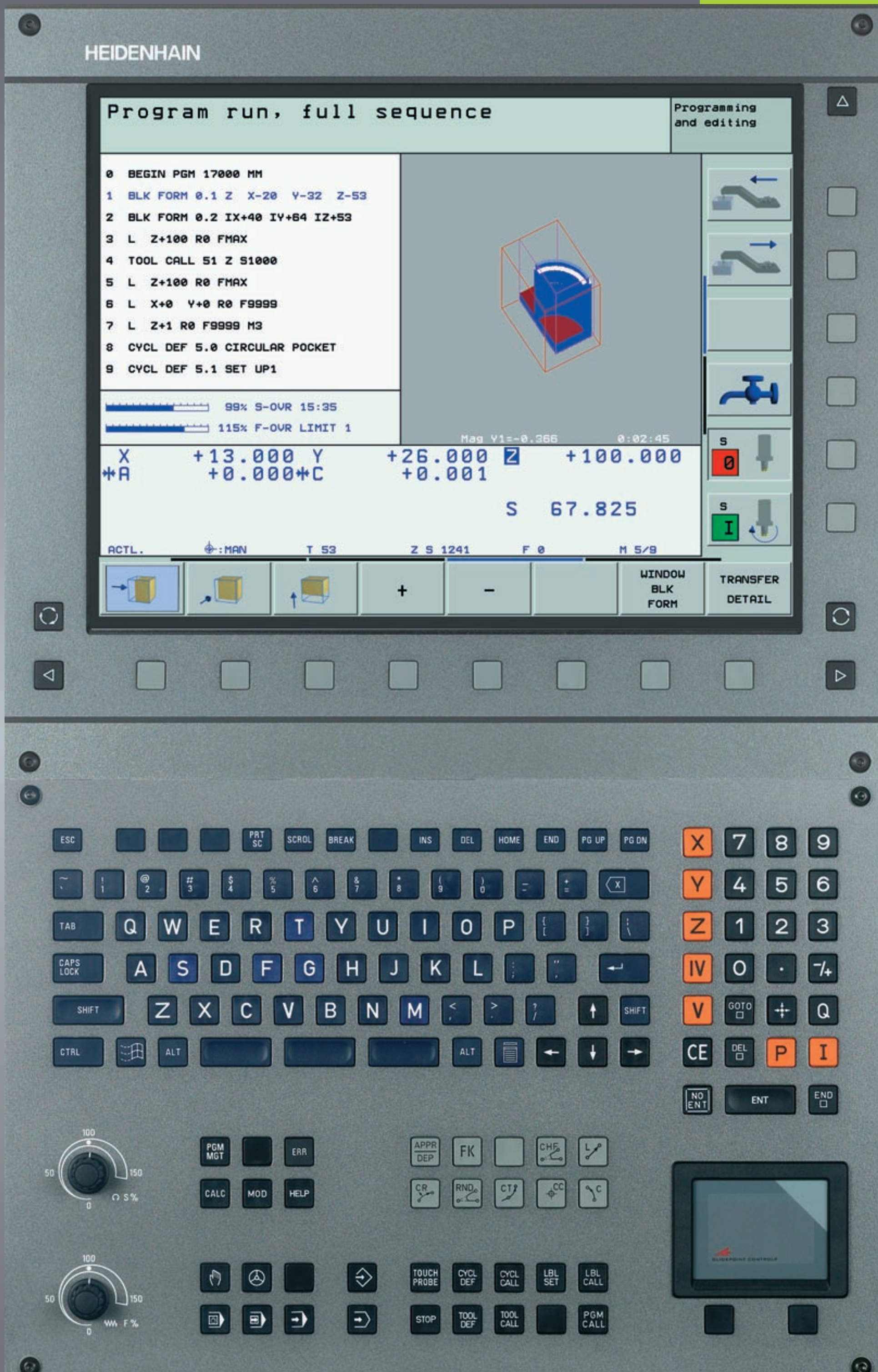


HEIDENHAIN

iTNC 530

NC Software
340 420-xx
340 421-xx

User's Manual HEIDENHAIN Conversational Format

English (en)
6/2003

Controls on the visual display unit

- Split screen layout
- Switch between machining or programming modes
- Soft keys for selecting functions in screen
- ◁ ▷ Switching the soft-key rows

Typewriter keyboard for entering letters and symbols

- Q W E R T Y — File names, Comments
- G F S T M — ISO programs

Machine operating modes

- MANUAL OPERATION
- ELECTRONIC HANDWHEEL
- POSITIONING WITH MDI
- PROGRAM RUN, SINGLE BLOCK
- PROGRAM RUN, FULL SEQUENCE

Programming modes

- PROGRAMMING AND EDITING
- TEST RUN

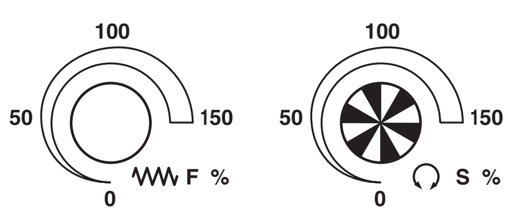
Program/file management, TNC functions

- PGM MGT — Select or delete programs and files, External data transfer
- PGM CALL — Enter program call in a program
- MOD — MOD Functions
- HELP — Displaying help texts for NC error messages
- CALC — Pocket calculator

Moving the highlight, going directly to blocks, cycles and parameter functions

- ↑ ↓ ← → — Move highlight
- GOTO □ — Go directly to blocks, cycles and parameter functions

Override control knobs for feed rate/spindle speed



Programming path movements

- APPR DEP — Approach/depart contour
- FK — FK free contour programming
- L — Straight line
- CC — Circle center/pole for polar coordinates
- C — Circle with center
- CR — Circle with radius
- CT — Circular arc with tangential connection
- CHF — Chamfer
- RND — Corner rounding

Tool functions

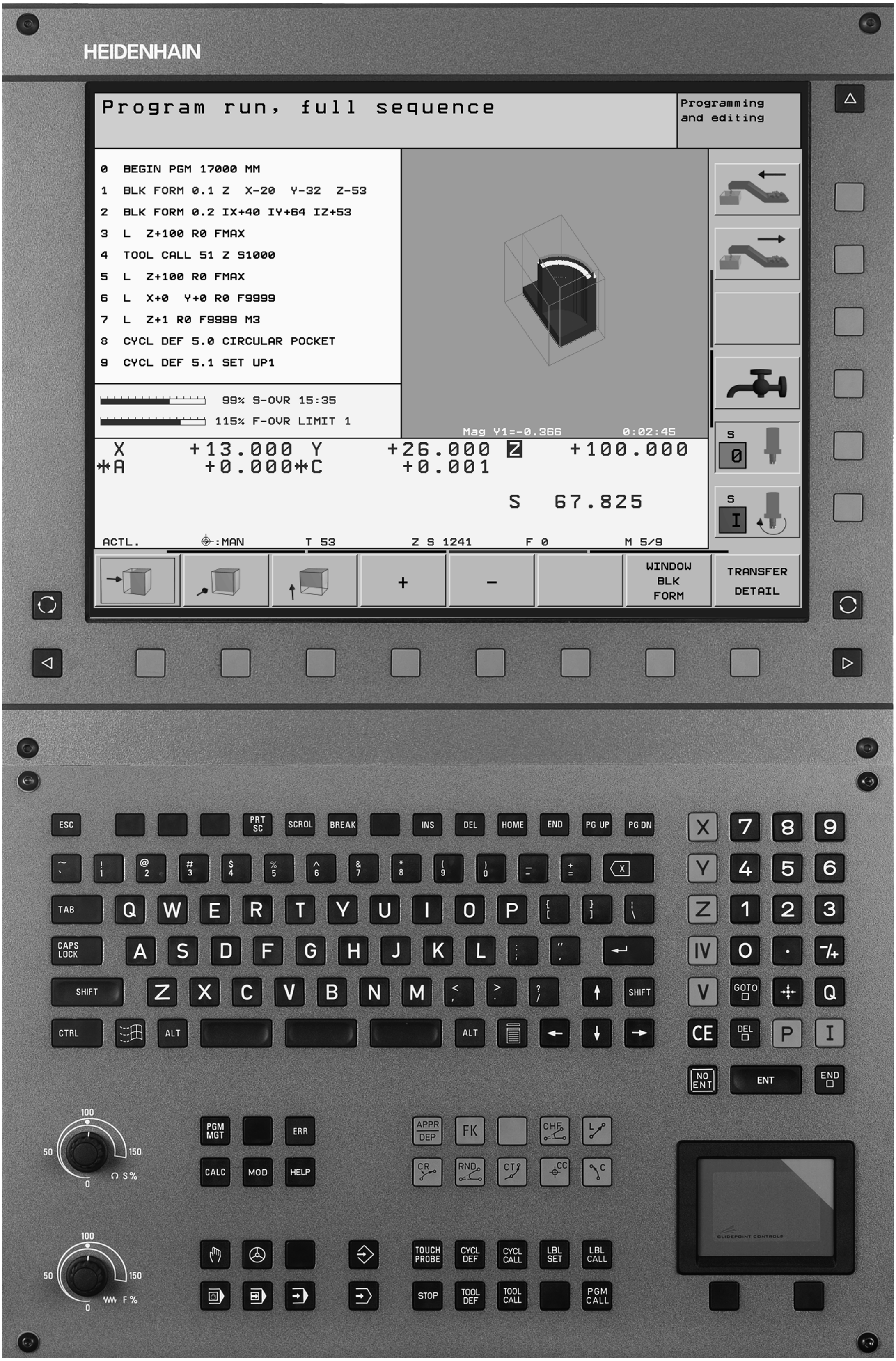
- TOOL DEF, TOOL CALL — Enter and call tool length and radius

Cycles, subprograms and program section repeats

- CYCL DEF, CYCL CALL — Define and call cycles
- LBL SET, LBL CALL — Enter and call labels for subprogramming and program section repeats
- STOP — Program stop in a program
- TOUCH PROBE — Enter touch probe functions in a program

Coordinate axes and numbers: Entering and editing

- X . . . V — Select coordinate axes or enter them into the program
- 0 . . . 9 — Numbers
- • — Decimal point
- −/+ — Change arithmetic sign
- P — Polar coordinates
- I — Incremental dimensions
- Q — Q parameters
- Capture actual position
- NO ENT — Skip dialog questions, delete words
- ENT — Confirm entry and resume dialog
- END □ — End block
- CE — Clear numerical entry or clear TNC error message
- DEL □ — Abort dialog, delete program section


HEIDENHAIN
Program run, full sequence
Programming and editing
0 BEGIN PGM 17000 MM
1 BLK FORM 0.1 Z X-20 Y-32 Z-53
2 BLK FORM 0.2 IX+40 IY+64 IZ+53
3 L Z+100 R0 FMAX
4 TOOL CALL 51 Z S1000
5 L Z+100 R0 FMAX
6 L X+0 Y+0 R0 F9999
7 L Z+1 R0 F9999 M3
8 CYCL DEF 5.0 CIRCULAR POCKET
9 CYCL DEF 5.1 SET UP1
99% S-OVR 15:35
115% F-OVR LIMIT 1
0:02:45
X +13.000 Y +26.000 Z +100.000
A +0.000 C +0.001
S 67.825
ACTL. :MAN T 53 Z S 1241 F 0 M 5/9
WINDOW BLK FORM
TRANSFER DETAIL
ESC
PRT SC
SCROL
BREAK
INS
DEL
HOME
END
PG UP
PG DN
TAB
CAPS LOCK
SHIFT
CTRL
ALT
PGM MGT
ERR
CALC
MOD
HELP
APPR DEP
FK
CHF
CR
RND
CT
CC
TOUCH PROBE
CYCL DEF
CYCL CALL
LBL SET
LBL CALL
STOP
TOOL DEF
TOOL CALL
PGM CALL
GOTO
CE
NO ENT
ENT
END
S %
F %

TNC Model, Software and Features

This manual describes functions and features provided by TNCs as of the following NC software numbers.

TNC model	NC software number
iTNC 530	340 420-xx
iTNC 530 E	340 421-xx

The suffix E indicates the export version of the TNC. The export version of the TNC has the following limitations:

- Linear movement is possible in no more than 4 axes simultaneously.

The machine tool builder adapts the useable features of the TNC to his machine by setting machine parameters. Some of the functions described in this manual may not be among the features provided by your machine tool.

TNC functions that may not be available on your machine include:

- Probing function for the 3-D touch probe
- Tool measurement with the TT 130
- Rigid tapping
- Returning to the contour after an interruption

In addition, the iTNC 530 also has two software option packets that can be enabled by you or your machine tool builder:

Software option 1
Cylinder surface interpolation (Cycles 27 and 28)
Feed rate in mm/min on rotary axes: M116
Tilting the machining plane (Cycle 19 and 3D-ROT soft key in the manual operating mode)
Circle in 3 axes (with tilted working plane)

Software option 2
Block processing time 0.5 ms instead of 3.6 ms
5 axis interpolation
Spline interpolation
3-D machining: ■ **M114:** Automatic compensation of machine geometry when working with tilted axes ■ **M128:** Maintaining the position of the tool tip when positioning with tilted axes (TCPM) ■ **M144:** Compensating the machine's kinematic configuration for ACTUAL/NOMINAL positions at end of block ■ Additional parameters **finishing/roughing** and **tolerance for rotary axes** in Cycle 32 (G62) ■ LN blocks (3-D compensation)

Please contact your machine tool builder to become familiar with the features of your machine.

Many machine manufacturers, as well as HEIDENHAIN, offer programming courses for the TNCs. We recommend these courses as an effective way of improving your programming skill and sharing information and ideas with other TNC users.

Touch Probe Cycles User's Manual:

All of the touch probe functions are described in a separate manual. Please contact HEIDENHAIN if you require a copy of this User's Manual. ID number: 369 280-xx.

Location of use

The TNC complies with the limits for a Class A device in accordance with the specifications in EN 55022, and is intended for use primarily in industrially-zoned areas.

New features of the NC software 340 420-xx

- Connecting the TNC to **Windows networks** via Ethernet (see "Network settings specific to the device" on page 454)
- Definition of overlapping contours with **contour formula** (see "SL Cycles with Contour Formula" on page 321)
- Stepwise **magnification/reduction** in the test graphic (see "Rotating and magnifying/reducing the 3-D view" on page 425)
- The additional status display was expanded to display the active datum table and the active datum number (see "Coordinate transformations" on page 11).
- **Find/Replace** any text (see "The TNC search function" on page 70)
- Changing the position of the current block on the screen (see "Editing a program" on page 67)
- New Q parameter functions: **Check sign** and **Calculate modulo value** when entering formulas (see "Entering Formulas Directly" on page 404)
- Generating a file with version numbers (see "Code Numbers" on page 445)
- Plunging feed rate for infeed for finishing new in Cycles 210 and 211 (see "SLOT (oblong hole) with reciprocating plunge-cut (Cycle 210)," page 281 and see "CIRCULAR SLOT (oblong hole) with reciprocating plunge-cut (Cycle 211)," page 283)

Changed features of the NC software 340 420-xx

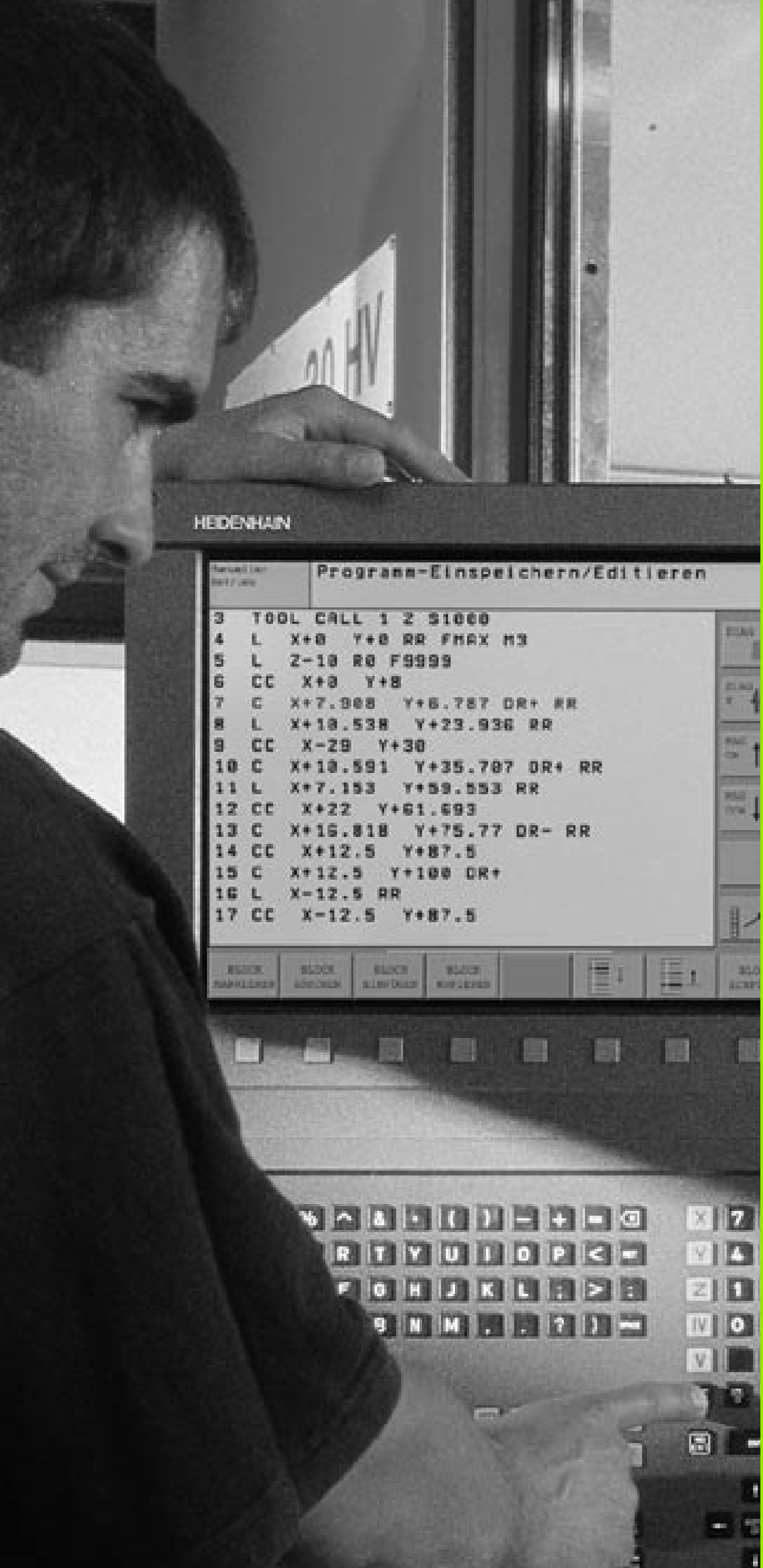
- Cycle 32 Tolerance was expanded so that different filter settings can be selected for High Speed Cutting (HSC) (see “TOLERANCE (Cycle 32)” on page 359).
- In Cycle 210 (Slot with reciprocating plunge), the approach behavior for finishing was changed (see “SLOT (oblong hole) with reciprocating plunge-cut (Cycle 210)” on page 281).
- The additional status display was expanded to display the active status of program section repeats and subprogram calls.(see “Program section repeats/subprograms” on page 12)
- When contents of Q parameters are checked, 16 parameters are now shown in a separate window.(see “Checking and Changing Q Parameters” on page 386)
- The number of contour elements permitted in SL Cycles, Group II, has been increased from approx. 256 to approx. 1024 (see “SL Cycles” on page 294).
- The transfer of the current tool position coordinates into the program has been improved (see “Actual position capture” on page 66).
- The transfer of the value that is calculated by using the on-screen pocket calculator into the program has been modified (see “Integrated Pocket Calculator” on page 80).
- Detail magnification is now also possible in plan view (see “Magnifying details” on page 426).
- When program sections are copied, the copied block remains highlighted after having been inserted (see “Marking, copying, deleting and inserting program sections” on page 69).

New/changed descriptions in this manual

- Meaning of software numbers after the MOD functions have been selected (see “Software Numbers and Option Numbers” on page 444).
- Connecting the iTNC directly with a Windows PC (see “Connecting the iTNC directly with a Windows PC” on page 451)

Contents

7 Programming: Miscellaneous-Functions 181



1

Introduction

1.1 The iTNC 530

HEIDENHAIN TNC controls are workshop-oriented contouring controls that enable you to program conventional machining operations right at the machine in an easy-to-use conversational programming language. They are designed for milling, drilling and boring machines, as well as for machining centers. The iTNC 530 can control up to 12 axes. You can also change the angular position of the spindle under program control.

An integrated hard disk provides storage for as many programs as you like, even if they were created off-line. For quick calculations you can call up the on-screen pocket calculator at any time.

Keyboard and screen layout are clearly arranged in such a way that the functions are fast and easy to use.

Programming: HEIDENHAIN conversational and ISO formats

HEIDENHAIN conversational programming is an especially easy method of writing programs. Interactive graphics illustrate the individual machining steps for programming the contour. If a production drawing is not dimensioned for NC, the HEIDENHAIN FK free contour programming does the necessary calculations automatically. Workpiece machining can be graphically simulated either during or before actual machining. It is also possible to program in ISO format or DNC mode.

You can also enter and test one program while the control is running another.

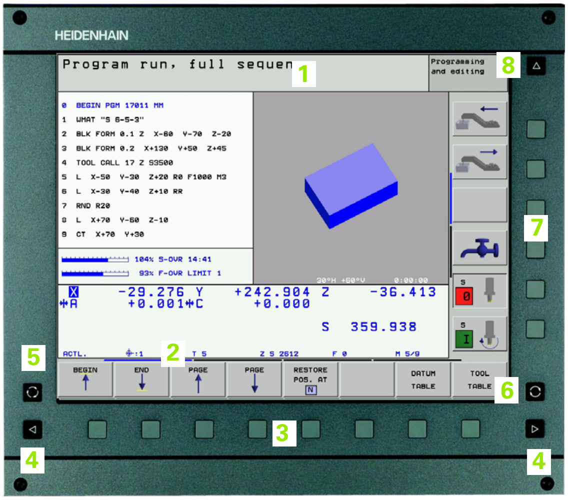
Compatibility

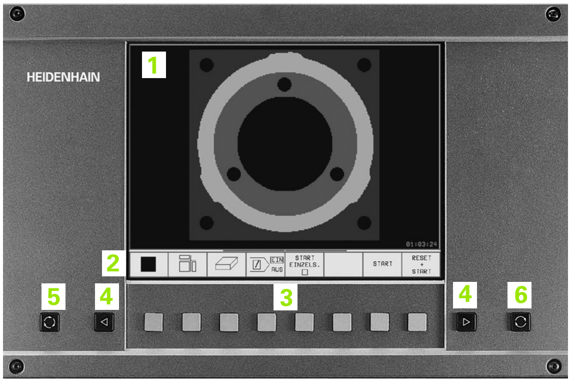
The TNC can run all part programs that were written on HEIDENHAIN controls TNC 150 B and later.

1.2 Visual Display Unit and Keyboard

Visual display unit

The TNC is available with either a BF 150 color TFT flat-panel display or the BF 120 color TFT flat-panel display. The figure at top right shows the keys and controls on the BF 150, and the figure at center right shows those of the BF 120.





1 Header

When the TNC is on, the selected operating modes are shown in the screen header: the machining mode at the left and the programming mode at right. The currently active mode is displayed in the larger box, where the dialog prompts and TNC messages also appear (unless the TNC is showing only graphics).

2 Soft keys

In the footer the TNC indicates additional functions in a soft-key row. You can select these functions by pressing the keys immediately below them. The lines immediately above the soft-key row indicate the number of soft-key rows that can be called with the black arrow keys to the right and left. The line representing the active soft-key row is highlighted.

3 Soft-key selection keys

4 Switches the soft-key rows

5 Sets the screen layout

6 Shift key for switchover between machining and programming modes

7 Soft-key selection keys for machine tool builders

8 Switches soft-key rows for machine tool builders

Screen layout

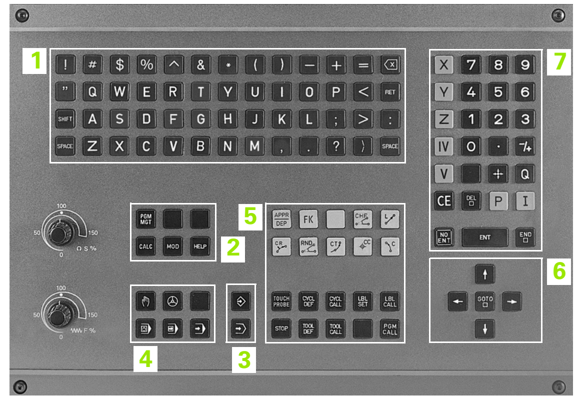
You select the screen layout yourself: In the PROGRAMMING AND EDITING mode of operation, for example, you can have the TNC show program blocks in the left window while the right window displays programming graphics. You could also display the program structure in the right window instead, or display only program blocks in one large window. The available screen windows depend on the selected operating mode.

To change the screen layout:

	Press the SPLIT SCREEN key: The soft-key row shows the available layout options (see "Modes of Operation," page 6).
PGM + GRAPHICS	Select the desired screen layout.

Keyboard

The TNC is available either with the TE 420 or TE 530 keyboard. The figure at upper right shows the operating elements of the TE 420 keyboard; the figure at center right shows the operating elements of the TE 530 keyboard:



1 Alphabetic keyboard for entering texts and file names, and for ISO programming.

  Dual-processor version: Additional keys for Windows operation

2
  - File management
  - Pocket calculator
  - MOD function
  - HELP function

3 Programming modes

4 Machine operating modes

5 Initiation of programming dialog

6 Arrow keys and GOTO jump command

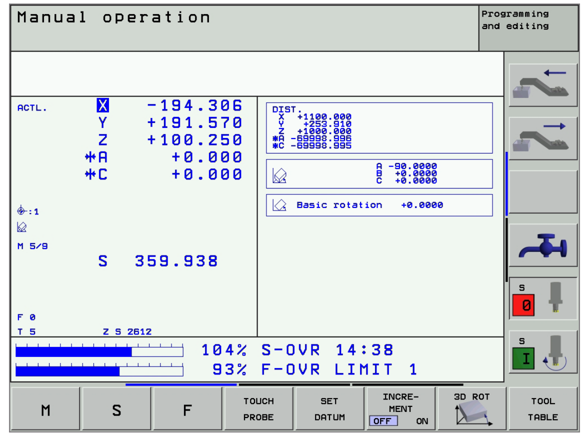
7 Numerical input and axis selection

8 Mouse pad: Only for operating the dual-processor version

The functions of the individual keys are described on the inside front cover. Machine panel buttons, e.g. NC START, are described in the manual for your machine tool.

1.3 Modes of Operation

Manual Operation and Electronic Handwheel



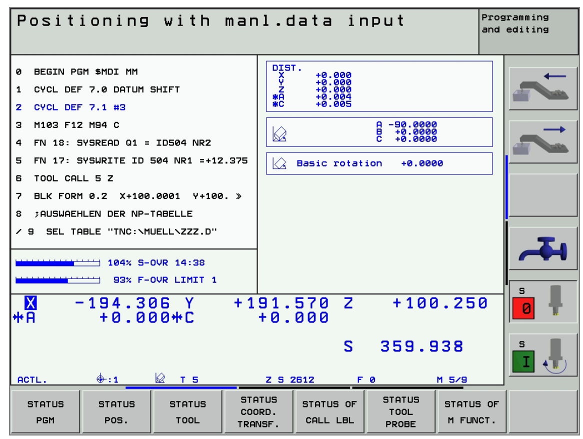
The Manual Operation mode is required for setting up the machine tool. In this operating mode you can position the machine axes manually or by increments, set the datums, and tilt the working plane.

The Electronic Handwheel mode of operation allows you to move the machine axes manually with the HR electronic handwheel.

Soft keys for selecting the screen layout (select as described previously)

Screen windows	Soft key
Positions	POSITION
Left: positions, right: status display	POSITION + STATUS

Positioning with Manual Data Input (MDI)

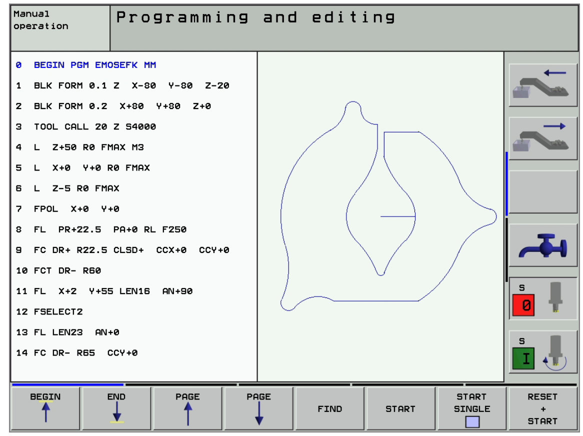


This mode of operation is used for programming simple traversing movements, such as for face milling or pre-positioning.

Soft keys for selecting the screen layout

Screen windows	Soft key
Program	PGM
Left: program blocks, right: status display	PGM + STATUS

Programming and editing

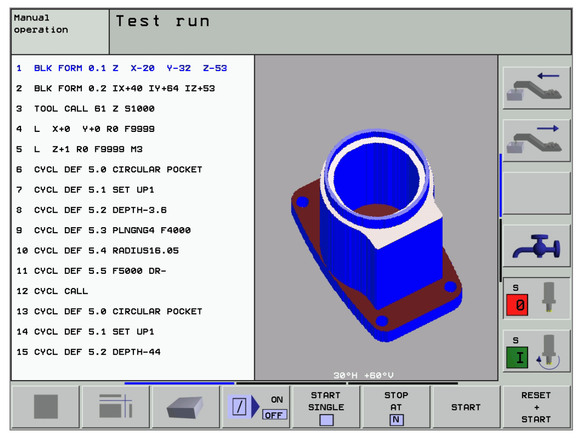


In this mode of operation you can write your part programs. The FK free programming feature, the various cycles and the Q parameter functions help you with programming and add necessary information. If desired, you can have the programming graphics show the individual steps.

Soft keys for selecting the screen layout

Screen windows	Soft key
Program	PGM
Left: program blocks, right: program structure	PGM + SECTS
Left: program, right: programming graphics	PGM + GRAPHICS

Test Run



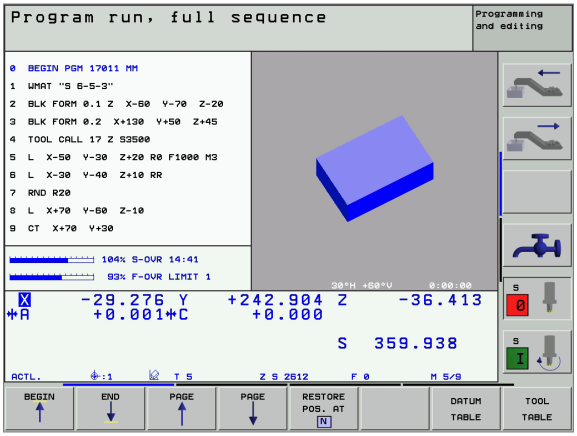
In the Test Run mode of operation, the TNC checks programs and program sections for errors, such as geometrical incompatibilities, missing or incorrect data within the program or violations of the work space. This simulation is supported graphically in different display modes.

Soft keys for selecting the screen layout: see "Program Run, Full Sequence and Program Run, Single Block," page 8.

Program Run, Full Sequence and Program Run, Single Block

In the Program Run, Full Sequence mode of operation the TNC executes a part program continuously to its end or to a manual or programmed stop. You can resume program run after an interruption.

In the Program Run, Single Block mode of operation you execute each block separately by pressing the machine START button.



Soft keys for selecting the screen layout

Screen windows	Soft key
Program	PGM
Left: program blocks, right: program structure	PGM + SECTS
Left: program, right: status	PGM + STATUS
Left: program, right: graphics	PGM + GRAPHICS
Graphics	GRAPHICS

Soft keys for selecting the screen layout for pallet tables

Screen windows	Soft key
Pallet table	PALLET
Left: program, right: pallet table	PGM + PALLET
Left: pallet table, right: status	PALLET + STATUS
Left: pallet table, right: graphics	PALLET + GRAPHICS

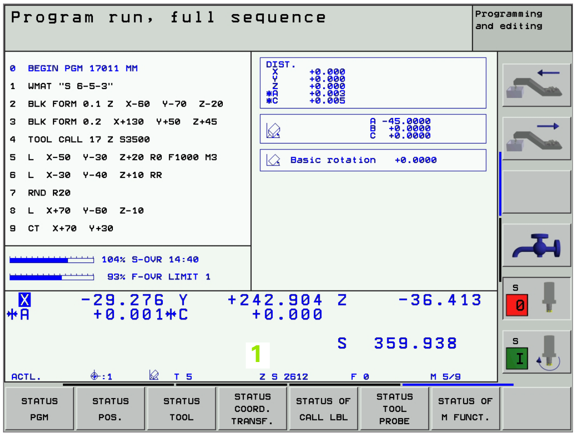
1.4 Status Displays

"General" status display

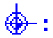
The status display **1** informs you of the current state of the machine tool. It is displayed automatically in the following modes of operation:

- Program Run, Single Block and Program Run, Full Sequence, except if the screen layout is set to display graphics only, and
- Positioning with Manual Data Input (MDI).

In the Manual mode and Electronic Handwheel mode the status display appears in the large window.



Information in the status display

Symbol	Meaning
ACTL.	Actual or nominal coordinates of the current position
XYZ	Machine axes; the TNC displays auxiliary axes in lower-case letters. The sequence and quantity of displayed axes is determined by the machine tool builder. Refer to your machine manual for more information
FSM	The displayed feed rate in inches corresponds to one tenth of the effective value. Spindle speed S, feed rate F and active M functions
	Program run started
	Axis locked
	Axis can be moved with the handwheel
	Axes are moving in a tilted working plane
	Axes are moving under a basic rotation
	Number of the active datum from the preset table. If the datum was set manually, the TNC displays the text `MAN` behind the symbol.

Additional status displays

The additional status displays contain detailed information on the program run. They can be called in all operating modes except for the Programming and Editing mode of operation.

To switch on the additional status display:

	Call the soft-key row for screen layout.
PGM + STATUS	Select the layout option for the additional status display.

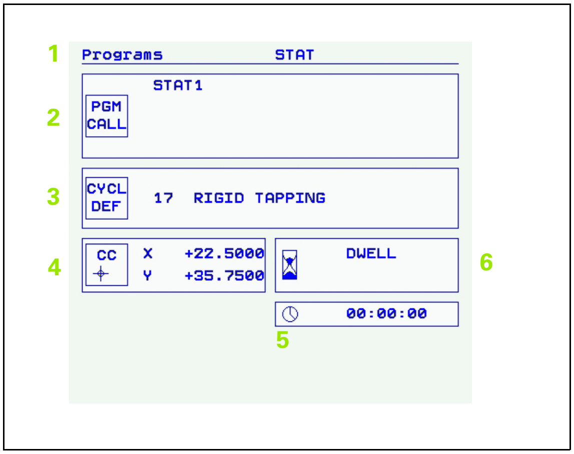
To select an additional status display:

▷	Shift the soft-key rows until the STATUS soft keys appear.
STATUS PGM	Select the desired additional status display, e.g. general program information.

You can choose between several additional status displays with the following soft keys:

STATUS PGM **General program information**

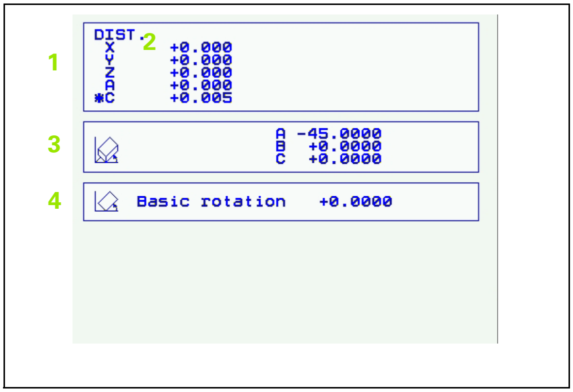
1 Name of main program
2 Active programs
3 Active machining cycle
4 Circle center CC (pole)
5 Operating time
6 Dwell time counter



STATUS POS.

Positions and coordinates

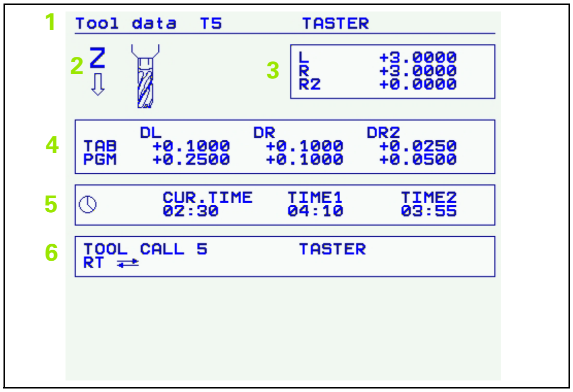
1 Position display
2 Type of position display, e.g. actual position
3 Tilt angle of the working plane
4 Angle of a basic rotation



STATUS TOOL

Information on tools

1 ■ T: Tool number and name
■ RT: Number and name of a replacement tool
2 Tool axis
3 Tool lengths and radii
4 Oversizes (delta values) from TOOL CALL (PGM) and the tool table (TAB)
5 Tool life, maximum tool life (TIME 1) and maximum tool life for TOOL CALL (TIME 2)
6 Display of the active tool and the (next) replacement tool

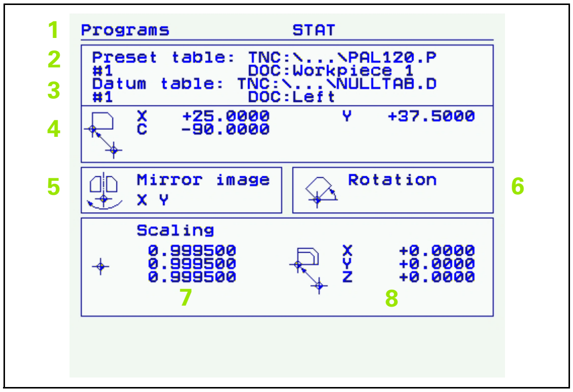


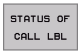
STATUS COORD. TRANSF.

Coordinate transformations

1 Name of main program
2 Name of the active datum table, active datum number (#), comment from the active line of the active datum number (**DOC**) from Cycle 7
3 Name of the active preset table, active preset number (#), comment from the active line of the active preset number (**DOC**)
4 Active datum shift (Cycle 7)
5 Mirrored axes (Cycle 8)
6 Active rotation angle (Cycle 10)
7 Active scaling factor(s) (Cycles 11 / 26)
8 Scaling datum

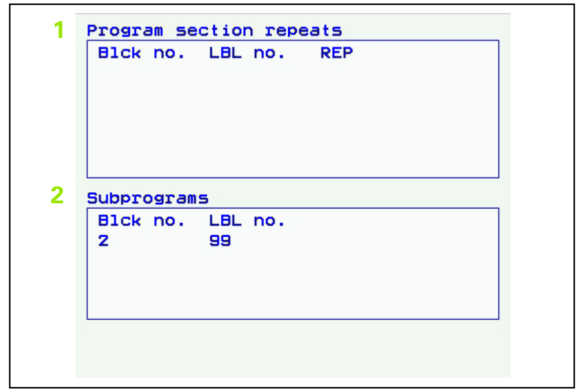
See “Coordinate Transformation Cycles” on page 338.





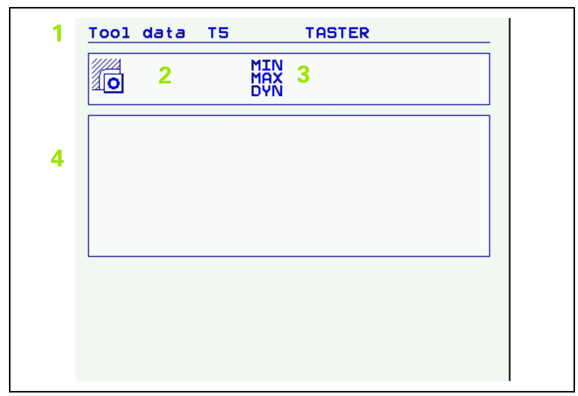
Program section repeats/subprograms

1 Active program section repeats with block number, label number, and number of programmed repeats/repeats yet to be run
2 Active subprogram numbers with block number in which the subprogram was called and the label number that was called



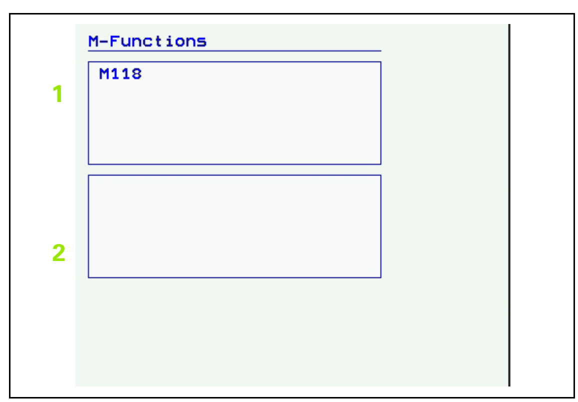
Tool measurement

1 Number of the tool to be measured
2 Display whether the tool radius or the tool length is being measured
3 MIN and MAX values of the individual cutting edges and the result of measuring the rotating tool (DYN = dynamic measurement)
4 Cutting edge number with the corresponding measured value. If the measured value is followed by an asterisk, the allowable tolerance in the tool table was exceeded



Active miscellaneous functions M

1 List of the active M functions with fixed meaning.
2 List of the active M functions with function assigned by machine manufacturer.



1.5 Accessories: HEIDENHAIN 3-D Touch Probes and Electronic Handwheels

3-D touch probes

With the various HEIDENHAIN 3-D touch probe systems you can:

- Automatically align workpieces
- Quickly and precisely set datums
- Measure the workpiece during program run
- Measure and inspect tools

> All of the touch probe functions are described in a separate manual. Please contact HEIDENHAIN if you require a copy of this User's Manual. Id. Nr.: 329 203-xx.

TS 220, TS 630 and TS 632 touch trigger probes

These touch probes are particularly effective for automatic workpiece alignment, datum setting and workpiece measurement. The TS 220 transmits the triggering signals to the TNC via cable and is a cost-effective alternative for applications where digitizing is not frequently required.

The TS 630 and TS 632 feature infrared transmission of the triggering signal to the TNC. This makes them highly convenient for use on machines with automatic tool changers.

Principle of operation: HEIDENHAIN triggering touch probes feature a wear resisting optical switch that generates an electrical signal as soon as the stylus is deflected. This signal is transmitted to the TNC, which stores the current position of the stylus as an actual value.

TT 130 tool touch probe for tool measurement

The TT 130 is a triggering 3-D touch probe for tool measurement and inspection. Your TNC provides three cycles for this touch probe with which you can measure the tool length and radius automatically either with the spindle rotating or stopped. The TT 130 features a particularly rugged design and a high degree of protection, which make it insensitive to coolants and swarf. The triggering signal is generated by a wear-resistant and highly reliable optical switch.

HR electronic handwheels

Electronic handwheels facilitate moving the axis slides precisely by hand. A wide range of traverses per handwheel revolution is available. Apart from the HR 130 and HR 150 integral handwheels, HEIDENHAIN also offers the HR 410 portable handwheel (see figure at center right).

2

Manual Operation and Setup

2.1 Switch-on, Switch-Off

Switch-on

Switch-on and Traversing the Reference Points can vary depending on the individual machine tool. Refer to your machine manual.

Switch on the power supply for control and machine. The TNC automatically initiates the following dialog

MEMORY TEST

The TNC memory is automatically checked.

POWER INTERRUPTED

CE — TNC message that the power was interrupted—clear the message.

TRANSLATE PLC PROGRAM

The PLC program of the TNC is automatically compiled.

RELAY EXT. DC VOLTAGE MISSING

I — Switch on external dc voltage. The TNC checks the functioning of the EMERGENCY STOP circuit.

MANUAL OPERATION
TRAVERSE REFERENCE POINTS

I — Cross the reference points manually in the displayed sequence: For each axis press the machine START button, or

X Y — Cross the reference points in any sequence: Press and hold the machine axis direction button for each axis until the reference point has been traversed.

The TNC is now ready for operation in the Manual Operation mode.

> The reference points need only be traversed if the machine axes are to be moved. If you intend only to write, edit or test programs, you can select the Programming and Editing or Test Run modes of operation immediately after switching on the control voltage.
>
> You can then traverse the reference points later by pressing the PASS OVER REFERENCE soft key in the Manual Operation mode.

Traversing the reference point in a tilted working plane

The reference point of a tilted coordinate system can be traversed by pressing the machine axis direction buttons. The “tilting the working plane” function must be active in the Manual Operation mode, see “To activate manual tilting:,” page 27. The TNC then interpolates the corresponding axes.

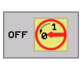
The NC START button is not effective. Pressing this button may result in an error message.

> Make sure that the angle values entered in the menu for tilting the working plane match the actual angles of the tilted axis.

Switch-off

To prevent data being lost at switch-off, you need to run down the operating system as follows:

- Select the Manual mode.



- Select the function for shutting down, confirm again with the YES soft key.
- When the TNC displays the message **`Now you can switch off the TNC`** in a superimposed window, you may cut off the power supply to the TNC.

> Inappropriate switch-off of the TNC can lead to data loss.

2.2 Moving the Machine Axes

Note

Traversing with the machine axis direction buttons is a machine-dependent function. The machine tool manual provides further information.

To traverse with the machine axis direction buttons:

Select the Manual Operation mode.

X

Press the machine axis-direction button and hold it as long as you wish the axis to move, or

X and I

Move the axis continuously: Press and hold the machine axis direction button, then press the machine START button

0

To stop the axis, press the machine STOP button.

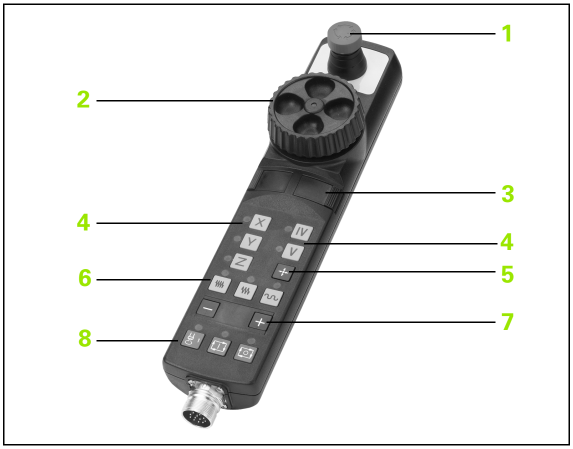
You can move several axes at a time with these two methods. You can change the feed rate at which the axes are traversed with the F soft key, see "Spindle Speed S, Feed Rate F and Miscellaneous Functions M," page 21.

Traversing with the HR 410 electronic handwheel

The portable HR 410 handwheel is equipped with two permissive buttons. The permissive buttons are located below the star grip.

You can only move the machine axes when an permissive button is depressed (machine-dependent function).

The HR 410 handwheel features the following operating elements:



1 EMERGENCY STOP
2 Handwheel
3 Permissive buttons
4 Axis address keys
5 Actual-position-capture key
6 Keys for defining the feed rate (slow, medium, fast; the feed rates are set by the machine tool builder)
7 Direction in which the TNC moves the selected axis
8 Machine function (set by the machine tool builder)

The red indicators show the axis and feed rate you have selected.

It is also possible to move the machine axes with the handwheel during a program run.

To move an axis:

Select the Electronic Handwheel operating mode.

Press and hold the permissive button.

Select the axis.

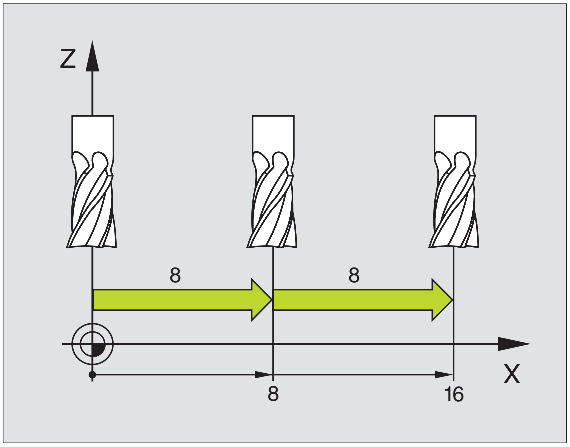
Select the feed rate.


or


Move the active axis in the positive or negative direction.

Incremental jog positioning

With incremental jog positioning you can move a machine axis by a preset distance.



Select the Manual or Electronic Handwheel mode of operation.

Select incremental jog positioning: Switch the INCREMENT soft key to ON

JOG INCREMENT =

8 ENT Enter the jog increment in millimeters, i.e. 8 mm.

X Press the machine axis direction button as often as desired.

2.3 Spindle Speed S, Feed Rate F and Miscellaneous Functions M

Function

In the operating modes Manual Operation and Electronic Handwheel, you can enter the spindle speed S, feed rate F and the miscellaneous functions M with soft keys. The miscellaneous functions are described in Chapter 7 "Programming: Miscellaneous Functions."

> The machine tool builder determines which miscellaneous functions M are available on your TNC and what effects they have.

Entering values

Spindle speed S, miscellaneous function M

S

To enter the spindle speed, press the S soft key.

SPINDLE SPEED S =

1000

I

Enter the desired spindle speed and confirm your entry with the machine START button.

The spindle speed S with the entered rpm is started with a miscellaneous function M. Proceed in the same way to enter a miscellaneous function M.

Feed rate F

After entering a feed rate F, you must confirm your entry with the ENT key instead of the machine START button.

The following is valid for feed rate F:

- If you enter F=0, then the lowest feed rate from MP1020 is effective
- F is not lost during a power interruption

Changing the spindle speed and feed rate

With the override knobs you can vary the spindle speed S and feed rate F from 0% to 150% of the set value.

> The override dial for spindle speed is only functional on machines with infinitely variable spindle drive.

2.4 Datum Setting (Without a 3-D Touch Probe)

Note

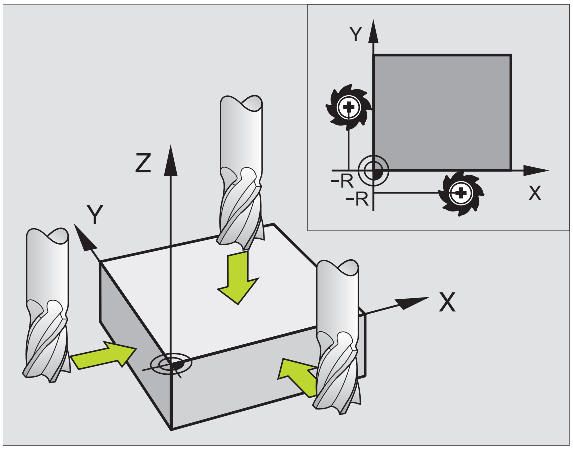
For datum setting with a 3-D touch probe, refer to the new Touch Probe Cycles Manual.

You fix a datum by setting the TNC position display to the coordinates of a known position on the workpiece.

Preparation

- Clamp and align the workpiece.
- Insert the zero tool with known radius into the spindle.
- Ensure that the TNC is showing actual position values.

Datum setting



Fragile workpiece?

If the workpiece surface must not be scratched, you can lay a metal shim of known thickness d on it. Then enter a tool axis datum value that is larger than the desired datum by the value d.

Select the **`Manual Operation`** mode.

X Y Z — Move the tool slowly until it touches the workpiece surface.

Select an axis (all axes can also be selected via the ASCII keyboard)

`DATUM SET Z=`

0 ENT — Zero tool in spindle axis: Set the display to a known workpiece position (here, 0) or enter the thickness *d* of the shim. In the tool axis, offset the tool radius.

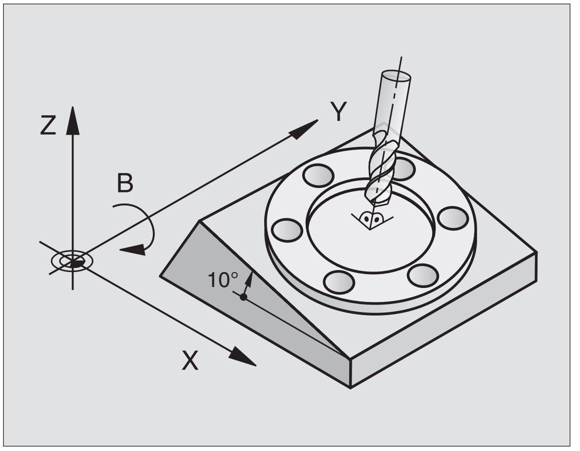
Repeat the process for the remaining axes.

If you are using a preset tool, set the display of the tool axis to the length *L* of the tool or enter the sum *Z=L+d*.

2.5 Tilting the Working Plane

Application, function

The functions for tilting the working plane are interfaced to the TNC and the machine tool by the machine tool builder. With some swivel heads and tilting tables, the machine tool builder determines whether the entered angles are interpreted as coordinates of the tilt axes or as angular components of a tilted plane. Refer to your machine manual.



The TNC supports the tilting functions on machine tools with swivel heads and/or tilting tables. Typical applications are, for example, oblique holes or contours in an oblique plane. The working plane is always tilted around the active datum. The program is written as usual in a main plane, such as the X/Y plane, but is executed in a plane that is tilted relative to the main plane.

There are two functions available for tilting the working plane

- 3-D ROT soft key in the Manual mode and Electronic Handwheel mode, see “To activate manual tilting:,” page 27
- Tilting under program control, Cycle 19 **WORKING PLANE** in the part program (see “WORKING PLANE (Cycle 19)” on page 349)

The TNC functions for “tilting the working plane” are coordinate transformations in which the working plane is always perpendicular to the direction of the tool axis.

When tilting the working plane, the TNC differentiates between two machine types

- **Machines with tilting tables:**
  - You must tilt the workpiece into the desired position for machining by positioning the tilting table, for example with an L block
  - The position of the transformed tool axis **does not change** in relation to the machine-based coordinate system. Thus if you rotate the table—and therefore the workpiece—by 90° for example, the coordinate system **does not rotate.** If you press the Z+ axis direction button in the Manual Operation mode, the tool moves in Z+ direction.
  - In calculating the transformed coordinate system, the TNC considers only the mechanically influenced offsets of the particular tilting table (the so-called “translational” components).

- **Machines with swivel heads**
  - You must bring the tool into the desired position for machining by positioning the swivel head, for example with an L block.
  - The position of the transformed tool axis changes in relation to the machine-based coordinate system. Thus if you rotate the swivel head of your machine—and therefore the tool—in the B axis by 90° for example, the coordinate system rotates also. If you press the Z+ axis direction button in the Manual Operation mode, the tool moves in X+ direction of the machine-based coordinate system
  - In calculating the transformed coordinate system, the TNC considers both the mechanically influenced offsets of the particular swivel head (the so-called "translational" components) and offsets caused by tilting of the tool (3-D tool length compensation).

Traversing the reference points in tilted axes

With tilted axes, you use the machine axis direction buttons to cross over the reference points. The TNC interpolates the corresponding axes. Be sure that the function for tilting the working plane is active in the Manual Operation mode and the actual angle of the tilted axis was entered in the menu field.

Setting the datum in a tilted coordinate system

After you have positioned the rotary axes, set the datum in the same way as for a non-tilted system. The TNC then converts the datum for the tilted coordinate system. If your machine tool features axis control, the angular values for this calculation are taken from the actual position of the rotary axis.

You must not set the datum in the tilted working plane if in machine parameter 7500 bit 3 is set. If you do, the TNC will calculate the wrong offset.

If your machine tool is not equipped with axis control, you must enter the actual position of the rotary axis in the menu for manual tilting: The actual positions of one or several rotary axes must match the entry. Otherwise the TNC will calculate an incorrect datum.

During datum setting, the TNC considers the position of the tilting axes, even if the tilted working plane function is inactive. Pay attention to the angular position of the rotary axes when you set the datum or make a correction. If you would like to machine with another angular position than that defined during datum setting, you must activate the tilted working plane function.

Datum setting on machines with rotary tables

The behavior of the TNC during datum setting depends on the machine. Refer to your machine manual.

The TNC automatically shifts the datum if you rotate the table and the tilted working plane function is active:

- **MP 7500, bit 3=0**
  To calculate the datum, the TNC uses the difference between the REF coordinate during datum setting and the REF coordinate of the tilting axis after tilting. The method of calculation is to be used when you have clamped your workpiece in proper alignment when the rotary table is in the 0° position (REF value).
- **MP 7500, bit 3=1**
  If you rotate the table to align a workpiece that has been clamped in an unaligned position, the TNC must no longer calculate the offset of the datum from the difference of the REF coordinates. Instead of the difference from the 0° position, the TNC uses the REF value of the tilting table after tilting. In other words, it assumes that you have properly aligned the workpiece before tilting.

MP 7500 is effective in the machine parameter list, or, if available, in the descriptive tables for tilted axis geometry. Refer to your machine manual.

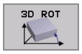
Position display in a tilted system

The positions displayed in the status window (**ACTL.** and **NOML.**) are referenced to the tilted coordinate system.

Limitations on working with the tilting function

- The touch probe function Basic Rotation cannot be used.
- PLC positioning (determined by the machine tool builder) is not possible.

To activate manual tilting:

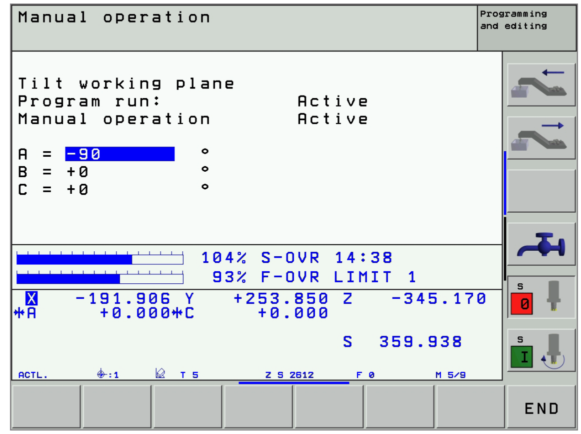


To select manual tilting, press the 3-D ROT soft key. You can now select the desired menu items with the arrow keys

Enter the tilt angle.

To set the desired operating mode in menu option "Tilt working plane" to Active, select the menu option and shift with the ENT key.

To conclude entry, press the END key.



To reset the tilting function, set the desired operating modes in menu "Tilt working plane" to Inactive.

If the tilted working plane function is active and the TNC moves the machine axes in accordance with the tilted axes, the status display shows the symbol

If you set the function "Tilt working plane" for the operating mode Program Run to Active, the tilt angle entered in the menu becomes active in the first block of the part program. If you are using Cycle 19 **WORKING PLANE** in the part program, the angular values defined in the cycle (starting at the cycle definition) are effective. Angular values entered in the menu will be overwritten.

3

Positioning with Manual Data Input (MDI)

3.1 Programming and Executing Simple Machining Operations

The Positioning with Manual Data Input mode of operation is particularly convenient for simple machining operations or pre-positioning of the tool. It enables you to write a short program in HEIDENHAIN conversational programming or in ISO format, and execute it immediately. You can also call TNC cycles. The program is stored in the file $MDI. In the operating mode Positioning with MDI, the additional status displays can also be activated.

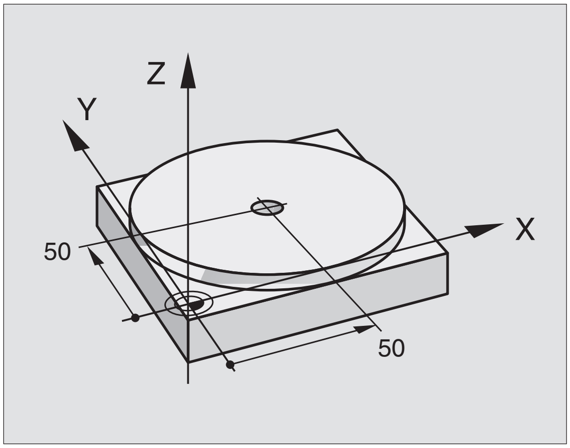
Positioning with manual data input (MDI)

Select the Positioning with MDI mode of operation. Program the file $MDI as you wish.

To start program run, press the machine START button.

Limitation

FK free contour programming, programming graphics and program run graphics cannot be used. The $MDI file must not contain a program call (**PGM CALL**).



Example 1

A hole with a depth of 20 mm is to be drilled into a single workpiece. After clamping and aligning the workpiece and setting the datum, you can program and execute the drilling operation in a few lines.

First you pre-position the tool in L blocks (straight-line blocks) to the hole center coordinates at a setup clearance of 5 mm above the workpiece surface. Then drill the hole with Cycle 1 **PECKING**.

0 BEGIN PGM $MDI MM	
1 TOOL DEF 1 L+0 R+5	Define tool: zero tool, radius 5
2 TOOL CALL 1 Z S2000	Call tool: tool axis Z
	Spindle speed 2000 rpm
3 L Z+200 R0 FMAX	Retract tool (F MAX = rapid traverse)
4 L X+50 Y+50 R0 FMAX M3	Move the tool at F MAX to a position above the hole.
	Spindle on
5 L Z+5 F2000	Position tool to 5 mm above hole.
6 CYCL DEF 1.0 PECKING	Define PECKING cycle:
7 CYCL DEF 1.1 SETUP 5	Set-up clearance of the tool above the hole

`8 CYCL DEF 1.2 DEPTH -20`	Total hole depth (Algebraic sign=working direction)
`9 CYCL DEF 1.3 PECKG 10`	Depth of each infeed before retraction
`10 CYCL DEF 1.4 DWELL 0:5`	Dwell time in seconds at the hole bottom
`11 CYCL DEF 1.5 F250`	Feed rate for pecking
`12 CYCL CALL`	Call PECKING cycle
`13 L Z+200 R0 FMAX M2`	Retract the tool
`14 END PGM $MDI MM`	End of program

Straight-line function L (see “Straight line L” on page 145), PECKING cycle (see “PECKING (Cycle 1)” on page 217).

Example 2: Correcting workpiece misalignment on machines with rotary tables

Use the 3-D touch probe to rotate the coordinate system. See “Touch Probe Cycles in the Manual and Electronic Handwheel Operating Modes,” section “Compensating workpiece misalignment,” in the new Touch Probes Cycles User’s Manual.

Write down the rotation angle and cancel the Basic Rotation.

Select operating mode: Positioning with MDI.

IV

Select the axis of the rotary table, enter the rotation angle you wrote down previously and set the feed rate. For example: **`L C+2.561 F50`**

END

Conclude entry.

I

Press the machine START button: The rotation of the table corrects the misalignment.

Protecting and erasing programs in $MDI

The $MDI file is generally intended for short programs that are only needed temporarily. Nevertheless, you can store a program, if necessary, by proceeding as described below:

Select the Programming and Editing mode of operation.

PGM MGT — To call the file manager, press the PGM MGT key (program management).

Move the highlight to the $MDI file.

COPY ABC → XYZ — To select the file copying function, press the COPY soft key.

TARGET FILE =

BOREHOLE — Enter the name under which you want to save the current contents of the $MDI file.

EXECUTE — Copy the file.

END — To close the file manager, press the END soft key.

Erasing the contents of the $MDI file is done in a similar way: Instead of copying the contents, however, you erase them with the DELETE soft key. The next time you select the operating mode Positioning with MDI, the TNC will display an empty $MDI file.

If you wish to delete $MDI, then

- you must not have selected the Positioning with MDI mode (not even in the background).
- you must not have selected the $MDI file in the Programming and Editing mode.

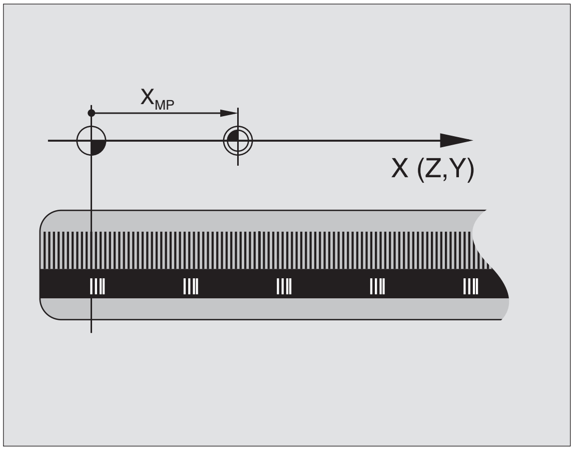
For further information, see "Copying a single file," page 53.

4

Fundamentals of NC, File Management, Programming Aids, Pallet Management

4.1 Fundamentals

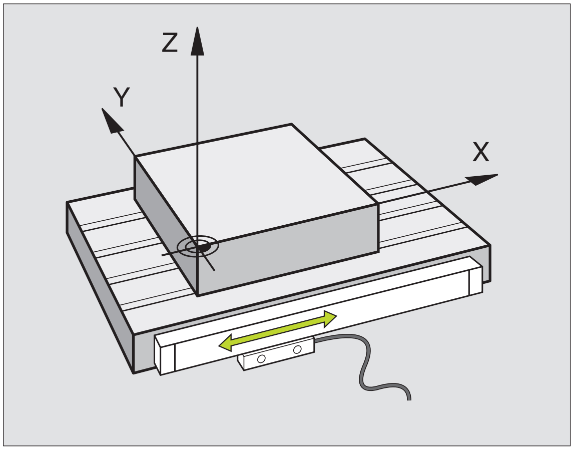
Position encoders and reference marks



The machine axes are equipped with position encoders that register the positions of the machine table or tool. Linear axes are usually equipped with linear encoders, rotary tables and tilting axes with angle encoders.

When a machine axis moves, the corresponding position encoder generates an electrical signal. The TNC evaluates this signal and calculates the precise actual position of the machine axis.

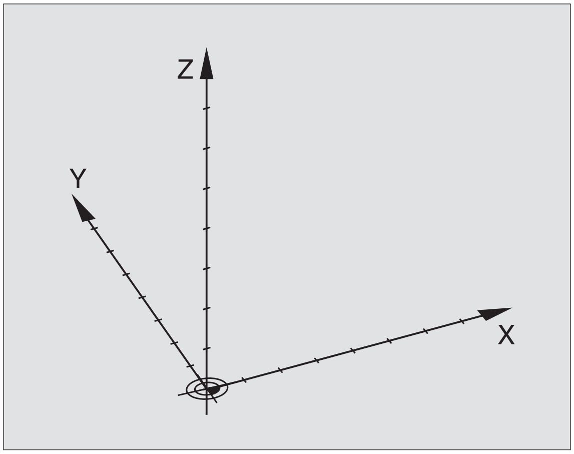
If there is a power interruption, the calculated position will no longer correspond to the actual position of the machine slide. To recover this association, incremental position encoders are provided with reference marks. The scales of the position encoders contain one or more reference marks that transmit a signal to the TNC when the axes pass over them. From the signal the TNC can re-establish the assignment of displayed positions to machine positions. For linear encoders with distance-coded reference marks the machine axes need to move by no more than 20 mm, for angle encoders by no more than 20°.



With absolute encoders, an absolute position value is transmitted to the control immediately upon switch-on. In this way the assignment of the actual position to the machine slide position is re-established directly after switch-on.

Reference system

A reference system is required to define positions in a plane or in space. The position data are always referenced to a predetermined point and are described through coordinates.

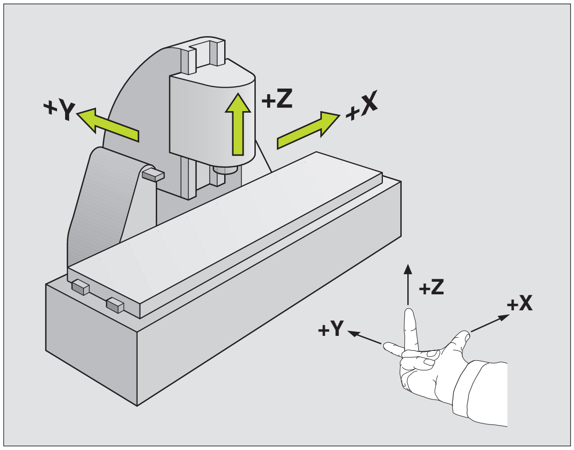


The Cartesian coordinate system (a rectangular coordinate system) is based on the three coordinate axes X, Y and Z. The axes are mutually perpendicular and intersect at one point called the datum. A coordinate identifies the distance from the datum in one of these directions. A position in a plane is thus described through two coordinates, and a position in space through three coordinates.

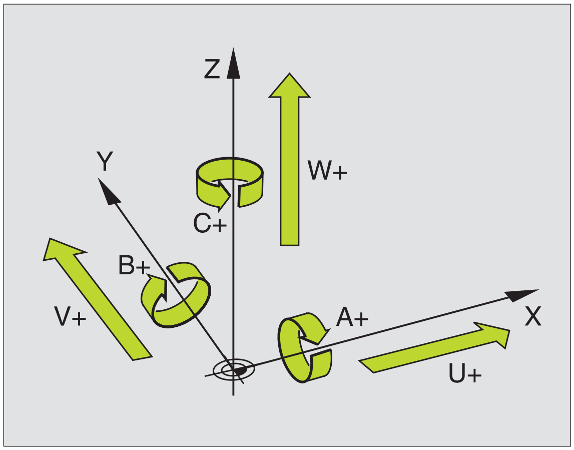
Coordinates that are referenced to the datum are referred to as absolute coordinates. Relative coordinates are referenced to any other known position (datum) you define within the coordinate system. Relative coordinate values are also referred to as incremental coordinate values.

Reference system on milling machines

When using a milling machine, you orient tool movements to the Cartesian coordinate system. The illustration at right shows how the Cartesian coordinate system describes the machine axes. The figure at center right illustrates the "right-hand rule" for remembering the three axis directions: the middle finger is pointing in the positive direction of the tool axis from the workpiece toward the tool (the Z axis), the thumb is pointing in the positive X direction, and the index finger in the positive Y direction.



The iTNC 530 can control up to 9 axes. The axes U, V and W are secondary linear axes parallel to the main axes X, Y and Z, respectively. Rotary axes are designated as A, B and C. The illustration at lower right shows the assignment of secondary axes and rotary axes to the main axes.



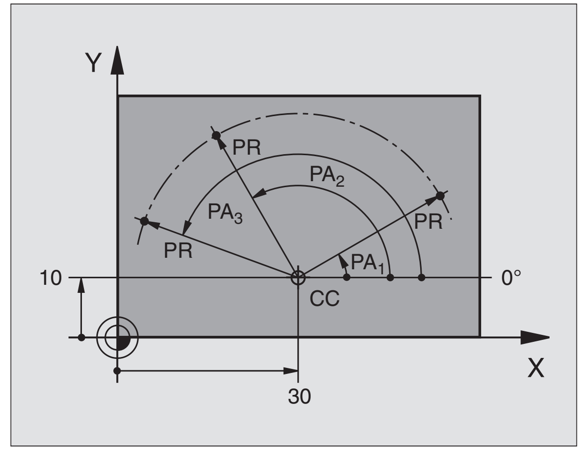
Polar coordinates

If the production drawing is dimensioned in Cartesian coordinates, you also write the part program using Cartesian coordinates. For parts containing circular arcs or angles it is often simpler to give the dimensions in polar coordinates.

While the Cartesian coordinates X, Y and Z are three-dimensional and can describe points in space, polar coordinates are two-dimensional and describe points in a plane. Polar coordinates have their datum at a circle center (CC), or pole. A position in a plane can be clearly defined by the:

- Polar Radius, the distance from the circle center CC to the position, and the
- Polar Angle, the size of the angle between the reference axis and the line that connects the circle center CC with the position.

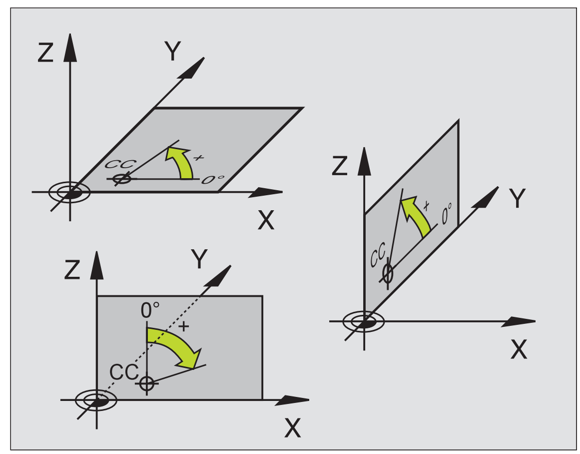
See figure at upper right.



Definition of pole and angle reference axis

The pole is set by entering two Cartesian coordinates in one of the three planes. These coordinates also set the reference axis for the polar angle PA.

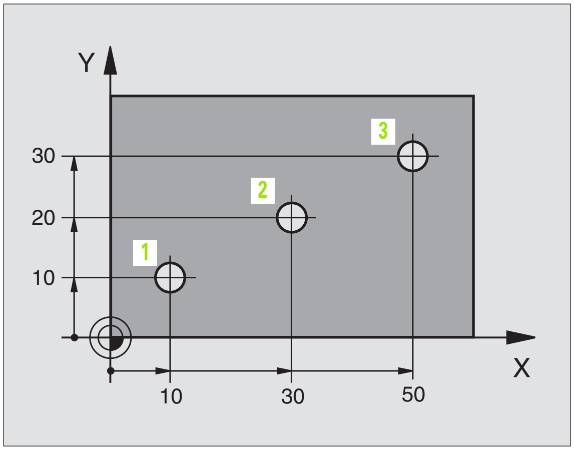
Coordinates of the pole (plane)	Reference axis of the angle
X/Y	+X
Y/Z	+Y
Z/X	+Z



Absolute and incremental workpiece positions

Absolute workpiece positions

Absolute coordinates are position coordinates that are referenced to the datum of the coordinate system (origin). Each position on the workpiece is uniquely defined by its absolute coordinates.

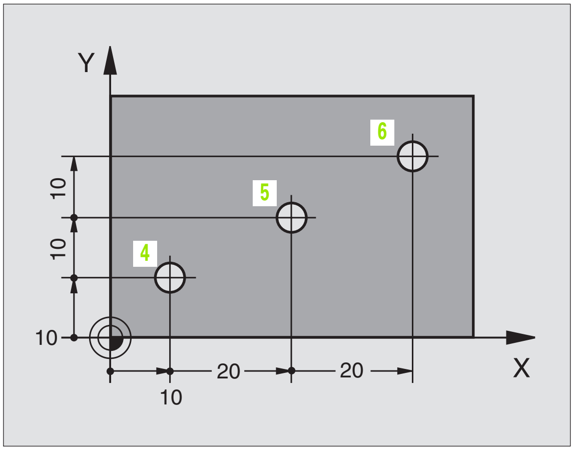


Example 1: Holes dimensioned in absolute coordinates

Hole 1	Hole 2	Hole 3
X = 10 mm	X = 30 mm	X = 50 mm
Y = 10 mm	Y = 20 mm	Y = 30 mm

Incremental workpiece positions

Incremental coordinates are referenced to the last programmed nominal position of the tool, which serves as the relative (imaginary) datum. When you write a part program in incremental coordinates, you thus program the tool to move by the distance between the previous and the subsequent nominal positions. Incremental coordinates are therefore also referred to as chain dimensions.



To program a position in incremental coordinates, enter the prefix "I" before the axis.

Example 2: Holes dimensioned in incremental coordinates

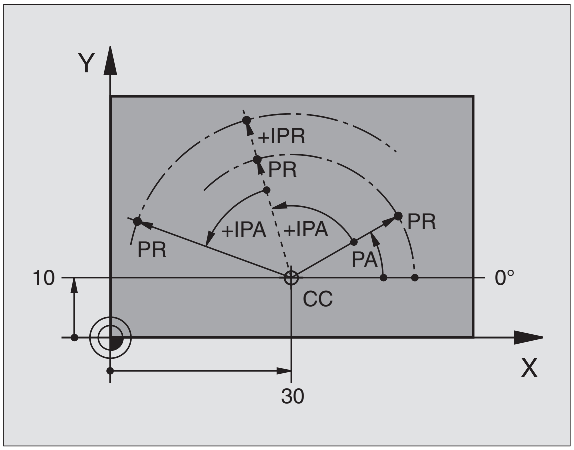
Absolute coordinates of hole 4

X = 10 mm
Y = 10 mm

Hole 6, referenced to 5	Hole 6, referenced to 5
X = 20 mm	X = 20 mm
Y = 10 mm	Y = 10 mm

Absolute and incremental polar coordinates

Absolute polar coordinates always refer to the pole and the reference axis.



Incremental coordinates always refer to the last programmed nominal position of the tool.

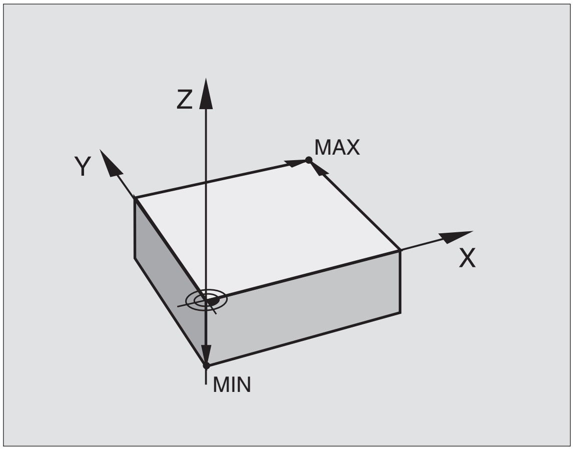
Setting the datum

A production drawing identifies a certain form element of the workpiece, usually a corner, as the absolute datum. Before setting the datum, you align the workpiece with the machine axes and move the tool in each axis to a known position relative to the workpiece. You then set the TNC display either to zero or to a predetermined position value. This establishes the reference system for the workpiece, which will be used for the TNC display and your part program.

If the production drawing is dimensioned in relative coordinates, simply use the coordinate transformation cycles. (see "Coordinate Transformation Cycles" on page 338).

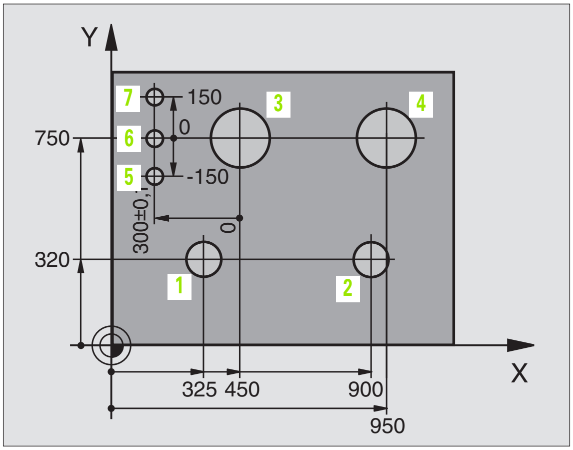
If the production drawing is not dimensioned for NC, set the datum at a position or corner on the workpiece which is suitable for deducing the dimensions of the remaining workpiece positions.

The fastest, easiest and most accurate way of setting the datum is by using a 3-D touch probe from HEIDENHAIN. See the new Touch Probe Cycles User's Manual, chapter "Setting the Datum with a 3-D Touch Probe."



Example

The workpiece drawing at right shows holes (**1** to **4**) whose dimensions are shown with respect to an absolute datum with the coordinates X=0, Y=0. The holes (**5** to **7**) are dimensioned with respect to a relative datum with the absolute coordinates X=450, Y=750. With the **DATUM SHIFT** cycle you can temporarily set the datum to the position X=450, Y=750, to be able to program the holes (**5** to **7**) without further calculations.



4.2 File Management: Fundamentals

> Using the MOD function PGM MGT (see “Configuring PGM MGT” on page 457), select between standard and advanced file management.
>
> If the TNC is connected to a network, then use file management with additional functions.

Files

Files in the TNC	Type
Programs	
In HEIDENHAIN format	.H
In ISO format	.I
Tables for	
Tools	.T
Tool changers	.TCH
Pallets	.P
Datums	.D
Points	.PNT
Presets	.PR
Cutting data	.CDT
Cutting materials, workpiece materials	.TAB
Dependent data (such as structure items)	.DEP
Texts as	
ASCII files	.A

When you write a part program on the TNC, you must first enter a file name. The TNC saves the program to the hard disk as a file with the same name. The TNC can also save texts and tables as files.

The TNC provides a special file management window in which you can easily find and manage your files. Here you can call, copy, rename and erase files.

You can manage an almost unlimited number of files with the TNC, at least **2000 MB.**

File names

When you store programs, tables and texts as files, the TNC adds an extension to the file name, separated by a period. This extension indicates the file type.

PROG20	.H
File name	File type
Maximum Length	See table “Files in the TNC.”

Data backup

We recommend saving newly written programs and files on a PC at regular intervals.

You can do this with the free backup program TNCBACK.EXE from HEIDENHAIN. Your machine tool builder can provide you with a copy of TNCBACK.EXE.

In addition, you need a floppy disk on which all machine-specific data, such as PLC program, machine parameters, etc., are stored. Please contact your machine tool builder for more information on both the backup program and the floppy disk.

Saving the contents of the entire hard disk (> 2 GB) can take up to several hours. In this case, it is a good idea to save the data outside of working hours, (e.g. overnight), or to use the PARALLEL EXECUTE function to copy in the background while you work.

Depending on operating conditions (e.g., vibration load), hard disks generally have a higher failure rate after three to five years of service. HEIDENHAIN therefore recommends having the hard disk inspected after three to five years.

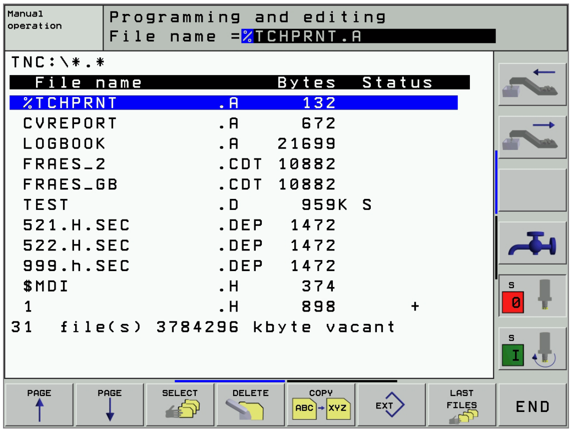
4.3 Standard File Management

Note

> The standard file management is best if you wish to save all files in one directory, or if you are well practiced in the file management of old TNC controls.
>
> To use the standard file management, set the MOD function **PGM MGT** (see “Configuring PGM MGT” on page 457) to **Standard**.

Calling the file manager

PGM MGT — Press the PGM MGT key: The TNC displays the file management window (see figure at right)



The window shows you all of the files that are stored in the TNC. Each file is shown with additional information:

Display	Meaning
FILE NAME	Name with up to 16 characters and file type
BYTE	File size in bytes
STATUS	File properties:
E	Program is selected in the Programming and Editing mode of operation.
S	Program is selected in the Test Run mode of operation.
M	Program is selected in a program run operating mode.
P	File is protected against editing and erasure.

Selecting a file

PGM MGT — Call the file manager.

Use the arrow keys or the arrow soft keys to move the highlight to the file you wish to select:

↓ ↑ — Moves the highlight up or down **file by file** in the window.

PAGE ↓ PAGE ↑ — Moves the highlight up or down **page by page** in the window.

SELECT or ENT — To select the file: Press the SELECT soft key or the ENT key.

Deleting a file

PGM MGT — Call the file manager.

Use the arrow keys or the arrow soft keys to move the highlight to the file you wish to delete:

↓ ↑ — Moves the highlight up or down **file by file** in the window.

PAGE ↓ PAGE ↑ — Moves the highlight up or down **page by page** in the window.

DELETE — To delete the file: Press the DELETE soft key.

DELETE ..... FILE?

YES — Confirm with the YES soft key.

NO — Abort with the NO soft key.

Copying a file

PGM MGT — Call the file manager.

Use the arrow keys or the arrow soft keys to move the highlight to the file you wish to copy:

↑ ↓ — Moves the highlight up or down **file by file** in the window.

PAGE ↑ PAGE ↓ — Moves the highlight up or down **page by page** in the window.

COPY ABC → XYZ — To copy the file: Press the COPY soft key.

TARGET FILE =

Enter the new name, and confirm your entry with the AUSFÜHREN soft key or the ENT key. A status window appears on the TNC, informing about the copying progress. As long as the TNC is copying, you can no longer work, or

If you wish to copy very long programs, enter the new file name and confirm with the PARALLEL EXECUTE soft key. The file will now be copied in the background, so you can continue to work while the TNC is copying.

When the copying process has been started with the EXECUTE soft key, the TNC displays a pop-up window with a progress indictor.

Data transfer to or from an external data medium

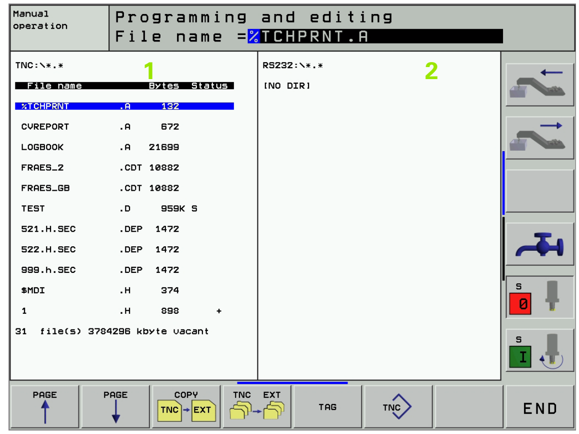
Before you can transfer data to an external data medium, you must setup the data interface(see “Setting the Data Interfaces” on page 446).

PGM MGT

Call the file manager.

EXT

Activate data transfer: Press the EXT soft key. In the left half of the screen **(1)** the TNC shows all files saved on its hard disk. In the right half of the screen **(2)** it shows all files saved on the external data medium.



Use the arrow keys to highlight the file(s) that you want to transfer:

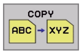
Moves the highlight up and down within a window

Moves the highlight from the left to the right window, and vice versa.

If you wish to copy from the TNC to the external data medium, move the highlight in the left window to the file to be transferred.

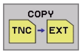
If you wish to copy from the external data medium to the TNC, move the highlight in the right window to the file to be transferred.

Tagging functions	Soft key
Tag a single file	TAG FILE
Tag all files	TAG ALL FILES
Untag a single file	UNTAG FILE
Untag all files	UNTAG ALL FILES
Copy all tagged files	COPY TAG



Transfer a single file: Press the COPY soft key, or

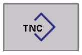
Transfer several files: Press the TAG soft key, or



Transfer all files: Press the TNC => EXT soft key.

Confirm with the EXECUTE or with the ENT key. A status window appears on the TNC, informing about the copying progress, or

If you wish to transfer more than one file or longer files, press the PARALLEL EXECUTE soft key. The TNC then copies the file in the background.

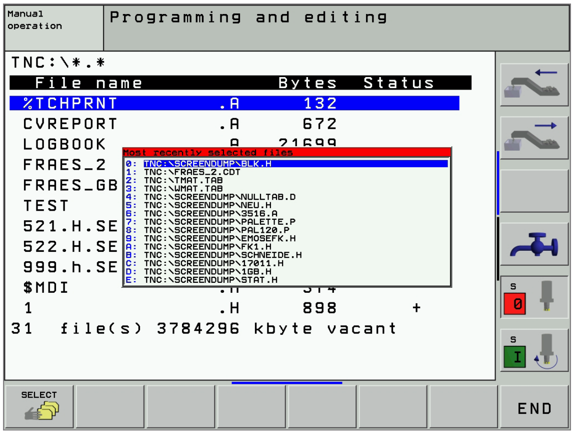


To stop transfer, press the TNC soft key. The standard file manager window is displayed again.

Selecting one of the last 10 files selected

PGM MGT — Call the file manager.

LAST FILES — Display the last 10 files selected: Press the LAST FILES soft key.



Use the arrow keys to move the highlight to the file you wish to select:

↑ ↓ — Move the highlight up or down.

SELECT or ENT — To select the file: Press the SELECT soft key or the ENT key.

Renaming a file

PGM MGT — Call the file manager.

Use the arrow keys or the arrow soft keys to move the highlight to the file you wish to rename:

↑ ↓ — Moves the highlight up or down **file by file** in the window.

PAGE ↑ PAGE ↓ — Moves the highlight up or down **page by page** in the window.

RENAME ABC = XYZ — Press the RENAME soft key to select the renaming function

TARGET FILE =

Enter the name of the new file and confirm your entry with the ENT key or EXECUTE soft key.

Protect file / Cancel file protection

PGM MGT — Call the file manager.

Use the arrow keys or arrow soft keys to move the highlight to the file you wish to protect or whose protection you wish to cancel:

Moves the highlight up or down **file by file** in the window.

PAGE PAGE — Moves the highlight up or down **page by page** in the window.

PROTECT — To enable file protection: Press the PROTECT soft key. The file now has status P, or

UNPROTECT — Press the UNPROTECT soft key to cancel file protection. The P status is canceled.

4.4 Advanced File Management

Note

Use the advanced file manager if you wish to keep your files in individual directories.

To use it, set the MOD function PGM MGT (see "Configuring PGM MGT" on page 457).

See also "File Management: Fundamentals" on page 39.

Directories

To ensure that you can easily find your files, we recommend that you organize your hard disk into directories. You can divide a directory into further directories, which are called subdirectories. With the –/+ key or ENT you can show or hide the subdirectories.

The TNC can manage up to 6 directory levels!

If you save more than 512 files in one directory, the TNC no longer sorts them alphabetically!

Directory names

The name of a directory can contain up to 16 characters and does not have an extension. If you enter more than 16 characters for the directory name, the TNC will display an error message.

Paths

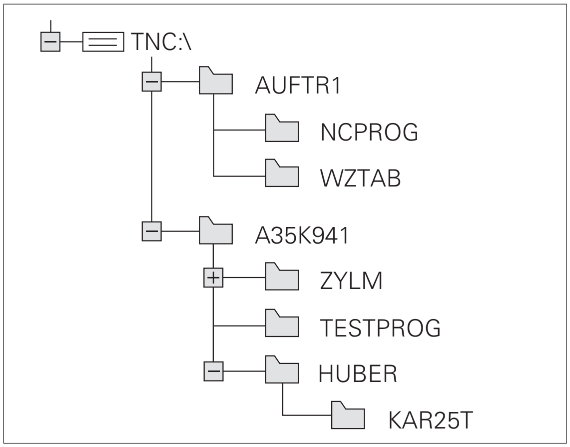
A path indicates the drive and all directories and subdirectories under which a file is saved. The individual names are separated by a backslash "\".

Example

On drive **TNC:** the subdirectory AUFTR1 was created. Then, in the directory **AUFTR1** the directory NCPROG was created and the part program PROG1.H was copied into it. The part program now has the following path:

TNC:\AUFTR1\NCPROG\PROG1.H

The chart at right illustrates an example of a directory display with different paths.



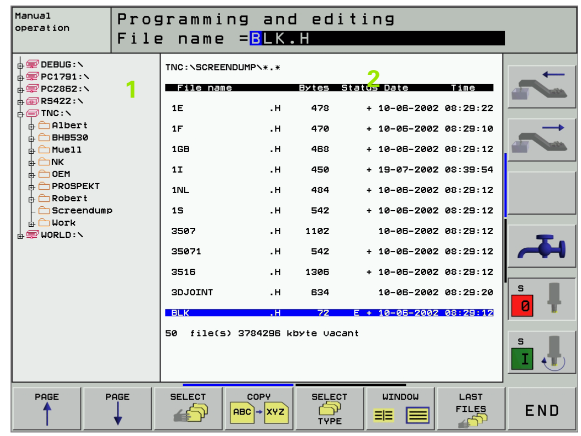
Overview: Functions of the expanded file manager

Function	Soft key
Copy (and convert) individual files	COPY ABC → XYZ
Select target directory	
Display a specific file type	SELECT TYPE
Display the last 10 files that were selected	LAST FILES
Erase a file or directory	DELETE
Tag a file	TAG
Renaming a file	RENAME ABC = XYZ
Protect a file against editing and erasure	PROTECT
Cancel file protection	UNPROTECT
Manage network drives	NET
Copy a directory	COPY DIR
Display all the directories of a particular drive	UPDATE TREE
Delete directory with all its subdirectories	DELETE ALL

Calling the file manager

PGM MGT

Press the PGM MGT soft key: The TNC displays the file management window. (The figure at top right shows the basic settings. If the TNC shows a different screen layout, press the WINDOW soft key.)



The narrow window at left **1** shows the available drives and directories. Drives designate devices with which data are stored or transferred. One drive is the hard disk of the TNC. Other drives are the interfaces (RS232, RS422, Ethernet), which can be used, for example, to connect a personal computer. A drive is always identified by a file symbol to the left and the directory name to the right. The control displays a subdirectory to the right of and below its parent directory. A box with the + symbol in from of the folder symbol indicates that there are further subdirectories, which can be shown with the –/+ key or ENT.

The wide window at right **2** shows you all of the files that are stored in the selected directory. Each file is shown with additional information that is illustrated in the table below.

Display	Meaning
FILE NAME	Name with up to 16 characters and file type
BYTE	File size in bytes
STATUS	File properties:
E	Program is selected in the Programming and Editing mode of operation.
S	Program is selected in the Test Run mode of operation.
M	Program is selected in a program run operating mode.
P	File is protected against editing and erasure.
DATE	Date the file was last changed
TIME	Time the file was last changed

Selecting drives, directories and files

PGM MGT

Call the file manager.

With the arrow keys or the soft keys, you can move the highlight to the desired position on the screen:

Moves the highlight from the left to the right window, and vice versa.

Moves the highlight up and down within a window

PAGE PAGE

Moves the highlight one page up or down within a window

1. step: Select a drive

Move the highlight to the desired drive in the left window:

SELECT

or

ENT

Select a drive: Press the SELECT soft key or the ENT key.

2. step: Select a directory

Move the highlight to the desired directory in the left-hand window — the right-hand window automatically shows all files stored in the highlighted directory.

3rd step: select a file

SELECT TYPE — Press the SELECT TYPE soft key.

SHOW .H — Press the soft key for the desired file type, or

SHOW ALL — Press the SHOW ALL soft key to display all files, or

`4*.H` ENT — Use wild card characters, e.g. to show all files of the file type .H that begin with 4.

Move the highlight to the desired file in the right window

SELECT or ENT — The selected file is opened in the operating mode from which you have called the file manager: Press the SELECT soft key or the ENT key.

Creating a new directory (only possible on the drive TNC:\)

Move the highlight in the left window to the directory in which you want to create a subdirectory.

`NEW` ENT — Enter the new file name, and confirm with ENT.

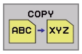
CREATE \NEW DIRECTORY?

YES — Press the YES soft key to confirm, or

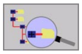
NO — Abort with the NO soft key.

Copying a single file

- Move the highlight to the file you wish to copy.



- Press the COPY soft key to select the copying function. The TNC displays a soft-key row with soft keys for different functions.



- Press the "Select target directory" soft key to select the desired directory in a pop-up window. After the target directory has been selected, the corresponding path is indicated. Use the Backspace key to position the cursor directly at the end of the path name and enter the name of the destination file.

- Enter the name of the destination file and confirm your entry with the ENT key or EXECUTE soft key: The TNC copies the file into the active directory or into the selected destination directory. The original file is retained, or

- Press the PARALLEL EXECUTE soft key to copy the file in the background. Copying in the background permits you to continue working while the TNC is copying. This can be useful if you are copying very large files that take a long time. While the TNC is copying in the background you can press the INFO PARALLEL EXECUTE soft key (under MORE FUNCTIONS, second soft-key row) to check the progress of copying.

> When the copying process has been started with the EXECUTE soft key, the TNC displays a pop-up window with a progress indictor.

Copying a table

If you are copying tables, you can overwrite individual lines or columns in the target table with the REPLACE FIELDS soft key. Prerequisites:

- The target table must exist.
- The file to be copied must only contain the columns or lines you want to replace.

> The **REPLACE FIELDS** soft key does not appear when you want to overwrite the table in the TNC with an external data transfer software, such as TNCremoNT. Copy the externally created file into a different directory, and then copy the desired fields with the TNC file management.

Example

With a tool presetter you have measured the length and radius of 10 new tools. The tool presetter then generates the tool table TOOL.T with 10 lines (for the 10 tools) and the columns

- Tool number (column **T**)
- Tool length (column **L**)
- Tool radius (column **R**)

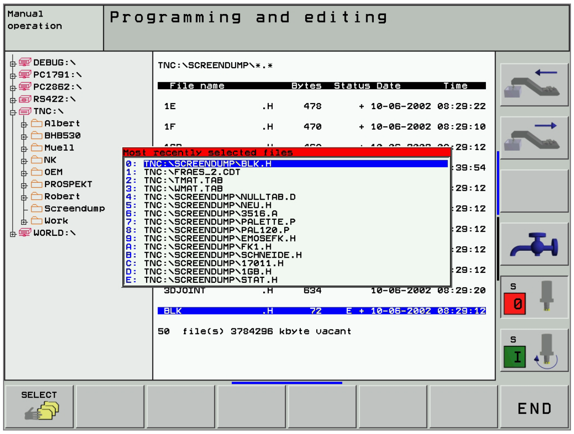
Copy this file to a directory other than the one containing the previous TOOL.T. If you wish to copy this file over the existing table using the TNC file management, the TNC asks if you wish to overwrite the existing TOOL.T tool table:

- If you press the YES soft key, the TNC will completely overwrite the current TOOL.T tool table. After this copying process the new TOOL.T table consists of 10 lines. The only remaining columns in the table are tool number, tool length and tool radius.
- Or, if you press the REPLACE FIELDS soft key, the TNC merely overwrites the first 10 lines of the columns number, length and radius in the TOOL.T file. The TNC does not change the data in the other lines and columns.

Copying a directory

Move the highlight in the left window onto the directory you want to copy. Instead of the COPY soft key, press the COPY DIR soft key. Subdirectories are also copied at the same time.

Choosing one of the last 10 files selected.



PGM MGT — Call the file manager.

LAST FILES — Display the last 10 files selected: Press the LAST FILES soft key.

Use the arrow keys to move the highlight to the file you wish to select:

↓ ↑ — Moves the highlight up and down within a window

SELECT — Select a drive: Press the SELECT soft key or the ENT key.

or

ENT

Deleting a file

- Move the highlight to the file you want to delete.

DELETE

- To select the erasing function, press the DELETE soft key. The TNC inquires whether you really intend to erase the file.
- To confirm, press the JA soft key;
- To abort erasure, press the NO soft key.

Deleting a directory

- Delete all files and subdirectories stored in the directory that you wish to erase.
- Move the highlight to the directory you want to delete.

DELETE

- To select the erasing function, press the DELETE soft key. The TNC inquires whether you really intend to erase the directory.
- To confirm, press the JA soft key;
- To abort erasure, press the NO soft key.

Tagging files

Tagging functions	Soft key
Tag a single file	TAG FILE
Tag all files in the directory	TAG ALL FILES
Untag a single file	UNTAG FILE
Untag all files	UNTAG ALL FILES
Copy all tagged files	COPY TAG

Some functions, such as copying or erasing files, can not only be used for individual files, but also for several files at once. To tag several files, proceed as follows:

Move the highlight to the first file.

TAG — To display the tagging functions, press the TAG soft key.

TAG FILE — Tag a file by pressing the TAG FILE soft key.

Move the highlight to the next file you wish to tag:

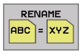
TAG FILE — To mark more files, press the TAG FILE soft key.

COPY TAG — To copy the tagged files, press the COPY TAG soft key, or

END DELETE — Delete the tagged files by pressing END to end the marking function, and then the DELETE to delete the tagged files.

Renaming a file

- Move the highlight to the file you want to rename.



- Select the renaming function.
- Enter the new file name; the file type cannot be changed.
- To execute renaming, press the ENT key.

Additional Functions

Protect file / Cancel file protection

- Move the highlight to the file you want to protect.

- To select the additional functions, press the MORE FUNCTIONS soft key.

- To enable file protection, press the PROTECT soft key. The file now has status P.
- To cancel file protection, proceed in the same way using the UNPROTECT soft key.

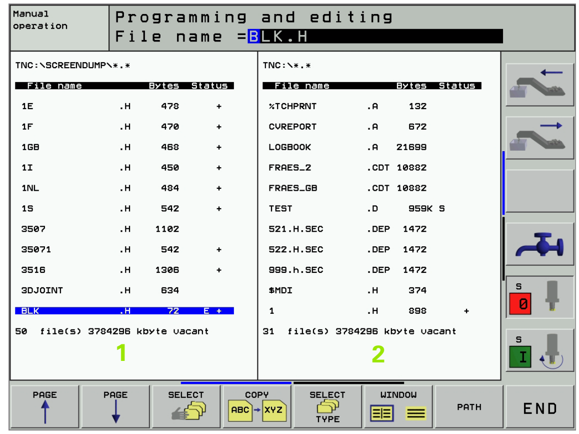
Erase a directory together with all its subdirectories and files.

- Move the highlight in the left window onto the directory you want to erase.

- To select the additional functions, press the MORE FUNCTIONS soft key.

- Press DELETE ALL to erase the directory together with its subdirectories.
- To confirm, press the YES soft key; To abort erasure, press the NO soft key.

Data transfer to or from an external data medium



Before you can transfer data to an external data medium, you must setup the data interface(see “Setting the Data Interfaces” on page 446).

PGM MGT — Call the file manager.

WINDOW — Select the screen layout for data transfer: press the WINDOW soft key. In the left half of the screen **(1)** the TNC shows all files saved on its hard disk. In the right half of the screen **(2)** it shows all files saved on the external data medium.

Use the arrow keys to highlight the file(s) that you want to transfer:

↑ ↓ — Moves the highlight up and down within a window

← → — Moves the highlight from the left to the right window, and vice versa.

If you wish to copy from the TNC to the external data medium, move the highlight in the left window to the file to be transferred.

If you wish to copy from the external data medium to the TNC, move the highlight in the right window to the file to be transferred.

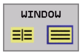
COPY ABC → XYZ — Transfer a single file: Press the COPY soft key, or

TAG — Transfer several files: Press the TAG soft key (in the second soft-key row, see “Tagging files,” page 56), or

COPY TNC → EXT — Transfer all files: Press the TNC => EXT soft key.

Confirm with the EXECUTE or with the ENT key. A status window appears on the TNC, informing about the copying progress, or

If you wish to transfer more than one file or longer files, press the PARALLEL EXECUTE soft key. The TNC then copies the file in the background.



To end data transfer, move the highlight into left window and then press the WINDOW soft key. The standard file manager window is displayed again.

To select another directory in the split-screen display, press the PFAD soft key. Select the desired directory in the pop-up window by using the arrow keys and the ENT key!

Copying files into another directory

- Select the screen layout with the two equally sized windows.
- To display directories in both windows, press the PATH soft key.

In the right window

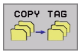
- Move the highlight to the directory into which you wish to copy the files, and display the files in this directory with the ENT key.

In the left window

- Select the directory with the files that you wish to copy and press ENT to display them.

- Display the file tagging functions.

- Move the highlight to the file you want to copy and tag it. You can tag several files in this way, as desired.



- Copy the tagged files into the target directory.

Additional tagging functions: see “Tagging files,” page 56

If you have marked files in the left and right windows, the TNC copies from the directory in which the highlight is located.

Overwriting files

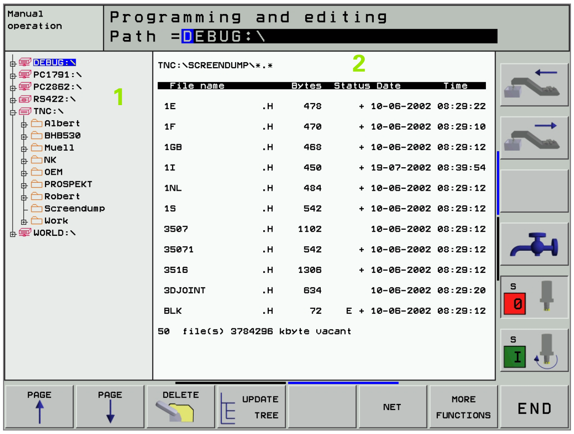
If you copy files into a directory in which other files are stored under the same name, the TNC will ask whether the files in the target directory should be overwritten:

- To overwrite all files, press the YES soft key, or
- To overwrite no files, press the NO soft key, or
- To confirm each file separately before overwriting it, press the CONFIRM soft key.

If you wish to overwrite a protected file, this must also be confirmed or aborted separately.

The TNC in a Network

> To connect the Ethernet card to your network, (see "Ethernet Interface" on page 450).
>
> The TNC logs error messages during network operation(see "Ethernet Interface" on page 450).



If the TNC is connected to a network, the directory window **1** displays up to 7 drives (see figure at right). All the functions described above (selecting a drive, copying files, etc.) also apply to network drives, provided that you have been given the corresponding rights.

Connecting and disconnecting network drive

PGM MGT

- To select the program management: Press the PGM MGT key. If necessary, press the WINDOW soft key to set up the screen as it is shown at the upper right.

NET

- To manage the network drives: Press the NETWORK soft key (second soft-key row). In the right-hand window **2** the TNC shows the network drives available for access. With the following soft keys you can define the connection for each drive.

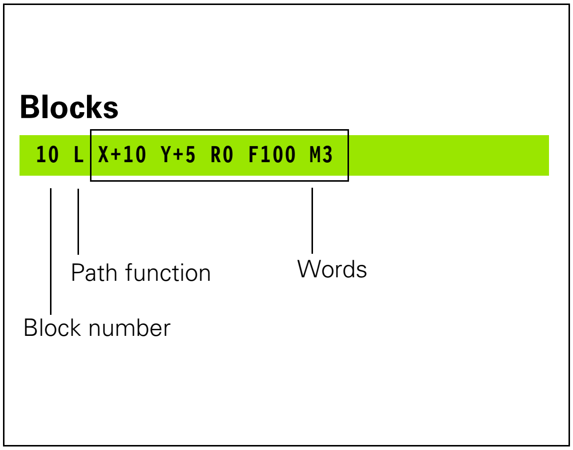
Function	Soft key
Establish network connection. If the connection is active, the TNC shows an **`M`** in the **`Mnt`** column. You can connect up to 7 additional drives with the TNC.	MOUNT DEVICE
Delete network connection	UNMOUNT DEVICE
Automatically establish network connection whenever the TNC is switched on. The TNC shows an **`A`** in the **`Auto`** column if the connection is established automatically.	AUTO MOUNT
Do not establish network connection automatically when the TNC is switched on.	NO AUTO MOUNT

It may take some time to mount a network device. At the upper right of the screen the TNC displays **`[READ DIR]`** to indicate that a connection is being established. The maximum transmission speed is 2 to 5 MB/s, depending on the type of file being transferred and how busy the network is.

4.5 Creating and Writing Programs

Organization of an NC program in HEIDENHAIN conversational format.

A part program consists of a series of program blocks. The figure at right illustrates the elements of a block.



The TNC numbers the blocks in ascending sequence.

The first block of a program is identified by **BEGIN PGM**, the program name and the active unit of measure.

The subsequent blocks contain information on:

- The workpiece blank
- Tool definitions, tool calls
- Feed rates and spindle speeds, as well as
- Path contours, cycles and other functions

The last block of a program is identified by **END PGM**, the program name and the active unit of measure.

Defining the blank form – BLK FORM

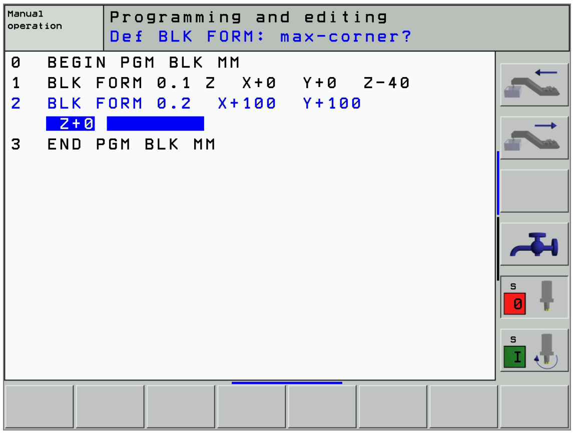
Immediately after initiating a new program, you define a cuboid workpiece blank. If you wish to define the blank at a later stage, press the BLK FORM soft key. This definition is needed for the TNC's graphic simulation feature. The sides of the workpiece blank lie parallel to the X, Y and Z axes and can be up to 100 000 mm long. The blank form is defined by two of its corner points:

- MIN point: the smallest X, Y and Z coordinates of the blank form, entered as absolute values.
- MAX point: the largest X, Y and Z coordinates of the blank form, entered as absolute or incremental values.

You only need to define the blank form if you wish to run a graphic test for the program!

Creating a new part program

You always enter a part program in the **Programming and Editing** mode of operation. Program initiation in an example:



Select the **Programming and Editing** mode of operation.

PGM MGT — To call the file manager, press the PGM MGT key.

Select the directory in which you wish to store the new program:

FILE NAME = OLD.H

ENT — Enter the new program name and confirm your entry with the ENT key.

MM — To select the unit of measure, press the MM or INCH soft key. The TNC switches the screen layout and initiates the dialog for defining the **BLK-FORM**.

WORKING SPINDLE AXIS X/Y/Z ?

Enter the spindle axis.

DEF BLK FORM: MIN-CORNER ?

0 ENT — Enter in sequence the X, Y and Z coordinates of the MIN point.

0 ENT

-40 ENT

DEF BLK FORM: MAX-CORNER ?

100 ENT — Enter in sequence the X, Y and Z coordinates of the MAX point.

100 ENT

0 ENT

Example: Display the BLK form in the NC program

`0 BEGIN PGM NEW MM`	Program begin, name, unit of measure
`1 BLK FORM 0.1 Z X+0 Y+0 Z-40`	Spindle axis, MIN point coordinates
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	MAX point coordinates
`3 END PGM NEW MM`	Program end, name, unit of measure

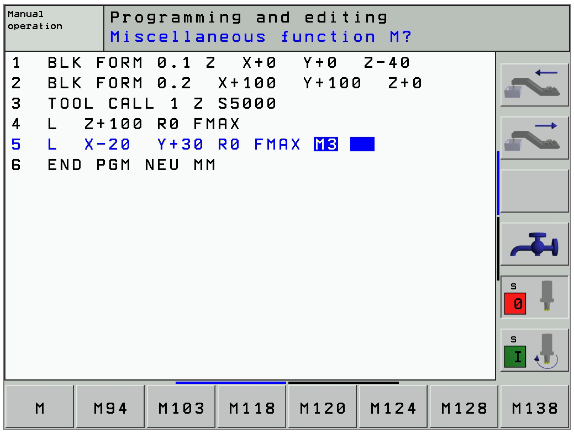
The TNC automatically generates the block numbers as well as the **`BEGIN`** and **`END`** blocks.

If you do not wish to define a blank form, cancel the dialog at **`Working spindle axis X/Y/Z`** by pressing the DEL key!

The TNC can display the graphics only if the shortest side is at least 50 µm long and the longest side is no longer than 99 999.999 mm.

Programming tool movements in conversational format

To program a block, initiate the dialog by pressing a function key. In the screen headline, the TNC then asks you for all the information necessary to program the desired function.



Example of a dialog

Dialog initiation

COORDINATES ?

X **10** Enter the target coordinate for the X axis.

Y **20** **ENT** Enter the target coordinate for the Y axis, and go to the next question with ENT.

RADIUS COMP. RL/RR/NO COMP. ?

ENT Enter “No radius compensation” and go to the next question with ENT.

FEED RATE F=? / F MAX = ENT

100 **ENT** Enter a feed rate of 100 mm/min for this path contour; go to the next question with ENT.

MISCELLANEOUS FUNCTION M?

3 **ENT** Enter the miscellaneous function **M3** “spindle ON”; pressing the ENT key will terminate this dialog.

The program blocks window will display the following line:

```
3 L X+10 Y+5 RO F100 M3
```

Functions for setting the feed rate	Soft key
Rapid traverse	F MAX
Traverse feed rate automatically calculated in **TOOL CALL**	F AUTO

Functions for conversational guidance	Key
Ignore the dialog question	NO ENT
End the dialog immediately	END
Abort the dialog and erase the block	DEL

Actual position capture

The TNC enables you to transfer the current tool position into the program, for example during

- Positioning-block programming.
- Cycle programming.
- Define the tools with **TOOL DEF**.

To transfer the correct position values, proceed as follows:

▶ Place the input box at the position in the block where you want to insert a position value.

▶ Select the actual position capture function: In the soft-key row the TNC displays the axes whose positions can be transferred.

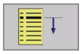
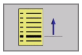
AXIS Z

▶ Select the axis: The TNC writes the current position of the selected axis into the active input box.

> In the working plane the TNC always captures the coordinates of the tool center even though tool radius compensation is active.
>
> In the tool axis the TNC always captures the coordinates of the tool tip and thus always considers the active tool length compensation.

Editing a program

While you are creating or editing a part program, you can select any desired line in the program or individual words in a block with the arrow keys or the soft keys:

Function	Soft keys/keys
Go to previous page	PAGE ↑
Go to next page	PAGE ↓
Go to beginning of program	BEGIN ↑
Go to end of program	END ↓
Changing the position of the current block on the screen. Press this soft key to display additional program blocks that are programmed before the current block.	
Changing the position of the current block on the screen. Press this soft key to display additional program blocks that are programmed after the current block.	
Move from one block to the next	↓ ↑
Select individual words in a block	← →

Function	Key/soft key
Set the selected word to zero	CE
Erase an incorrect number	CE
Clear a (non-blinking) error message	CE
Delete the selected word	NO ENT
Delete the selected block	DEL
Erase cycles and program sections	DEL
Insert the block that was last edited or deleted.	INSERT LAST NC BLOCK

Inserting blocks at any desired location

- Select the block after which you want to insert a new block and initiate the dialog.

Editing and inserting words

- Select a word in a block and overwrite it with the new one. The plain-language dialog is available while the word is highlighted.
- To accept the change, press the END key.

If you want to insert a word, press the horizontal arrow key repeatedly until the desired dialog appears. You can then enter the desired value.

Looking for the same words in different blocks

For this function, set the AUTO DRAW soft key to OFF.

→	To select a word in a block, press the arrow keys repeatedly until the highlight is on the desired word.
↓	Select a block with the arrow keys.

The word that is highlighted in the new block is the same as the one you selected previously.

Finding any text

- To select the search function, press the FIND soft key. The TNC displays the dialog prompt **`Find text:`**
- Enter the text that you wish to find.
- To find the text, press the EXECUTE soft key.

Marking, copying, deleting and inserting program sections

The TNC provides certain functions for copying program sections within an NC program or into another NC program—see the table at right.

To copy a program section, proceed as follows:

- Select the soft-key row using the marking function.
- Select the first (last) block of the section you wish to copy.
- To mark the first (last) block: Press the SELECT BLOCK soft key. The TNC then highlights the first character of the block and superimposes the soft key CANCEL SELECTION.
- Move the highlight to the last (first) block of the program section you wish to copy or delete. The TNC shows the marked blocks in a different color. You can end the marking function at any time by pressing the CANCEL SELECTION soft key.
- To copy the selected program section: Press the COPY BLOCK soft key, and to delete the selected section: Press the DELETE BLOCK soft key. The TNC stores the selected block.
- Using the arrow keys, select the block after which you wish to insert the copied (deleted) program section.

> To insert the section into another program, select the corresponding program using the File Manager and then mark the block after which you wish to insert the copied block.

- To insert the block: Press the INSERT BLOCK soft key.
- To end the marking function, press the CANCEL SELECTION soft key.

Function	Soft key
Switch on marking function	SELECT BLOCK
Switch off marking function	CANCEL SELECTION
Delete marked block	DELETE BLOCK
Insert block that is stored in the buffer memory	INSERT BLOCK
Copy marked block	COPY BLOCK

The TNC search function

With the search function of the TNC, you can search for any text within a program and replace it by a new text, if required.

Searching for texts

- If required, select the block containing the word you wish to find.

FIND
- Select the search function: The TNC superimposes the search window and displays the available search functions in the soft-key row (see table of search functions).

X +40
- Enter the text to be searched for. Please note that the search is case-sensitive.

EXECUTE
- Start the searching process: The TNC displays the available search options in the soft-key row (see the table of search options on the next page).

WHOLE WORD OFF ON
- If required, change the search options.

EXECUTE
- Start the searching process: The TNC moves to the next block containing the text you wish to find.

EXECUTE
- Repeat the searching process: The TNC moves to the next block containing the text you wish to find.

END
- End the search function.

Search functions	Soft key
Show the superimposed window containing the last search items. Use the arrow keys to select a search item and confirm with the ENT key.	LAST SEARCH ELEMENTS
Show the superimposed window containing possible search elements of the current block. Use the arrow keys to select a search item and confirm with the ENT key.	CURRENT BLOCK ELEMENTS
Show the superimposed window containing a selection of the most important NC functions. Use the arrow keys to select a search item and confirm with the ENT key.	NC BLOCKS
Activate the Find/Replace function.	SEARCH + REPLACE

Search options	Soft key
Define the search direction.	UPWARD / DOWNWARD
Define the end of the search: With COMPLETE, the program is searched from the current block to the last block.	COMPLETE / BEGIN/END
Start a new search.	NEW SEARCH

Find/Replace any text

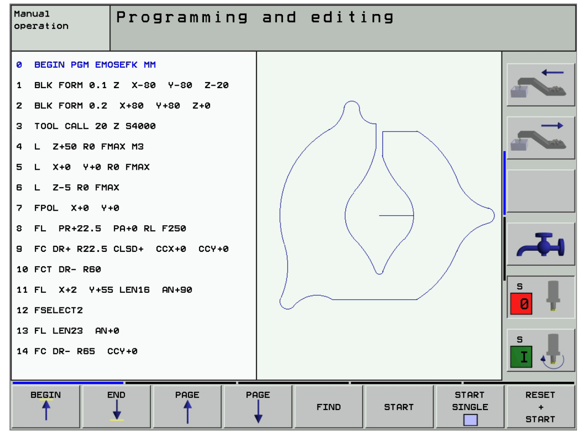
- If required, select the block containing the word you wish to find.

FIND	Select the search function: The TNC superimposes the search window and displays the available search functions in the soft-key row.
SEARCH + REPLACE	Activate the Replace function: The TNC superimposes a window for entering the text to be inserted.
X	Enter the text to be searched for. Please note that the search is case-sensitive. Then confirm with the ENT key.
Z	Enter the text to be inserted. Please note that the entry is case-sensitive.
EXECUTE	Start the searching process: The TNC displays the available search options in the soft-key row (see the table of search options).
WHOLE WORD OFF ON	If required, change the search options.
EXECUTE	Start the searching process: The TNC moves to the next text you wish to find.
EXECUTE	If you wish to replace the text and then move to the next position where the text was found, press the REPLACE soft key. If you do not want to replace the text but move to the next position where the text was found, press the DO NOT REPLACE soft key.
END	End the search function.

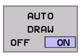
4.6 Interactive Programming Graphics

To generate/not generate graphics during programming:

While you are writing the part program, you can have the TNC generate a 2-D pencil-trace graphic of the programmed contour.



- To switch the screen layout to displaying program blocks to the left and graphics to the right, press the SPLIT SCREEN key and PGM + GRAPHICS soft key.



- Set the AUTO DRAW soft key to EIN. While you are entering the program lines, the TNC generates each path contour you program in the graphics window in the right screen half.

If you do not wish to have graphics generated during programming, set the AUTO DRAW soft key to OFF.

Even when AUTO DRAW ON is active, graphics are not generated for program section repeats.

Generating a graphic for an existing program

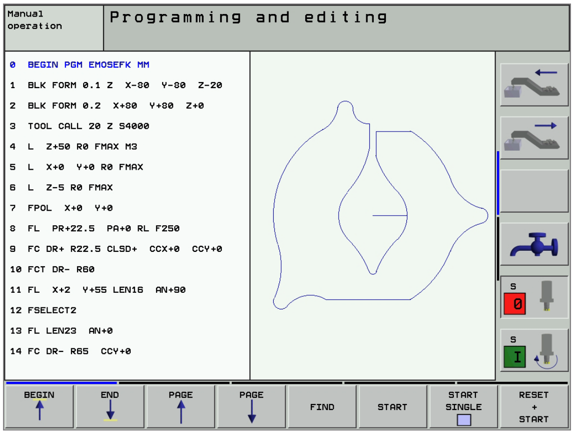
- Use the arrow keys to select the block up to which you want the graphic to be generated, or press GOTO and enter the desired block number.

- To generate graphics, press the RESET + START soft key.

Additional functions:

Function	Soft key
Generate a complete graphic	RESET + START
Generate interactive graphic blockwise	START SINGLE
Generate a complete graphic or complete it after RESET + START	START
Stop the programming graphics. This soft key only appears while the TNC generates the interactive graphics	STOP

Block number display ON/OFF



▷

SHOW OMIT BLOCK NR.

- Shift the soft-key row (see figure at upper right).
- To show block numbers: Set the SHOW OMIT BLOCK NR. soft key to SHOW.
- To show block numbers: Set the SHOW OMIT BLOCK NR. soft key to OMIT.

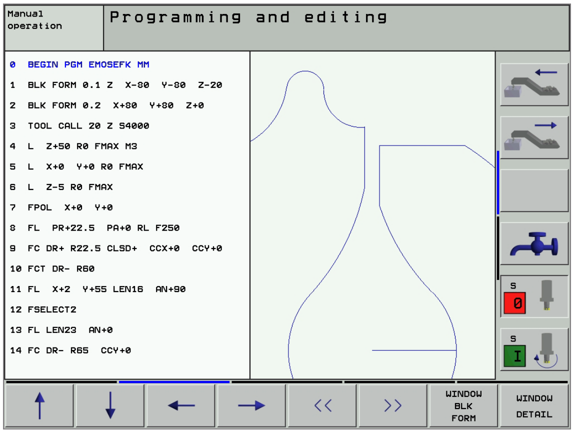
To erase the graphic:

▷

CLEAR GRAPHICS

- Shift the soft-key row (see figure at upper right).
- Delete graphic: Press CLEAR GRAPHIC soft key.

Magnifying or reducing a detail



You can select the graphics display by selecting a detail with the frame overlay. You can now magnify or reduce the selected detail.

- Select the soft-key row for detail magnification/reduction (second row, see figure at center right).

The following functions are available:

Function	Soft key
Show and move the frame overlay. Press and hold the desired soft key to move the frame overlay.	← → ↓ ↑
Reduce the frame overlay—press and hold the soft key to reduce the detail	<<
Enlarge the frame overlay—press and hold the soft key to magnify the detail	>>

WINDOW DETAIL

- Confirm the selected area with the WINDOW DETAIL soft key.

With the WINDOW BLK FORM soft key, you can restore the original section.

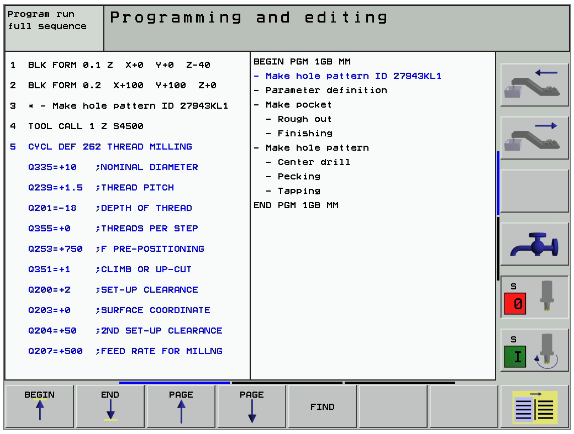
4.7 Structuring Programs

Definition and applications

This TNC function enables you to comment part programs in structuring blocks. Structuring blocks are short texts with up to 37 characters and are used as comments or headlines for the subsequent program lines.

With the aid of appropriate structuring blocks, you can organize long and complex programs in a clear and comprehensible way.

This function is particularly convenient if you want to change the program later. Structuring blocks can be inserted into the part program at any point. They can also be displayed in a separate window, and edited or added to, as desired.



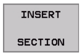
To display the program structure window / change the active window:

▶ To display the program structure window, select the screen display PGM+SECTS.

▶ To change the active window, press the "Change window" soft key.

To insert a structuring block in the (left) program window

▶ Select the block after which the structuring block is to be inserted.



▶ Press the INSERT STRUCTURE soft key or the * key on the ASCII keyboard.

▶ Enter the structuring text with the alphabetic keyboard.

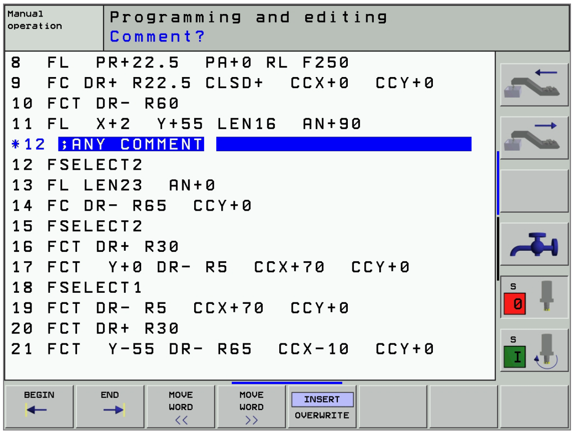
Selecting blocks in the program structure window

If you are scrolling through the program structure window block by block, the TNC at the same time automatically moves the corresponding NC blocks in the program window. This way you can quickly skip large program sections.

4.8 Adding Comments

Function

You can add comments to any desired block in the part program to explain program steps or make general notes. There are three possibilities to add comments:



Entering comments during programming

- Enter the data for a program block, then press the semicolon key ";" on the alphabetic keyboard—the TNC displays the dialog prompt **COMMENT ?**
- Enter your comment and conclude the block by pressing the END key.

Inserting comments after program entry

- Select the block to which a comment is to be added.
- Select the last word in the block with the right arrow key: A semicolon appears at the end of the block and the TNC displays the dialog prompt **COMMENT ?**
- Enter your comment and conclude the block by pressing the END key.

Entering a comment in a separate block

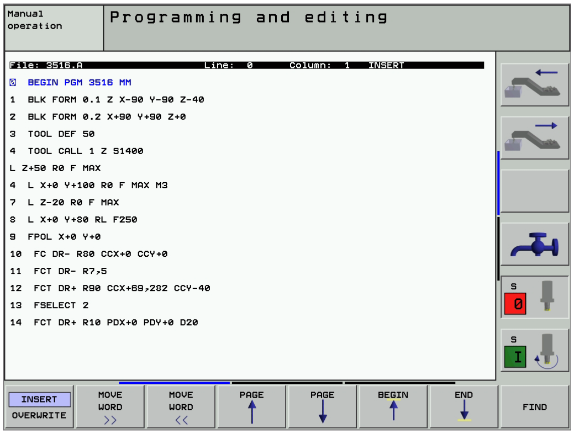
- Select the block after which the comment is to be inserted.
- Initiate the programming dialog with the semicolon key ";" on the alphabetic keyboard.
- Enter your comment and conclude the block by pressing the END key.

Functions for editing of the comment

Function	Soft key
Jump to the beginning of the comment.	BEGIN ←
Jump to the end of the comment.	END →
Jump to the beginning of a word. Words are to be separated by a space.	MOVE WORD <<
Jump to the end of a word. Words are to be separated by a space.	MOVE WORD >>
Switch between insert mode and overwrite mode.	INSERT OVERWRITE

4.9 Creating Text Files

Function



You can use the TNC's text editor to write and edit texts. Typical applications:

- Recording test results
- Documenting working procedures
- Creating formularies

Text files are type .A files (ASCII files). If you want to edit other types of files, you must first convert them into type .A files.

Opening and exiting text files

- Select the Programming and Editing mode of operation.
- To call the file manager, press the PGM MGT key.
- To display type .A files, press the SELECT TYPE and then the SHOW .A soft keys.
- Select a file and open it with the SELECT soft key or ENT key, or create a new file by entering the new file name and confirming your entry with the ENT key.

To leave the text editor, call the file manager and select a file of a different file type, for example a part program.

Cursor movements	Soft key
Move one word to the right	MOVE WORD >>
Move one word to the left	MOVE WORD <<
Go to next screen page	PAGE ↓
Go to previous screen page	PAGE ↑
Go to beginning of file	BEGIN ↑
Go to end of file	END ↓

Editing functions	Key
Begin a new line	RET
Erase the character to the left of the cursor	X
Insert a blank space	SPACE
Switch between upper and lower case letters	SHIFT SPACE

Editing texts

The first line of the text editor is an information headline which displays the file name, and the location and writing mode of the cursor:

File:	Name of the text file
Line:	Line in which the cursor is presently located
Column:	Column in which the cursor is presently located
INSERT:	Insert new text, pushing the existing text to the right
OVERWRITE:	Write over the existing text, erasing it where it is replaced with the new text.

The text is inserted or overwritten at the location of the cursor. You can move the cursor to any desired position in the text file by pressing the arrow keys.

The line in which the cursor is presently located is depicted in a different color. A line can have up to 77 characters. To start a new line, press the RET key or the ENT key.

Erasing and inserting characters, words and lines

With the text editor, you can erase words and even lines, and insert them at any desired location in the text.

- Move the cursor to the word or line you wish to erase and insert at a different place in the text.
- Press the DELETE WORD or DELETE LINE soft key: The text is placed in the buffer memory.
- Move the cursor to the location where you wish insert the text, and press the RESTORE LINE/WORD soft key.

Function	Soft key
Delete and temporarily store a line	DELETE LINE
Delete and temporarily store a word	DELETE WORD
Delete and temporarily store a character	DELETE CHAR
Insert a line or word from temporary storage	INSERT LINE / WORD

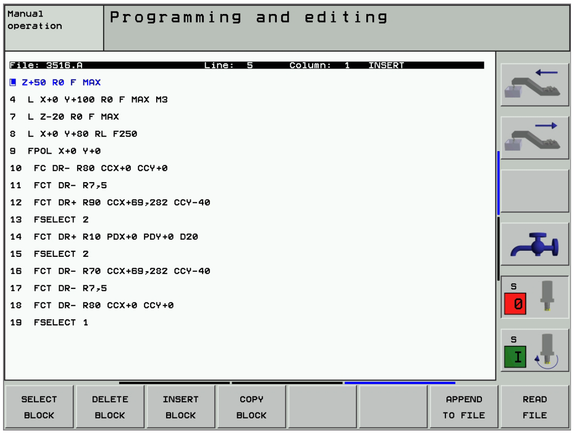
Editing text blocks

You can copy and erase text blocks of any size, and insert them at other locations. Before carrying out any of these editing functions, you must first select the desired text block:

- To select a text block, move the cursor to the first character of the text you wish to select.

SELECT BLOCK

- Press the SELECT BLOCK soft key.
- Move the cursor to the last character of the text you wish to select. You can select whole lines by moving the cursor up or down directly with the arrow keys—the selected text is shown in a different color.



After selecting the desired text block, you can edit the text with the following soft keys:

Function	Soft key
Delete the selected text and store temporarily	DELETE BLOCK
Store marked block temporarily without erasing (copy)	INSERT BLOCK

If necessary, you can now insert the temporarily stored block at a different location

- Move the cursor to the location where you want to insert the temporarily stored text block.

INSERT BLOCK

- Press the INSERT BLOCK soft key: The text block is inserted.

You can insert the temporarily stored text block as often as desired.

To transfer the selected text to a different file

- Select the text block as described previously.

APPEND TO FILE

- Press the APPEND TO FILE soft key. The TNC displays the dialog prompt **`Destination file =`**
- Enter the path and name of the target file. The TNC appends the selected text to the end of the specified file. If no target file with the specified name is found, the TNC creates a new file with the selected text.

To insert another file at the cursor position

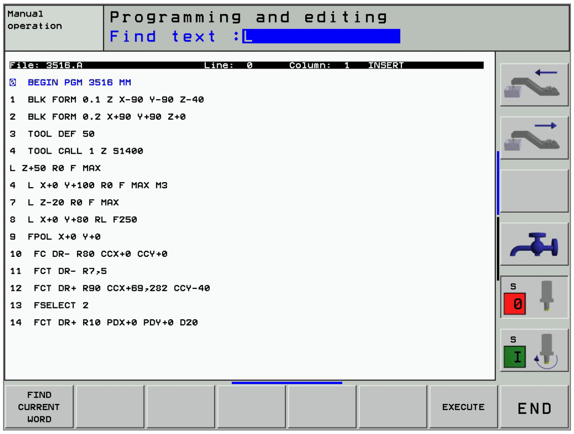
- Move the cursor to the location in the text where you wish to insert another file.

READ FILE

- Press the READ FILE soft key. The TNC displays the dialog prompt **`File name =`**
- Enter the path and name of the file you want to insert.

Finding text sections

With the text editor, you can search for words or character strings in a text. Two functions are available:



Finding the current text

The search function is to find the next occurrence of the word in which the cursor is presently located:

- Move the cursor to the desired word.
- To select the search function, press the FIND soft key.
- Press the FIND CURRENT WORD soft key.
- To leave the search function, press the END soft key.

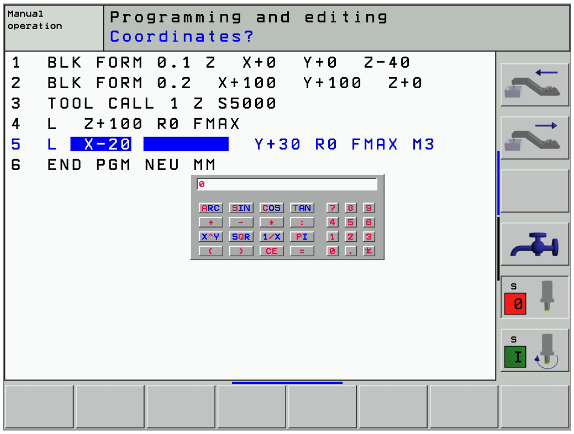
Finding any text

- To select the search function, press the FIND soft key. The TNC displays the dialog prompt **`Find text:`**
- Enter the text that you wish to find.
- To find the text, press the EXECUTE soft key.
- To leave the search function, press the END soft key.

4.10 Integrated Pocket Calculator

Operation

The TNC features an integrated pocket calculator with the basic mathematical functions.



- ▶ Use the CALC key to show and hide the on-line pocket calculator.
- ▶ The calculator is operated with short commands through the alphabetic keyboard. The commands are shown in a special color in the calculator window:

Mathematical function	Command (key)
Addition	+
Subtraction	–
Multiplication	*
Division	:
Sine	S
Cosine	C
Tangent	T
Arc sine	AS
Arc cosine	AC
Arc tangent	AT
Powers	^
Square root	Q
Inversion	/
Parenthetic calculations	( )
p (3.14159265359)	P
Display result	=

To transfer the calculated value into the program,

- ▶ Select the word into which the calculated value is to be transferred by using the arrow keys.
- ▶ Superimpose the on-line calculator by using the CALC key and perform the desired calculation.
- ▶ Press the actual position capture key for the TNC to superimpose a soft-key row.
- ▶ Press the CALC soft key for the TNC to transfer the value into the active input box and to close the calculator.

4.11 Immediate Help for NC Error Messages

Displaying error messages

The TNC automatically generates error messages when it detects problems such as

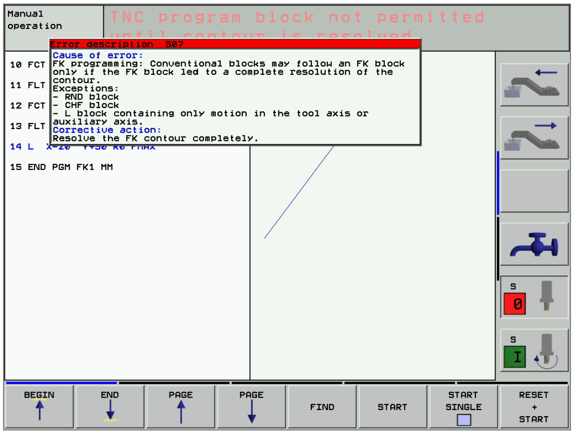
- Incorrect data input
- Logical errors in the program
- Contour elements that are impossible to machine
- Incorrect use of the touch probe system

An error message that contains a program block number was caused by an error in the indicated block or in the preceding block. The TNC error messages can be canceled with the CE key, after the cause of the error has been removed.

If you require more information on a particular error message, press the HELP key. A window is then superimposed where the cause of the error is explained and suggestions are made for correcting the error.

Display HELP

- ▶ To display Help, press the HELP key.
- ▶ Read the description of the error and the possibilities for correcting it. Close the Help window with the CE, thus canceling the error message.
- ▶ Remove the cause of the error as described in the Help window.

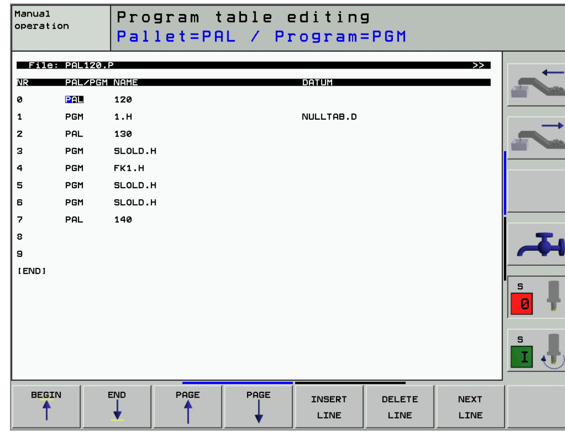


The TNC displays the Help text automatically if the error message is flashing. The TNC needs to be restarted after blinking error messages. To restart the TNC, press the END key and hold for two seconds.

4.12 Pallet Management

Function

> Pallet table management is a machine-dependent function. The standard functional range will be described in the following. Refer to your machine manual for more information.



Pallet tables are used for machining centers with pallet changer: The pallet table calls the part programs that are required for the different pallets, and activates datum shifts or datum tables.

You can also use pallet tables to run in succession several programs that have different datums.

Pallet tables contain the following information:

- **PAL/PGM** (entry obligatory):
  Identification for pallet or NC program (select with ENT or NO ENT)
- **NAME** (entry obligatory):
  Pallet or program name. The machine tool builder determines the pallet name (see Machine Manual). The program name must be stored in the same directory as the pallet table. Otherwise you must enter the full path name for the program.
- **DATUM** (entry optional):
  Name of the datum table. The datum table must be stored in the same directory as the pallet table. Otherwise you must enter the full path name for the datum table. Datums from the datum table can be activated in the NC program with Cycle 7 **DATUM SHIFT.**
- **X, Y, Z** (entry optional, other axes also possible):
  For pallet names, the programmed coordinates are referenced to the machine datum. For NC programs, the programmed coordinates are referenced to the pallet datum. These entries overwrite the datum that you last set in the Manual mode of operation. With the miscellaneous function M104 you can reactivate the datum that was last set. With the actual-position-capture key, the TNC opens a window that enables you to have the TNC enter various points as datums (see table below):

Position	Meaning
Actual values	Enter the coordinates of the current tool position relative to the active coordinate system.
Reference values	Enter the coordinates of the current tool position relative to the machine datum.
IST measured values	Enter the coordinates relative to the active coordinate system of the datum last probed in the Manual operating mode.
REF measured values	Enter the coordinates relative to the machine datum of the datum last probed in the Manual operating mode.

With the arrow keys and ENT, select the position that you wish to confirm. Then press the ALL VALUES soft key so that the TNC saves the respective coordinates of all active axes in the pallet table. With the PRESENT VALUE soft key, the TNC saves the coordinates of the axis on which the highlight in the pallet table is presently located.

> If you have not defined a pallet before an NC program, the programmed coordinates are then referenced to the machine datum. If you do not define an entry, the datum that was set manually remains active.

Editing function	Soft key
Select beginning of table	BEGIN ↑
Select end of table	END ↓
Select previous page in table	PAGE ↑
Select next page in table	PAGE ↓
Insert the last line in the table	INSERT LINE
Delete the last line in the table	DELETE LINE
Go to the beginning of the next line	NEXT LINE
Add the entered number of lines to the end of the table	APPEND N LINES
Copy the highlighted field (2nd soft-key row)	COPY FIELD
Insert the copied field (2nd soft-key row)	PASTE FIELD

Selecting a pallet table

- Call the file manager in the Programming and Editing or Program Run mode: Press the PGM MGT key.
- To display all type .P files, press the soft keys SELECT TYPE and SHOW .P.
- Select a pallet table with the arrow keys, or enter a new file name to create a new table.
- Confirm your entry with the ENT key.

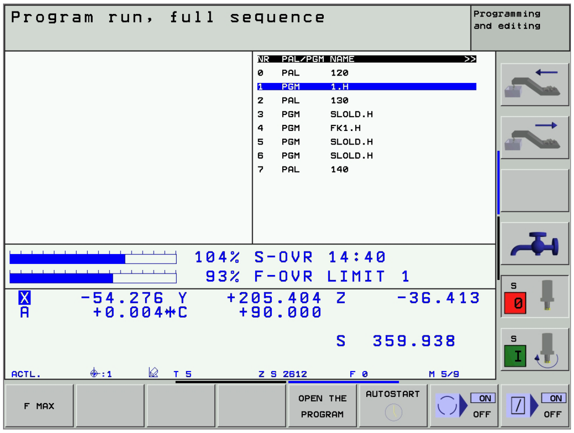
Leaving the pallet file

- To call the file manager, press the PGM MGT soft key.
- To select a different type of file, press the SELECT TYPE soft key and the soft key for the desired file type, for example SHOW.H.
- Select the desired file.

Executing the pallet file

> In MP7683, set whether the pallet table is to be executed blockwise or continuously (see "General User Parameters" on page 470).

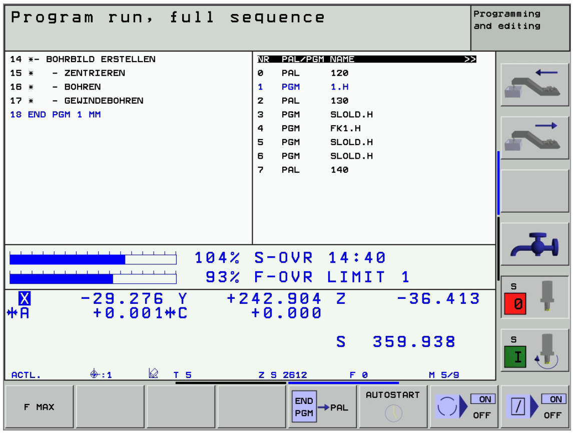
- Select the file manager in the Program Run, Full Sequence or Program Run, Single Block operating modes: Press the PGM MGT key.
- To display all type .P files, press the soft keys SELECT TYPE and SHOW .P.
- Select the pallet table with the arrow keys and confirm with ENT.
- To execute the pallet table: Press the NC Start button. The TNC executes the pallets as set in MP7683.



Screen layout for executing pallet tables

You can have the TNC display the program contents and pallet file contents on the screen together by selecting the screen layout PGM + PALLET. During execution, the TNC then shows program blocks to the left and the pallet to the right. To check the program contents before execution, proceed as follows:

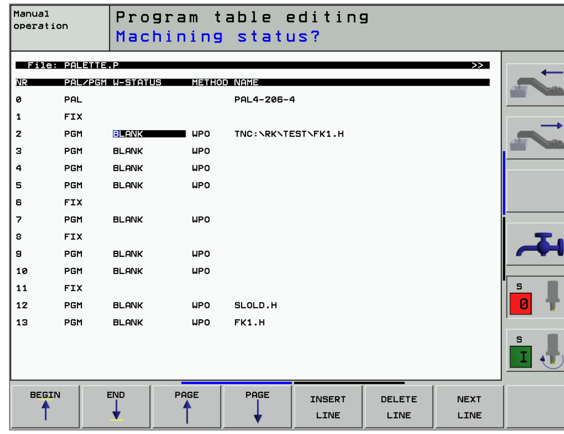
- Select a pallet table.
- With the arrow keys, choose the program you would like to check.
- Press the OPEN PGM soft key: The TNC displays the selected program on the screen. You can now page through the program with the arrow keys.
- To return to the pallet table, press the END PGM soft key.



4.13 Pallet Operation with Tool-Oriented Machining

Function

Pallet management in combination with tool-oriented machining is a machine-dependent function. The standard functional range will be described in the following. Refer to your machine manual for more information.



Pallet tables are used for machining centers with pallet changer: The pallet table calls the part programs that are required for the different pallets, and activates datum shifts or datum tables.

You can also use pallet tables to run in succession several programs that have different datums.

Pallet tables contain the following information:

- **PAL/PGM** (entry obligatory):
  The entry **PAL** identifies the pallet, **FIX** marks the fixture plane and **PGM** is used to enter the workpiece.
- **W-STATE:**
  Current machining status. The machining status is used to determine the current stage of machining. Enter **BLANK** for an unmachined (raw) workpiece. During machining, the TNC changes this entry to **INCOMPLETE**, and after machining has finished, to **ENDED.** The entry **EMPTY** is used to identify a space at which no workpiece is to be clamped or where no machining is to take place.
- **METHOD** (entry obligatory):
  Entry which determines the method of program optimization. Machining is workpiece-oriented if **WPO** is entered. Machining of the piece is tool-oriented if **TO** is entered. In order to include subsequent workpieces in the tool-oriented machining, you must enter **CTO** (continued tool oriented). Tool-oriented machining is also possible with pallet fixtures, but not for multiple pallets.
- **NAME** (entry obligatory):
  Pallet or program name. The machine tool builder determines the pallet name (see Machine Manual). Programs must be stored in the same directory as the pallet table. Otherwise you must enter the full path name for the program.

- **DATUM** (entry optional):
  Name of the datum table. The datum table must be stored in the same directory as the pallet table. Otherwise you must enter the full path name for the datum table. Datums from the datum table can be activated in the NC program with Cycle 7 **DATUM SHIFT.**
- **X, Y, Z** (entry optional, other axes also possible):
  For pallets and fixtures, the programmed coordinates are referenced to the machine datum. For NC programs, the programmed coordinates are referenced to the pallet or fixture datum. These entries overwrite the datum that you last set in the Manual mode of operation. With the miscellaneous function M104 you can reactivate the datum that was last set. With the actual-position-capture key, the TNC opens a window that enables you to have the TNC enter various points as datums (see table below):

Position	Meaning
Actual values	Enter the coordinates of the current tool position relative to the active coordinate system.
Reference values	Enter the coordinates of the current tool position relative to the machine datum.
IST measured values	Enter the coordinates relative to the active coordinate system of the datum last probed in the Manual operating mode.
REF measured values	Enter the coordinates relative to the machine datum of the datum last probed in the Manual operating mode.

With the arrow keys and ENT, select the position that you wish to confirm. Then press the ALL VALUES soft key so that the TNC saves the respective coordinates of all active axes in the pallet table. With the PRESENT VALUE soft key, the TNC saves the coordinates of the axis on which the highlight in the pallet table is presently located.

If you have not defined a pallet before an NC program, the programmed coordinates are then referenced to the machine datum. If you do not define an entry, the datum that was set manually remains active.

- **SP-X, SP-Y, SP-Z** (entry optional, other axes also possible):
  Safety positions can be entered for the axes. These positions can be read with SYSREAD FN18 ID510 NR 6 from NC macros. SYSREAD FN18 ID510 NR 5 can be used to determine if a value was programmed in the column. The positions entered are only approached if these values are read and correspondingly programmed in the NC macros.

- **CTID** (entered by the TNC):
  The context ID number is assigned by the TNC and contains instructions about the machining progress. Machining cannot be resumed if the entry is deleted or changed.

Editing function in table mode	Soft key
Select beginning of table	BEGIN ↑
Select end of table	END ↓
Select previous page in table	PAGE ↑
Select next page in table	PAGE ↓
Insert the last line in the table	INSERT LINE
Delete the last line in the table	DELETE LINE
Go to the beginning of the next line	NEXT LINE
Add the entered number of lines to the end of the table	APPEND N LINES
Copy the highlighted field (2nd soft-key row)	COPY FIELD
Insert the copied field (2nd soft-key row)	PASTE FIELD

Editing function in entry-form mode	Soft key
Select previous pallet	PALLET ↑
Select next pallet	PALLET ↓
Select previous fixture	FIXTURE ↑
Select next fixture	FIXTURE ↓
Select previous workpiece	WORKPIECE ↑
Select next workpiece	WORKPIECE ↓

Editing function in entry-form mode	Soft key
Switch to pallet plane	VIEW PALLET PLANE
Switch to fixture plane	VIEW FIXTURE PLANE
Switch to workpiece plane	VIEW WORKPIECE PLANE
Select standard pallet view	PALLET DETAIL OF PALLET
Select detailed pallet view	PALLET DETAIL OF PALLET
Select standard fixture view	FIXTURE DETAIL OF FIXTURE
Select detailed fixture view	FIXTURE DETAIL OF FIXTURE
Select standard workpiece view	WORKPIECE DETAIL OF WORKPIECE
Select detailed workpiece view	WORKPIECE DETAIL OF WORKPIECE
Insert pallet	INSERT PALLET
Insert fixture	INSERT FIXTURE
Insert workpiece	INSERT WORKPIECE
Delete pallet	DELETE PALLET
Delete fixture	DELETE FIXTURE
Delete workpiece	DELETE WORKPIECE
Copy all fields to clipboard	COPY ALL FIELDS
Copy highlighted field to clipboard	COPY SELECTED FIELD
Insert the copied field	PASTE FIELDS
Delete clipboard contents	ERASE INTERMED. MEMORY

Editing function in entry-form mode	Soft key
Tool-optimized machining	TOOL ORIENTAT.
Workpiece-optimized machining	WORKPIECE ORIENTAT.
Connecting or separating the types of machining	CONNECTED DIS- CONNECTED
Mark plane as being empty	EMPTY POSITION
Mark plane as being unmachined	BLANK

Selecting a pallet file

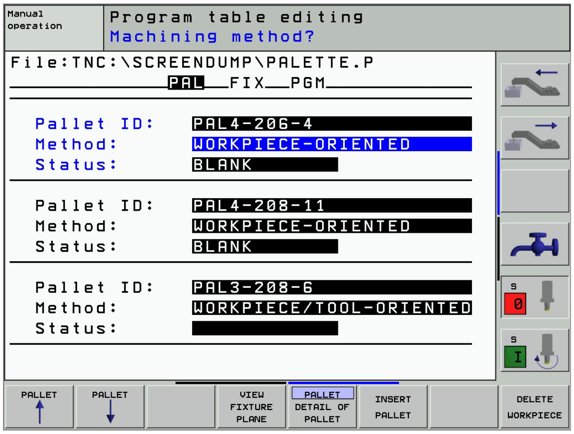
- Call the file manager in the Programming and Editing or Program Run mode: Press the PGM MGT key.
- Display all type .P files: Press the soft keys SELECT TYPE and SHOW .P.
- Select a pallet table with the arrow keys, or enter a new file name to create a new table.
- Confirm your entry with the ENT key.

Setting up the pallet file with the entry form

Pallet operation with tool- or workpiece-oriented machining is divided into three planes:

- Pallet plane **PAL**
- Fixture plane **FIX**
- Workpiece plane **PGM**

You can switch to a detail view in each plane. Set the machining method and the pallet, fixture and workpiece statuses in the standard view. If you are editing an existing pallet file, the updated entries are displayed. Use the detail view for setting up the pallet file.



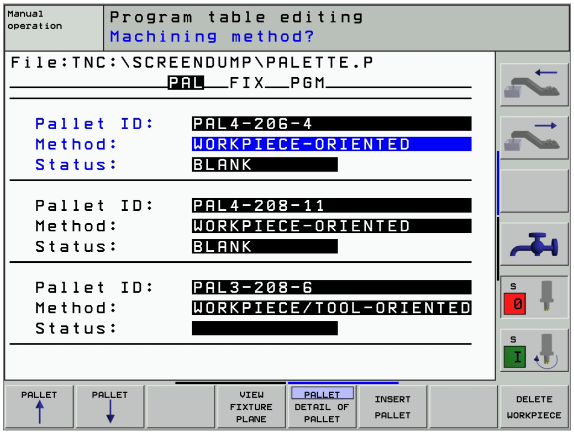
> Set up the pallet file according to the machine configuration. If you only have one fixture with multiple workpieces, then defining one fixture **FIX** with the workpieces **PGM** is sufficient. However, if one pallet contains several fixtures, or if a fixture is machined from more than one side, you must define the pallet **PAL** with the corresponding fixture planes **FIX.**
>
> Use the screen layout button to switch between table view and form view.
>
> Graphic support for form entry is not yet available.

The various planes of the entry form can be reached with the appropriate soft keys. The current plane is highlighted in the status line of the entry form. When you switch to table view with the screen layout button, the cursor is placed in the same plane as it was in the form view.

Setting up the pallet plane

- **`Pallet Id`**: The pallet name is displayed
- **`Method`**: You can choose between the WORKPIECE ORIENTED and TOOL ORIENTED machining methods. The selected method is assumed for the workpiece plane and overwrites any existing entries. In tabular view, WORKPIECE ORIENTED appears as **`WPO`**, and TOOL ORIENTED appears as **`TO`**.

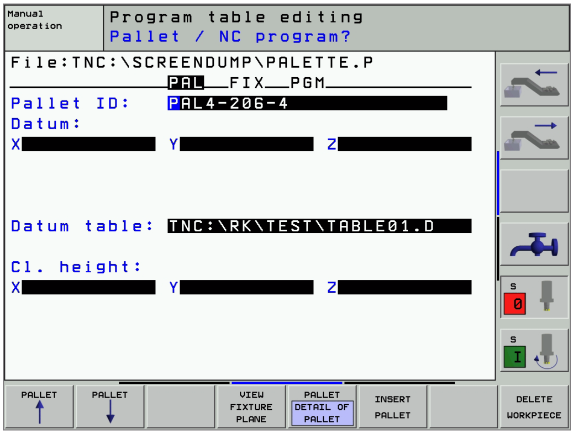
> The TO-/WP-ORIENTED entry cannot be made via soft key. It only appears when different machining methods were chosen for the workpieces in the workpiece or machining plane.
>
> If the machining method was determines in the fixture plane, the entries are carried over to the workpiece plane, where they overwrite any existing entries.



- **`Status`**: The soft key **`BLANK`** identifies the pallet and the corresponding fixtures and workpieces as not yet having been machined, and enters **`BLANK`** in the Status field. Use the soft key **`EMPTY POSITION`** if you want to skip the pallet during machining. **`EMPTY`**appears in the Status field.

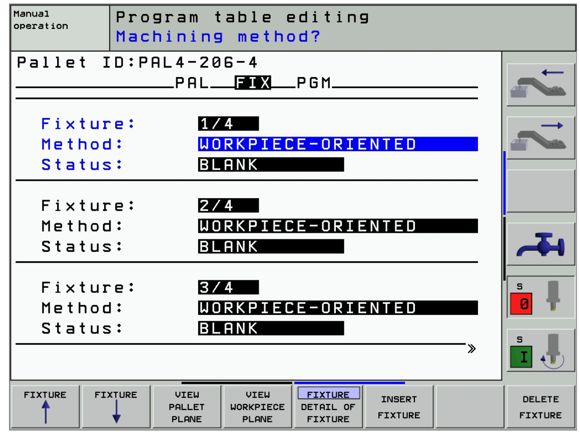
Setting up details in the pallet plane

- **`Pallet ID:`** Enter the pallet name
- **`Datum:`** Enter the pallet datum
- **`Datum table:`** Enter the name and path of the datum table of the workpiece. The data is carried over to the fixture and workpiece planes.
- **`Safe height:`** (optional): Safe position for the individual axes referenced to the pallet. The positions entered are only approached if these values were read and correspondingly programmed in the NC macros.



Setting up the fixture plane

- **Fixture:** The number of the fixture is displayed. The number of fixtures within this plane is shown after the slash.
- **Method**: You can choose between the WORKPIECE ORIENTED and TOOL ORIENTED machining methods. The selected method is assumed for the workpiece plane and overwrites any existing entries. In tabular view, entry WORKPIECE ORIENTED appears as **WPO**, and TOOL ORIENTED appears as **TO**.
  Use the **CONNECT/SEPARATE** soft key to mark fixtures that are to be included for calculating the machining process for tool-oriented machining. Connected fixtures are marked with a dashed line, whereas separated fixtures are connected with a solid line. Connected workpieces are marked in tabular view with the entry **CTO** in the METHOD column.

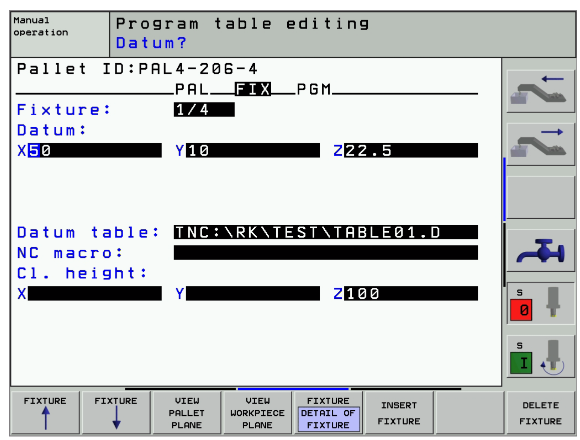


> The TO-/WP-ORIENTED entry cannot be made via soft key. It only appears when different machining methods were chosen for the workpieces in the workpiece plane.
>
> If the machining method was determines in the fixture plane, the entries are carried over to the workpiece plane, where they overwrite any existing entries.

- **Status**: The soft key **BLANK** identifies the fixture and the corresponding workpieces as not yet having been machined, and enters BLANK in the Status field. Use the soft key **EMPTY POSITION** if you want to skip the fixture during machining. **EMPTY**appears in the Status field.

Setting up details in the fixture plane

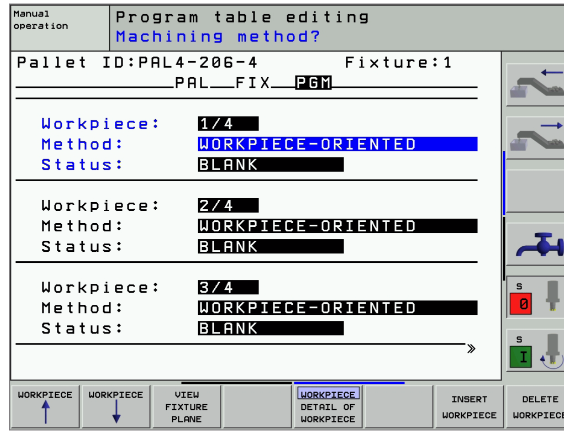
- **Fixture:** The number of the fixture is displayed. The number of fixtures within this plane is shown after the slash.
- **Datum:** Enter the fixture datum
- **Datum table:** Enter the name and path of the datum table valid for machining the workpiece. The data is carried over to the workpiece plane.
- **NC macro:** In tool-oriented machining, the macro TCTOOLMODE is carried out instead of the normal tool-change macro.
- **Safe height:** (optional): Safe position for the individual axes referenced to the fixture.



> Safety positions can be entered for the axes. These positions can be read with SYSREAD FN18 ID510 NR 6 from NC macros. SYSREAD FN18 ID510 NR 5 can be used to determine if a value was programmed in the column. The positions entered are only approached if these values are read and correspondingly programmed in the NC macros.

Setting up the workpiece plane

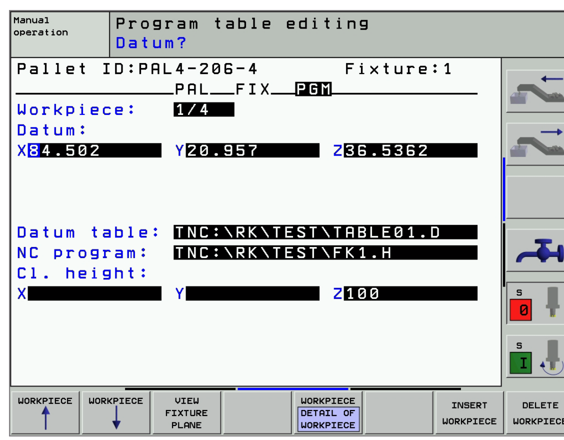
- **Workpiece:** The number of the workpiece is displayed. The number of workpieces within this fixture plane is shown after the slash.
- **Method**: You can choose between the WORKPIECE ORIENTED and TOOL ORIENTED machining methods. In tabular view, entry WORKPIECE ORIENTED appears as **WPO**, and TOOL ORIENTED appears as **TO**.
  Use the **CONNECT/SEPARATE** soft key to mark workpieces that are to be included for calculating the machining process for tool-oriented machining. Connected workpieces are marked with a dashed line, whereas separated workpieces are connected with a solid line. Connected workpieces are marked in tabular view with the entry **CTO** in the METHOD column.
- **Status**: The soft key **BLANK** identifies the workpiece as not yet having been machined, and enters BLANK in the Status field. Use the soft key **EMPTY POSITION** if you want to skip the workpiece during machining. EMPTY appears in the Status field.



> Enter the method and status in the pallet or fixture plane. Then the entry will be assumed for all corresponding workpieces.
>
> For several workpiece variants within one plane, the workpieces of one variant should be entered together. This way, the workpieces of each variant can be marked with the CONNECT/SEPARATE soft key, and can be machined in groups.

Setting up details in the workpiece plane

- **Workpiece:** The number of the workpiece is displayed. The number of workpieces within this fixture or pallet plane is shown after the slash.
- **Datum:** Enter the workpiece datum
- **Datum table:** Enter the name and path of the datum table valid for machining the workpiece. If you use the same datum table for all workpieces, enter the name and path in the pallet or fixture planes. The data is automatically carried over to the workpiece plane.
- **NC program:** Enter the path of the NC program that is necessary for machining the workpiece
- **Safe height:** (optional): Safe position for the individual axes referenced to the workpiece. The positions entered are only approached if these values were read and correspondingly programmed in the NC macros.



Sequence of tool-oriented machining

> The TNC only carries out tool-oriented machining if the TOOL ORIENTED method was selected, and TO or CTO is entered in the table.

- The entry TO or CTO in the Method field tells the TNC that the oriented machining is valid beyond these lines.
- The pallet management starts the NC program given in the line with the entry TO.
- The first workpiece is machined until the next tool call is pending. Departure from the workpiece is coordinated by a special tool-change macro.
- The entry in the column W-STATE is changed from BLANK to INCOMPLETE, and the TNC enters a hexadecimal value in the field CTID.

> The value entered in the field CTID is a unique identifier of the machining progress for the TNC. If these value is deleted or changed, machining cannot be continued, nor is mid-program startup or resumption of machining possible.

- All lines in the pallet file that contain the entry CTO in the Method field are machined in the same manner as the first workpiece. Workpieces in several fixtures can be machined.
- The TNC uses the next tool for the following machining steps again from the line with the entry TO if one of the following situations applies:
  - If the entry PAL is in the PAL/PGM field in the next line.
  - If the entry TO or WPO is in the Method field in the next line.
  - If in the lines already machined there are entries under Method which do not have the status EMPTY or ENDED.
- The NC program is continued at the stored location based on the value entered in the CTID field. Usually the tool is changed for the first piece, but the TNC suppresses the tool change for the following workpieces.
- The entry in the CTID field is updated after every machining step. If an END PGM or M02 is executed in an NC program, then an existing entry is deleted and ENDED is entered in the Machining Status field.

- If the entries TO or CTO for all workpieces within a group contain the status ENDED, the next lines in the pallet file are run.

> In mid-program startup, only one tool-oriented machining is possible. Following pieces are machined according to the method entered.
>
> The value entered in the CTID field is stored for a maximum of one week. Within this time the machining can be continued at the stored location. After this time the value is deleted, in order to prevent large amounts of unnecessary data on the hard disk.
>
> The operating mode can be changed after executing a group of entries with TO or CTO.
>
> The following functions are not permitted:
>
> - Switching the traverse range
> - PLC datum shift
> - M118

To leave the pallet file:

- To call the file manager, press the PGM MGT soft key.
- To select a different type of file, press the SELECT TYPE soft key and the soft key for the desired file type, for example SHOW.H.
- Select the desired file.

Executing the pallet file

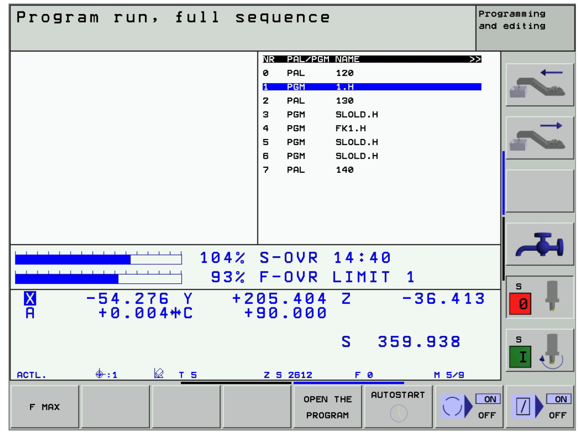
> In machine parameter 7683, set whether the pallet table is to be executed blockwise or continuously (see “General User Parameters” on page 470).

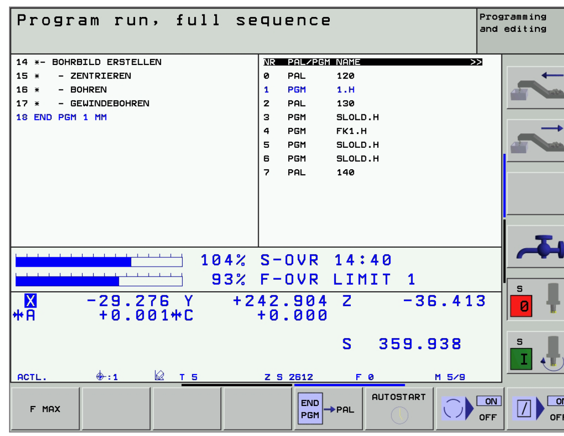
- Select the file manager in the operating mode Program Run, Full Sequence or Program Run, Single Block: Press the PGM MGT key.
- Display all type .P files: Press the soft keys SELECT TYPE and SHOW .P.
- Select pallet table with the arrow keys and confirm with ENT.
- To execute pallet table: Press the NC Start button. The TNC executes the pallets as set in Machine Parameter 7683.

Screen layout for executing pallet tables

You can have the TNC display the program contents and pallet file contents on the screen together by selecting the screen layout PGM + PALLET. During execution, the TNC then shows program blocks to the left and the pallet to the right. To check at the program contents before execution, proceed as follows:

- Select a pallet table.
- With the arrow keys, choose the program you would like to check.
- Press the OPEN PGM soft key: The TNC displays the selected program on the screen. You can now page through the program with the arrow keys.
- To return to the pallet table, press the END PGM soft key.



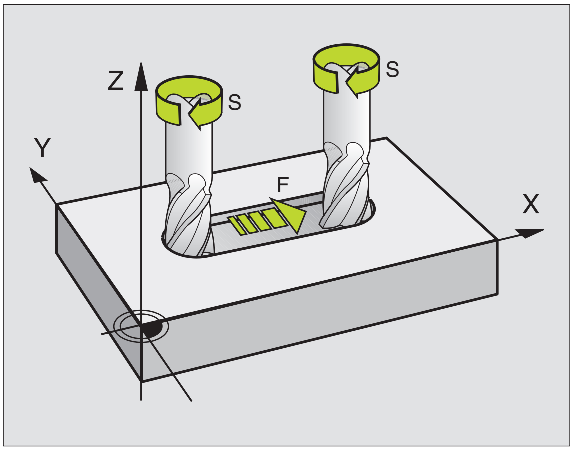


5

Programming: Tools

5.1 Entering Tool-Related Data

Feed rate F



The feed rate **F** is the speed (in millimeters per minute or inches per minute) at which the tool center moves. The maximum feed rates can be different for the individual axes and are set in machine parameters.

Input

You can enter the feed rate in the **TOOL CALL** block and in every positioning block (see “Creating the program blocks with the path function keys” on page 135).

Rapid traverse

If you wish to program rapid traverse, enter **F MAX.** To enter **F MAX,** press the ENT key or the F MAX soft key when the dialog question **FEED RATE F = ?** appears on the TNC screen.

> To move your machine in rapid traverse, you can also program the corresponding numerical value, e.g. **F30000**. Unlike FMAX, this rapid traverse remains in effect not only in the individual block but in all blocks until you program a new feed rate.

Duration of effect

A feed rate entered as a numerical value remains in effect until a block with a different feed rate is reached. **F MAX** is only effective in the block in which it is programmed. After the block with **F MAX** is executed, the feed rate will return to the last feed rate entered as a numerical value.

Changing during program run

You can adjust the feed rate during program run with the feed-rate override knob.

Spindle speed S

The spindle speed S is entered in revolutions per minute (rpm) in a **TOOL CALL** block.

Programmed change

In the part program, you can change the spindle speed in a TOOL CALL block by entering the spindle speed only:

TOOL CALL

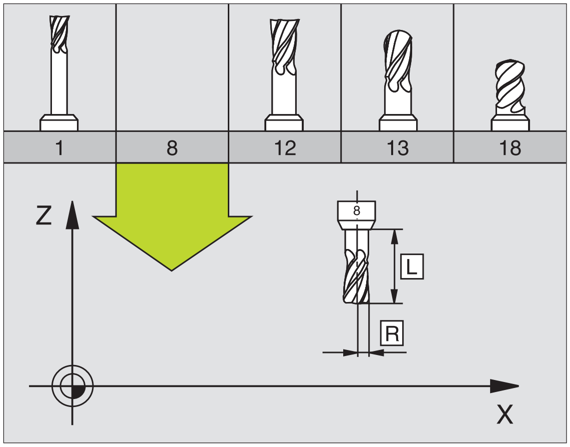
- To program a tool call, press the TOOL CALL key.
- Ignore the dialog question for **Tool number ?** with the NO ENT key.
- Ignore the dialog question for **Working spindle axis X/Y/Z ?** with the NO ENT key.
- Enter the new spindle speed for the dialog question **Spindle speed S= ?,** and confirm with END.

Changing during program run

You can adjust the spindle speed during program run with the spindle-speed override knob.

5.2 Tool Data

Requirements for tool compensation



You usually program the coordinates of path contours as they are dimensioned in the workpiece drawing. To allow the TNC to calculate the tool center path - i.e. the tool compensation - you must also enter the length and radius of each tool you are using.

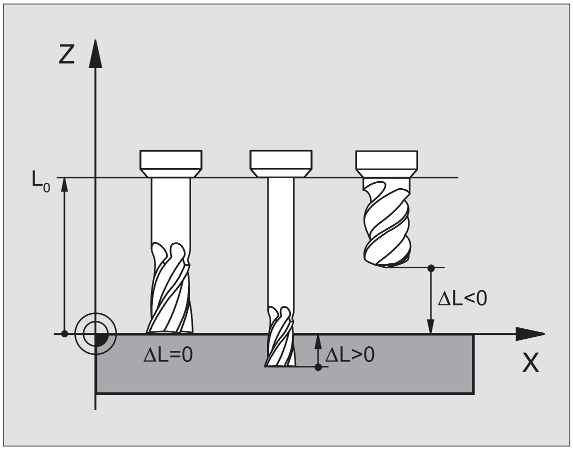
Tool data can be entered either directly in the part program with TOOL DEF or separately in a tool table. In a tool table, you can also enter additional data on the specific tool. The TNC will consider all the data entered for the tool when executing the part program.

Tool numbers and tool names

Each tool is identified by a number between 0 and 254. If you are working with tool tables, you can use higher numbers and you can also enter a tool name for each tool.

The tool number 0 is automatically defined as the zero tool with the length L=0 and the radius R=0. In tool tables, tool 0 should also be defined with L=0 and R=0.

Tool length L



There are two ways to determine the tool length L:

Determining the difference between the length of the tool and that of a zero tool L0

For the algebraic sign:

L>L0:	The tool is longer than the zero tool
L<L0:	The tool is shorter than the zero tool

To determine the length:

- ▶ Move the zero tool to the reference position in the tool axis (e.g. workpiece surface with Z=0).
- ▶ Set the datum in the tool axis to 0 (datum setting).
- ▶ Insert the desired tool.
- ▶ Move the tool to the same reference position as the zero tool.
- ▶ The TNC displays the difference between the current tool and the zero tool.
- ▶ Enter the value in the TOOL DEF block or in the tool table by pressing the actual-position-capture key.

Determining the length L with a tool presetter

Enter the determined value directly in the TOOL DEF tool definition block or in the tool table without further calculations.

Tool radius R

You can enter the tool radius R directly.

Delta values for lengths and radii

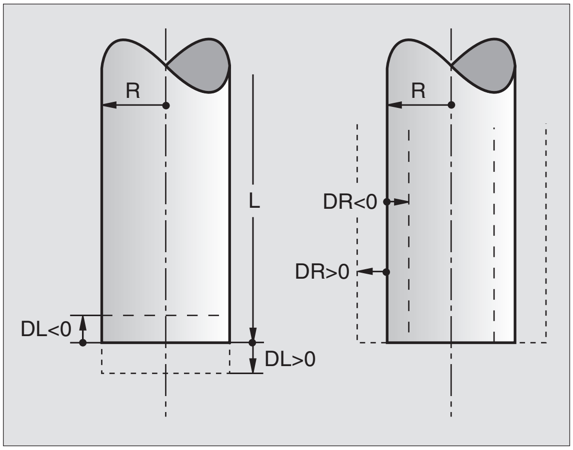
Delta values are offsets in the length and radius of a tool.

A positive delta value describes a tool oversize (DL, DR, DR2>0). If you are programming the machining data with an allowance, enter the oversize value in the TOOL CALL block of the part program.

A negative delta value describes a tool undersize (DL, DR, DR2<0). An undersize is entered in the tool table for wear.

Delta values are usually entered as numerical values. In a TOOL CALL block, you can also assign the values to Q parameters.

Input range: You can enter a delta value with up to ± 99.999 mm.



> Delta values from the tool table, together with the tool length and radius, result in the physical (measurable) size of a tool. By defining the delta values in the program you simply change the calculated size of a tool and, with it, the contour to be machined.

Entering tool data into the program

The number, length and radius of a specific tool is defined in the TOOL DEF block of the part program.

▶ To select tool definition, press the TOOL DEF key.

▶ Tool number : Each tool is uniquely identified by its tool number.

▶ Tool length : Compensation value for the tool length

▶ Tool radius : Compensation value for the tool radius

> In the programming dialog, you can insert the values for tool length and radius directly into the dialog box. Simply press the actual-position capture key and the desired soft key.

Example

```
4 TOOL DEF 5 L+10 R+5
```

Entering tool data in tables

You can define and store up to 32767 tools and their tool data in a tool table. In Machine Parameter 7260, you can define how many tools are to be stored by the TNC when a new table is set up. See also the Editing Functions at a later stage in this Chapter. In order to be able to assign various compensation data to a tool (indexing tool number), machine parameter 7262 must not be equal to 0.

You must use tool tables if

- you wish to use indexed tools such as stepped drills with more than one length compensation value (page 108),
- your machine tool has an automatic tool changer,
- you want to measure tools automatically with the TT 130 touch probe (see the new Touch Probe Cycles User's Manual, Chapter 4),
- you want to rough-mill the contour with Cycle 22 (see "ROUGH-OUT (Cycle 22)" on page 301)
- you want to work with automatic cutting data calculations.

Tool table: Standard tool data

Abbr.	Input	Dialog
T	Number by which the tool is called in the program (e.g. 5, indexed: 5.2)	–
NAME	Name by which the tool is called in the program	**Tool name?**
L	Value for tool length compensation L	**Tool length?**
R	Compensation value for the tool radius R	**Tool radius R?**
R2	Tool radius R2 for toroid cutters (only for 3-D radius compensation or graphical representation of a machining operation with spherical or toroid cutters)	**Tool radius R2?**
DL	Delta value for tool radius R2	**Tool length oversize?**
DR	Delta value for tool radius R	**Tool radius oversize?**
DR2	Delta value for tool radius R2	**Tool radius oversize R2?**
LCUTS	Tooth length of the tool for Cycle 22	**Tooth length in the tool axis?**
ANGLE	Maximum plunge angle of the tool for reciprocating plunge-cut in Cycles 22 and 208	**Maximum plunge angle?**
TL	Set tool lock (**TL**: **T**ool **L**ocked)	**Tool locked?** **Yes = ENT / No = NO ENT**
RT	Number of a replacement tool (**RT**), if available (see also TIME2)	**Replacement tool?**
TIME1	Maximum tool life in minutes. This function can vary depending on the individual machine tool. Your machine manual provides more information on TIME1.	**Maximum tool age?**

Abbr.	Input	Dialog
TIME2	Maximum tool life in minutes during TOOL CALL: If the current tool age exceeds this value, the TNC changes the tool during the next TOOL CALL (see also CUR.TIME).	**Maximum tool age for TOOL CALL?**
CUR.TIME	Time in minutes the tool has been in use: The TNC automatically counts the current tool age. A starting value can be entered for used tools.	**Current tool life?**
DOC	Comment on tool (up to 16 characters)	**Tool description?**
PLC	Information on this tool that is to be sent to the PLC	**PLC status?**
PLC VAL	Value of this tool that is to be sent to the PLC	**PLC value?**
PTYP	Tool type for evaluation in the pocket table	**Tool type for pocket table?**

Tool table: Tool data required for automatic tool measurement

For a description of the cycles governing automatic tool measurement, see the new Touch Probe Cycles Manual, Chapter 4.

Abbr.	Input	Dialog
CUT	Number of teeth (20 teeth maximum)	**Number of teeth ?**
LTOL	Permissible deviation from tool length L for wear detection. If the entered value is exceeded, the TNC locks the tool (status **L**). Input range: 0 to 0.9999 mm	**Wear tolerance: length ?**
RTOL	Permissible deviation from tool radius R for wear detection. If the entered value is exceeded, the TNC locks the tool (status **L**). Input range: 0 to 0.9999 mm	**Wear tolerance: radius ?**
DIRECT.	Cutting direction of the tool for measuring the tool during rotation	**Cutting direction (M3 = –) ?**
TT:R-OFFS	For tool length measurement: tool offset between stylus center and tool center. Preset value: Tool radius R (NO ENT means **R**).	**Tool offset: radius ?**
TT:L-OFFS	Tool radius measurement: tool offset in addition to MP6530 between upper surface of stylus and lower surface of tool. Default: 0	**Tool offset: length ?**
LBREAK	Permissible deviation from tool length L for breakage detection. If the entered value is exceeded, the TNC locks the tool (status **L**). Input range: 0 to 0.9999 mm	**Breakage tolerance: length ?**
RBREAK	Permissible deviation from tool radius R for breakage detection. If the entered value is exceeded, the TNC locks the tool (status L). Input range: 0 to 0.9999 mm	**Breakage tolerance: radius ?**

Tool table: Tool data for automatic speed/feed rate calculations.

Abbr.	Input	Dialog
`TYPE`	Tool type (**`MILL`**=for milling, **`DRILL`** for drilling or boring, TAP for tapping): Press the SELECT TYPE soft key (3rd soft-key row): The TNC superimposes a window where you can select the type of tool you want.	**`Tool type?`**
`TMAT`	Tool material: Press the SELECT MATERIAL soft key (3rd soft-key row): The TNC superimposes a window where you can select the type of material you want.	**`Tool material ?`**
`CDT`	Cutting data table: Press the SELECT CDT soft key (3rd soft-key row): The TNC superimposes a window where you can select a cutting data table.	**`Name of cutting data table ?`**

Tool table: Tool data for 3-D touch trigger probe (only when bit 1 is set in MP7411 = 1, see also the Touch Probe Cycles Manual)

Abbr.	Input	Dialog
`CAL-OF1`	During calibration, the TNC stores in this column the center misalignment in the reference axis of the 3-D probe, if a tool number is indicated in the calibration menu	**`Center misalignmt. in ref. axis?`**
`CAL-OF2`	During calibration, the TNC stores in this column the center misalignment in the minor axis of the 3-D probe, if a tool number is indicated in the calibration menu	**`Center misalignment minor axis?`**
`CAL-ANG`	During calibration, the TNC stores in this column the spindle angle at which the 3-D probe was calibrated, if a tool number is indicated in the calibration menu	**`Spindle angle for calibration?`**

Editing tool tables

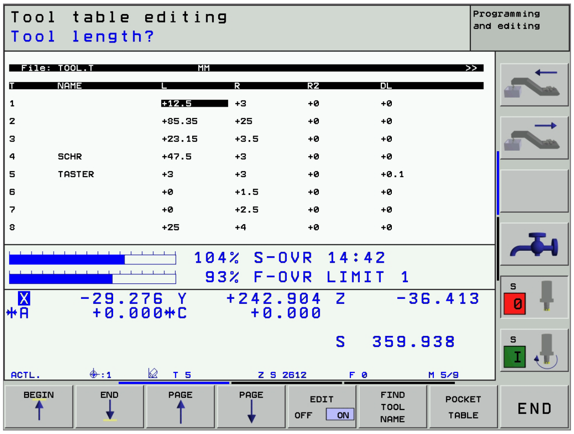
The tool table that is active during execution of the part program is designated as TOOL.T. TOOL.T must be saved in the directory TNC:\, and can only be edited in one of the machine operating modes. Other tool tables that are used for archiving or test runs are given different file names with the extension ".T".

To open the tool table TOOL.T:

▶ Select any machine operating mode.

▶ To select the tool table, press the TOOL TABLE soft key.

▶ Set the EDIT soft key to ON.



To open any other tool table:

- Select the Programming and Editing mode of operation.

PGM MGT

- Call the file manager.
- To select the file type, press the SELECT TYPE soft key.
- To show type .T files, press the SHOW .T soft key.
- Select a file or enter a new file name. Conclude your entry with the ENT key or the SELECT soft key.

When you have opened the tool table, you can edit the tool data by moving the cursor to the desired position in the table with the arrow keys or the soft keys. You can overwrite the stored values, or enter new values at any position. The available editing functions are illustrated in the table below.

If the TNC cannot show all positions in the tool table in one screen page, the highlight bar at the top of the table will display the symbol "**>>**" or "**<<**".

Editing functions for tool tables	Soft key
Select beginning of table	BEGIN ↑
Select end of table	END ↓
Select previous page in table	PAGE ↑
Select next page in table	PAGE ↓
Look for the tool name in the table	FIND TOOL NAME
Show tool information in columns or show all information on one tool on one screen page	LIST FORM
Move to beginning of line	BEGIN LINE ←
Move to end of line	END LINE →
Copy highlighted field	COPY FIELD
Insert copied field	PASTE FIELD
Add the entered number of lines (tools) to the end of the table.	APPEND N LINES

Editing functions for tool tables	Soft key
Insert a line for the indexed tool number after the active line. The function is only active if you are permitted to store various compensation data for a tool (machine parameter 7262 not equal to 0). The TNC inserts a copy of the tool data after the last available index and increases the index by 1. Application: e.g. stepped drill with more than one length compensation value.	INSERT LINE
Delete current line (tool)	DELETE LINE
Display / Do not display pocket numbers	POCKET # DISPLAY HIDE
Display all tools / only those tools that are stored in the pocket table	TOOLS DISPLAY HIDE

Leaving the tool table

- Call the file manager and select a file of a different type, such as a part program.

Additional notes on tool tables

Machine parameter 7266.x defines which data can be entered in the tool table and in what sequence the data is displayed.

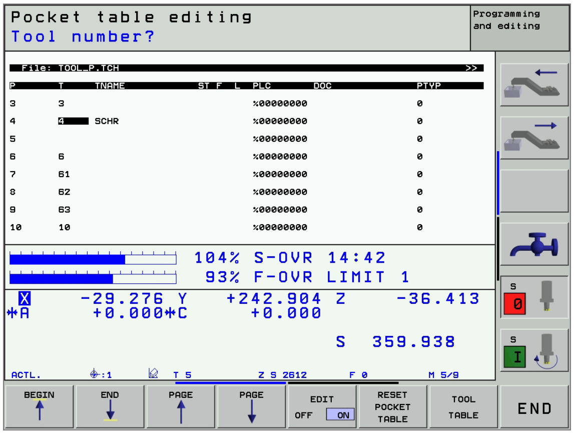
You can overwrite individual columns or lines of a tool table with the contents of another file. Prerequisites:

- The target file must exist.
- The file to be copied must contain only the columns (or lines) you want to replace.

To copy individual columns or lines, press the REPLACE FIELDS soft key(see “Copying a single file” on page 53).

Pocket table for tool changer

For automatic tool changing you need the pocket table TOOL_P.TCH. The TNC can manage several pocket tables with any file names. To activate a specific pocket table for program run you must select it in the file management of a Program Run mode of operation (status M). In order to be able to manage various magazines in a tool-pocket table (indexing pocket number), machine parameters 7261.0 to 7261.3 must not be equal to 0.



Editing a pocket table in a Program Run operating mode

TOOL TABLE

- To select the tool table, press the TOOL TABLE soft key.

POCKET TABLE

- To select the pocket table, press the POCKET TABLE soft key.

EDIT OFF ON

- Set the EDIT soft key to ON.

Selecting a pocket table in the Programming and Editing Editing operating mode

PGM MGT

- Call the file manager.
- To select the file type, press the SELECT TYPE soft key.
- To show files of the type .TCH, press the soft key TCH FILES (second soft-key row).
- Select a file or enter a new file name. Conclude your entry with the ENT key or the SELECT soft key.

Abbr.	Input	Dialog
P	Pocket number of the tool in the tool magazine	–
T	Tool number	Tool number ?
ST	Special tool with a large radius requiring several pockets in the tool magazine. If your special tool takes up pockets in front of and behind its actual pocket, these additional pockets need to be locked in column L (status L).	Special tool ?
F	Fixed tool number. The tool is always returned to the same pocket in the tool magazine	Fixed pocket? Yes = ENT / No = NO ENT
L	Locked pocket (see also column ST)	Pocket locked Yes = ENT / No = NO ENT
PLC	Information on this tool pocket that is to be sent to the PLC	PLC status?
TNAME	Display of the tool name from TOOL.T	–
DOC	Display of the comment to the tool from TOOL.T	–

Editing functions for pocket tables	Soft key
Select beginning of table	BEGIN
Select end of table	END
Select previous page in table	PAGE
Select next page in table	PAGE
Reset pocket table	RESET POCKET TABLE
Go to the beginning of the next line	NEXT LINE
Reset tool number column T	RESET COLUMN T

Calling tool data

A TOOL CALL block in the part program is defined with the following data:

- Select the tool call function with the TOOL CALL key.

TOOL CALL

- **Tool number:** Enter the number or name of the tool. The tool must already be defined in a **TOOL DEF** block or in the tool table. The TNC places puts a the tool name in quotation marks. The tool name always refers to the entry in the active tool table TOOL .T. If you wish to call a tool with other compensation values, enter also the index you defined in the tool table after the decimal point.
- **Working spindle axis X/Y/Z:** Enter the tool axis.
- **Spindle speed S:** Enter the spindle speed directly or allow the TNC to calculate the spindle speed if you are working with cutting data tables. Press the S CALCULATE AUTOMAT. soft key. The TNC limits the spindle speed to the maximum value set in MP 3515.
- **Feed rate F:** Enter the feed rate directly or allow the TNC to calculate the feed rate if you are working with cutting data tables. Press the F CALCULATE AUTOMAT. soft key. The TNC limits the feed rate to the maximum feed rate of the slowest axis (set in MP 1010). F is effective until you program a new feed rate in a positioning or TOOL CALL block.
- **Tool length oversize DL:** Enter the delta value for the tool length.
- **Tool radius oversize DR:** Enter the delta value for the tool radius.
- **Tool radius oversize 2:** Enter the delta value for the tool radius 2.

Example: Tool call

Call tool number 5 in the tool axis Z with a spindle speed of 2500 rpm and a feed rate of 350 mm/min. The tool length is to be programmed with an oversize of 0.2 mm, the tool radius 2 with an oversize of 0.05 mm, and the tool radius with an undersize of 1 mm.

```
20 TOOL CALL 5.2 Z S2500 F350 DL+0.2 DR-1 DR2+0.05
```

The character **D** preceding **L** and **R** designates delta values.

Tool preselection with tool tables

If you are working with tool tables, use **TOOL DEF** to preselect the next tool. Simply enter the tool number or a corresponding Q parameter, or type the tool name in quotation marks.

Tool change

The tool change function can vary depending on the individual machine tool. The machine tool manual provides further information.

Tool change position

A tool change position must be approachable without collision. With the miscellaneous functions **M91** and **M92**, you can enter machine-referenced (rather than workpiece-referenced) coordinates for the tool change position. If **TOOL CALL 0** is programmed before the first tool call, the TNC moves the tool spindle in the tool axis to a position that is independent of the tool length.

Manual tool change

To change the tool manually, stop the spindle and move the tool to the tool change position:

- Move to the tool change position under program control.
- Interrupt program run, see "Interrupting machining," page 433
- Change the tool.
- Resume the program run, see "Resuming program run after an interruption," page 435

Automatic tool change

If your machine tool has automatic tool changing capability, the program run is not interrupted. When the TNC reaches a **TOOL CALL**, it replaces the inserted tool by another from the tool magazine.

Automatic tool change if the tool life expires: M101

The function of **M101** can vary depending on the individual machine tool. The machine tool manual provides further information.

The TNC automatically changes the tool if the tool life **TIME2** expires during program run. To use this miscellaneous function, activate **M101** at the beginning of the program. **M101** is reset with **M102**.

The tool is not always changed immediately, but, depending on the workload of the control, a few NC blocks later.

Prerequisites for standard NC blocks with radius compensation R0, RR, RL

The radius of the replacement tool must be the same as that of the original tool. If the radii are not equal, the TNC displays an error message and does not replace the tool.

Prerequisites for NC blocks with surface-normal vectors and 3-D compensation

See "Three-Dimensional Tool Compensation," page 118The radius of the replacement tool can differ from the radius of the original tool. The tool radius is not included in program blocks transmitted from CAD systems. You can enter the delta value (**DR**) either in the tool table or in the **TOOL CALL** block.

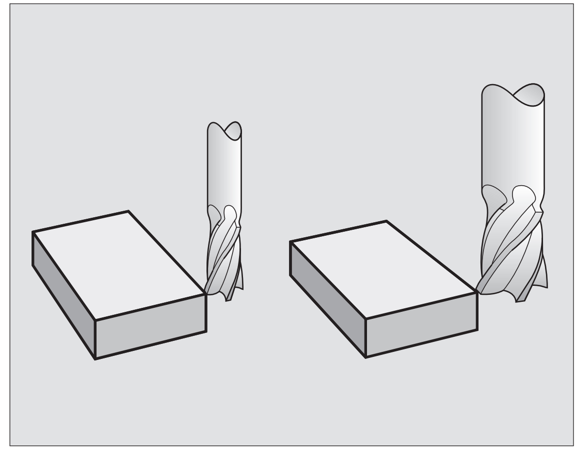
If **DR** is positive, the TNC displays an error message and does not replace the tool. You can suppress this message with the M function **M107,** and reactivate it with **M108.**

5.3 Tool Compensation

Introduction

The TNC adjusts the spindle path in the tool axis by the compensation value for the tool length. In the working plane, it compensates the tool radius.

If you are writing the part program directly on the TNC, the tool radius compensation is effective only in the working plane. The TNC accounts for the compensation value in up to five axes including the rotary axes.



> If a part program generated by a CAD system contains surface-normal vectors, the TNC can perform three-dimensional tool compensation, see "Three-Dimensional Tool Compensation," page 118.

Tool length compensation

Length compensation becomes effective automatically as soon as a tool is called and the tool axis moves. To cancel length compensation, call a tool with the length L=0.

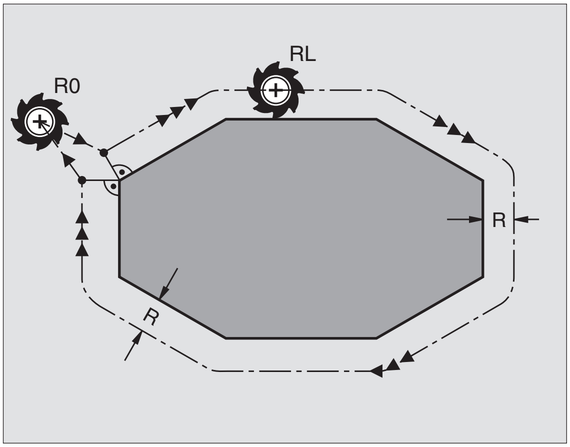
> If you cancel a positive length compensation with **TOOL CALL 0**, the distance between tool and workpiece will be reduced.
>
> After **TOOL CALL**, the path of the tool in the tool axis, as entered in the part program, is adjusted by the difference between the length of the previous tool and that of the new one.

For tool length compensation, the TNC takes the delta values from both the **TOOL CALL** block and the tool table into account:

Compensation value = $\mathbf{L} + \mathbf{DL}_{\text{TOOL CALL}} + \mathbf{DL}_{\text{TAB}}$ where

L	is the tool length **L** from the **TOOL DEF** block or tool table.
$\mathbf{DL}_{\text{TOOL CALL}}$	is the oversize for length **DL** in the **TOOL CALL** block (not taken into account by the position display).
$\mathbf{DL}_{\text{TAB}}$	is the oversize for length **DL** in the tool table

Tool radius compensation



The NC block for programming a tool movement contains:

- **RL** or **RR** for radius compensation.
- **R+** or **R–**, for radius compensation in single-axis movements.
- **R0**, if there is no radius compensation.

Radius compensation becomes effective as soon as a tool is called and is moved with a straight line block in the working plane with RL or RR.

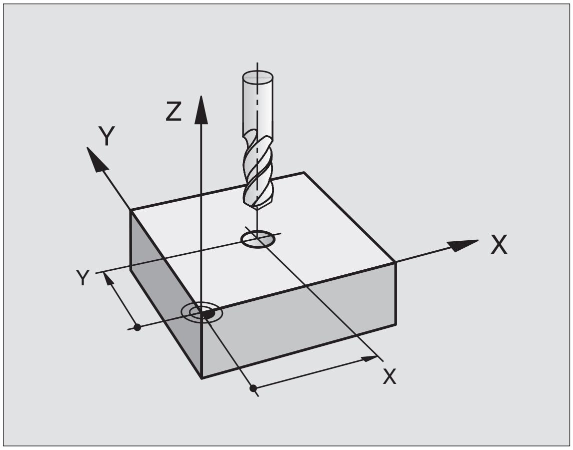
> The TNC automatically cancels radius compensation if you:
> - program a straight line block with **R0**
> - depart the contour with the **DEP** function
> - program a **PGM CALL**
> - select a new program with PGM MGT

For tool radius compensation, the TNC takes the delta values from both the **TOOL CALL** block and the tool table into account:

Compensation value = **R** + $\mathbf{DR}_{\text{TOOL CALL}}$ + $\mathbf{DR}_{\text{TAB}}$ where

R	is the tool radius **R** from the **TOOL DEF** block or tool table.
DR TOOL CALL	is the oversize for radius **DR** in the **TOOL CALL** block (not taken into account by the position display).
DR TAB	is the oversize for radius **DR** in the tool table

Contouring without radius compensation: R0



The tool center moves in the working plane to the programmed path or coordinates.

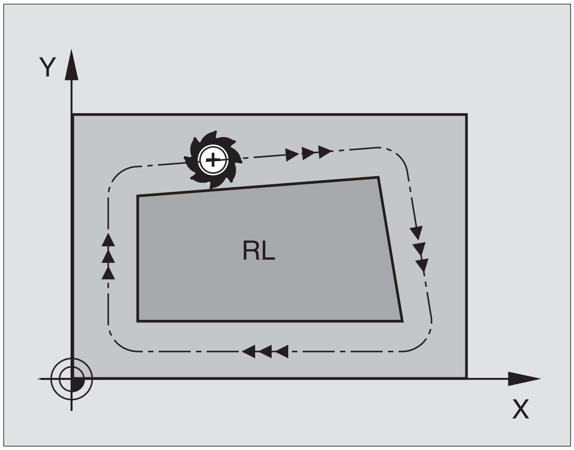
Applications: Drilling and boring, pre-positioning.

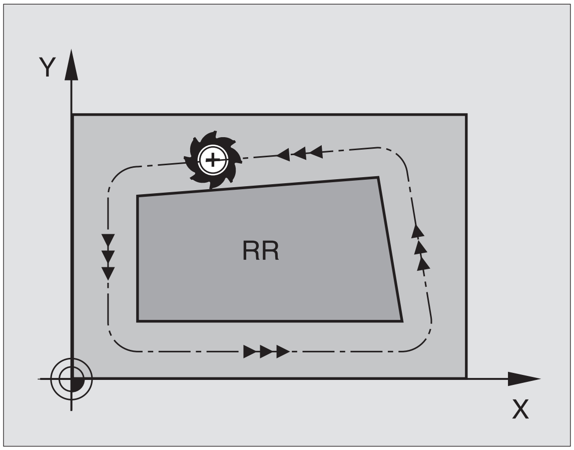
Tool movements with radius compensation: RR and RL

RR The tool moves to the right of the programmed contour

RL The tool moves to the left of the programmed contour

The tool center moves along the contour at a distance equal to the radius. "Right" or "left" are to be understood as based on the direction of tool movement along the workpiece contour See figures at right.





Between two program blocks with different radius compensations (**RR** and **RL**) you must program at least one traversing block in the working plane without radius compensation (that is, with **R0**).

Radius compensation does not take effect until the end of the block in which it is first programmed.

You can also activate the radius compensation for secondary axes in the working plane. Program the secondary axes as well in each following block, since otherwise the TNC will execute the radius compensation in the principal axis again.

Whenever radius compensation is activated with **RR/RL** or canceled with **R0,** the TNC positions the tool perpendicular to the programmed starting or end position. Position the tool at a sufficient distance from the first or last contour point to prevent the possibility of damaging the contour.

Entering radius compensation

Program any desired path function, enter the coordinates of the target point and confirm your entry with ENT.

RADIUS COMP. RL/RR/NO COMP. ?

RL — To select tool movement to the left of the contour, press the RL soft key, or

RR — To select tool movement to the right of the contour, press the RR soft key, or

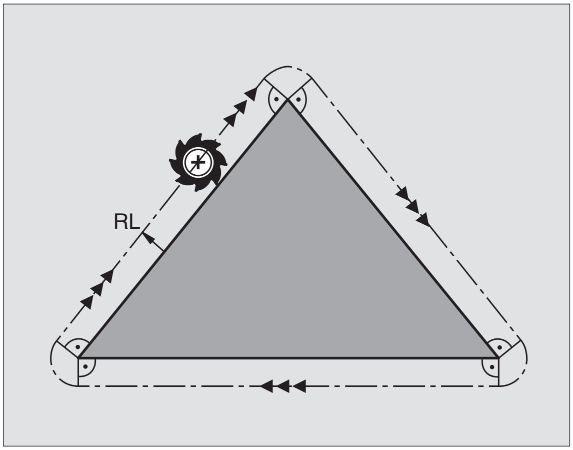
ENT — To select tool movement without radius compensation or to cancel radius compensation, press the ENT key.

END — To terminate the block, press the END key.

Radius compensation: Machining corners

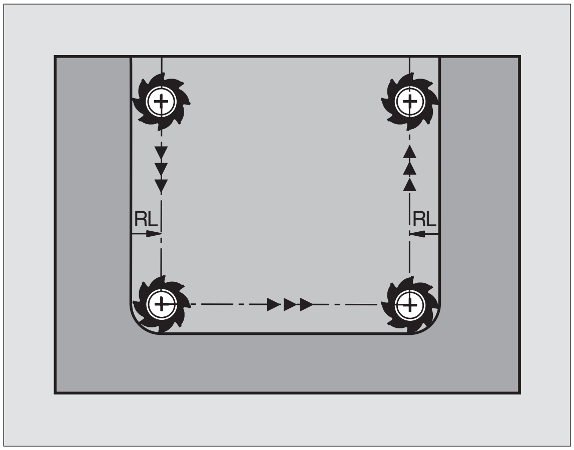
- Outside corners
  If you program radius compensation, the TNC moves the tool around outside corners either on a transitional arc or on a spline (selectable via MP7680). If necessary, the TNC reduces the feed rate at outside corners to reduce machine stress, for example at very great changes of direction.
- Inside corners
  The TNC calculates the intersection of the tool center paths at inside corners under radius compensation. From this point it then starts the next contour element. This prevents damage to the workpiece. The permissible tool radius, therefore, is limited by the geometry of the programmed contour.

> To prevent the tool from damaging the contour, be careful not to program the starting or end position for machining inside corners at a corner of the contour.



Machining corners without radius compensation

If you program the tool movement without radius compensation, you can change the tool path and feed rate at workpiece corners with the miscellaneous function **M90**, See “Smoothing corners: M90,” page 187.



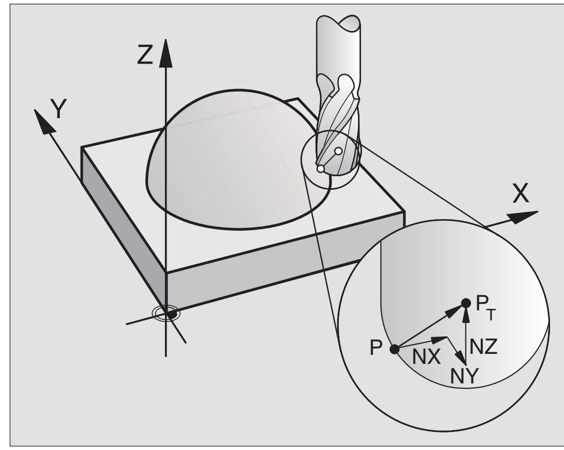
5.4 Three-Dimensional Tool Compensation

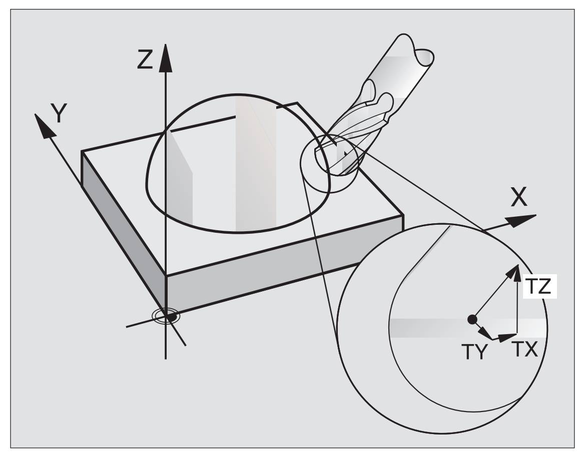
Introduction

The TNC can carry out a three-dimensional tool compensation (3-D compensation) for straight-line blocks. Apart from the X, Y and Z coordinates of the straight-line end point, these blocks must also contain the components NX, NY and NZ of the surface-normal vector (see figure above right and explanation further down on this page).

If, in addition, you want to carry out a tool orientation or a three-dimensional radius compensation, these blocks need also a normalized vector with the components TX, TY and TZ, which determines the tool orientation (see figure at center right).

The straight-line end point, the components for the surface-normal vector as well as those for the tool orientation must be calculated by a CAD system.



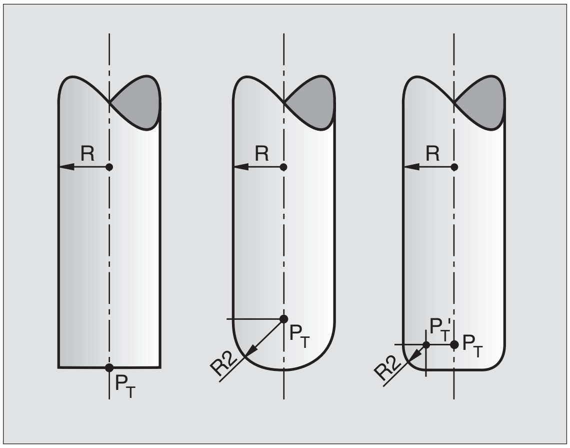


Application possibilities

- Use of tools with dimensions that do not correspond with the dimensions calculated by the CAD system (3-D compensation without definition of the tool orientation)
- Face milling: compensation of the milling machine geometry in the direction of the surface-normal vector (3-D compensation with and without definition of the tool orientation). Cutting is usually with the end face of the tool
- Peripheral milling: compensation of the mill radius perpendicular to the direction of movement and perpendicular to the tool direction (3-D radius compensation with definition of the tool orientation). Cutting is usually with the lateral surface of the tool

Definition of a normalized vector

A normalized vector is a mathematical quantity with a value of 1 and a direction. The TNC requires up to two normalized vectors for LN blocks, one to determine the direction of the surface-normal vector, and another (optional) to determine the tool orientation direction. The direction of a surface-normal vector is determined by the components NX, NY and NZ. With an end mill and a radius mill, this direction is perpendicular from the workpiece surface to be machined to the tool datum PT, and with a toroid cutter through PT‘ or PT (see figure at upper right). The direction of the tool orientation is determined by the components TX, TY and TZ.



The coordinates for the X, Y, Z positions and the surface-normal components NX, NY, NZ, as well as TX, TY, TZ must be in the same sequence in the NC block.

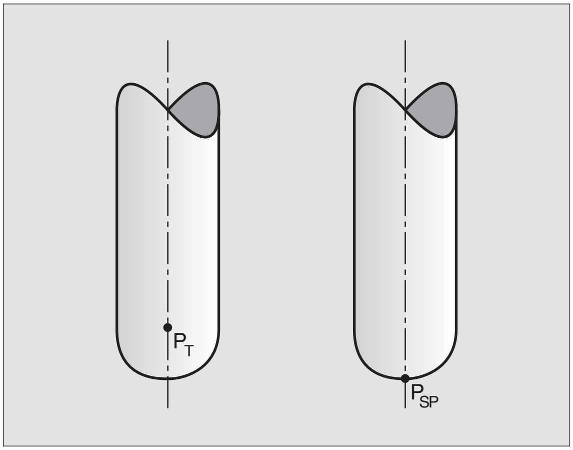
Always indicate all of the coordinates and all of the surface-normal vectors in an LN block, even if the values have not changed from the previous block.

3-D compensation with surface-normal vectors is only effective for coordinates in the main axes X, Y, Z.

If you insert a tool with oversize (positive delta value), the TNC outputs an error message. You can suppress the error message with the M function **M107** (see “Prerequisites for NC blocks with surface-normal vectors and 3-D compensation,” page 113).

The TNC will not display an error message if an entered tool oversize would cause damage to the contour.

Machine parameter 7680 defines whether the CAD system has calculated the tool length compensation from the center of sphere P_T or the south pole of the sphere P_{SP} (see figure at right).



Permissible tool forms

You can describe the permissible tool shapes in the tool table via tool radius **R** and **R2** (see figure at upper right):

- Tool radius **R:** Distance from the tool center to the tool circumference.
- Tool radius 2: **R2:** Radius of the curvature between tool tip and tool circumference.

The ratio of **R** to **R2** determines the shape of the tool:

- **R2** = 0: End mill
- **R2** = **R:** ball-nose cutter.
- 0 < **R2** < **R:** Toroid cutter

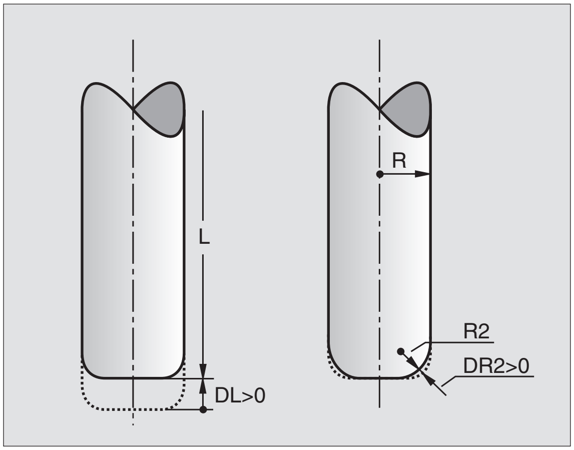
These data also specify the coordinates of the tool datum PT.

Using other tools: Delta values

If you want to use tools that have different dimensions than the ones you originally programmed, you can enter the difference between the tool lengths and radii as delta values in the tool table or **TOOL CALL**:

- Positive delta value **DL, DR, DR2:** The tool is larger than the original tool (oversize).
- Negative delta value **DL, DR, DR2:** The tool is smaller than the original tool (undersize).

The TNC then compensates the tool position by the sum of the delta values from the tool table and the tool call.



3-D compensation without tool orientation

The TNC displaces the tool in the direction of the surface-normal vectors by the sum of the delta values (tool table and **TOOL CALL**).

Example: Block format with surface-normal vectors

```
1 LN X+31.737 Y+21.954 Z+33.165
  NX+0.2637581 NY+0.0078922 NZ-0.8764339 F1000 M3
```

LN:	Straight line with 3-D compensation
X, Y, Z:	Compensated coordinates of the straight-line end point
NX, NY, NZ:	Components of the surface-normal vector
F:	Feed rate
M:	Miscellaneous function

The feed rate F and miscellaneous function M can be entered and changed in the Programming and Editing mode of operation.

The coordinates of the straight-line end point and the components of the surface-normal vectors are to be defined by the CAD system.

Face Milling: 3-D compensation with and without tool orientation

The TNC displaces the tool in the direction of the surface-normal vectors by the sum of the delta values (tool table and **TOOL CALL).**

If **M128** (see "Maintaining the position of the tool tip when positioning with tilted axes (TCPM*): M128," page 201) is active, the TNC maintains the tool perpendicular to the workpiece contour if no tool orientation is programmed in the LN block.

If there is a tool orientation defined in the LN block, then the TNC will position the rotary axes automatically so that the tool can reach the defined orientation.

This function is possible only on machines for which you can define spatial angles for the tilting axis configuration. Refer to your machine manual.

The TNC is not able to automatically position the rotary axes on all machines. Refer to your machine manual.

Danger of collision

On machines whose rotary axes only allow limited traverse, sometimes automatic positioning can require the table to be rotated by 180°. In this case, make sure that the tool head does not collide with the workpiece or the clamps.

Example: Block format with surface-normal vectors without tool orientation

```
LN X+31.737 Y+21.954 Z+33.165
   NX+0.2637581 NY+0.0078922 NZ–0.8764339 F1000 M128
```

Example: Block format with surface-normal vectors and tool orientation

```
LN X+31.737 Y+21.954 Z+33.165
   NX+0.2637581 NY+0.0078922 NZ0.8764339
   TX+0.0078922 TY–0.8764339 TZ+0.2590319 F1000 M128
```

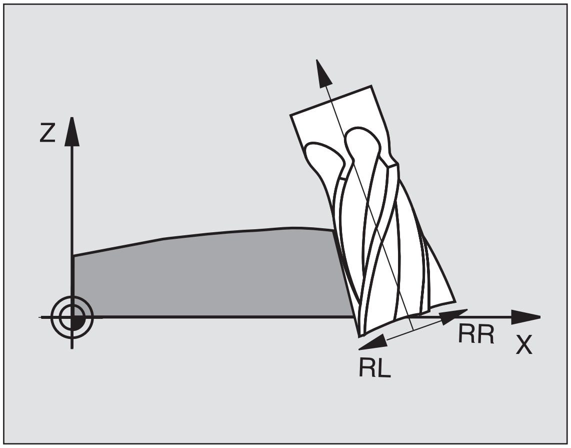
LN:	Straight line with 3-D compensation
X, Y, Z:	Compensated coordinates of the straight-line end point
NX, NY, NZ:	Components of the surface-normal vector
TX, TY, TZ:	Components of the normalized vector for workpiece orientation
F:	Feed rate
M:	Miscellaneous function

The feed rate **F** and miscellaneous function **M** can be entered and changed in the Programming and Editing mode of operation.

The coordinates of the straight-line end point and the components of the surface-normal vectors are to be defined by the CAD system.

Peripheral milling: 3-D radius compensation with workpiece orientation

The TNC displaces the tool perpendicular to the direction of movement and perpendicular to the tool direction by the sum of the delta values **DR** (tool table and **TOOL CALL**). Determine the compensation direction with radius compensation **RL/RR** (see figure at upper right, traverse direction Y+). For the TNC to be able to reach the set tool orientation, you need to activate the function **M128** (see "Maintaining the position of the tool tip when positioning with tilted axes (TCPM*): M128" on page 201). The TNC then positions the rotary axes automatically so that the tool can reach the defined orientation with the active compensation.



The TNC is not able to automatically position the rotary axes on all machines. Refer to your machine manual.

Danger of collision

On machines whose rotary axes only allow limited traverse, sometimes automatic positioning can require the table to be rotated by 180°. In this case, make sure that the tool head does not collide with the workpiece or the clamps.

There are two ways to define the tool orientation:

- In an LN block with the components TX, TY and TZ
- In an L block by indicating the coordinates of the rotary axes

Example: Block format with tool orientation

```
1 LN X+31.737 Y+21.954 Z+33.165
  TX+0.0078922 TY0.8764339 TZ+0.2590319 F1000 M128
```

LN:	Straight line with 3-D compensation
X, Y, Z:	Compensated coordinates of the straight-line end point
TX, TY, TZ:	Components of the normalized vector for workpiece orientation
F:	Feed rate
M:	Miscellaneous function

Example: Block format with rotary axes

```
1 L X+31.737 Y+21.954 Z+33.165
  B+12.357 C+5.896 F1000 M128
```

L	Straight line
X, Y, Z:	Compensated coordinates of the straight-line end point
B, C:	Coordinates of the rotary axes for tool orientation
F:	Feed rate
M:	Miscellaneous function

5.5 Working with Cutting Data Tables

Note

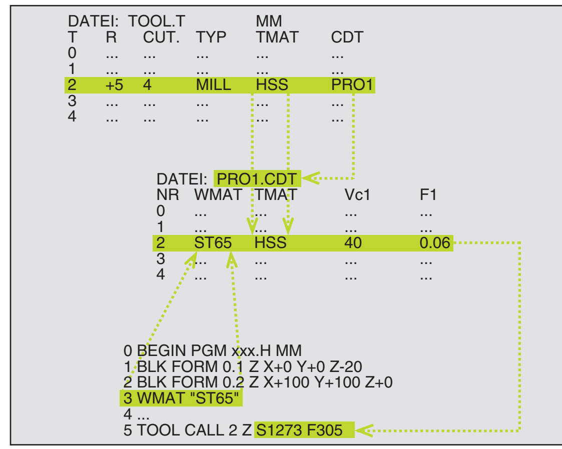
The TNC must be specially prepared by the machine tool builder for the use of cutting data tables.

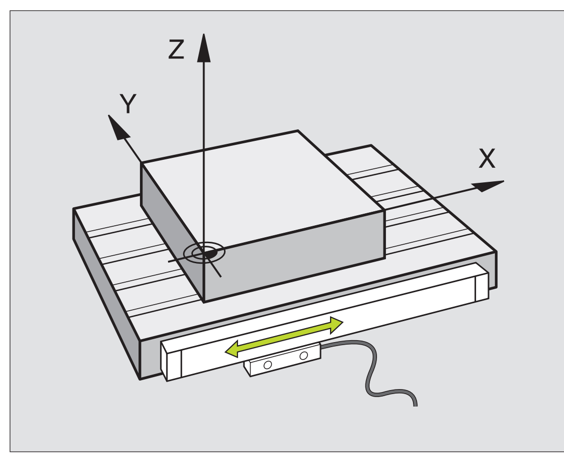
Some functions or additional functions described here may not be provided on your machine tool. Refer to your machine manual.

Applications

In cutting data tables containing various workpiece and cutting material combinations, the TNC can use the cutting speed V_C and the tooth feed f_Z to calculate the spindle speed S and the feed rate F. This calculation is only possible if you defined the workpiece material in the program and various tool-specific features in the tool table.

Before you let the TNC automatically calculate the cutting data, the tool table from which the TNC is to take the tool-specific data must be first be activated in the Test Run mode (status S).

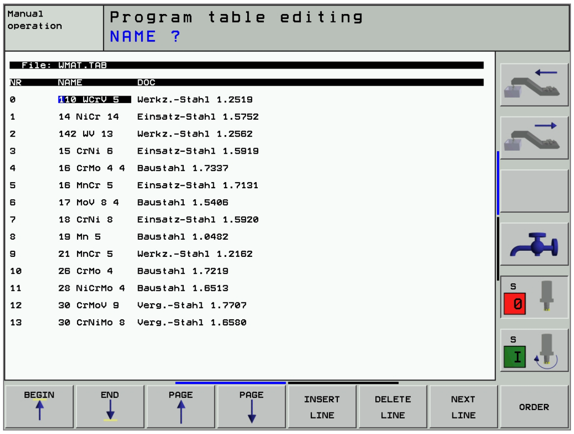




Editing function for cutting data tables	Soft key
Insert line	INSERT LINE
Delete line	DELETE LINE
Go to the beginning of the next line	NEXT LINE
Sort the table	ORDER N
Copy the highlighted field (2nd soft-key row)	COPY FIELD
Insert the copied field (2nd soft-key row)	PASTE FIELD
Edit the table format (2nd soft-key row)	EDIT FORMAT

Table for workpiece materials

Workpiece materials are defined in the table WMAT.TAB (see figure at upper right). WMAT.TAB is stored in the TNC:\ directory and can contain as many materials as you want. The name of the material type can have a max. of 32 characters (including spaces). The TNC displays the contents of the NAME column when you are defining the workpiece material in the program (see the following section).



If you change the standard workpiece material table, you must copy it into a new directory. Otherwise your changes will be overwritten during a software update by the HEIDENHAIN standard data. Define the path in the TNC.SYS file with the code word WMAT= (see “Configuration file TNC.SYS,” page 130).

To avoid losing data, save the WMAT.TAB file at regular intervals.

Defining the workpiece material in the NC program

In the NC program select the workpiece material from the WMAT.TAB table using the WMAT soft key:

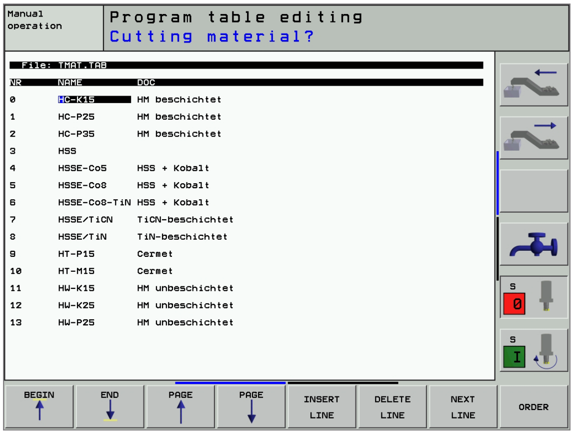
- Program the workpiece material: In the Programming and Editing operating mode, press the WMAT soft key.

- The WMAT.TAB table is superimposed: Press the SELECTION WINDOW soft key and the TNC displays in a second window the list of materials that are stored in the WMAT.TAB table.
- Select your workpiece material by using the arrow keys to move the highlight onto the material you wish to select and confirming with the ENT key. The TNC transfers the selected material to the WMAT block.
- To terminate the dialog, press the END key.

If you change the WMAT block in a program, the TNC outputs a warning. Check whether the cutting data stored in the TOOL CALL block are still valid.

Table for tool cutting materials

Tool cutting materials are defined in the TMAT.TAB table. TMAT.TAB is stored in the TNC:\ directory and can contain as many material names as you want (see figure at upper right). The name of the cutting material type can have a max. of 16 characters (including spaces). The TNC displays the NAME column when you are defining the tool cutting material in the TOOL.T tool table.



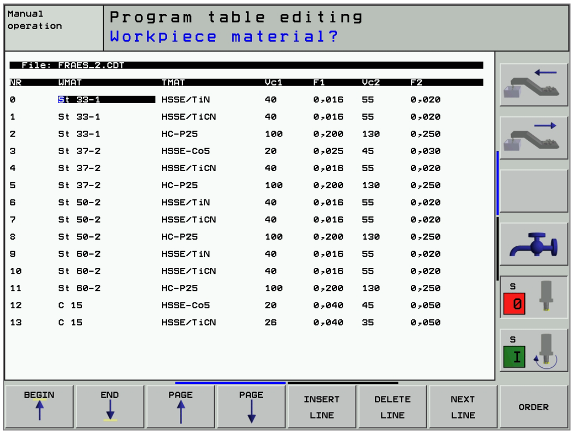
NR	NAME	DOC
0	HC-K15	HM beschichtet
1	HC-P25	HM beschichtet
2	HC-P35	HM beschichtet
3	HSS	
4	HSSE-Co5	HSS + Kobalt
5	HSSE-Co8	HSS + Kobalt
6	HSSE-Co8-TiN	HSS + Kobalt
7	HSSE/TiCN	TiCN-beschichtet
8	HSSE/TiN	TiN-beschichtet
9	HT-P15	Cermet
10	HT-M15	Cermet
11	HW-K15	HM unbeschichtet
12	HW-K25	HM unbeschichtet
13	HW-P25	HM unbeschichtet

If you change the standard tool cutting material table, you must copy it into a new directory. Otherwise your changes will be overwritten during a software update by the HEIDENHAIN standard data. Define the path in the TNC.SYS file with the code word TMAT= (see “Configuration file TNC.SYS,” page 130).

To avoid losing data, save the TMAT.TAB file at regular intervals.

Table for cutting data

Define the workpiece material/cutting material combinations with the corresponding cutting data in a file table with the file name extension .CDT; see figure at center right. You can freely configure that entries in the cutting data table. Besides the obligatory columns NR, WMAT and TMAT, the TNC can also manage up to four cutting speed (V_C)/ feed rate (F)combinations.



NR	WMAT	TMAT	Vc1	F1	Vc2	F2
0	St 33-1	HSSE/TiN	40	0,016	55	0,020
1	St 33-1	HSSE/TiCN	40	0,016	55	0,020
2	St 33-1	HC-P25	100	0,200	130	0,250
3	St 37-2	HSSE-Co5	20	0,025	45	0,030
4	St 37-2	HSSE/TiCN	40	0,016	55	0,020
5	St 37-2	HC-P25	100	0,200	130	0,250
6	St 50-2	HSSE/TiN	40	0,016	55	0,020
7	St 50-2	HSSE/TiCN	40	0,016	55	0,020
8	St 50-2	HC-P25	100	0,200	130	0,250
9	St 60-2	HSSE/TiN	40	0,016	55	0,020
10	St 60-2	HSSE/TiCN	40	0,016	55	0,020
11	St 60-2	HC-P25	100	0,200	130	0,250
12	C 15	HSSE-Co5	20	0,040	45	0,050
13	C 15	HSSE/TiCN	26	0,040	35	0,050

The standard cutting data table FRAES_2.CDT is stored in the directory TNC:\. You can edit FRAES_2.CDT, or add as many new cutting-data tables as you wish.

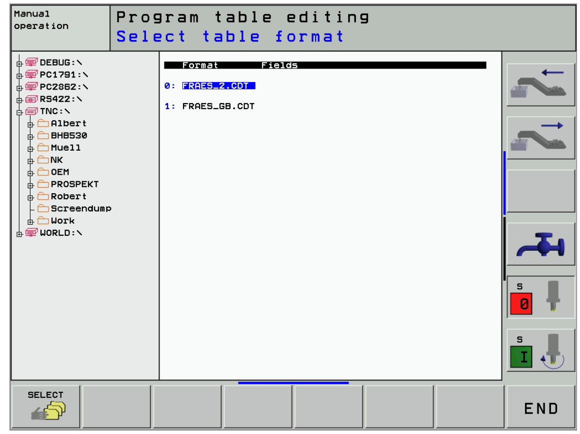
If you change the standard cutting data table, you must copy it into a new directory. Otherwise your changes will be overwritten during a software update by the HEIDENHAIN standard data (see “Configuration file TNC.SYS,” page 130).

All of the cutting data tables must be stored in the same directory. If the directory is not the standard directory TNC:\, then behind the code word PCDT= you must enter the path in which your cutting data is stored.

To avoid losing data, save your cutting data tables at regular intervals.

Creating a new cutting data table.

- Select the Programming and Editing mode of operation.
- To select the file manager, press the PGM MGT key.
- Select the directory where the cutting data table is to be stored.
- Enter any file name with file name extension .CDT, and confirm with ENT.
- On the right half of the screen, the TNC displays various table formats (machine-dependent, see example in figure at right). These tables differ from each other in the number of cutting speed/feed rate combinations they allow. Use the arrow keys to move the highlight onto the table format you wish to select and confirm with ENT. The TNC generates a new, empty cutting data table.



Data required for the tool table

- Tool radius—under R (DR)
- Number of teeth (only with tools for milling)—under CUT
- Tool type—under TYPE
- The tool type influences the calculation of the feed rate:
  Milling tool: $F = S \cdot f_Z \cdot z$
  All other tools: $F = S \cdot f_U$
  S: Spindle speed
  f_Z: Feed per tooth
  f_U: Feed per revolution
  z: Number of teeth
- Tool cutting material—under TMAT
- Name of the cutting data table for which this tool will be used—under CDT
- In the tool table, select the tool type, tool cutting material and the name of the cutting data table via soft key (see “Tool table: Tool data for automatic speed/feed rate calculations.,” page 106).

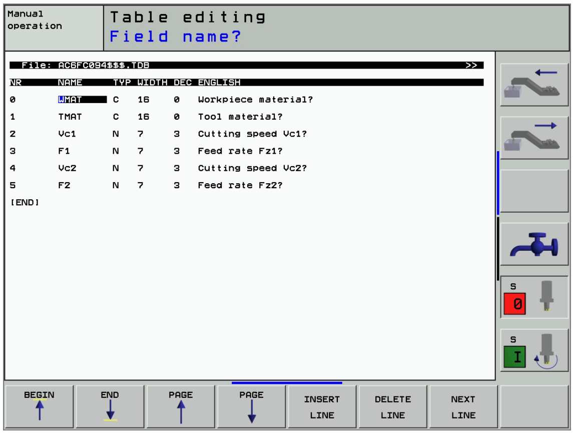
Working with automatic speed/feed rate calculation

1. If it has not already been entered, enter the type of workpiece material in the file WMAT.TAB
2. If it has not already been entered, enter the type of cutting material in the file TMAT.TAB.
3. If not already entered, enter all of the required tool-specific data in the tool table:
   - Tool radius
   - Number of teeth
   - Tool type
   - Tool material
   - The cutting data table for each tool
4. If not already entered, enter the cutting data in any cutting data table (CDT file).
5. Test Run operating mode: Activate the tool table from which the TNC is to take the tool-specific data (status S).
6. In the NC program, set the workpiece material by pressing the WMAT soft key.
7. In the NC program, let the TOOL CALL block automatically calculate spindle speed and feed rate via soft key.

Changing the table structure

Cutting data tables constitute so-called “freely-definable tables” for the TNC. You can change the format of freely definable tables by using the structure editor.

> The TNC can process up to 200 characters per line and up to 30 column.
>
> If you insert an additional column into an existing table, the TNC does not automatically shift the values that have been entered.



Calling the structure editor

Press the EDIT FORMAT soft key (2nd soft-key level). The TNC opens the editing window (see figure at right), in which the table structure is shown “rotated by 90°.” In other words, a line in the editing window defines a column in the associated table. The meanings of the structure commands (header entries) are shown in the table at right.

Exiting the structure editor

Press the END key. The TNC changes data that was already in the table into the new format. Elements that the TNC could not convert into the new structure are indicated with a hash mark # (e.g., if you have narrowed the column width).

Structure command	Meaning
NR	Column number
NAME	Overview of columns
TYPE	N: Numerical input C: Alphanumeric input
WIDTH	Width of column For type Nincluding algebraic sign, comma, and decimalplaces
DEC	Number of decimal places (max. 4, effective only for type N)
ENGLISH to HUNGARIAN	Language-dependent dialogs (max. 32 characters)

Data transfer from cutting data tables

If you output a file type .TAB or .CDT via an external data interface, the TNC also transfers the structural definition of the table. The structural definition begins with the line #STRUCTBEGIN and ends with the line #STRUCTEND. The meanings of the individual code words are shown in the table "Structure Command" (see "Changing the table structure," page 128). Behind #STRUCTEND the TNC saves the actual content of the table.

Configuration file TNC.SYS

You must use the configuration file TNC.SYS if your cutting data tables are not stored in the standard directory TNC:\. In TNC.SYS you must then define the paths in which you have stored your cutting data tables.

> The TNC.SYS file must be stored in the root directory TNC:\.

Entries in TNC.SYS	Meaning
WMAT=	Path for workpiece material table
TMAT=	Path for cutting material table
PCDT=	Path for cutting data tables

Example of TNC.SYS

```
WMAT=TNC:\CUTTAB\WMAT_GB.TAB
TMAT=TNC:\CUTTAB\TMAT_GB.TAB
PCDT=TNC:\CUTTAB\
```

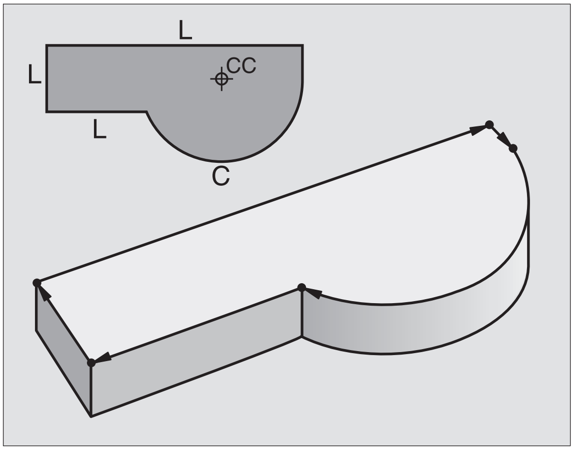
6

Programming: Programming Contours

6.1 Tool Movements

Path functions

A workpiece contour is usually composed of several contour elements such as straight lines and circular arcs. With the path functions, you can program the tool movements for **straight lines** and **circular arcs.**



FK Free Contour Programming

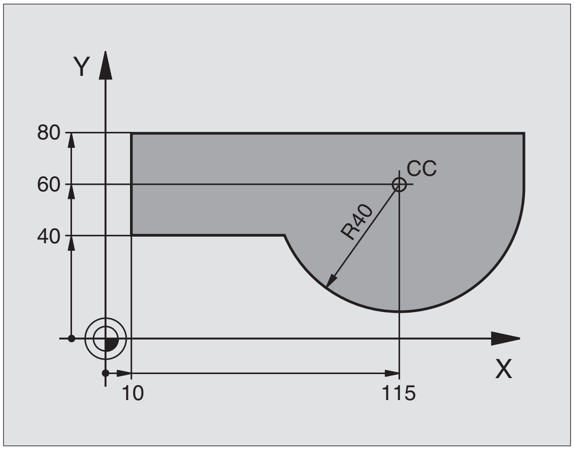
If a production drawing is not dimensioned for NC and the dimensions given are not sufficient for creating a part program, you can program the workpiece contour with the FK free contour programming and have the TNC calculate the missing data.

With FK programming, you also program tool movements for **straight lines** and **circular arcs**.

Miscellaneous functions M

With the miscellaneous functions of the TNC you can control:

- Program run, e.g., a program interruption
- Machine functions, such as switching spindle rotation and coolant supply on and off
- Contouring behavior of the tool



Subprograms and Program Section Repeats

If a machining sequence occurs several times in a program, you can save time and reduce the chance of programming errors by entering the sequence once and then defining it as a subprogram or program section repeat. If you wish to execute a specific program section only under certain conditions, you also define this machining sequence as a subprogram. In addition, you can have a part program call a separate program for execution.

Programming with subprograms and program section repeats is described in Chapter 9.

Programming with Q parameters

Instead of programming numerical values in a part program, you enter markers called Q parameters. You assign the values to the Q parameters separately with the Q parameter functions. You can use the Q parameters for programming mathematical functions that control program execution or describe a contour.

In addition, parametric programming enables you to measure with the 3-D touch probe during program run.

Programming with Q parameters is described in Chapter 10.

6.2 Fundamentals of Path Functions

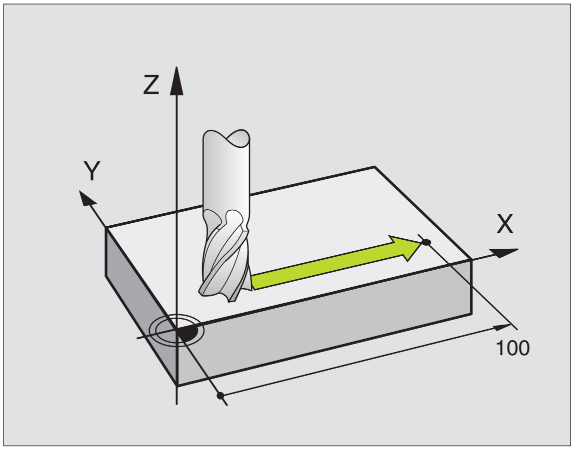
Programming tool movements for workpiece machining

You create a part program by programming the path functions for the individual contour elements in sequence. You usually do this by entering **the coordinates of the end points of the contour elements** given in the production drawing. The TNC calculates the actual path of the tool from these coordinates, and from the tool data and radius compensation.

The TNC moves all axes programmed in a single block simultaneously.

Movement parallel to the machine axes

The program block contains only one coordinate. The TNC thus moves the tool parallel to the programmed axis.



Depending on the individual machine tool, the part program is executed by movement of either the tool or the machine table on which the workpiece is clamped. Nevertheless, you always program path contours as if the tool moves and the workpiece remains stationary.

Example:

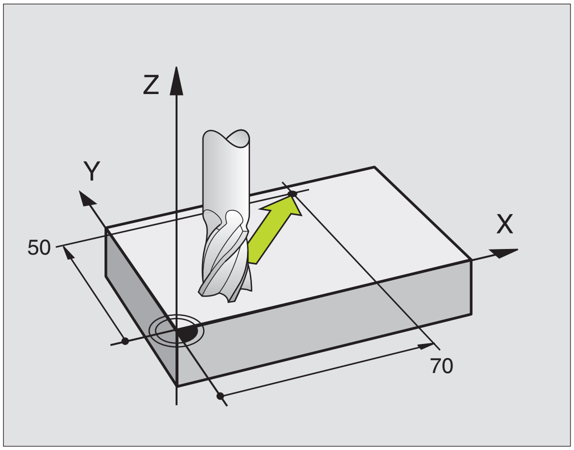
```
L X+100
```

L	Path function for “straight line”
X+100	Coordinate of the end point

The tool retains the Y and Z coordinates and moves to the position X=100 (see figure at upper right).

Movement in the main planes

The program block contains two coordinates. The TNC thus moves the tool in the programmed plane.



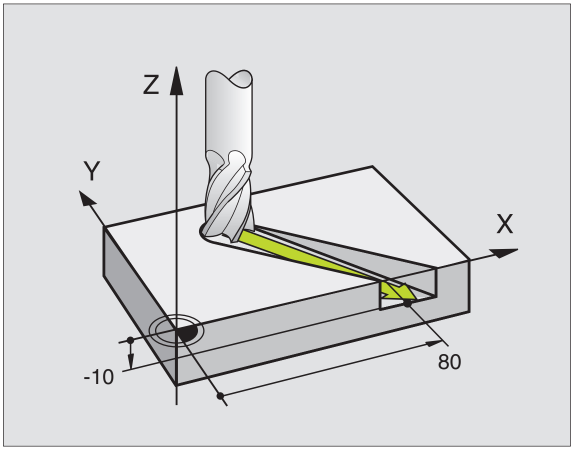
Example:

```
L X+70 Y+50
```

The tool retains the Z coordinate and moves in the XY plane to the position X=70, Y=50 (see figure at center right).

Three-dimensional movement

The program block contains three coordinates. The TNC thus moves the tool in space to the programmed position.



Example:

```
L X+80 Y+0 Z-10
```

Entering more than three coordinates

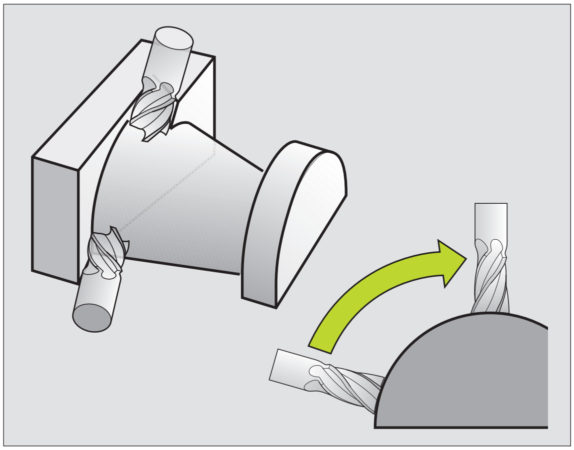
The TNC can control up to 5 axes simultaneously. Machining with 5 axes, for example, moves 3 linear and 2 rotary axes simultaneously.

Such programs are too complex to program at the machine, however, and are usually created with a CAD system.

Example:

```
L X+20 Y+10 Z+2 A+15 C+6 R0 F100 M3
```

The TNC graphics cannot simulate movements in more than three axes.

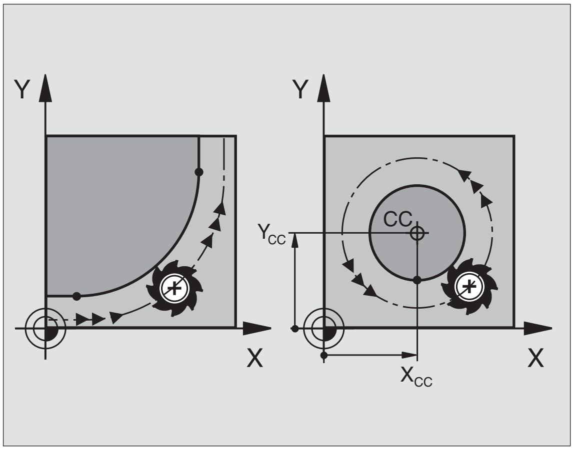


Circles and circular arcs

The TNC moves two axes simultaneously in a circular path relative to the workpiece. You can define a circular movement by entering the circle center CC.

When you program a circle, the control assigns it to one of the main planes. This plane is defined automatically when you set the spindle axis during a TOOL CALL:

Tool axis	Main plane
Z	**XY**, also UV, XV, UY
Y	**ZX**, also WU, ZU, WX
X	**YZ**, also VW, YW, VZ

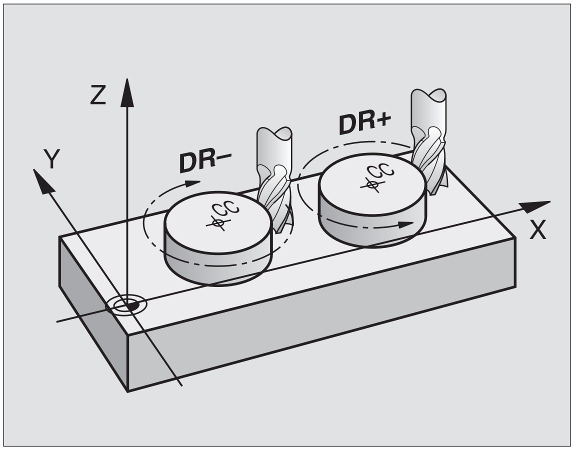


You can program circles that do not lie parallel to a main plane by using the function for tilting the working plane (see “WORKING PLANE (Cycle 19),” page 349) or Q parameters (see “Principle and Overview,” page 376).

Direction of rotation DR for circular movements

When a circular path has no tangential transition to another contour element, enter the direction of rotation DR:

Clockwise direction of rotation: DR–
Counterclockwise direction of rotation: DR+



Radius compensation

The radius compensation must be in the block in which you move to the first contour element. You cannot begin radius compensation in a circle block. It must be activated beforehand in a straight-line block (see “Path Contours—Cartesian Coordinates,” page 144) or approach block (APPR block, see “Contour Approach and Departure,” page 137).

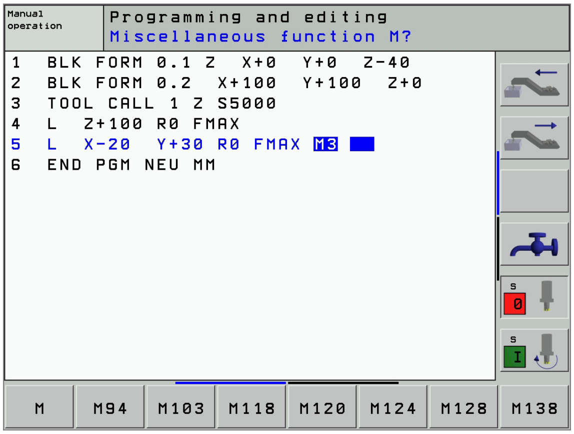
Pre-positioning

Before running a part program, always pre-position the tool to prevent the possibility of damaging it or the workpiece.

Creating the program blocks with the path function keys

The gray path function keys initiate the plain language dialog. The TNC asks you successively for all the necessary information and inserts the program block into the part program.

Example—programming a straight line:



L	Initiate the programming dialog, e.g. for a straight line.

COORDINATES ?

X 10	Enter the coordinates of the straight-line end point.
Y 5	
ENT	

RADIUS COMP. RL/RR/NO COMP. ?

RL	Select the radius compensation (here, press the RL soft key—the tool moves to the left of the programmed contour).

FEED RATE F=? / F MAX = ENT

100 ENT	Enter the feed rate (here, 100 mm/min), and confirm your entry with ENT. For programming in inches, enter 100 for a feed rate of 10 ipm.
F MAX	Move at rapid traverse: press the FMAX soft key, or
F AUTO	Move at automatically calculated speed (cutting data table): press the FAUTO soft key.

MISCELLANEOUS FUNCTION M?

3 ENT — Enter a miscellaneous function (here, M3), and terminate the dialog with ENT.

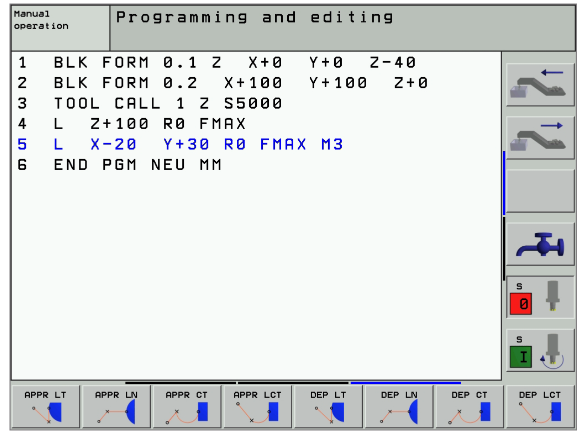
The part program now contains the following line:

```
L X+10 Y+5 RL F100 M3
```

6.3 Contour Approach and Departure

Overview: Types of paths for contour approach and departure

The functions for contour approach APPR and departure DEP are activated with the APPR/DEP key. You can then select the desired path function with the corresponding soft key:



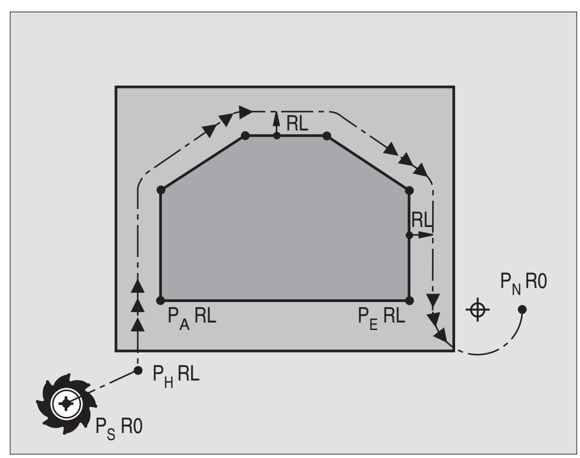
Function Soft key	Approach	Departure
Straight line with tangential connection	APPR LT	DEP LT
Straight line perpendicular to a contour point	APPR LN	DEP LN
Circular arc with tangential connection	APPR CT	DEP CT
Circular arc with tangential connection to the contour. Approach and departure to an auxiliary point outside of the contour on a tangentially connecting line.	APPR LCT	DEP LCT

Approaching and departing a helix

The tool approaches and departs a helix on its extension by moving in a circular arc that connects tangentially to the contour. You program helix approach and departure with the APPR CT and DEP CT functions.

Important positions for approach and departure

- Starting point P_S
  You program this position in the block before the APPR block. Ps lies outside the contour and is approached without radius compensation (R0).
- Auxiliary point P_H
  Some of the paths for approach and departure go through an auxiliary point P_H that the TNC calculates from your input in the APPR or DEP block.
- First contour point P_A and last contour point P_E
  You program the first contour point P_A in the APPR block. The last contour point P_E can be programmed with any path function. If the APPR block also contains a Z axis coordinate, the TNC will first move the tool to P_H in the working plane, and then move it to the entered depth in the tool axis.



- End point P_N
  The position P_N lies outside of the contour and results from your input in the DEP block. If the DEP block also contains a Z axis coordinate, the TNC will first move the tool to P_H in the working plane, and then move it to the entered height in the tool axis.

Abbreviation	Meaning
APPR	Approach
DEP	Departure
L	Line
C	Circle
T	Tangential (smooth connection)
N	Normal (perpendicular)

The TNC does not check whether the programmed contour will be damaged when moving from the actual position to the auxiliary point P_H. Use the test graphics to simulate approach and departure before executing the part program.

With the **APPR LT**, **APPR LN** and **APPR CT** functions, the TNC moves the tool from the actual position to the auxiliary point P_H at the feed rate that was last programmed. With the **APPR LCT** function, the TNC moves to the auxiliary point P_H at the feed rate programmed with the APPR block.

Polar coordinates

You can also program the contour points for the following approach/departure functions over polar coordinates!

- **APPR LT** becomes **APPR PLT**
- **APPR LN** becomes **APPR PLN**
- **APPR CT** becomes **APPR PCT**
- **APPR LCT** becomes **APPR PLCT**
- **DEP LCT** becomes **DEP PLCT**

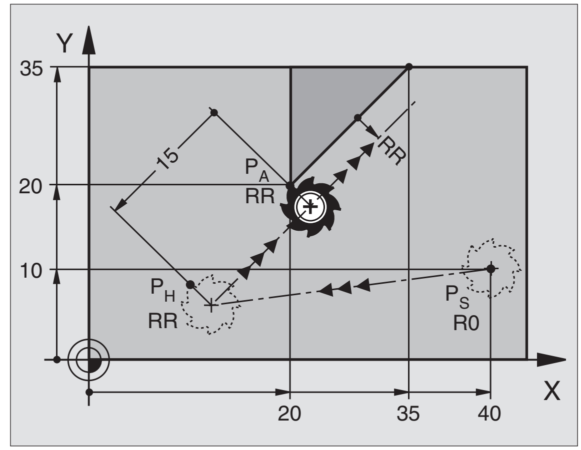
Select by soft key an approach or departure function, then press the orange P key.

Radius compensation

The tool radius compensation is programmed together with the first contour point P_A in the APPR block. The DEP blocks automatically discard the tool radius compensation.

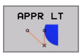
Contour approach without radius compensation: If you program the APPR block with R0, the TNC will calculate the tool path for a tool radius of 0 mm and a radius compensation RR! The radius compensation is necessary to set the direction of contour approach and departure in the APPR/DEP LN and APPR/DEP CT functions.

Approaching on a straight line with tangential connection: APPR LT



The tool moves on a straight line from the starting point P_S to an auxiliary point P_H. It then moves to the first contour point P_A on a straight line that connects tangentially to the contour. The auxiliary point P_H is separated from the first contour point P_A by the distance LEN.

- Use any path function to approach the starting point P_S.
- Initiate the dialog with the APPR/DEP key and APPR LT soft key:

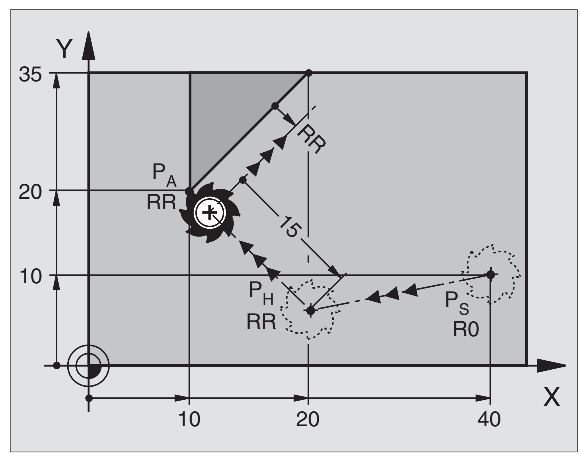


- Coordinates of the first contour point P_A
- LEN: Distance from the auxiliary point P_H to the first contour point P_A
- Radius compensation RR/RL for machining

Example NC blocks

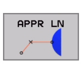
`7 L X+40 Y+10 R0 FMAX M3`	Approach P_S without radius compensation
`8 APPR LT X+20 Y+20 Z-10 LEN15 RR F100`	P_A with radius comp. RR, distance P_H to P_A: LEN=15
`9 L Y+35 Y+35`	End point of the first contour element
`10 L ...`	Next contour element

Approaching on a straight line perpendicular to the first contour point: APPR LN



The tool moves on a straight line from the starting point P_S to an auxiliary point P_H. It then moves to the first contour point P_A on a straight line perpendicular to the first contour element. The auxiliary point P_H is separated by the distance LEN plus the tool radius from the first contour point P_A.

- Use any path function to approach the starting point P_S.
- Initiate the dialog with the APPR/DEP key and APPR LN soft key:

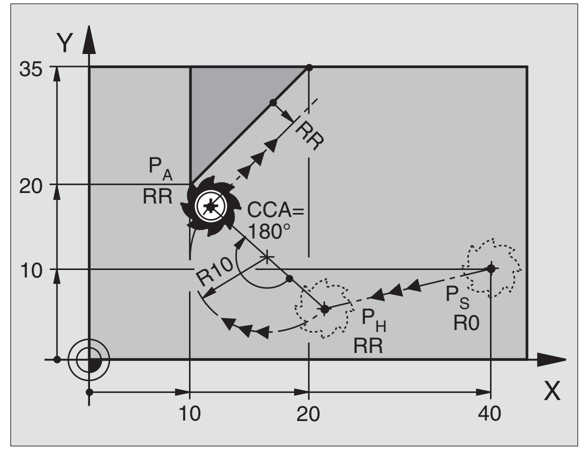


- Coordinates of the first contour point P_A
- Length: Distance to the auxiliary point P_H. Always enterLEN as a positive value!
- Radius compensation RR/RL for machining

Example NC blocks

`7 L X+40 Y+10 R0 FMAX M3`	Approach P_S without radius compensation
`8 APPR LN X+10 Y+20 Z-10 LEN15 RR F100`	P_A with radius comp. RR
`9 L X+20 Y+35`	End point of the first contour element
`10 L ...`	Next contour element

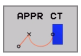
Approaching on a circular path with tangential connection: APPR CT



The tool moves on a straight line from the starting point P_S to an auxiliary point P_H. It then moves to the first contour point P_A following a circular arc that is tangential to the first contour element.

The arc from P_H to P_A is determined through the radius R and the center angle CCA. The direction of rotation of the circular arc is automatically derived from the tool path for the first contour element.

- Use any path function to approach the starting point P_S.
- Initiate the dialog with the APPR/DEP key and APPR CT soft key:

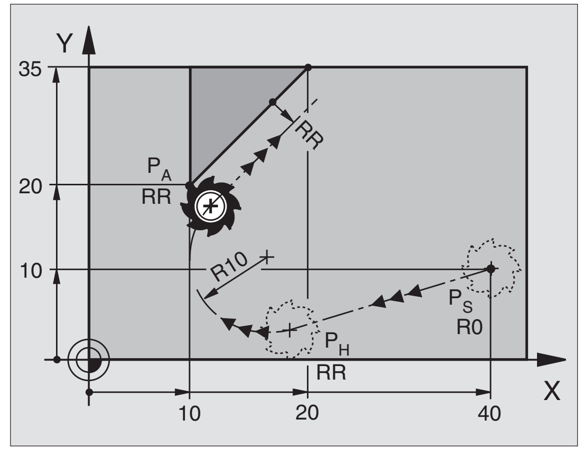


- Coordinates of the first contour point P_A
- Radius R of the circular arc
  - If the tool should approach the workpiece in the direction defined by the radius compensation: Enter R as a positive value.
  - If the tool should approach the workpiece opposite to the radius compensation: Enter R as a negative value.
- Center angle CCA of the arc
  - CCA can be entered only as a positive value.
  - Maximum input value 360°
- Radius compensation RR/RL for machining

Example NC blocks

`7 L X+40 Y+10 R0 FMAX M3`	Approach P_S without radius compensation
`8 APPR CT X+10 Y+20 Z-10 CCA180 R+10 RR F100`	P_A with radius comp. RR, radius R=10
`9 L X+20 Y+35`	End point of the first contour element
`10 L ...`	Next contour element

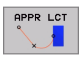
Approaching on a circular arc with tangential connection from a straight line to the contour: APPR LCT



The tool moves on a straight line from the starting point P_S to an auxiliary point P_H. It then moves to the first contour point P_A on a circular arc. The feed rate programmed in the APPR block is in effect.

The arc is connected tangentially both to the line P_S – P_H as well as to the first contour element. Once these lines are known, the radius then suffices to completely define the tool path.

- Use any path function to approach the starting point P_S.
- Initiate the dialog with the APPR/DEP key and APPR LCT soft key:



- Coordinates of the first contour point P_A
- Radius R of the circular arc. Enter R as a positive value.
- Radius compensation RR/RL for machining

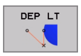
Example NC blocks

`7 L X+40 Y+10 R0 FMAX M3`	Approach P_S without radius compensation
`8 APPR LCT X+10 Y+20 Z-10 R10 RR F100`	P_A with radius comp. RR, radius R=10
`9 L X+20 Y+35`	End point of the first contour element
`10 L ...`	Next contour element

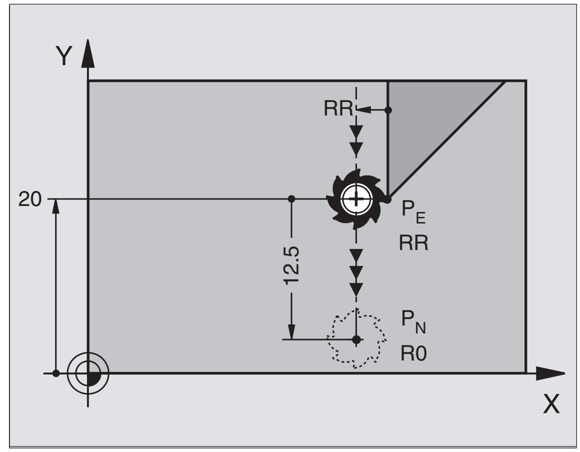
Departing on a straight line with tangential connection: DEP LT

The tool moves on a straight line from the last contour point P_E to the end point P_N. The line lies in the extension of the last contour element. P_N is separated from P_E by the distance LEN.

- Program the last contour element with the end point P_E and radius compensation.
- Initiate the dialog with the APPR/DEP key and DEP LT soft key:



- LEN: Enter the distance from the last contour element P_E to the end point P_N.



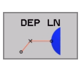
Example NC blocks

`23 L Y+20 RR F100`	Last contour element: P_E with radius compensation
`24 DEP LT LEN12.5 F100`	Depart contour by LEN=12.5 mm
`25 L Z+100 FMAX M2`	Retract in Z, return to block 1, end program

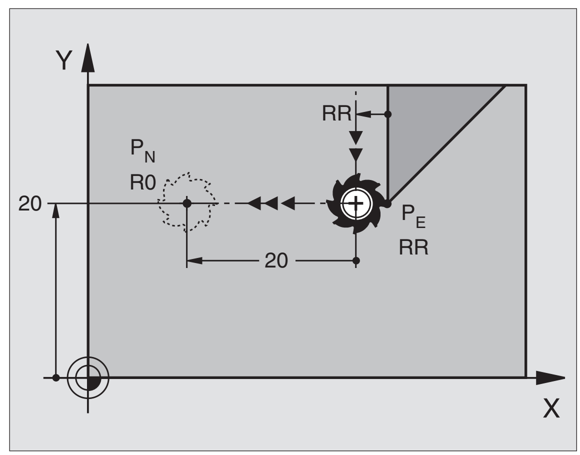
Departing on a straight line perpendicular to the last contour point: DEP LN

The tool moves on a straight line from the last contour point P_E to the end point P_N. The line departs on a perpendicular path from the last contour point P_E. P_N is separated from P_E by the distance LEN. plus the tool radius.

- Program the last contour element with the end point P_E and radius compensation.
- Initiate the dialog with the APPR/DEP key and DEP LN soft key:



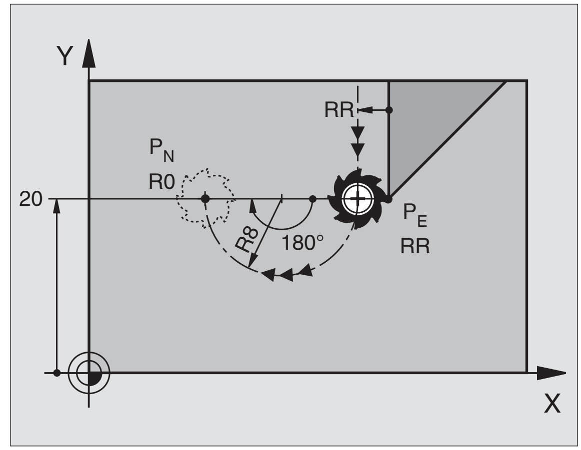
- LEN: Enter the distance from the last contour element P_N.
  Always enter LEN as a positive value!



Example NC blocks

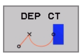
`23 L Y+20 RR F100`	Last contour element: P_E with radius compensation
`24 DEP LN LEN+20 F100`	Depart perpendicular to contour by LEN=20 mm
`25 L Z+100 FMAX M2`	Retract in Z, return to block 1, end program

Departure on a circular path with tangential connection: DEP CT



The tool moves on a circular arc from the last contour point P_E to the end point P_N. The arc is tangentially connected to the last contour element.

- Program the last contour element with the end point P_E and radius compensation.
- Initiate the dialog with the APPR/DEP key and DEP CT soft key:

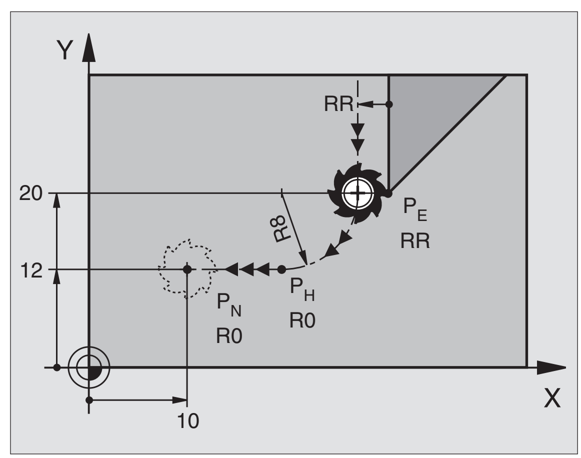


- Center angle CCA of the arc
- Radius R of the circular arc
  - If the tool should depart the workpiece in the direction of the radius compensation (i.e. to the right with RR or to the left with RL): Enter R as a positive value.
  - If the tool should depart the workpiece on the direction **opposite** to the radius compensation: Enter R as a negative value.

Example NC blocks

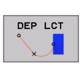
`23 L Y+20 RR F100`	Last contour element: P_E with radius compensation
`24 DEP CT CCA 180 R+8 F100`	Center angle=180°,
	arc radius=8 mm
`25 L Z+100 FMAX M2`	Retract in Z, return to block 1, end program

Departing on a circular arc tangentially connecting the contour and a straight line: DEP LCT



The tool moves on a circular arc from the last contour point P_S to an auxiliary point P_H. It then moves on a straight line to the end point P_N. The arc is tangentially connected both to the last contour element and to the line from P_H to P_N. Once these lines are known, the radius R then suffices to completely define the tool path.

- Program the last contour element with the end point P_E and radius compensation.
- Initiate the dialog with the APPR/DEP key and DEP LCT soft key:



- Enter the coordinates of the end point P_N.
- Radius R of the circular arc. Enter R as a positive value.

Example NC blocks

`23 L Y+20 RR F100`	Last contour element: P_E with radius compensation
`24 DEP LCT X+10 Y+12 R+8 F100`	Coordinates P_N, arc radius=8 mm
`25 L Z+100 FMAX M2`	Retract in Z, return to block 1, end program

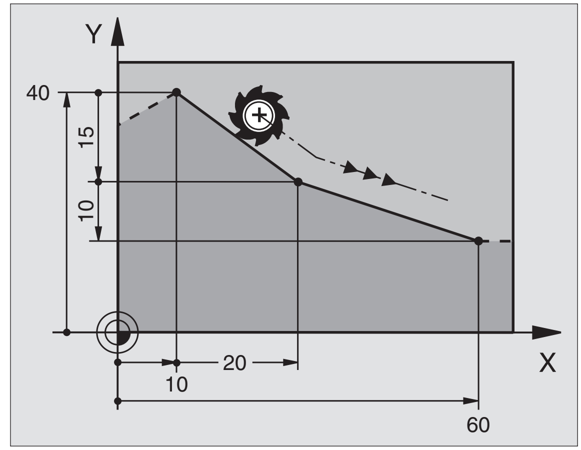
6.4 Path Contours—Cartesian Coordinates

Overview of path functions

Function	Path function key	Tool movement	Required input
Line **L**	L	Straight line	Coordinates of the end points of the straight line
Chamfer **CHF**	CHF	Chamfer between two straight lines	Chamfer side length
Circle Center **CC**	CC	No tool movement	Coordinates of the circle center or pole
Circle **C**	C	Circular arc around a circle center CC to an arc end point	Coordinates of the arc end point, direction of rotation
Circular Arc **CR**	CR	Circular arc with a certain radius	Coordinates of the arc end point, arc radius, direction of rotation
Circular Arc **CT**	CT	Circular arc with tangential connection to the preceding and subsequent contour elements	Coordinates of the arc end point
Corner Rounding **RND**	RND	Circular arc with tangential connection to the preceding and subsequent contour elements	Rounding-off radius R
FK Free Contour Programming	FK	Straight line or circular path with any connection to the preceding contour element	see "Path Contours—FK Free Contour Programming," page 164

Straight line L

The TNC moves the tool in a straight line from its current position to the straight-line end point. The starting point is the end point of the preceding block.



- **`Coordinates`** of the end point of the straight line

Further entries, if necessary:

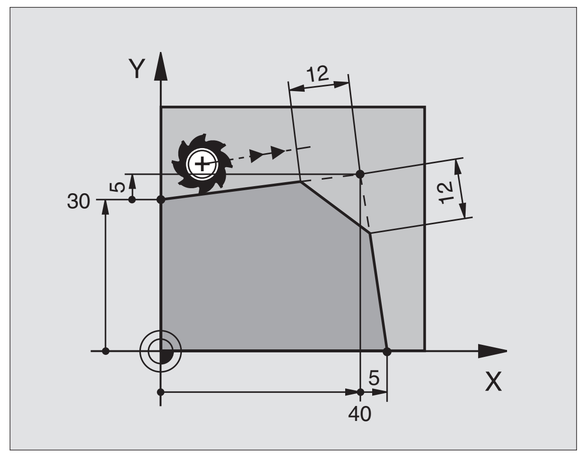
- **`Radius compensation RL/RR/R0`**
- **`Feed rate F`**
- **`Miscellaneous function M`**

Example NC blocks

```
7 L X+10 Y+40 RL F200 M3
8 L IX+20 IY-15
9 L X+60 IY-10
```

Actual position capture

You can also generate a straight-line block (L block) by using the ACTUAL-POSITION-CAPTURE key:



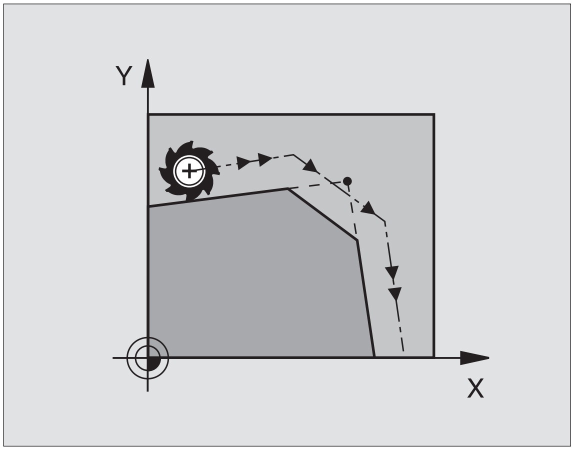
- In the Manual Operation mode, move the tool to the position you wish to capture.
- Switch the screen display to Programming and Editing.
- Select the program block after which you want to insert the L block.
- Press the ACTUAL-POSITION-CAPTURE key: The TNC generates an L block with the actual position coordinates.

In the MOD function, you define the number of axes that the TNC saves in an L block (see “MOD functions,” page 442).

Inserting a chamfer CHF between two straight lines

The chamfer enables you to cut off corners at the intersection of two straight lines.

- The blocks before and after the CHF block must be in the same working plane.
- The radius compensation before and after the chamfer block must be the same.
- An inside chamfer must be large enough to accommodate the current tool.



CHF

▶ **`Chamfer side length:`** Length of the chamfer

Further entries, if necessary:

▶ **`Feed rate F`** (only effective in CHF block)

Example NC blocks

```
7 L X+0 Y+30 RL F300 M3
8 L X+40 IY+5
9 CHF 12 F250
10 L IX+5 Y+0
```

You cannot start a contour with a CHF block.

A chamfer is possible only in the working plane.

The corner point is cut off by the chamfer and is not part of the contour.

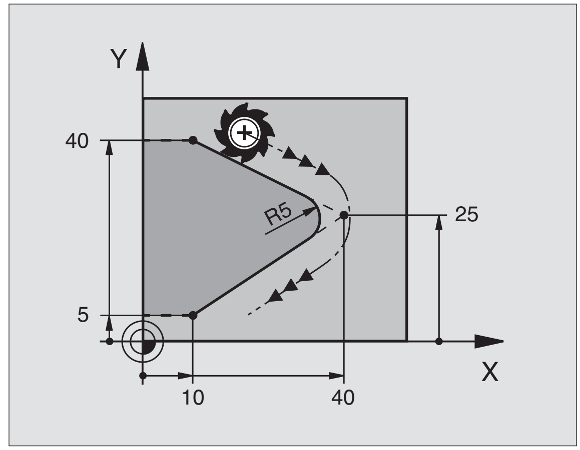
A feed rate programmed in the CHF block is effective only in that block. After the CHF block, the previous feed rate becomes effective again.

Corner rounding RND

The RND function is used for rounding off corners.

The tool moves on an arc that is tangentially connected to both the preceding and subsequent contour elements.

The rounding arc must be large enough to accommodate the tool.



- **`Rounding-off radius:`** Enter the radius

Further entries, if necessary:
- **`Feed rate F`** (only effective in RND block)

Example NC blocks

```
5 L X+10 Y+40 RL F300 M3
6 L X+40 Y+25
7 RND R5 F100
8 L X+10 Y+5
```

In the preceding and subsequent contour elements, both coordinates must lie in the plane of the rounding arc. If you machine the contour without tool-radius compensation, you must program both coordinates in the working plane.

The corner point is cut off by the rounding arc and is not part of the contour.

A feed rate programmed in the RND block is effective only in that block. After the RND block, the previous feed rate becomes effective again.

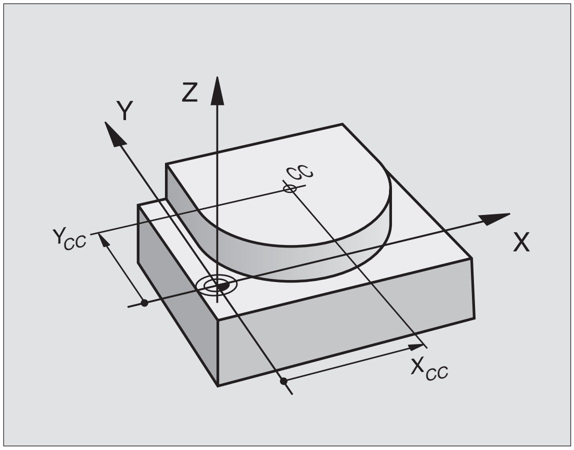
You can also use an RND block for a tangential contour approach if you do not want to use an APPR function.

Circle center CC

You can define a circle center CC for circles that are programmed with the C key (circular path C). This is done in the following ways:

- Entering the Cartesian coordinates of the circle center, or
- Using the circle center defined in an earlier block, or
- Capturing the coordinates with the ACTUAL-POSITION-CAPTURE key.

▶ **Coordinates** CC: Enter the circle center coordinates, or
If you want to use the last programmed position, do not enter any coordinates.



Example NC blocks

```
5 CC X+25 Y+25
```

or

```
10 L X+25 Y+25
11 CC
```

The program blocks 10 and 11 do not refer to the illustration.

Duration of effect

The circle center definition remains in effect until a new circle center is programmed. You can also define a circle center for the secondary axes U, V and W.

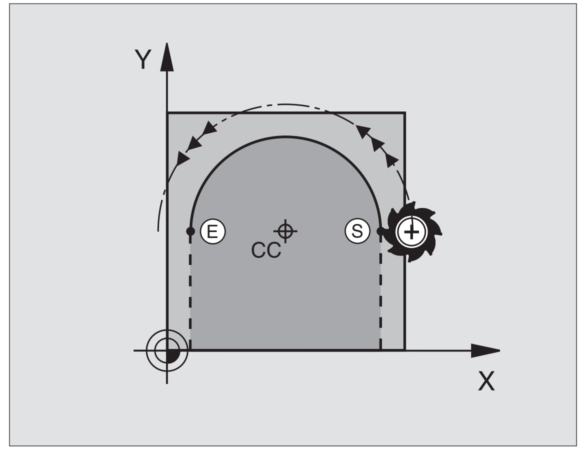
Entering the circle center CC incrementally

If you enter the circle center with incremental coordinates, you have programmed it relative to the last programmed position of the tool.

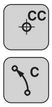
> The only effect of CC is to define a position as circle center: The tool does not move to this position.
>
> The circle center is also the pole for polar coordinates.

Circular path C around circle center CC

Before programming a circular path C, you must first enter the circle center CC. The last programmed tool position before the C block is used as the circle starting point.



- Move the tool to the circle starting point.



- **`Coordinates`** of the circle center
- **`Coordinates`** of the arc end point
- **`Direction of rotation DR`**

Further entries, if necessary:

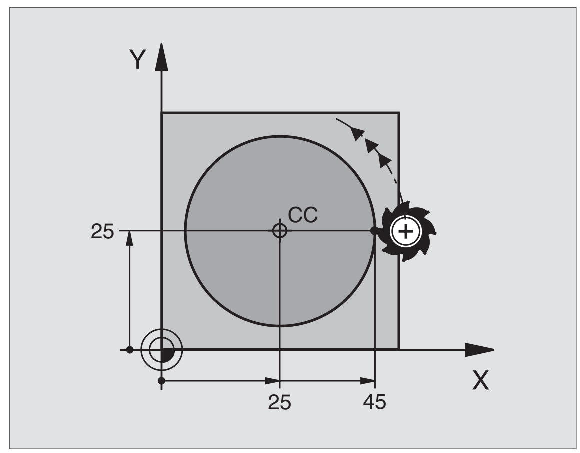
- **`Feed rate F`**
- **`Miscellaneous function M`**

Example NC blocks

```
5 CC X+25 Y+25
6 L X+45 Y+25 RR F200 M3
7 C X+45 Y+25 DR+
```

Full circle

Enter the same point you used as the starting point for the end point in a C block.



> The starting and end points of the arc must lie on the circle.
>
> Input tolerance: up to 0.016 mm (selected with MP7431).

Circular path CR with defined radius

The tool moves on a circular path with the radius R.

▶ **Coordinates** of the arc end point

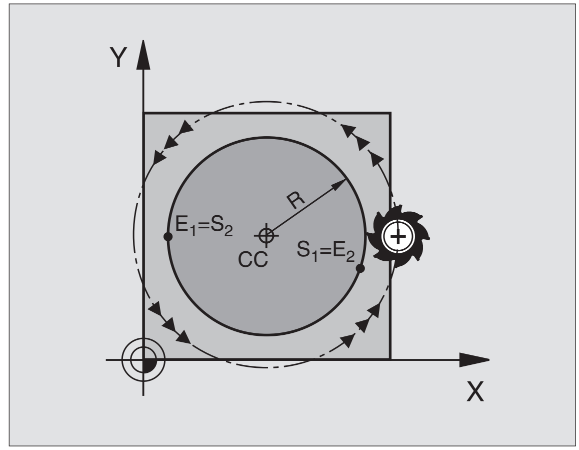
▶ **Radius R**
Note: The algebraic sign determines the size of the arc!

▶ **Direction of rotation DR**
Note: The algebraic sign determines whether the arc is concave or convex!

Further entries, if necessary:

▶ **Miscellaneous function M**

▶ **Feed rate F**



Full circle

For a full circle, program two CR blocks in succession:

The end point of the first semicircle is the starting point of the second. The end point of the second semicircle is the starting point of the first.

Central angle CCA and arc radius R

The starting and end points on the contour can be connected with four arcs of the same radius:

Smaller arc: CCA<180°
Enter the radius with a positive sign R>0

Larger arc: CCA>180°
Enter the radius with a negative sign R<0

The direction of rotation determines whether the arc is curving outward (convex) or curving inward (concave):

Convex: Direction of rotation DR– (with radius compensation RL)

Concave: Direction of rotation DR+ (with radius compensation RL)

Example NC blocks

```
10 L X+40 Y+40 RL F200 M3
11 CR X+70 Y+40 R+20 DR- (ARC 1)
```

or

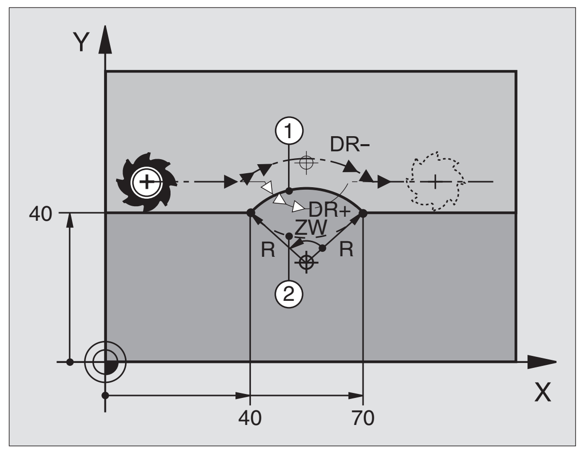
```
11 CR X+70 Y+40 R+20 DR+ (ARC 2)
```

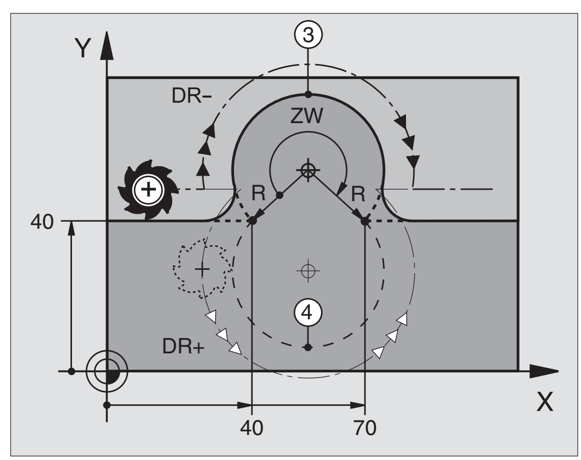
or

```
11 CR X+70 Y+40 R-20 DR- (ARC 3)
```

or

```
11 CR X+70 Y+40 R-20 DR+ (ARC 4)
```





The distance from the starting and end points of the arc diameter cannot be greater than the diameter of the arc.

The maximum radius is 99.9999 m.

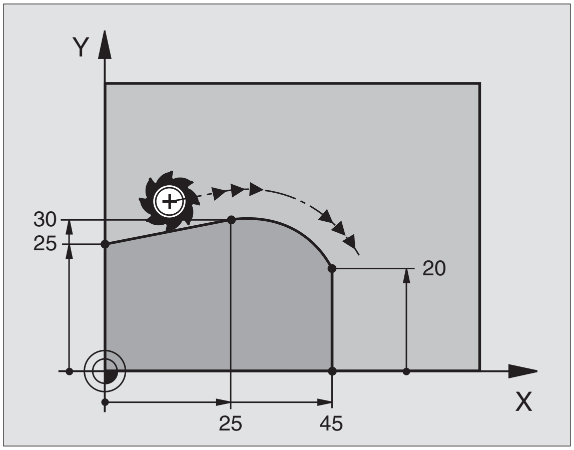
You can also enter rotary axes A, B and C.

Circular path CT with tangential connection

The tool moves on an arc that starts at a tangent with the previously programmed contour element.

A transition between two contour elements is called tangential when there is no kink or corner at the intersection between the two contours—the transition is smooth.

The contour element to which the tangential arc connects must be programmed immediately before the CT block. This requires at least two positioning blocks.



CT

▶ **Coordinates** of the arc end point

Further entries, if necessary:

▶ **Feed rate F**

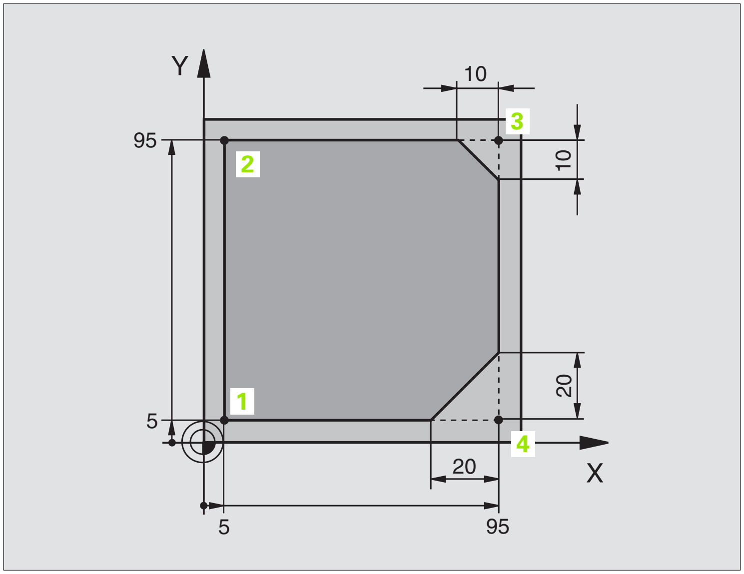
▶ **Miscellaneous function M**

Example NC blocks

```
7 L X+0 Y+25 RL F300 M3
8 L X+25 Y+30
9 CT X+45 Y+20
10 L Y+0
```

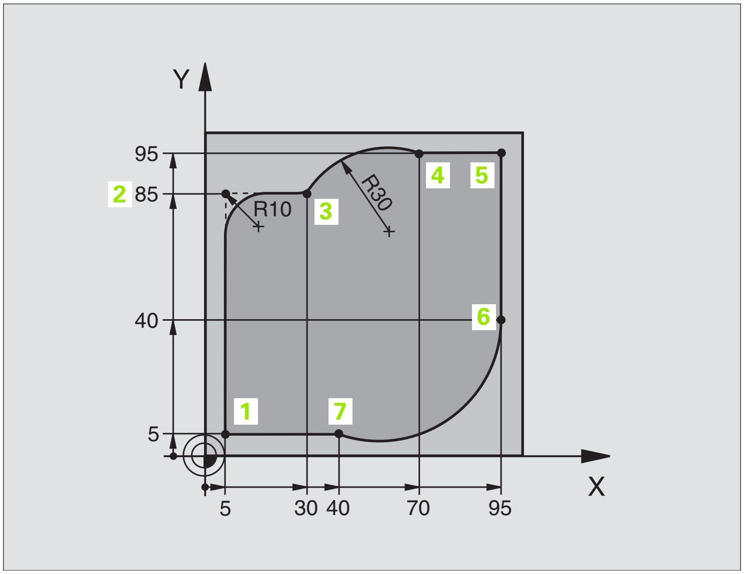
A tangential arc is a two-dimensional operation: the coordinates in the CT block and in the contour element preceding it must be in the same plane as the arc.

Example: Linear movements and chamfers with Cartesian coordinates



0 BEGIN PGM LINEAR MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define blank form for graphic workpiece simulation
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+10	Define tool in the program
4 TOOL CALL 1 Z S4000	Call tool in the spindle axis and with the spindle speed S
5 L Z+250 R0 FMAX	Retract tool in the spindle axis at rapid traverse FMAX
6 L X-10 Y-10 R0 FMAX	Pre-position the tool
7 L Z-5 R0 F1000 M3	Move to working depth at feed rate F = 1000 mm/min
8 APPR LT X+5 X+5 LEN10 RL F300	Approach the contour at point 1 on a straight line with
	tangential connection
9 L Y+95	Move to point 2
10 L X+95	Point 3: first straight line for corner 3
11 CHF 10	Program chamfer with length 10 mm
12 L Y+5	Point 4: 2nd straight line for corner 3, 1st straight line for corner 4
13 CHF 20	Program chamfer with length 20 mm
14 L X+5	Move to last contour point 1, second straight line for corner 4
15 DEP LT LEN10 F1000	Depart the contour on a straight line with tangential connection
16 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
17 END PGM LINEAR MM	

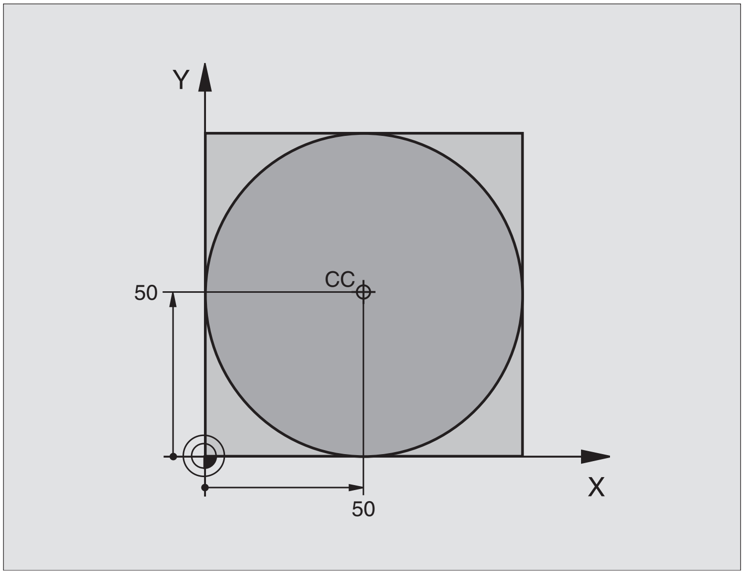
Example: Circular movements with Cartesian coordinates



0 BEGIN PGM CIRCULAR MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define blank form for graphic workpiece simulation
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+10	Define tool in the program
4 TOOL CALL 1 Z X4000	Call tool in the spindle axis and with the spindle speed S
5 L Z+250 R0 FMAX	Retract tool in the spindle axis at rapid traverse FMAX
6 L X-10 Y-10 R0 FMAX	Pre-position the tool
7 L Z-5 R0 F1000 M3	Move to working depth at feed rate F = 1000 mm/min
8 APPR LCT X+5 Y+5 R5 RL F300	Approach the contour at point 1 on a circular arc with
	tangential connection
9 L X+5 Y+85	Point 2: first straight line for corner 2
10 RND R10 F150	Insert radius with R = 10 mm, feed rate: 150 mm/min
11 L X+30 Y+85	Move to point 3: Starting point of the arc with CR
12 CR X+70 Y+95 R+30 DR-	Move to point 4: End point of the arc with CR, radius 30 mm
13 L X+95	Move to point 5
14 L X+95 Y+40	Move to point 6
15 CT X+40 Y+5	Move to point 7: End point of the arc, radius with tangential
	connection to point 6, TNC automatically calculates the radius

`16 L X+5`	Move to last contour point 1
`17 DEP LCT X-20 Y-20 R5 F1000`	Depart the contour on a circular arc with tangential connection
`18 L Z+250 R0 FMAX M2`	Retract in the tool axis, end program
`19 END PGM CIRCULAR MM`	

Example: Full circle with Cartesian coordinates



0 BEGIN PGM C-CC MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
2 BLK FORM 2.0 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+12.5	Define the tool
4 TOOL CALL 1 Z S3150	Tool call
5 CC X+50 Y+50	Define the circle center
6 L Z+250 R0 FMAX	Retract the tool
7 L X-40 Y+50 R0 FMAX	Pre-position the tool
8 L Z-5 R0 F1000 M3	Move to working depth
9 APPR LCT X+0 Y+50 R5 RL F300	Approach the starting point of the circle on a circular arc with
	connection
10 C X+0 DR-	Move to the circle end point (= circle starting point)
11 DEP LCT X-40 Y+50 R5 F1000	Depart the contour on a circular arc with tangential
	connection
12 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
13 END PGM C-CC MM	

6.5 Path Contours—Polar Coordinates

Overview

With polar coordinates you can define a position in terms of its angle PA and its distance PR relative to a previously defined pole CC (see “Fundamentals,” page 164).

Polar coordinates are useful with:

- Positions on circular arcs
- Workpiece drawing dimensions in degrees, e.g. bolt hole circles

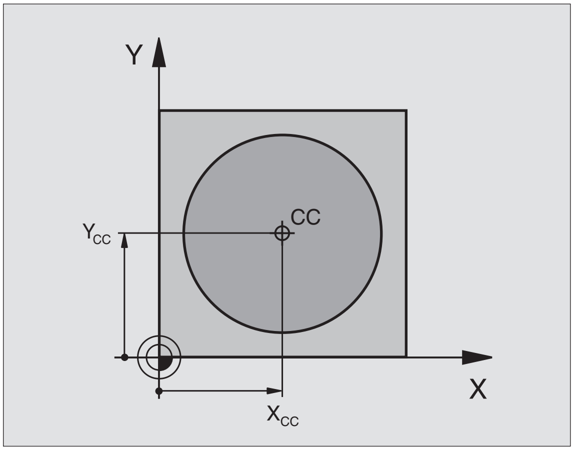
Overview of path functions with polar coordinates

Function	Path function key	Tool movement	Required input
Line **LP**	L + P	Straight line	Polar radius, polar angle of the straight-line end point
Circular Arc **CP**	C + P	Circular path around circle center/ pole CC to arc end point	Polar angle of the arc end point, direction of rotation
Circular Arc **CTP**	CT + P	Circular arc with tangential connection to the preceding contour element	Polar radius, polar angle of the arc end point
Helical interpolation	C + P	Combination of a circular and a linear movement	Polar radius, polar angle of the arc end point, coordinate of the end point in the tool axis

Polar coordinate origin: Pole CC

You can define the pole CC anywhere in the part program before blocks containing polar coordinates. Enter the pole in Cartesian coordinates as a circle center in a CC block.

- **Coordinates** CC: Enter Cartesian coordinates for the pole, or
  If you want to use the last programmed position, do not enter any coordinates. Before programming polar coordinates, define the pole CC. You can only define the pole CC in Cartesian coordinates. The pole CC remains in effect until you define a new pole CC.

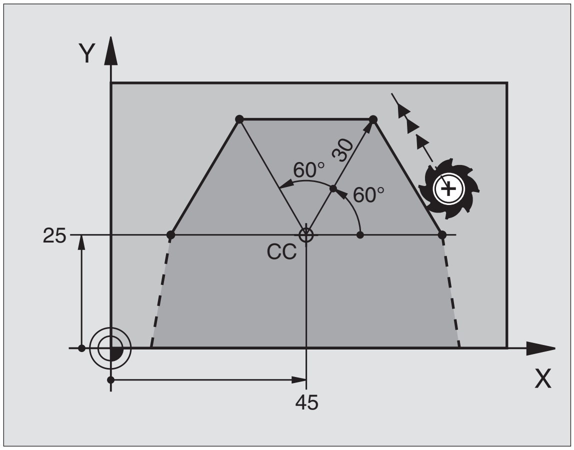


Example NC blocks

```
12 CC X+45 Y+25
```

Straight line LP

The tool moves in a straight line from its current position to the straight-line end point. The starting point is the end point of the preceding block.



- **Polar coordinates radius PR:** Enter the distance from the pole CC to the straight-line end point.
- **Polar coordinates angle PA:** Angular position of the straight-line end point between –360° and +360°.

The sign of PA depends on the angle reference axis:

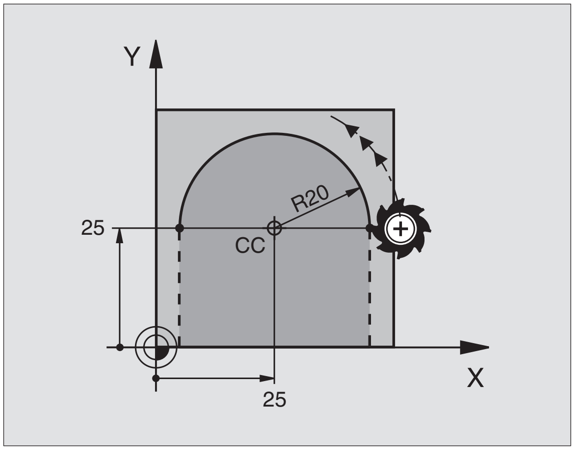
- Angle from angle reference axis to PR is counterclockwise: PA>0
- Angle from angle reference axis to PR is clockwise: PA<0

Example NC blocks

```
12 CC X+45 Y+25
13 LP PR+30 PA+0 RR F300 M3
14 LP PA+60
15 LP IPA+60
16 LP PA+180
```

Circular path CP around pole CC

The polar coordinate radius PR is also the radius of the arc. It is defined by the distance from the starting point to the pole CC. The last programmed tool position before the CP block is the starting point of the arc.



- **Polar-coordinates angle PA:** Angular position of the arc end point between –5400° and +5400°
- **Direction of rotation DR**

Example NC blocks

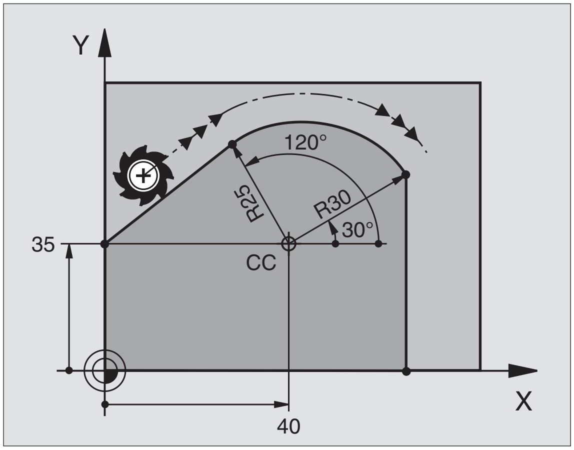
```
18 CC X+25 Y+25
19 LP PR+20 PA+0 RR F250 M3
20 CP PA+180 DR+
```

For incremental coordinates, enter the same sign for DR and PA.

Circular path CTP with tangential connection

The tool moves on a circular path, starting tangentially from a preceding contour element.

- **Polar coordinates radius PR:** Distance from the arc end point to the pole CC
- **Polar coordinates angle PA:** Angular position of the arc end point



Example NC blocks

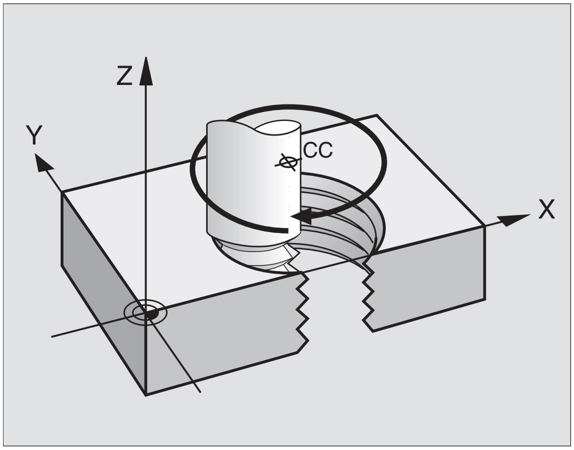
```
12 CC X+40 Y+35
13 L X+0 Y+35 RL F250 M3
14 LP PR+25 PA+120
15 CTP PR+30 PA+30
16 L Y+0
```

The pole CC is **not** the center of the contour arc!

Helical interpolation

A helix is a combination of a circular movement in a main plane and a line movement perpendicular to this plane.

A helix is programmed only in polar coordinates.



Application

- Large-diameter internal and external threads
- Lubrication grooves

Calculating the helix

To program a helix, you must enter the total angle through which the tool is to move on the helix in incremental dimensions, and the total height of the helix.

For calculating a helix that is to be cut in a upward direction, you need the following data:

Thread revolutions *n*	Thread revolutions + thread overrun at the start and end of the thread
Total height *h*	Thread pitch P times thread revolutions *n*
Incremental total angle IPA	Number of revolutions times 360° + angle for beginning of thread + angle for thread overrun
Starting coordinate Z	Pitch P times (thread revolutions + thread overrun at start of thread)

Shape of the helix

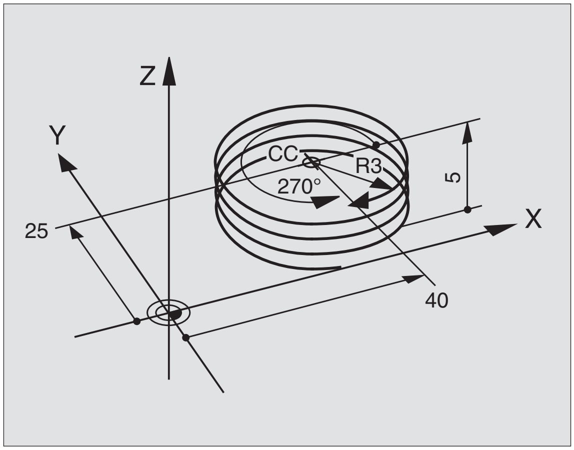
The table below illustrates in which way the shape of the helix is determined by the work direction, direction of rotation and radius compensation.

Internal thread	Work direction	Direction	Radius comp.
Right-handed Left-handed	Z+ Z+	DR+ DR–	RL RR
Right-handed Left-handed	Z– Z–	DR– DR+	RR RL
External thread			
Right-handed Left-handed	Z+ Z+	DR+ DR–	RR RL
Right-handed Left-handed	Z– Z–	DR– DR+	RL RR

Programming a helix

Always enter the same algebraic sign for the direction of rotation DR and the incremental total angle IPA. The tool may otherwise move in a wrong path and damage the contour.

For the total angle IPA, you can enter a value from –5400° to +5400°. If the thread has more than 15 revolutions, program the helix in a program section repeatsee “Program Section Repeats,” page 364.

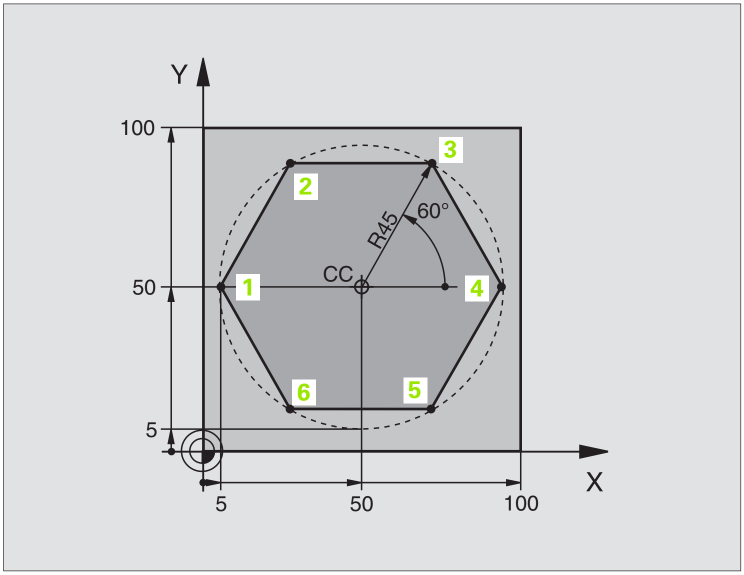


- **Polar coordinates angle:** Enter the total angle of tool traverse along the helix in incremental dimensions. **After entering the angle, specify the tool axis with an axis selection key.**
- **Coordinate:** Enter the coordinate for the height of the helix in incremental dimensions.
- **Direction of rotation DR**
  Clockwise helix: DR–
  Counterclockwise helix: DR+

Example NC blocks: Thread M6 x 1 mm with 5 revolutions

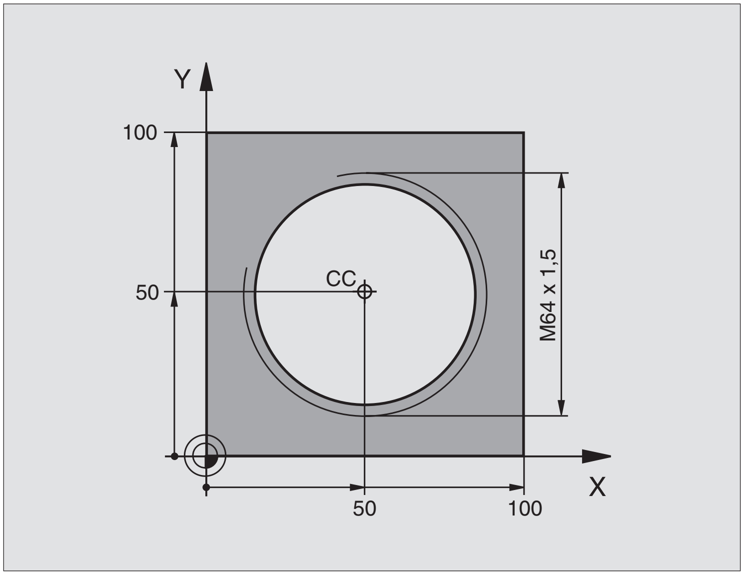
```
12 CC X+40 Y+25
13 L Z+0 F100 M3
14 LP PR+3 PA+270 RL F50
15 CP IPA-1800 IZ+5 DR-
```

Example: Linear movement with polar coordinates



0 BEGIN PGM LINEARPO MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+7.5	Define the tool
4 TOOL CALL 1 Z S4000	Tool call
5 CC X+50 Y+50	Define the datum for polar coordinates
6 L Z+250 R0 FMAX	Retract the tool
7 LP PR+60 PA+180 R0 FMAX	Pre-position the tool
8 L Z-5 R0 F1000 M3	Move to working depth
9 APPR PLCT PR+45 PA+180 R5 RL F250	Approach the contour at point 1 on a circular arc with
	tangential connection
10 LP PA+120	Move to point 2
11 LP PA+60	Move to point 3
12 LP PA+0	Move to point 4
13 LP PA-60	Move to point 5
14 LP PA-120	Move to point 6
15 LP PA+180	Move to point 1
16 DEP PLCT PR+60 PA+180 R5 F1000	Depart the contour on a circular arc with tangential connection
17 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
18 END PGM LINEARPO MM	

Example: Helix



`0 BEGIN PGM HELIX MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-20`	Define the workpiece blank
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	
`3 TOOL DEF 1 L+0 R+5`	Define the tool
`4 TOOL CALL 1 Z S1400`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 L X+50 Y+50 R0 FMAX`	Pre-position the tool
`7 CC`	Transfer the last programmed position as the pole
`8 L Z-12.75 R0 F1000 M3`	Move to working depth
`9 APPR PCT PR+32 PA-182 CCA180 R+2 RL F100`	Approach the contour on a circular arc with tangential connection
`10 CP IPA+3240 IZ+13.5 DR+ F200`	Helical interpolation
`11 DEP CT CCA180 R+2`	Depart the contour on a circular arc with tangential connection
`12 L Z+250 R0 FMAX M2`	Retract in the tool axis, end program
`13 END PGM HELIX MM`	

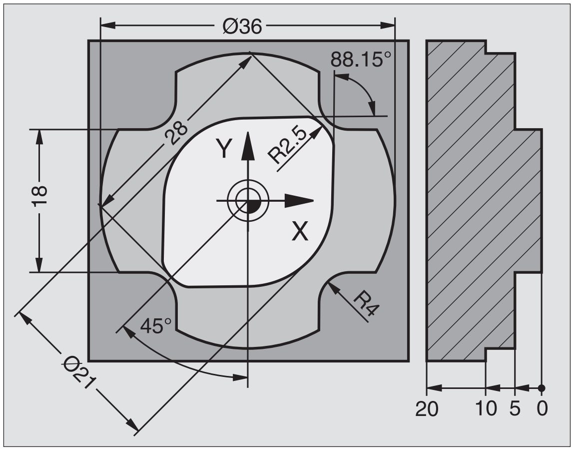
To cut a thread with more than 16 revolutions

`...`	
`8 L Z-12.75 R0 F1000`	
`9 APPR PCT PR+32 PA-180 CCA180 R+2 RL F100`	

10 LBL 1	Identify beginning of program section repeat
11 CP IPA+360 IZ+1.5 DR+ F200	Enter the thread pitch as an incremental IZ dimension
12 CALL LBL 1 REP 24	Program the number of repeats (thread revolutions)
13 DEP CT CCA180 R+2	

6.6 Path Contours—FK Free Contour Programming

Fundamentals



Workpiece drawings that are not dimensioned for NC often contain unconventional coordinate data that cannot be entered with the gray path function keys. You may, for example, have only the following data on a specific contour element:

- Known coordinates on the contour element or in its proximity
- Coordinate data that are referenced to another contour element
- Directional data and data regarding the course of the contour

You can enter such dimensional data directly by using the FK free contour programming function. The TNC derives the contour from the known coordinate data and supports the programming dialog with the interactive programming graphics. The figure to the upper right shows a workpiece drawing for which FK programming is the most convenient programming method.

The following prerequisites for FK programming must be observed:

The FK free contour programming feature can only be used for programming contour elements that lie in the working plane. The working plane is defined in the first BLK FORM block of the part program.

You must enter all available data for every contour element. Even the data that does not change must be entered in every block—otherwise it will not be recognized.

Q parameters are permissible in all FK elements, except in elements with relative references (e.g. RX or RAN), or in elements that are referenced to other NC blocks.

If both FK blocks and conventional blocks are entered in a program, the FK contour must be fully defined before you can return to conventional programming.

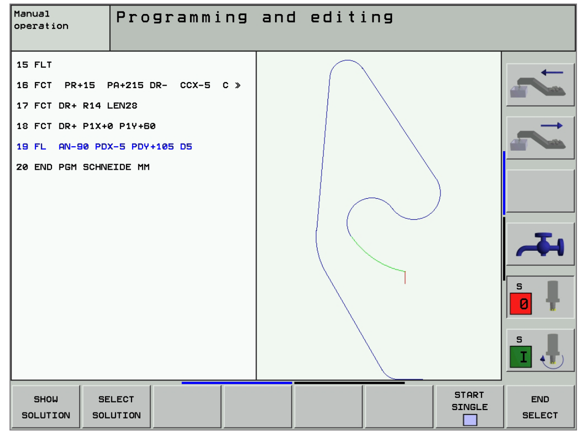
The TNC needs a fixed point from which it can calculate the contour elements. Use the gray path function keys to program a position that contains both coordinates of the working plane immediately before programming the FK contour. Do not enter any Q parameters in this block.

If the first block of an FK contour is an FCT or FLT block, you must program at least two NC block with the gray path function keys to fully define the direction of contour approach.

Do not program an FK contour immediately after an LBL label.

Graphics during FK programming

> If you wish to use graphic support during FK programming, select the PGM + GRAPHICS screen layout (see “Program Run, Full Sequence and Program Run, Single Block,” page 8).



Incomplete coordinate data often are not sufficient to fully define a workpiece contour. In this case, the TNC indicates the possible solutions in the FK graphic. You can then select the contour that matches the drawing. The FK graphic displays the elements of the workpiece contour in different colors:

White	The contour element is fully defined.
Green	The entered data describe a limited number of possible solutions: select the correct one.
Red	The entered data are not sufficient to determine the contour element: enter further data.

If the entered data permit a limited number of possible solutions and the contour element is displayed in green, select the correct contour element as follows:

SHOW SOLUTION

- Press the SHOW soft key repeatedly until the correct contour element is displayed.

SELECT SOLUTION

- If the displayed contour element matches the drawing, select the contour element with FSELECT.

Select the green contour elements as soon as possible with the FSELECT soft key. In this way, you can reduce the ambiguity of subsequent elements.

If you do not yet wish to select a green contour element, press the EDIT soft key to continue the FK dialog.

> The machine tool builder may use other colors for the FK graphics.
>
> NC blocks from a program that you called with PGM CALL are displayed in another color.

Initiating the FK dialog

If you press the gray FK button, the TNC displays the soft keys you can use to initiate an FK dialog: See the following table. Press the FK button a second time to deselect the soft keys.

If you initiate the FK dialog with one of these soft keys, the TNC shows additional soft-key rows that you can use for entering known coordinates, directional data and data regarding the course of the contour.

Contour element	Soft key
Straight line with tangential connection	FLT
Straight line without tangential connection	FL
Circular arc with tangential connection	FCT
Circular arc without tangential connection	FC
Pole for FK programming	FPOL

Free programming of straight lines

Straight line without tangential connection

FK

- To display the soft keys for free contour programming, press the FK key.

FL

- To initiate the dialog for free programming of straight lines, press the FL soft key. The TNC displays additional soft keys.
- Enter all known data in the block by using these soft keys. The FK graphic displays the programmed contour element in red until sufficient data are entered. If the entered data describe several solutions, the graphic will display the contour element in green (see “Graphics during FK programming,” page 165).

Straight line with tangential connection

If the straight line connects tangentially to another contour element, initiate the dialog with the FLT soft key:

FK

- To display the soft keys for free contour programming, press the FK key.

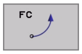
FLT

- To initiate the dialog, press the FLT soft key.
- Enter all known data in the block by using the soft keys.

Free programming of circular arcs

Circular arc without tangential connection

- To display the soft keys for free contour programming, press the FK key.

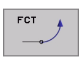


- To initiate the dialog for free programming of circular arcs, press the FC soft key. The TNC displays soft keys with which you can enter direct data on the circular arc or data on the circle center.
- Enter all known data in the block by using these soft keys. The FK graphic displays the programmed contour element in red until sufficient data are entered. If the entered data describe several solutions, the graphic will display the contour element in green (see "Graphics during FK programming," page 165).

Circular arc with tangential connection

If the circular arc connects tangentially to another contour element, initiate the dialog with the FCT soft key:

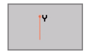
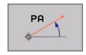
- To display the soft keys for free contour programming, press the FK key.

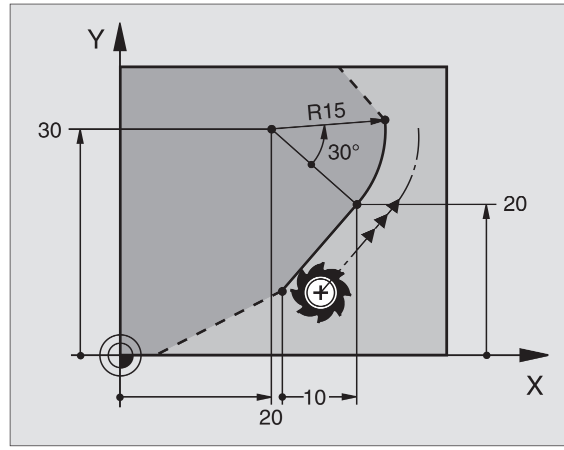


- To initiate the dialog, press the FCT soft key.
- Enter all known data in the block by using the soft keys.

Input possibilities

End point coordinates

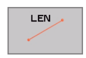
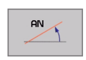
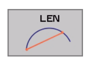
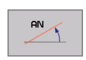
Known data	Soft keys	
Cartesian coordinates X and Y		
Polar coordinates referenced to FPOL		

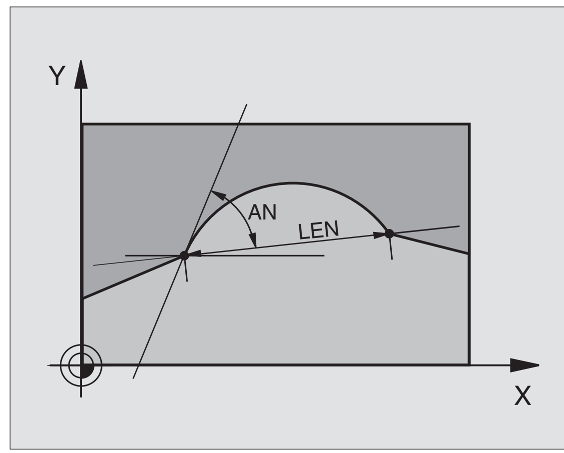


Example NC blocks

```
7 FPOL X+20 Y+30
8 FL IX+10 Y+20 RR F100
9 FCT PR+15 IPA+30 DR+ R15
```

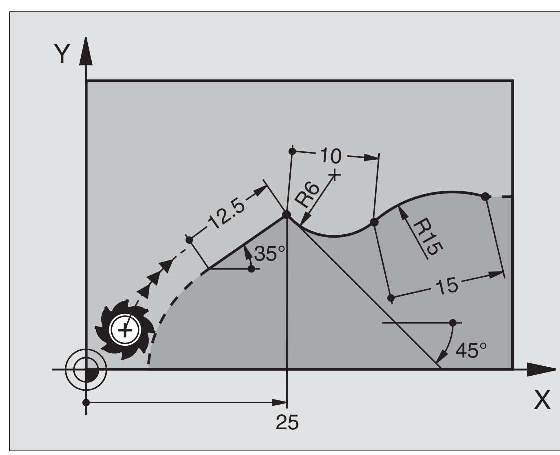
Direction and length of contour elements

Known data	Soft keys
Length of a straight line	
Gradient angle of a straight line	
Chord length LEN of the arc	
Gradient angle AN of the entry tangent	



Example NC blocks

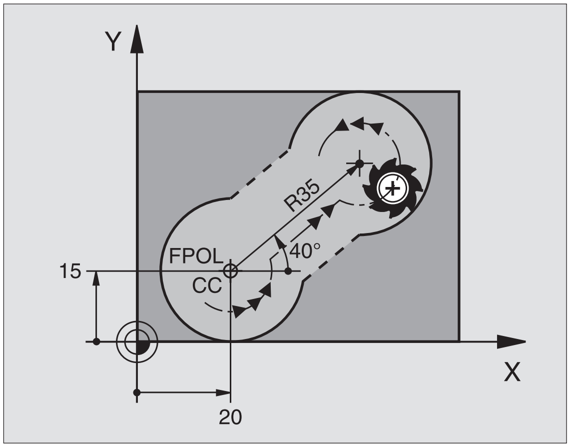
```
27 FLT X+25 LEN 12.5 AN+35 RL F200
28 FC DR+ R6 LEN 10 A-45
29 FCT DR- R15 LEN 15
```



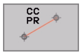
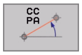
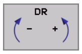
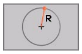
Circle center CC, radius and direction of rotation in the FC/FCT block

The TNC calculates a circle center for free-programmed arcs from the data you enter. This makes it possible to program full circles in an FK program block.

If you wish to define the circle center in polar coordinates you must use FPOL, not CC, to define the pole. FPOL is entered in Cartesian coordinates and remains in effect until the TNC encounters a block in which another FPOL is defined.



> A circle center that was calculated or programmed conventionally is then no longer valid as a pole or circle center for the new FK contour: If you enter conventional polar coordinates that refer to a pole from a CC block you have defined previously, then you must enter the pole again in a CC block after the FK contour.

Known data	Soft keys	
Circle center in Cartesian coordinates		
Circle center in polar coordinates		
Rotational direction of the arc		
Radius of the arc		

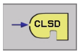
Example NC blocks

```
10 FC CCX+20 CCY+15 DR+ R15
11 FPOL X+20 Y+15
12 FL AN+40
13 FC DR+ R15 CCPR+35 CCPA+40
```

Closed contours

You can identify the beginning and end of a closed contour with the CLSD soft key. This reduces the number of possible solutions for the last contour element.

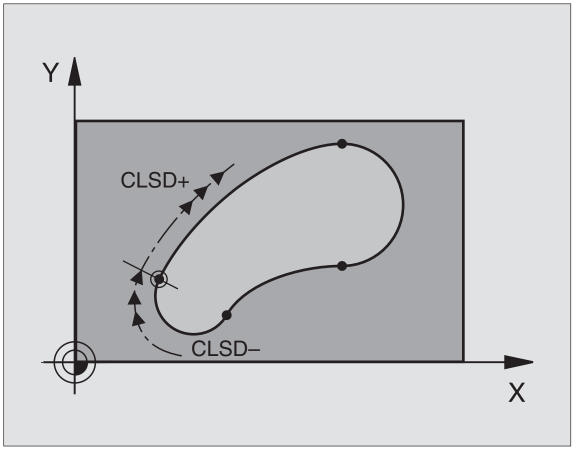
Enter CLSD as an addition to another contour data entry in the first and last blocks of an FK section.



Beginning of contour:	CLSD+
End of contour:	CLSD-

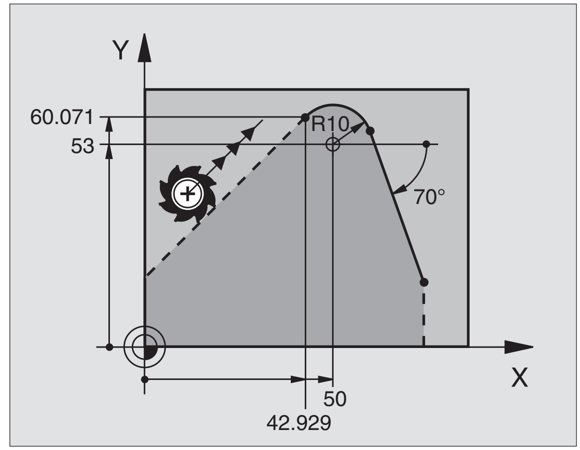
Example NC blocks

```
12 L X+5 Y+35 RL F500 M3
13 FC DR- R15 CLSD CCX+20 CCY+35
...
17 FCT DR- R+15 CLSD-
```



Auxiliary points

You can enter the coordinates of auxiliary points that are located on the contour or in its proximity for both free-programmed straight lines and free-programmed circular arcs.



Auxiliary points on a contour

The auxiliary points are located on a straight line or on the extension of a straight line, or on a circular arc.

Known data	Soft keys		
X coordinate of an auxiliary point P1 or P2 of a straight line	P1X	P2X	
Y coordinate of an auxiliary point P1 or P2 of a straight line	P1Y	P2Y	
X coordinate of an auxiliary point P1, P2 or P3 of a circular arc	P1X	P2X	P3X
Y coordinate of an auxiliary point P1, P2 or P3 of a circular arc	P1Y	P2Y	P3Y

Auxiliary points near a contour

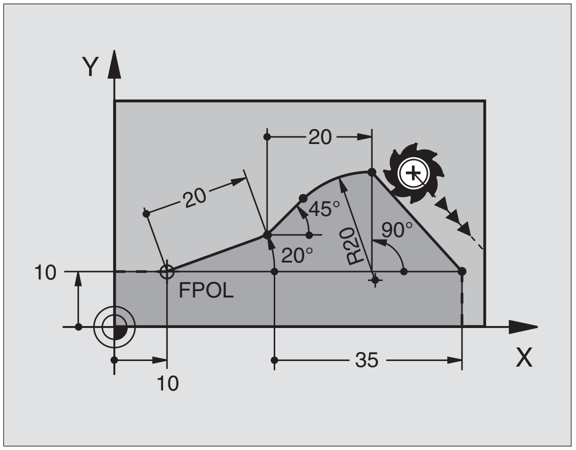
Known data	Soft keys	
X and Y coordinates of an auxiliary point near a straight line	PDX	PDY
Distance auxiliary point/straight line	D	
X and Y coordinates of an auxiliary pointnear a circular arc	PDX	PDY
Distance auxiliary point/circular arc	D	

Example NC blocks

```
13 FC DR- R10 P1X+42.929 P1Y+60.071
14 FLT AH-70 PDX+50 PDY+53 D10
```

Relative data

Data whose values are based on another contour element are called relative data. The soft keys and program words for entries begin with the letter **"R"** for **R**elative. The figure at right shows the entries that should be programmed as relative data.



The coordinates and angles for relative data are always programmed in incremental dimensions. You must also enter the block number of the contour element on which the data are based.

The block number of the contour element on which the relative data are based can only be located up to 64 positioning blocks before the block in which you program the reference.

If you delete a block on which relative data are based, the TNC will display an error message. Change the program first before you delete the block.

Data relative to block N: End point coordinates

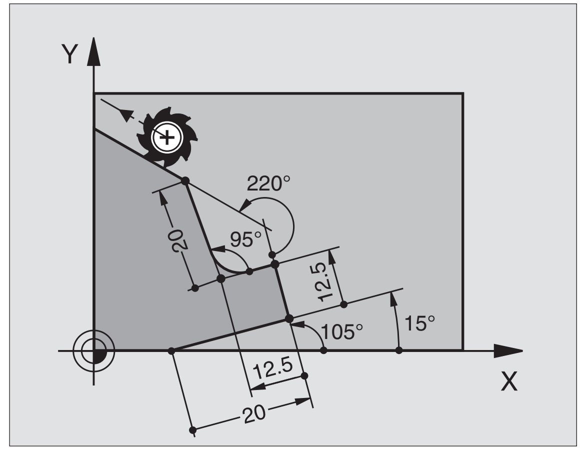
Known data	Soft keys	
Cartesian coordinates relative to block N	RX N	RY N
Polar coordinates relative to block N	RPR N	RPA N

Example NC blocks

```
12 FPOL X+10 Y+10
13 FL PR+20 PA+20
14 FL AH+45
15 FCT IX+20 DR- R20 CCA+90 RX 13
16 FL IPR+35 FA+0 RPR 13
```

Data relative to block N: Direction and distance of the contour element

Known data	Soft key
Angle between a straight line and another element or between the entry tangent of the arc and another element	RAN N
Straight line parallel to another contour element	PAR N
Distance from a straight line to a parallel contour element	DP

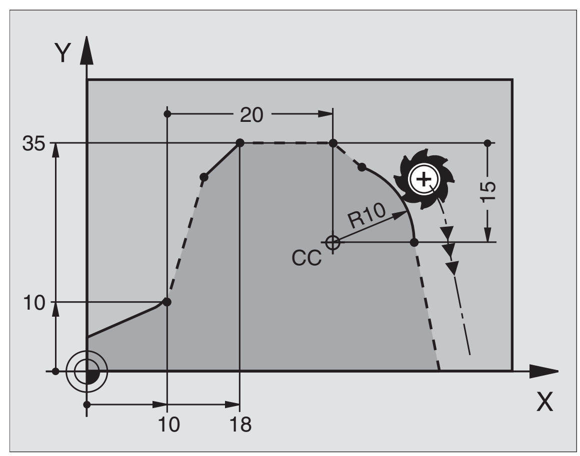


Example NC blocks

```
17 FL LEN 20 AH+15
18 FL AN+105 LEN 12.5
19 FL PAR 17 DP 12.5
20 FSELECT 2
21 FL LEN 20 IAH+95
22 FL IAH+220 RAN 18
```

Data relative to block N: Circle center CC

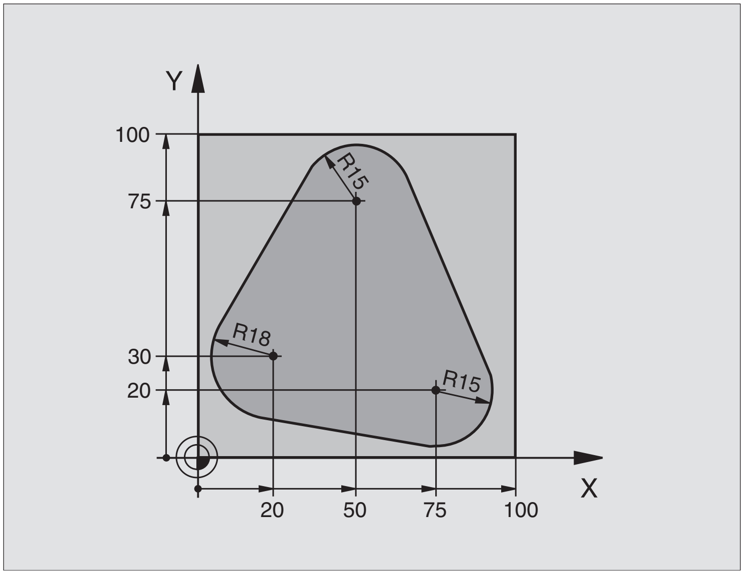
Known data	Soft key	
Cartesian coordinates of the circle center relative to block N	RCCX N	RCCY N
Polar coordinates of the circle center relative to block N	RCCPR N	RCCPA N



Example NC blocks

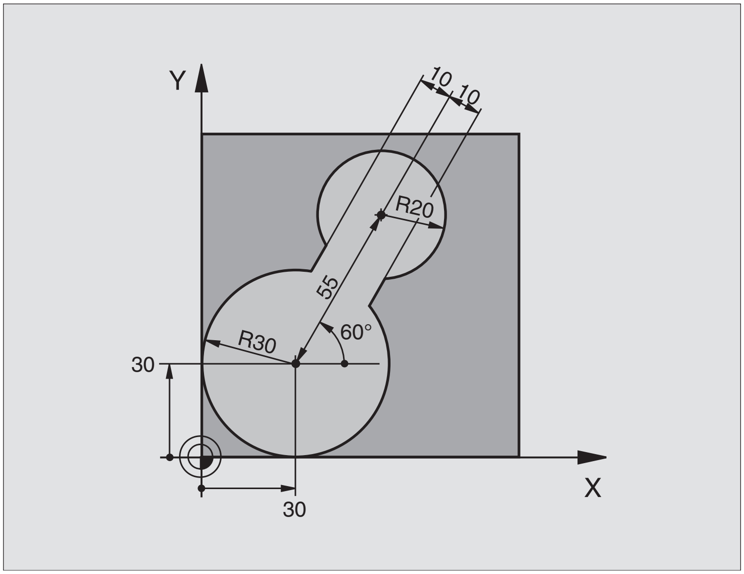
```
12 FL X+10 Y+10 RL
13 FL ...
14 FL X+18 Y+35
15 FL ...
16 FL ...
17 FC DR- R10 CCA+0 ICCX+20 ICCY-15 RCCX12 RCCY14
```

Example: FK programming 1



0 BEGIN PGM FK1 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+10	Define the tool
4 TOOL CALL 1 Z S500	Tool call
5 L Z+250 R0 FMAX	Retract the tool
6 L X-20 Y+30 R0 FMAX	Pre-position the tool
7 L Z-10 R0 F1000 M3	Move to working depth
8 APPR CT X+2 Y+30 CCA90 R+5 RL F250	Approach the contour on a circular arc with tangential connection
9 FC DR- R18 CLSD+ CCX+20 CCY+30	FK contour:
10 FLT	Program all known data for each contour element
11 FCT DR- R15 CCX+50 CCY+75	
12 FLT	
13 FCT DR- R15 CCX+75 CCY+20	
14 FLT	
15 FCT DR- R18 CLSD- CCX+20 CCY+30	
16 DEP CT CCA90 R+5 F1000	Depart the contour on a circular arc with tangential connection
17 L X-30 Y+0 R0 FMAX	
18 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
19 END PGM FK1 MM	

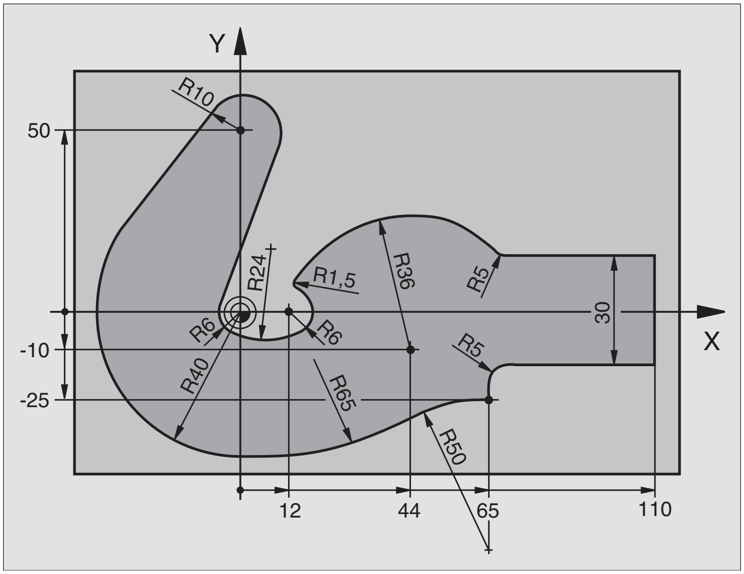
Example: FK programming 2



0 BEGIN PGM FK2 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+2	Define the tool
4 TOOL CALL 1 Z S4000	Tool call
5 L Z+250 R0 FMAX	Retract the tool
6 L X+30 Y+30 R0 FMAX	Pre-position the tool
7 L Z+5 R0 FMAX M3	Pre-position the tool in the tool axis
8 L Z-5 R0 F100	Move to working depth

9 APPR LCT X+0 Y+30 R5 RR F350	Approach the contour on a circular arc with tangential connection
10 FPOL X+30 Y+30	FK contour:
11 FC DR- R30 CCX+30 CCY+30	Program all known data for each contour element
12 FL AN+60 PDX+30 PDY+30 D10	
13 FSELECT 3	
14 FC DR- R20 CCPR+55 CCPA+60	
15 FSELECT 2	
16 FL AN-120 PDX+30 PDY+30 D10	
17 FSELECT 3	
18 FC X+0 DR- R30 CCX+30 CCY+30	
19 FSELECT 2	
20 DEP LCT X+30 Y+30 R5	Depart the contour on a circular arc with tangential connection
21 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
22 END PGM FK2 MM	

Example: FK programming 3



`0 BEGIN PGM FK3 MM`	
`1 BLK FORM 0.1 Z X-45 Y-45 Z-20`	Define the workpiece blank
`2 BLK FORM 0.2 X+120 Y+70 Z+0`	
`3 TOOL DEF 1 L+0 R+3`	Define the tool
`4 TOOL CALL 1 Z S4500`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 L X-70 Y+0 R0 FMAX`	Pre-position the tool
`7 L Z-5 R0 F1000 M3`	Move to working depth

8 APPR CT X-40 Y+0 CCA90 R+5 RL F250	Approach the contour on a circular arc with tangential connection
9 FC DR- R40 CCX+0 CCY+0	FK contour:
10 FLT	Program all known data for each contour element
11 FCT DR- R10 CCX+0 CCY+50	
12 FLT	
13 FCT DR+ R6 CCX+0 CCY+0	
14 FCT DR+ R24	
15 FCT DR+ R6 CCX+12 CCY+0	
16 FSELECT 2	
17 FCT DR- R1.5	
18 FCT DR- R36 CCX+44 CCY-10	
19 FSELECT 2	
20 FCT CT+ R5	
21 FLT X+110 Y+15 AN+0	
22 FL AN-90	
23 FL X+65 AN+180 PAR21 DP30	
24 RND R5	
25 FL X+65 Y-25 AN-90	
26 FC DR+ R50 CCX+65 CCY-75	
27 FCT DR- R65	
28 FSELECT	
29 FCT Y+0 DR- R40 CCX+0 CCY+0	
30 FSELECT 4	
31 DEP CT CCA90 R+5 F1000	Depart the contour on a circular arc with tangential connection
32 L X-70 R0 FMAX	
33 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
34 END PGM FK3 MM	

6.7 Path Contours—Spline Interpolation

Function

If you wish to machine contours that are described in a CAD system as splines, you can transfer them directly to the TNC and execute them. The TNC features a spline interpolator for executing third-degree polynomials in two, three, four, or five axes.

> You cannot edit spline blocks in the TNC. Exception: Feed rate **F** and miscellaneous function **M** in the spline block.

Example: Block format for three axes

`7 L X+28.338 Y+19.385 Z-0.5 FMAX`	Spline starting point

`8 SPL X24.875 Y15.924 Z-0.5`
`K3X-4.688E-002 K2X2.459E-002 K1X3.486E+000`
`K3Y-4.563E-002 K2Y2.155E-002 K1Y3.486E+000`
`K3Z0.000E+000 K2Z0.000E+000 K1Z0.000E+000 F10000`
	Spline end point
	Spline parameters for X axis
	Spline parameters for Y axis
	Spline parameters for Z axis

`9 SPL X17.952 Y9.003 Z-0.500`
`K3X5.159E-002 K2X-5.644E-002 K1X6.928E+000`
`K3Y3.753E-002 K2Y-2.644E-002 K1Y6.910E+000`
`K3Z0.000E+000 K2Z0.000E+000 K1Z0.000E+000`
	Spline end point
	Spline parameters for X axis
	Spline parameters for Y axis
	Spline parameters for Z axis

`10 ...`	

The TNC executes the spline block according to the following third-degree polynomials:

$X(t) = K3X \cdot t^3 + K2X \cdot t^2 + K1X \cdot t + X$

$Y(t) = K3Y \cdot t^3 + K2Y \cdot t^2 + K1Y \cdot t + Y$

$Z(t) = K3Z \cdot t^3 + K2Z \cdot t^2 + K1Z \cdot t + Z$

whereby the variable *t* runs from 1 to 0. The incrementation of *t* depends on the feed rate and the length of the spline.

Example: Block format for five axes

`7 L X+33.909 X-25.838 Z+75.107 A+17 B-10.103 FMAX`	Spline starting point

`8 SPL X+39.824 Y-28.378 Z+77.425 A+17.32 B-12.75`
`K3X+0.0983 K2X-0.441 K1X-5.5724`
`K3Y-0.0422 K2Y+0.1893 1Y+2.3929`
`K3Z+0.0015 K2Z-0.9549 K1Z+3.0875`
`K3A+0.1283 K2A-0.141 K1A-0.5724`
`K3B+0.0083 K2B-0.413 E+2 K1B-1.5724 E+1 F10000`
	Spline end point
	Spline parameters for X axis
	Spline parameters for Y axis
	Spline parameters for Z axis
	Spline parameters for A axis
	Spline parameters for B axis with exponential notation

`9 ...`	

The TNC executes the spline block according to the following third-degree polynomials:

$X(t) = K3X \cdot t^3 + K2X \cdot t^2 + K1X \cdot t + X$

$Y(t) = K3Y \cdot t^3 + K2Y \cdot t^2 + K1Y \cdot t + Y$

$Z(t) = K3Z \cdot t^3 + K2Z \cdot t^2 + K1Z \cdot t + Z$

$A(t) = K3A \cdot t^3 + K2A \cdot t^2 + K1A \cdot t + A$

$B(t) = K3B \cdot t^3 + K2B \cdot t^2 + K1B \cdot t + B$

whereby the variable *t* runs from 1 to 0. The incrementation of *t* depends on the feed rate and the length of the spline.

For every end-point coordinate in the spline block, the spline parameters K3 to K1 must be programmed. The end-point coordinates can be programmed any sequence within the spline block.

The TNC always expects the spline parameters K for each axis in the sequence K3, K2, K1.

Besides the principal axes X, Y and Z the TNC can also process the secondary axes U, V and W, and the rotary axes A, B and C. The respective corresponding axis must then be programmed in the spline parameter K (e.g. K3A+0.0953 K2A-0.441 K1A+0.5724).

If the absolute value of a spline parameter K becomes greater than 9.999 999 99, then the post processor must output K in exponential notation (e.g. K3X+1.2750 E2).

The TNC can execute a program with spline blocks even when the working plane is tilted.

Ensure that the transitions from one spline to the next are as tangential as possible (directional changes of less than 0.1°). The TNC otherwise performs an exact stop if the filter functions are disabled, resulting in a jolting of the machine tool. If the filter functions are active, the TNC decreases the feed rate accordingly at these positions.

Input ranges

- Spline end point: –99 999.9999 to +99 999.9999
- Spline parameter K: –9.999 999 99 to +9.999 999 99
- Exponent for spline parameter K: –255 to +255 (whole number).

7

Programming: Miscellaneous-Functions

7.1 Entering Miscellaneous Functions M and STOP

Fundamentals

With the TNC's miscellaneous functions—also called M functions—you can affect:

- Program run, e.g., a program interruption
- Machine functions, such as switching spindle rotation and coolant supply on and off
- Contouring behavior of the tool

The machine tool builder may add some M functions that are not described in this User's Manual. Refer to your machine manual.

You can enter up to two M functions at the end of a positioning block. The TNC then displays the following dialog question:

`Miscellaneous function M?`

You usually enter only the number of the M function in the programming dialog. Some M functions can be programmed with additional parameters. In this case, the dialog is continued for the parameter input.

In the Manual Operation and Electronic Handwheel modes of operation, the M functions are entered with the M soft key.

Please note that some M functions become effective at the start of a positioning block, and others at the end.

M functions come into effect in the block in which they are called. Unless the M function is only effective blockwise, it is canceled in a subsequent block or at the end of the program. Some M functions are effective only in the block in which they are called.

Entering an M function in a STOP block

If you program a STOP block, the program run or test run is interrupted at the block, for example for tool inspection. You can also enter an M function in a STOP block:

STOP

- To program an interruption of program run, press the STOP key.
- Enter miscellaneous function M

Example NC blocks

```
87 STOP M6
```

7.2 Miscellaneous Functions for Program Run Control, Spindle and Coolant

Overview

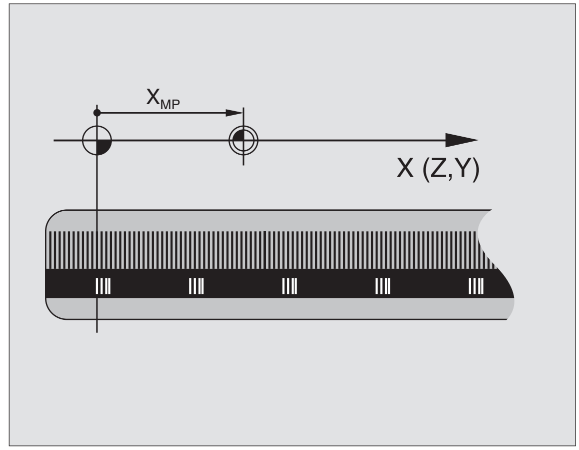
M	Effect	Effective at block - start	end
M00	Stop program run Spindle STOP Coolant OFF		■
M01	Optional program STOP		■
M02	Stop program run Spindle STOP Coolant OFF Go to block 1 Clear the status display (dependent on machine parameter 7300)		■
M03	Spindle ON clockwise	■	
M04	Spindle ON counterclockwise	■	
M05	Spindle STOP		■
M06	Tool change Spindle STOP Program run stop (dependent on machine parameter 7440)		■
M08	Coolant ON	■	
M09	Coolant OFF		■
M13	Spindle ON clockwise Coolant ON	■	
M14	Spindle ON counterclockwise Coolant ON	■	
M30	Same as M02		■

7.3 Miscellaneous Functions for Coordinate Data

Programming machine-referenced coordinates: M91/M92

Scale reference point

On the scale, a reference mark indicates the position of the scale reference point.



Machine datum

The machine datum is required for the following tasks:

- Defining the limits of traverse (software limit switches)
- Moving to machine-referenced positions (such as tool change positions)
- Setting the workpiece datum

The distance in each axis from the scale reference point to the machine datum is defined by the machine tool builder in a machine parameter.

Standard behavior

The TNC references coordinates to the workpiece datum (see "Datum Setting (Without a 3-D Touch Probe)," page 22).

Behavior with M91—Machine datum

If you want the coordinates in a positioning block to be referenced to the machine datum, end the block with M91.

The coordinate values on the TNC screen are shown with respect to the machine datum. Switch the display of coordinates in the status display to REF (see "Status Displays," page 9).

Behavior with M92—Additional machine datum

In addition to the machine datum, the machine tool builder can also define an additional machine-based position as a reference point.

For each axis, the machine tool builder defines the distance between the machine datum and this additional machine datum. Refer to the machine manual for more information.

If you want the coordinates in a positioning block to be based on the additional machine datum, end the block with M92.

Radius compensation remains the same in blocks that are programmed with M91 or M92. The tool length, however, is **not** compensated.

Effect

M91 and M92 are effective only in the blocks in which they are programmed.

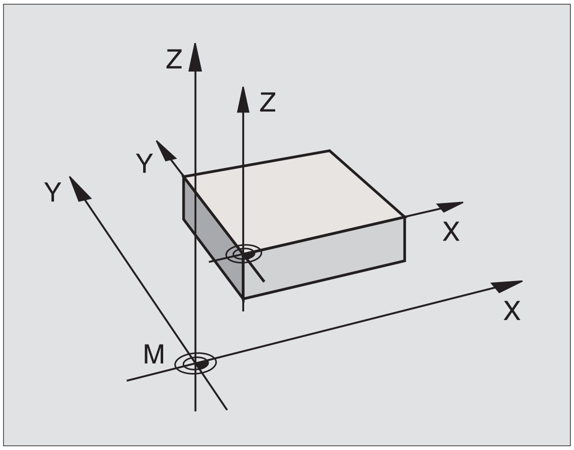
M91 and M92 take effect at the start of block.

Workpiece datum

If you want the coordinates to always be referenced to the machine datum, you can inhibit datum setting for one or more axes.

If datum setting is inhibited for all axes, the TNC no longer displays the soft key DATUM SET in the Manual Operation mode.

The figure at right shows coordinate systems with the machine datum and workpiece datum.



M91/M92 in the test run mode

In order to be able to graphically simulate M91/M92 movements, you need to activate working space monitoring and display the workpiece blank referenced to the set datum see “Showing the Workpiece in the Working Space,” page 459.

Activating the most recently entered datum: M104

Function

When processing pallet tables, the TNC may overwrite your most recently entered datum with values from the pallet table. With M104 you can reactivate the original datum.

Effect

M104 is effective only in the blocks in which it is programmed.

M104 becomes effective at the end of block.

Moving to position in an non-tilted coordinate system with a tilted working plane: M130

Standard behavior with a tilted working plane

The TNC places the coordinates in the positioning blocks in the tilted coordinate system.

Behavior with M130

The TNC places coordinates in straight line blocks in the untilted coordinate system.

The TNC then positions the (tilted) tool to the programmed coordinates of the untilted system.

Following positioning blocks or fixed cycles are carried out in a tilted coordinate system. This can lead to problems in fixed cycles with absolute pre-positioning.

The function M130 is allowed only if the tilted working plane function is active.

Effect

M130 functions blockwise in straight-line blocks without tool radius compensation.

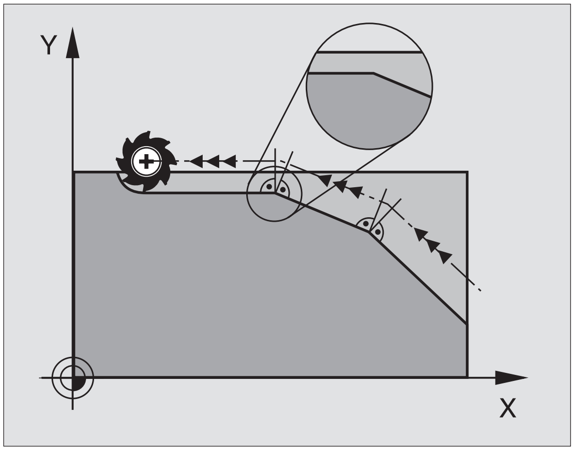
7.4 Miscellaneous Functions for Contouring Behavior

Smoothing corners: M90

Standard behavior

The TNC stops the tool briefly in positioning blocks without tool radius compensation. This is called an accurate stop.

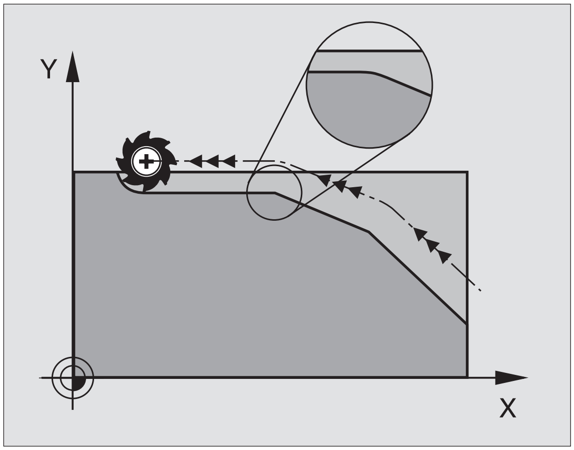
In program blocks with radius compensation (RR/RL), the TNC automatically inserts a transition arc at outside corners.



Behavior with M90

The tool moves at corners with constant speed: This provides a smoother, more continuous surface. Machining time is also reduced. See figure at center right.

Example application: Surface consisting of a series of straight line segments.



Effect

M90 is effective only in the blocks in which it is programmed with M90.

M90 becomes effective at the start of block. Operation with servo lag must be active.

Insert rounding arc between straight lines: M112

Compatibility

For reasons of compatibility, the M112 function is still available. However, to define the tolerance for fast contour milling, HEIDENHAIN recommends the use of the TOLERANCE cycle, see "Special Cycles," page 356.

Do not include points when executing non-compensated line blocks: M124

Standard behavior

The TNC runs all line blocks that have been entered in the active program.

Behavior with M124

When running **non-compensated line blocks** with very small point intervals, you can use parameter **T** to define a minimum point interval up to which the TNC will not include points during execution.

Effect

M124 becomes effective at the start of block.

The TNC automatically resets M124 if you select a new program.

Programming M124

If you enter M124 in a positioning block, the TNC continues the dialog for this block by asking you the minimum distance between points **T**.

You can also define **T** through Q parameters (see "Programming: Q Parameters" on page 375).

Machining small contour steps: M97

Standard behavior

The TNC inserts a transition arc at outside corners. If the contour steps are very small, however, the tool would damage the contour.

In such cases the TNC interrupts program run and generates the error message "Tool radius too large."

Behavior with M97

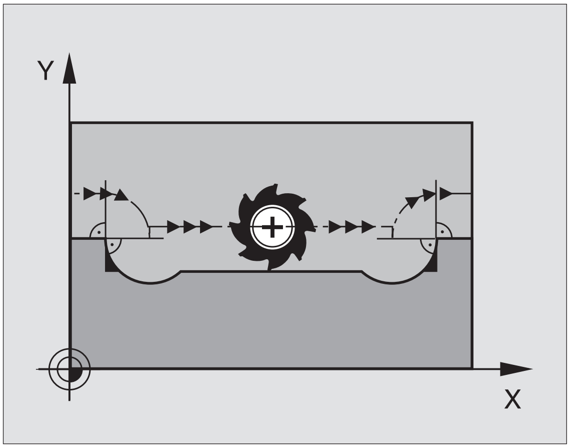
The TNC calculates the intersection of the contour elements—as at inside corners—and moves the tool over this point.

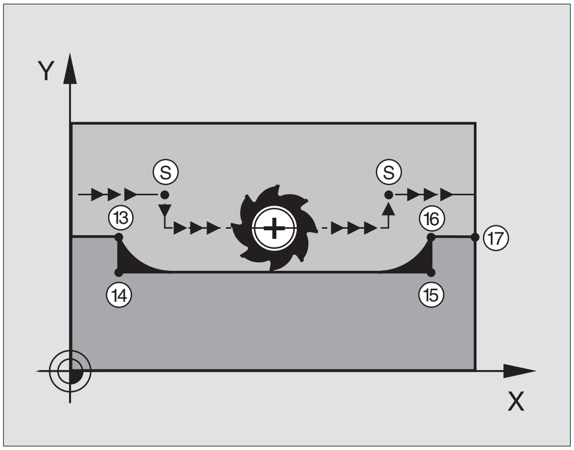
Program M97 in the same block as the outside corner.

Effect

M97 is effective only in the blocks in which it is programmed.

A corner machined with M97 will not be completely finished. You may wish to rework the contour with a smaller tool.

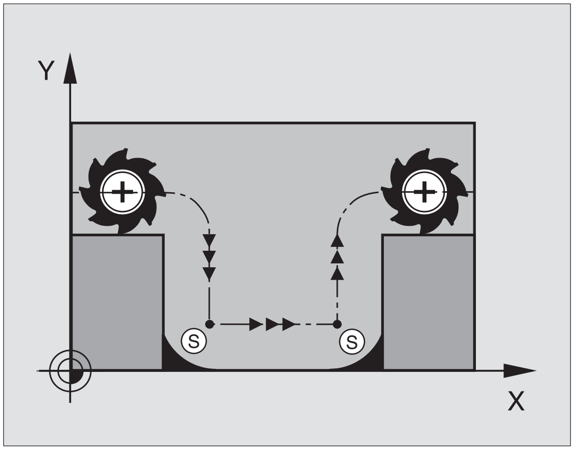




Example NC blocks

`5 TOOL DEF L ... R+20`	Large tool radius
`...`	
`13 L X... Y... R... F... M97`	Move to contour point 13
`14 L IY-0.5 ... R... F...`	Machine small contour step 13 to 14
`15 L IX+100 ...`	Move to contour point 15
`16 L IY+0.5 ... R... F... M97`	Machine small contour step 15 to 16
`17 L X... Y...`	Move to contour point 17

Machining open contours: M98



Standard behavior

The TNC calculates the intersections of the cutter paths at inside corners and moves the tool in the new direction at those points.

If the contour is open at the corners, however, this will result in incomplete machining.

Behavior with M98

With the miscellaneous function M98, the TNC temporarily suspends radius compensation to ensure that both corners are completely machined.

Effect

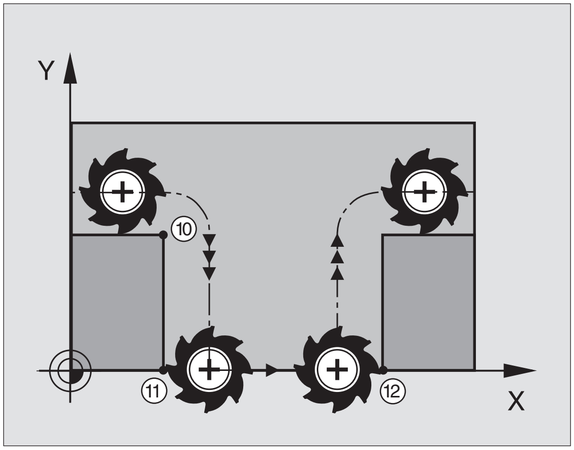
M98 is effective only in the blocks in which it is programmed.

M98 takes effect at the end of block.

Example NC blocks

Move to the contour points 10, 11 and 12 in succession:

```
10 L X... Y... RL F
11 L X... IY... M98
12 L IX+ ...
```



Feed rate factor for plunging movements: M103

Standard behavior

The TNC moves the tool at the last programmed feed rate, regardless of the direction of traverse.

Behavior with M103

The TNC reduces the feed rate when the tool moves in the negative direction of the tool axis. The feed rate for plunging FZMAX is calculated from the last programmed feed rate FPROG and a factor F%:

FZMAX = FPROG x F%

Programming M103

If you enter M103 in a positioning block, the TNC continues the dialog by asking you the factor F.

Effect

M103 becomes effective at the start of block.
To cancel M103, program M103 once again without a factor.

Example NC blocks

The feed rate for plunging is to be 20% of the feed rate in the plane.

`...`	Actual contouring feed rate (mm/min):
`17 L X+20 Y+20 RL F500 M103 F20`	500
`18 L Y+50`	500
`19 L IZ-2.5`	100
`20 L IY+5 IZ-5`	141
`21 L IX+50`	500
`22 L Z+5`	500

Feed rate in millimeters per spindle revolution: M136

Standard behavior

The TNC moves the tool at the programmed feed rate F in mm/min.

Behavior with M136

With M136, the TNC does not move the tool in mm/min, but rather at the programmed feed rate F in millimeters per spindle revolution. If you change the spindle speed by using the spindle override, the TNC changes the feed rate accordingly.

Effect

M136 becomes effective at the start of block.

You can cancel M136 by programming M137.

Feed rate at circular arcs: M109/M110/M111

Standard behavior

The TNC applies the programmed feed rate to the path of the tool center.

Behavior at circular arcs with M109

The TNC adjusts the feed rate for circular arcs at inside and outside contours such that the feed rate at the tool cutting edge remains constant.

Behavior at circular arcs with M110

The TNC keeps the feed rate constant for circular arcs at inside contours only. At outside contours, the feed rate is not adjusted.

> M110 is also effective for the inside machining of circular arcs using contour cycles. If you define M109 or M110 before calling a machining cycle, the adjusted feed rate is also effective for circular arcs within machining cycles. The initial state is restored after finishing or aborting a machining cycle.

Effect

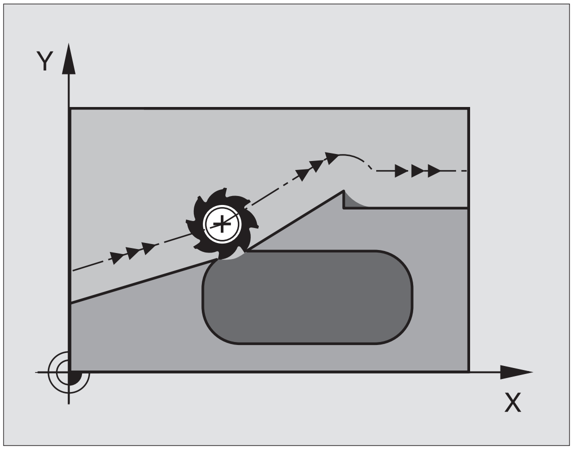
M109 and M110 become effective at the start of block.
To cancel M109 and M110, enter M111.

Calculating the radius-compensated path in advance (LOOK AHEAD): M120

Standard behavior

If the tool radius is larger than the contour step that is to be machined with radius compensation, the TNC interrupts program run and generates an error message. M97(see “Machining small contour steps: M97” on page 189): Although you can use M97 to inhibit the error message, this will result in dwell marks and will also move the corner.

If the programmed contour contains undercut features, the tool may damage the contour.



Behavior with M120

The TNC checks radius-compensated paths for contour undercuts and tool path intersections, and calculates the tool path in advance from the current block. Areas of the contour that might be damaged by the tool, are not machined (dark areas in figure at right). You can also use M120 to calculate the radius compensation for digitized data or data created on an external programming system. This means that deviations from the theoretical tool radius can be compensated.

Use LA (**L**ook **A**head) after M120 to define the number of blocks (maximum: 99) that you want the TNC to calculate in advance. Note that the larger the number of blocks you choose, the higher the block processing time will be.

Input

If you enter M120 in a positioning block, the TNC continues the dialog for this block by asking you the number of blocks LA that are to be calculated in advance.

Effect

M120 must be located in an NC block that also contains radius compensation RL or RR. M120 is then effective from this block until

- radius compensation is canceled, or
- M120 LA0 is programmed, or
- M120 is programmed without LA.
- another program is called with PGM CALL

M120 becomes effective at the start of block.

Limitations

- After an external or internal stop, you can only re-enter the contour with the function RESTORE POS. AT N.
- If you are using the path functions RND and CHF, the blocks before and after RND or CHF must contain only coordinates in the working plane.
- If you want to approach the contour on a tangential path, you must use the function APPR LCT. The block with APPR LCT must contain only coordinates of the working plane.
- If you want to approach the contour on a tangential path, use the function DEP LCT. The block with DEP LCT must contain only coordinates of the working plane.

Superimposing handwheel positioning during program run: M118

Standard behavior

In the program run modes, the TNC moves the tool as defined in the part program.

Behavior with M118

M118 permits manual corrections by handwheel during program run. You can use this miscellaneous function by entering axis-specific values X, Y and Z (in mm) behind M118.

Input

If you enter M118 in a positioning block, the TNC continues the dialog for this block by asking you the axis-specific values. The coordinates are entered with the orange axis direction buttons or the ASCII keyboard.

Effect

Cancel handwheel positioning by programming M118 once again without X, Y and Z.

M118 becomes effective at the start of block.

Example NC blocks

You wish to be able to use the handwheel during program run to move the tool in the working plane X/Y by ±1 mm of the programmed value:

```
L X+0 Y+38.5 RL F125 M118 X1 Y1
```

M118 is always effective in the original coordinate system, even if the working plane is tilted.

M118 also functions in the Positioning with MDI mode of operation!

If M118 is active, the MANUAL OPERATION function is not available after a program interruption.

Retraction from the contour in the tool-axis direction: M140

Standard behavior

In the program run modes, the TNC moves the tool as defined in the part program.

Behavior with M104

With M140 MB (move back) you can enter a path in the direction of the tool axis for departure from the contour.

Input

If you enter M140 in a positioning block, the TNC continues the dialog and asks for the desired path of tool departure from the contour. Enter the requested path that the tool should follow when departing the contour, or press the MAX soft key to move to the limit of the traverse range.

Effect

M140 is effective only in the block in which it is programmed.

M140 becomes effective at the start of the block.

Example NC blocks

Block 250: Retract the tool 50 mm from the contour.

Block 251: Move the tool to the limit of the traverse range.

```
250 L X+0 Y+38.5 F125 M140 MB 50
251 L X+0 Y+38.5 F125 M140 MB MAX
```

M140 is also effective if the tilted-working-plane function, M114 or M128 is active. On machines with tilting heads, the TNC then moves the tool in the tilted coordinate system.

With the **FN18: SYSREAD ID230 NR6** function you can find the distance from the current position to the limit of the traverse range in the positive tool axis.

With **M140 MB MAX** you can only retract in positive direction.

Suppressing touch probe monitoring: M141

Standard behavior

When the stylus is deflected, the TNC outputs an error message as soon as you attempt to move a machine axis.

Behavior with M141

The TNC moves the machine axes even if the touch probe is deflected. This function is required if you wish to write your own measuring cycle in connection with measuring cycle 3 in order to retract the stylus by means of a positioning block after it has been deflected.

> If you use M141, make sure that you retract the touch probe in the correct direction.
>
> M141 functions only for movements with straight-line blocks.

Effect

M141 is effective only in the block in which it is programmed.

M141 becomes effective at the start of the block.

Delete modal program information: M142

Standard behavior

The TNC resets modal program information in the following situations:

- Select a new program
- Execute a miscellaneous function M02, M30, or an END PGM block (depending on machine parameter 7300)
- Defining cycles for basic behavior with a new value

Behavior with M142

All modal program information except for basic rotation, 3-D rotation and Q parameters are reset.

Effect

M142 is effective only in the block in which it is programmed.

M142 becomes effective at the start of the block.

Delete basic rotation: M143

Standard behavior

The basic rotation remains in effect until it is reset or is overwritten with a new value.

Behavior with M143

The TNC erases a programmed basic rotation from the NC program.

Effect

M143 is effective only in the block in which it is programmed.

M143 becomes effective at the start of the block.

7.5 Miscellaneous Functions for Rotary Axes

Feed rate in mm/min on rotary axes A, B, C: M116

Standard behavior

The TNC interprets the programmed feed rate in a rotary axis in degrees per minute. The contouring feed rate therefore depends on the distance from the tool center to the center of the rotary axis.

The larger this distance becomes, the greater the contouring feed rate.

Feed rate in mm/min on rotary axes with M116

The machine geometry must be entered in machine parameters 7510 and following by the machine tool builder.

The TNC interprets the programmed feed rate in a rotary axis in mm/min. With this miscellaneous function, the TNC calculates the feed rate for each block at the start of the individual block. With a rotary axis, the feed rate is not changed during execution of the block even if the tool moves toward the center of the rotary axis.

Effect

M116 is effective in the working plane.
With M117 you can reset M116. M116 is also canceled at the end of the program.

M116 becomes effective at the start of block.

Shorter-path traverse of rotary axes: M126

Standard behavior

The standard behavior of the TNC while positioning rotary axes whose display has been reduced to values less than 360° is dependent on machine parameter 7682. In machine parameter 7682 is set whether the TNC should consider the difference between nominal and actual position, or whether the TNC should always (even without M126) choose the shortest path traverse to the programmed position. Examples:

Actual position	Nominal position	Traverse
350°	10°	–340°
10°	340°	+330°

Behavior with M126

With M126, the TNC will move the axis on the shorter path of traverse if you reduce display of a rotary axis to a value less than 360°. Examples:

Actual position	Nominal position	Traverse
350°	10°	+20°
10°	340°	–30°

Effect

M126 becomes effective at the start of block.
To cancel M126, enter M127. At the end of program, M126 is automatically canceled.

Reducing display of a rotary axis to a value less than 360°: M94

Standard behavior

The TNC moves the tool from the current angular value to the programmed angular value.

Example:

Current angular value:	538°
Programmed angular value:	180°
Actual distance of traverse:	–358°

Behavior with M94

At the start of block, the TNC first reduces the current angular value to a value less than 360° and then moves the tool to the programmed value. If several rotary axes are active, M94 will reduce the display of all rotary axes. As an alternative you can enter a rotary axis after M94. The TNC then reduces the display only of this axis.

Example NC blocks

To reduce display of all active rotary axes:

```
L M94
```

To reduce display of the C axis only

```
L M94
```

To reduce display of all active rotary axes and then move the tool in the C axis to the programmed value:

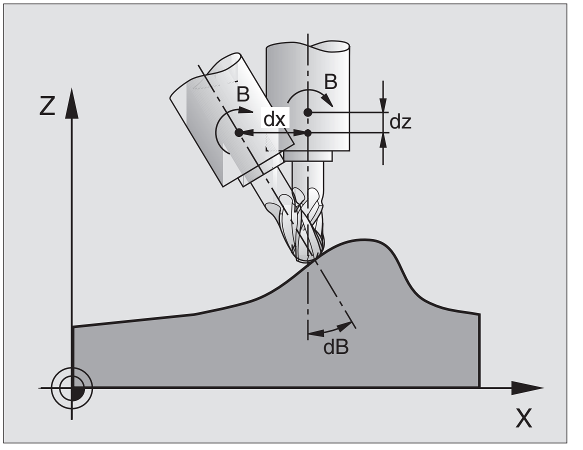
```
L C+180 FMAX M94
```

Effect

M94 is effective only in the block in which it is programmed.

M94 becomes effective at the start of block.

Automatic compensation of machine geometry when working with tilted axes: M114



Standard behavior

The TNC moves the tool to the positions given in the part program. If the position of a tilted axis changes in the program, the resulting offset in the linear axes must be calculated by a postprocessor and traversed in a positioning block. As the machine geometry is also relevant, the NC program must be calculated separately for each machine tool.

Behavior with M114

If the position of a controlled tilted axis changes in the program, the TNC automatically compensates the tool offset by a 3-D length compensation. As the geometry of the individual machine tools is set in machine parameters, the TNC also compensates machine-specific offsets automatically. Programs only need to be calculated by the postprocessor once, even if they are being run on different machines with TNC control.

If your machine tool does not have controlled tilted axes (head tilted manually or positioned by the PLC), you can enter the current valid swivel head position after M114 (e.g. M114 B+45, Q parameters permitted).

The radius compensation must be calculated by a CAD system or by a postprocessor. A programmed radius compensation RL/RR will result in an error message.

If the tool length compensation is calculated by the TNC, the programmed feed rate refers to the point of the tool. Otherwise it refers to the tool datum.

If you machine tool is equipped with a swivel head that can be tilted under program control, you can interrupt program run and change the position of the tilted axis, for example with the handwheel.

With the RESTORE POS. AT N function, you can then resume program run at the block at which the part program was interrupted. If M114 is active, the TNC automatically calculates the new position of the tilted axis.

If you wish to use the handwheel to change the position of the tilted axis during program run, use M118 in conjunction with M128.

Effect

M114 becomes effective at the start of block, M115 at the end of block. M114 is not effective when tool radius compensation is active.

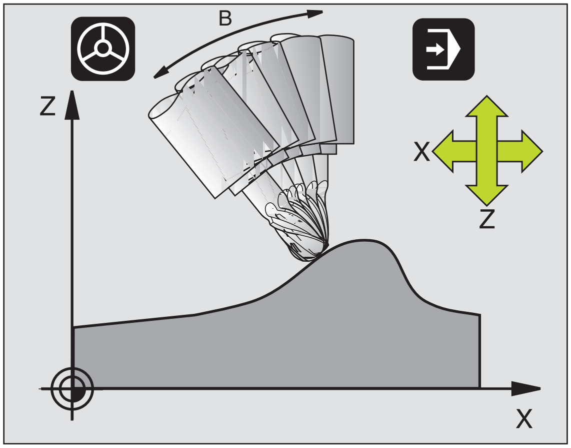
To cancel M114, enter M115. At the end of program, M114 is automatically canceled.

The machine geometry must be entered in machine parameters 7510 and following by the machine tool builder.

Maintaining the position of the tool tip when positioning with tilted axes (TCPM*): M128

Standard behavior

The TNC moves the tool to the positions given in the part program. If the position of a tilted axis changes in the program, the resulting offset in the linear axes must be calculated and traversed in a positioning block (see figure with M114).



Behavior with M128

If the position of a controlled tilted axis changes in the program, the position of the tool tip to the workpiece remains the same.

If you wish to use the handwheel to change the position of the tilted axis during program run, use M118 in conjunction with M128. Handwheel positioning in a machine-based coordinate system is possible when M128 is active.

> For tilted axes with Hirth coupling: Do not change the position of the tilted axis until after retracting the tool. Otherwise you might damage the contour.

After M128 you can program another feed rate, at which the TNC will carry out the compensation movements in the linear axes. If you program no feed rate here, or if you program a larger feed rate than is defined in MP7471, the feed rate from MP7471 will be effective.

> Reset M128 before positioning with M91 or M92 and before a TOOL CALL.
>
> To avoid contour gouging you must use only spherical cutters with M128.
>
> The tool length must refer to the spherical center of the tool tip.
>
> If M128 is active, the TNC shows the symbol in the status display.

M128 on tilting tables

If you program a tilting table movement while M128 is active, the TNC rotates the coordinate system accordingly. If for example you rotate the C axis by 90° (through a positioning command or datum shift) and then program a movement in the X axis, the TNC executes the movement in the machine axis Y.

The TNC also transforms the defined datum, which has been shifted by the movement of the rotary table.

M128 with 3-D tool compensation

If you perform a 3-D tool compensation with active M128 and active radius compensation RL/RR, the TNC will automatically position the rotary axes for certain machine geometrical configurations (peripheral milling,see “Three-Dimensional Tool Compensation,” page 118).

Effect

M128 becomes effective at the start of block, M129 at the end of block. M128 is also effective in the manual operating modes and remains active even after a change of mode. The feed rate for the compensation movement will be effective until you program a new feed rate or until you reset M128 with M129.

To cancel M128, enter M129. The TNC also resets M128 if you select a new program in a program run operating mode.

The machine geometry must be entered in machine parameters 7510 and following by the machine tool builder.

Example NC blocks

Moving at 1000 mm/min to compensate a radius.

```
L X+0 Y+38.5 RL F125 M128 F1000
```

Exact stop at corners with nontangential transitions: M134

Standard behavior

The standard behavior of the TNC during positioning with rotary axes is to insert a transitional element in nontangential contour transitions. The contour of the transitional element depends on the acceleration, the rate of acceleration (jerk), and the defined tolerance for contour deviation.

> With the machine parameters 7440 you can change the standard behavior of the TNC so that M134 becomes active automatically whenever a program is selected, see "General User Parameters," page 470.

Behavior with M134

The moves the tool during positioning with rotary axes so as to perform an exact stop at nontangential contour transitions.

Effect

M134 becomes effective at the start of block, M135 at the end of block.

You can reset M134 with M135. The TNC also resets M134 if you select a new program in a program run operating mode.

Selecting tilting axes: M138

Standard behavior

The TNC performs M114 and M128, and tilts the working plane, only in those axes for which the machine tool builder has set the appropriate machine parameters.

Behavior with M138

The TNC performs the above functions only in those tilting axes that you have defined using M138.

Effect

M138 becomes effective at the start of block.

You can reset M138 by reprogramming it without entering any axes.

Example NC blocks

Perform the above-mentioned functions only in the tilting axis C:

```
L Z+100 R0 FMAX M138 C
```

Compensating the machine's kinematic configuration for ACTUAL/NOMINAL positions at end of block: M144

Standard behavior

The TNC moves the tool to the positions given in the part program. If the position of a tilted axis changes in the program, the resulting offset in the linear axes must be calculated, and traversed in a positioning block.

Behavior with M144

The TNC calculates into the position value any changes in the machine's kinematic configuration which result, for example, from adding a spindle attachment. If the position of a controlled tilted axis changes, the position of the tool tip to the workpiece is also changed. The resulting offset is calculated in the position display.

> Positioning blocks with M91/M92 are permitted if M144 is active.
>
> The position display in the operating modes FULL SEQUENCE and SINGLE BLOCK does not change until the tilting axes have reached their final position.

Effect

M144 becomes effective at the start of the block. M144 does not function in connection with M114, M128 or a tilted working plane.

You can cancel M144 by programming M145.

> The machine geometry must be defined by the machine tool builder in the machine parameters 7502 and following. The machine tool builder decides upon the behavior of the machine in the automatic and manual operating modes. Refer to your machine manual.

7.6 Miscellaneous Functions for Laser Cutting Machines

Principle

The TNC can control the cutting efficiency of a laser by transferring voltage values through the S-analog output. You can influence laser efficiency during program run through the miscellaneous functions M200 to M204.

Entering miscellaneous functions for laser cutting machines

If you enter an M function for laser cutting machines in a positioning block, the TNC continues the dialog by asking you the required parameters for the programmed function.

All miscellaneous functions for laser cutting machines become effective at the start of the block.

Output the programmed voltage directly: M200

Behavior with M200

The TNC outputs the value programmed after M200 as the voltage V.

Input range: 0 to 9 999 V

Effect

M200 remains in effect until a new voltage is output through M200, M201, M202, M203 or M204.

Output voltage as a function of distance: M201

Behavior with M201

M201 outputs the voltage in dependence on the distance to be covered. The TNC increases or decreases the current voltage linearly to the value programmed for V.

Input range: 0 to 9 999 V

Effect

M201 remains in effect until a new voltage is output through M200, M201, M202, M203 or M204.

Output voltage as a function of speed: M202

Behavior with M202

The TNC outputs the voltage as a function of speed. In the machine parameters, the machine tool builder defines up to three characteristic curves FNR in which specific feed rates are assigned to specific voltages. Use miscellaneous function M202 to select the curve FNR from which the TNC is to determine the output voltage.

Input range: 1 to 3

Effect

M202 remains in effect until a new voltage is output through M200, M201, M202, M203 or M204.

Output voltage as a function of time (time-dependent ramp): M203

Behavior with M203

The TNC outputs the voltage V as a function of the time TIME. The TNC increases or decreases the current voltage linearly to the value programmed for V within the time programmed for TIME.

Input range

Voltage V:	0 to 9.999 Volt
TIME:	0 to 1.999 seconds

Effect

M203 remains in effect until a new voltage is output through M200, M201, M202, M203 or M204.

Output voltage as a function of time (time-dependent pulse): M204

Behavior with M204

The TNC outputs a programmed voltage as a pulse with a programmed duration TIME.

Input range

Voltage V:	0 to 9.999 Volt
TIME:	0 to 1.999 seconds

Effect

M204 remains in effect until a new voltage is output through M200, M201, M202, M203 or M204.

8

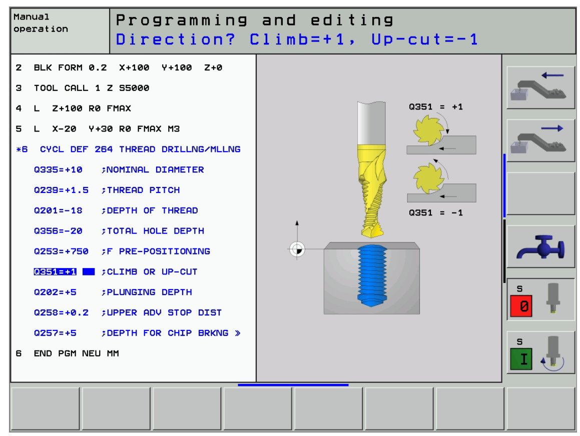
Programming: Cycles

8.1 Working with Cycles

Frequently recurring machining cycles that comprise several working steps are stored in the TNC memory as standard cycles. Coordinate transformations and other special cycles are also provided as standard cycles (see table on next page).

Fixed cycles with numbers 200 and above use Q parameters as transfer parameters. Parameters with specific functions that are required in several cycles always have the same number: For example, Q200 is always assigned the set-up clearance, Q202 the plunging depth, etc.

Defining a cycle using soft keys



CYCL DEF

- The soft-key row shows the available groups of cycles

DRILLING/ THREAD

- Press the soft key for the desired group of cycles, for example DRILLING for the drilling cycles

262

- Select the desired cycle, for example THREAD MILLING. The TNC initiates the programming dialog and asks all required input values. At the same time a graphic of the input parameters is displayed in the right screen window. The parameter that is asked for in the dialog prompt is highlighted
- Enter all parameters asked by the TNC and conclude each entry with the ENT key
- The TNC terminates the dialog when all required data has been entered.

Defining a cycle using the GOTO function

CYCL DEF

- The soft-key row shows the available groups of cycles

GOTO

- The TNC shows an overview of cycles in a window. Use the arrow keys to select the desired cycle, or enter the cycle number. Confirm with ENT. The TNC then initiates the cycle dialog as described above.

Example NC blocks

```
7 CYCL DEF 200 DRILLING
    Q200=2          ;SAFETY CLEARANCE
    Q201=3          ;DEPTH
    Q206=150        ;FEED RATE FOR PLUNGING
    Q202=5          ;INFEED DEPTH
    Q210=0          ;DWELL TIME AT TOP
    Q203=+0         ;SURFACE COORDINATE
    Q204=50         ;2ND SAFETY CLEARANCE
    Q211=0.25       ;DWELL TIME AT DEPTH
```

Group of cycles	Soft key
Cycles for pecking, reaming, boring, counterboring, tapping and thread cutting	DRILLING/ THREAD
Cycles for milling pockets, studs and slots	POCKETS/ STUDS/ SLOTS
Cycles for producing hole patterns, such as circular or linear patterns	PATTERN
SL (Subcontour List) cycles which allow the contour-parallel machining of relatively complex contours consisting of several overlapping subcontours, cylinder surface interpolation	SL II
Cycles for face milling of flat or twisted surfaces	MULTIPASS MILLING
Coordinate transformation cycles which enable datum shift, rotation mirror image, enlarging and reducing for various contours	COORD. TRANSF.
Special cycles such as dwell time, program call, oriented spindle stop and tolerance	SPECIAL CYCLES

If you use indirect parameter assignments in fixed cycles with numbers greater than 200 (e.g. Q210 = Q1), any change in the assigned parameter (e.g. Q1) will have no effect after the cycle definition. Define the cycle parameter (e.g. Q210) directly in such cases.

In order to be able to run Cycles 1 to 17 on older TNC models, you must program an additional negative sign before the values for safety clearance and plunging depth.

If you want to delete a block that is part of a cycle, the TNC asks you whether you want to delete the whole cycle.

Calling a cycle

Prerequisites

The following data must always be programmed before a cycle call:

- `BLK FORM` for graphic display (needed only for test graphics)
- Tool call
- Direction of spindle rotation (M functions M3/M4)
- Cycle definition (CYCL DEF).

For some cycles, additional prerequisites must be observed. They are described with the individual cycle.

The following cycles become effective automatically as soon as they are defined in the part program. These cycles cannot and must not be called:

- Cycle 220 for circular and Cycle 221 for linear hole patterns
- SL Cycle 14 CONTOUR GEOMETRY
- SL Cycle 20 CONTOUR DATA
- Cycle 32 TOLERANZ
- Coordinate transformation cycles
- Cycle 9 DWELL TIME

All other cycles are called as described below:

1 If the TNC is to execute the cycle once after the last programmed block, program the cycle call with the miscellaneous functionM99 or with CYCL CALL::

CYCL CALL

- To program the cycle call, press the CYCL CALL key.
- Press the CYCL CALL M soft key to enter a cycle call.
- Enter a miscellaneous function M or press END to end the dialog.

2 If the TNC is to execute the cycle automatically after every positioning block, program the cycle call with M89 (depending on machine parameter 7440).

3 If the TNC is to execute the cycle at every position that is defined in a point table, use the function **`CYCL CALL.`** (see “Point Tables” on page 212)

To cancel M89, enter

- `M99` or
- `CYCL CALL` or
- `CYCL DEF`

Working with the secondary axes U/V/W

The TNC performs infeed movements in the axis that was defined in the TOOL CALL block as the spindle axis. It performs movements in the working plane only in the principle axes X, Y or Z. Exceptions:

- You program secondary axes for the side lengths in cycles 3 SLOT MILLING and 4 POCKET MILLING.
- You program secondary axes in the contour geometry subprogram of an SL cycle.

8.2 Point Tables

Function

You should create a point table whenever you want to run a cycle, or several cycles in sequence, on an irregular point pattern.

If you are using drilling cycles, the coordinates of the working plane in the point table represent the hole centers. If you are using milling cycles, the coordinates of the working plane in the point table represent the starting-point coordinates of the respective cycle (e.g. center-point coordinates of a circular pocket). Coordinates in the spindle axis correspond to the coordinate of the workpiece surface.

Creating a point table

Select the **`Programming and Editing`** mode of operation.

PGM MGT — To call the file manager, press the PGM MGT key.

`FILE NAME ?`

NEW.PNT ENT — Enter the name and file type of the point table and confirm your entry with the ENT key.

MM — To select the unit of measure, press the MM or INCH soft key. The TNC changes to the program blocks window and displays an empty point table.

INSERT LINE — With the soft key INSERT LINE, insert new lines and enter the coordinates of the desired machining position.

Repeat the process until all desired coordinates have been entered.

> With the soft keys X OFF/ON, Y OFF/ON, Z OFF/ON (second soft-key row), you can specify which coordinates you want to enter in the point table.

Selecting a point table in the program

In the Programming and Editing mode of operation, select the program for which you want to activate the point table:

PGM CALL — Press the PGM CALL key to call the function for selecting the point table.

POINT TABLE — Press the POINT TABLE soft key.

Enter the name of the point table and confirm your entry with the ENT key. If the point table is not stored in the same directory as the NC program, you must enter the complete path.

Example NC block

```
7 SEL PATTERN „TNC:\DIRKT5\NUST35.PNT
```

Calling a cycle in connection with point tables

With **CYCL CALL PAT** the TNC runs the points table that you last defined (even if you have defined the point table in a program that was nested with **CALL PGM**.

The TNC uses the coordinate in the spindle axis as the clearance height, where the tool is located during cycle call. A clearance height or 2nd setup clearance that is defined separately in a cycle must not be greater than the clearance height defined in the global pattern..

If you want the TNC to call the last defined fixed cycle at the points defined in a point table, then program the cycle call with **CYCLE CALL PAT**:

CYCL CALL

- To program the cycle call, press the CYCL CALL key.
- Press the CYCL CALL PAT soft key to call a point table.
- Enter the feed rate at which the TNC is to move from point to point (if you make no entry the TNC will move at the last programmed feed rate, FMAX not valid).
- If required, enter miscellaneous function M, then confirm with the END key.

The TNC moves the tool back to the safe height over each successive starting point (safe height = the spindle axis coordinate for cycle call). To use this procedure also for the cycles number 200 and greater, you must define the 2nd set-up clearance (Q204) as 0.

If you want to move at reduced feed rate when pre-positioning in the spindle axis, use the miscellaneous function M103 (see “Feed rate factor for plunging movements: M103” on page 191).

Effect of the point tables with Cycles 1 to 5, 17 and 18

The TNC interprets the points of the working plane as coordinates of the hole centers. The coordinate of the spindle axis defines the upper surface of the workpiece, so the TNC can pre-position automatically (first in the working plane, then in the spindle axis).

Effect of the point tables with SL cycles and Cycle 12

The TNC interprets the points as an additional datum shift.

Effect of the point tables with Cycles 200 to 208 and 262 to 267

The TNC interprets the points of the working plane as coordinates of the hole centers. If you want to use the coordinate defined in the point table for the spindle axis as the starting point coordinate, you must define the workpiece surface coordinate (Q203) as 0.

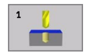
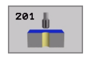
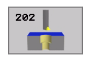
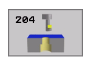
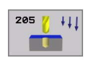
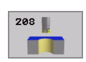
Effect of the point tables with Cycles 210 to 215

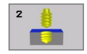
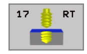
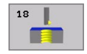
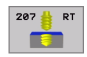
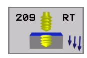
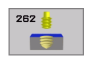
The TNC interprets the points as an additional datum shift. If you want to use the points defined in the point table as starting-point coordinates, you must define the starting points and the workpiece surface coordinate (Q203) in the respective milling cycle as 0.

8.3 Cycles for Drilling, Tapping and Thread Milling

Overview

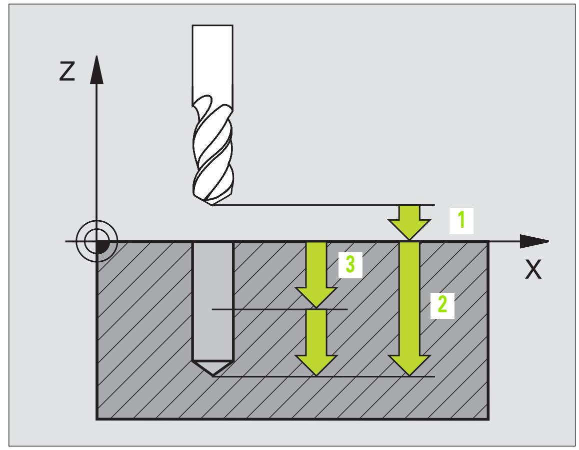
The TNC offers 19 cycles for all types of drilling operations:

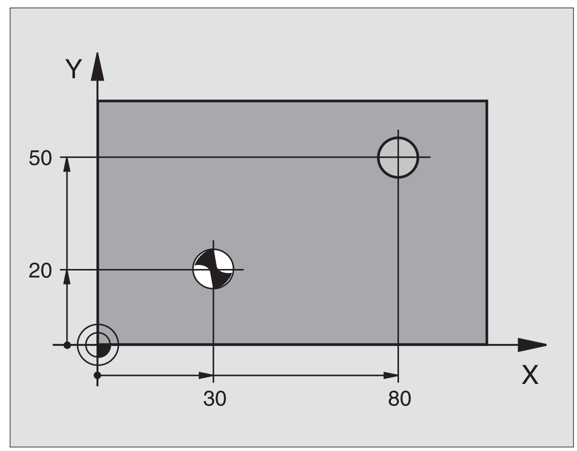
Cycle	Soft key
1 PECKING Without automatic pre-positioning	
200 DRILLING With automatic pre-positioning, 2nd set-up clearance	
201 REAMING With automatic pre-positioning, 2nd set-up clearance	
202 BORING With automatic pre-positioning, 2nd set-up clearance	
203 UNIVERSAL DRILLING With automatic pre-positioning, 2nd set-up clearance, chip breaking, and decrementing	
204 BACK BORING With automatic pre-positioning, 2nd set-up clearance	
205 UNIVERSAL PECKING With automatic pre-positioning, 2nd set-up clearance, chip breaking, and advanced stop distance	
208 BORE MILLING With automatic pre-positioning, 2nd set-up clearance	

Cycle	Soft key
2 TAPPING With a floating tap holder	
17 RIGID TAPPING Without a floating tap holder	
18 THREAD CUTTING	
206 TAPPING NEW With a floating tap holder, with automatic pre-positioning, 2nd set-up clearance	
207 RIGID TAPPING NEW Without a floating tap holder, with automatic pre-positioning, 2nd set-up clearance	
209 TAPPING W/ CHIP BRKG Without a floating tap holder, with automatic pre-positioning, 2nd set-up clearance, chip breaking	
262 THREAD MILLING Cycle for milling a thread in pre-drilled material	
263 THREAD MLLNG/CNTSNKG Cycle for milling a thread in pre-drilled material and machining a countersunk chamfer	
264 THREAD DRILLING/MLLNG Cycle for drilling into the solid material with subsequent milling of the thread with a tool	
265 HEL.THREAD DRLG/MLG Cycle for milling the thread into the solid material	
267 OUTSIDE THREAD MLLNG Cycle for milling an external thread and machining a countersunk chamfer	

PECKING (Cycle 1)

1 The tool drills from the current position to the first plunging depth at the programmed feed rate F.
2 When it reaches the first plunging depth, the tool retracts in rapid traverse FMAX to the starting position and advances again to the first plunging depth minus the advanced stop distance t.
3 The advanced stop distance is automatically calculated by the control:
   - At a total hole depth of up to 30 mm: t = 0.6 mm
   - At a total hole depth exceeding 30 mm: t = hole depth / 50
   - Maximum advanced stop distance: 7 mm
4 The tool then advances with another infeed at the programmed feed rate F.
5 The TNC repeats this process (1 to 4) until the programmed depth is reached.
6 After a dwell time at the hole bottom, the tool is returned to the starting position in rapid traverse FMAX for chip breaking.



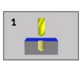


Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

Program a positioning block for the starting point in the tool axis (set-up clearance above the workpiece surface).

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.



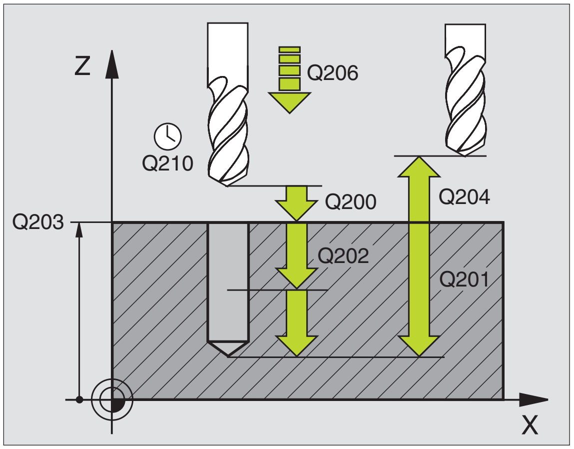
- **Set-up clearance** 1 (incremental value): Distance between tool tip (at starting position) and workpiece surface
- **Depth** 2 (incremental value): Distance between workpiece surface and bottom of hole (tip of drill taper)
- **Plunging depth** 3 (incremental value): Infeed per cut The total hole depth does not have to be a multiple of the plunging depth. The tool will drill to the total hole depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the total hole depth
- **Dwell time in seconds**: Amount of time the tool remains at the total hole depth for chip breaking
- **Feed rate F**: Traversing speed of the tool during drilling in mm/min

Example: NC blocks

```
5 L Z+100 R0 FMAX
6 CYCL DEF 1.0 PECKING
7 CYCL DEF 1.1 SETUP 2
8 CYCL DEF 1.2 DEPTH -15
9 CYCL DEF 1.3 PECKG 7.5
10 CYCL DEF 1.4 DWELL 1
11 CYCL DEF 1.5 F80
12 L X+30 Y+20 FMAX M3
13 L Z+2 FMAX M99
14 L X+80 Y+50 FMAX M99
15 L Z+100 FMAX M2
```

DRILLING (Cycle 200)

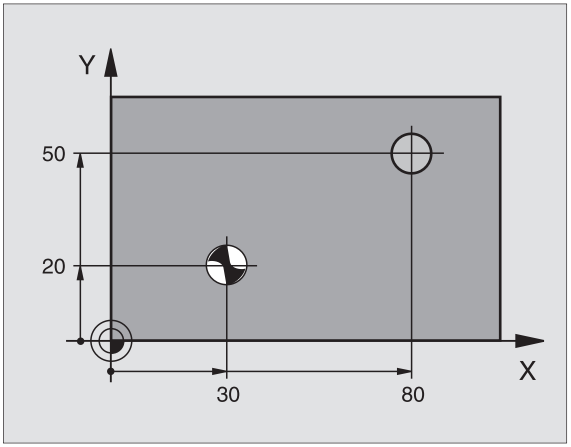
1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the set-up clearance above the workpiece surface.
2 The tool drills to the first plunging depth at the programmed feed rate F.
3 The TNC returns the tool at FMAX to the setup clearance, dwells there (if a dwell time was entered), and then moves at FMAX to the setup clearance above the first plunging depth.
4 The tool then advances with another infeed at the programmed feed rate F.
5 The TNC repeats this process (2 to 4) until the programmed depth is reached.
6 At the hole bottom, the tool path is retraced to set-up clearance or—if programmed—to the 2nd set-up clearance at rapid traverse FMAX.



Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

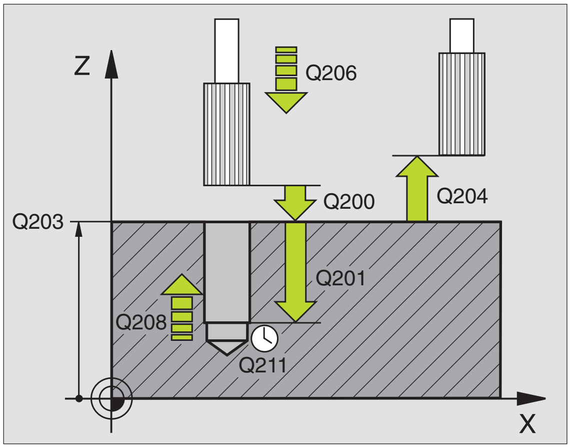


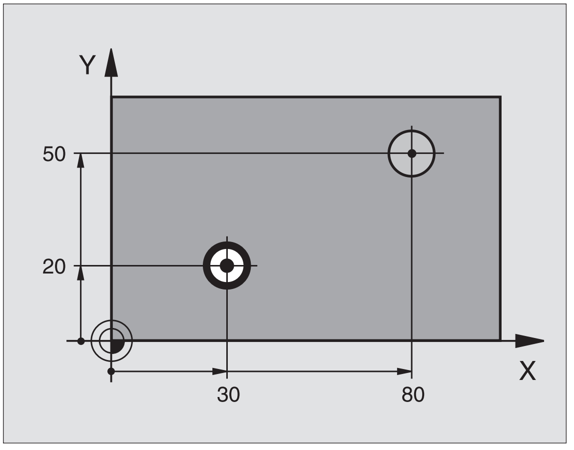
- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface. Enter a positive value.
- **`Depth`** Q201 (incremental value): Distance between workpiece surface and bottom of hole (tip of drill taper)
- **`Feed rate for plunging`** Q206: Traversing speed of the tool during drilling in mm/min
- **`Plunging depth`** Q202 (incremental value): Infeed per cut. The depth does not have to be a multiple of the plunging depth. The TNC will go to depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth
- **`Dwell time at top`** Q210: Time in seconds that the tool remains at set-up clearance after having been retracted from the hole for chip release.
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Dwell time at depth`** Q211: Time in seconds that the tool remains at the hole bottom

Example: NC blocks

```
10 L Z+100 R0 FMAX
11 CYCL DEF 200 DRILLING
     Q200=2         ;SAFETY CLEARANCE
     Q291=-15       ;DEPTH
     Q206=250       ;FEED RATE FOR PLUNGING
     Q202=5         ;INFEED DEPTH
     Q210=0         ;DWELL TIME AT TOP
     Q203=+20       ;SURFACE COORDINATE
     Q204=100       ;2ND SAFETY CLEARANCE
     Q211=0.1       ;DWELL TIME AT DEPTH
12 L X+30 Y+20 FMAX M3
13 CYCL CALL
14 L X+80 Y+50 FMAX M99
15 L Z+100 FMAX M2
```

REAMING (Cycle 201)



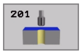


1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.
2. The tool reams to the entered depth at the programmed feed rate F.
3. If programmed, the tool remains at the hole bottom for the entered dwell time.
4. The tool then retracts to set-up clearance at the feed rate F, and from there—if programmed—to the 2nd set-up clearance in FMAX.

Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.



- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **`Depth`** Q201 (incremental value): Distance between workpiece surface and bottom of hole.
- **`Feed rate for plunging`** Q206: Traversing speed of the tool during reaming in mm/min
- **`Dwell time at depth`** Q211: Time in seconds that the tool remains at the hole bottom
- **`Retraction feed rate`** Q208: Traversing speed of the tool in mm/min when retracting from the hole. If you enter Q208 = 0, the tool retracts at the reaming feed rate.
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.

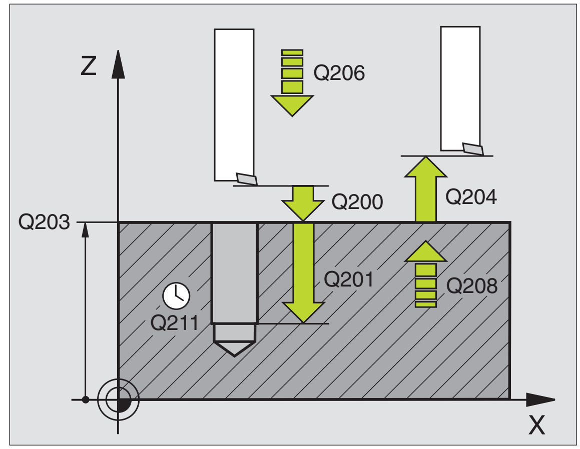
Example: NC blocks

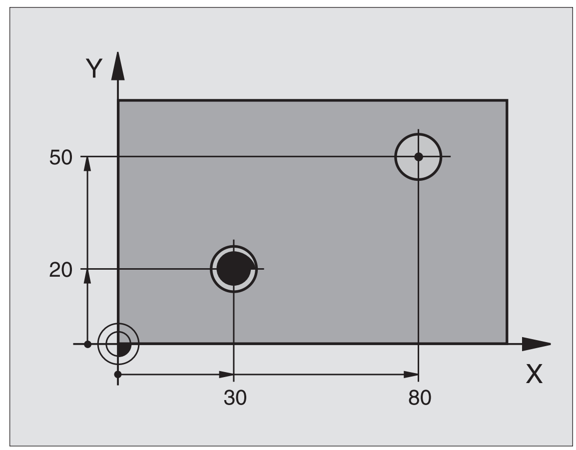
```
10 L Z+100 R0 FMAX
11 CYCL DEF 201 REIBEN
    Q200=2          ;SAFETY CLEARANCE
    Q201=-15        ;DEPTH
    Q206=100        ;FEED RATE FOR PLUNGING
    Q211=0.5        ;DWELL TIME AT DEPTH
    Q208=250        ;RETRACTION FEED RATE
    Q203=+20        ;SURFACE COORDINATE
    Q204=100        ;2ND SAFETY CLEARANCE
12 L X+30 Y+20 FMAX M3
13 CYCL CALL
14 L X+80 Y+50 FMAX M9
15 L Z+100 FMAX M2
```

BORING (Cycle 202)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the set-up clearance above the workpiece surface.
2. The tool drills to the programmed depth at the feed rate for plunging.
3. If programmed, the tool remains at the hole bottom for the entered dwell time with active spindle rotation for cutting free.
4. The TNC then orients the spindle to the position that is defined in parameter Q336.
5. If retraction is selected, the tool retracts in the programmed direction by 0.2 mm (fixed value).
6. The TNC moves the tool at the retraction feed rate to the set-up clearance and then, if entered, to the 2nd set-up clearance with FMAX. If Q214=0 the tool point remains on the wall of the hole.



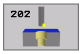


Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

After the cycle is completed, the TNC restores the coolant and spindle conditions that were active before the cycle call.



- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **`Depth`** Q201 (incremental value): Distance between workpiece surface and bottom of hole.
- **`Feed rate for plunging`** Q206: Traversing speed of the tool during boring in mm/min
- **`Dwell time at depth`** Q211: Time in seconds that the tool remains at the hole bottom
- **`Retraction feed rate`** Q208: Traversing speed of the tool in mm/min when retracting from the hole. If you enter Q208 = 0, the tool retracts at feed rate for plunging.
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Disengaging direction`** (0/1/2/3/4) Q214: Determine the direction in which the TNC retracts the tool at the hole bottom (after spindle orientation).

  0 Do not retract tool
  1 Retract tool in the negative ref. axis direction
  2 Retract tool in the neg. secondary axis direction
  3 Retract tool in the positive ref. axis direction
  4 Retract tool in the pos. secondary axis direction

Danger of collision

Select a disengaging direction in which the tool moves away from the edge of the hole.

Check the position of the tool tip when you program a spindle orientation to the angle that you enter in Q336 (for example, in the Positioning with Manual Data Input mode of operation). Set the angle so that the tool tip is parallel to a coordinate axis.

During retraction the TNC automatically takes an active rotation of the coordinate system into account.

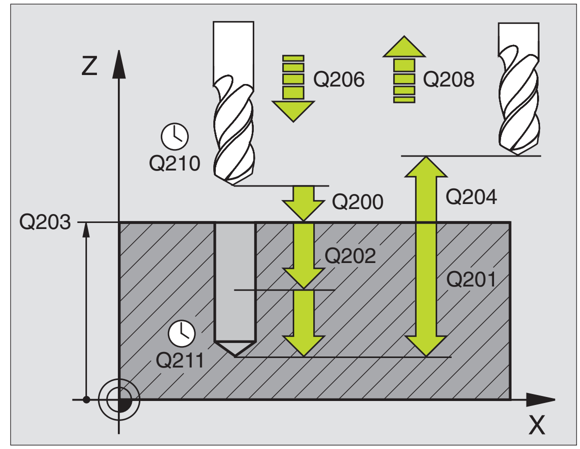
- **`Angle for spindle orientation`** Q336 (absolute value): Angle at which the TNC positions the tool before retracting it.

Example:

```
10 L Z+100 R0 FMAX
11 CYCL DEF 202 REAMING
     Q200=2           ;SAFETY CLEARANCE
     Q201=-15         ;DEPTH
     Q206=100         ;FEED RATE FOR PLUNGING
     Q211=0.5         ;DWELL TIME AT DEPTH
     Q208=250         ;RETRACTION FEED RATE
     Q203=+20         ;SURFACE COORDINATE
     Q204=100         ;2ND SAFETY CLEARANCE
     Q214=1           ;DISENGAGING DIRECTION
     Q336=0           ;ANGLE OF SPINDLE
12 L X+30 Y+20 FMAX M3
13 CYCL CALL
14 L X+80 Y+50 FMAX M99
```

UNIVERSAL DRILLING (Cycle 203)

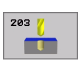
1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.
2. The tool drills to the first plunging depth at the programmed feed rate F.
3. If you have programmed chip breaking, the tool then retracts by the entered retraction value. If you are working without chip breaking, the tool retracts at the retraction feed rate to setup clearance, remains there—if programmed—for the entered dwell time, and advances again in FMAX to the setup clearance above the first PLUNGING DEPTH.
4. The tool then advances with another infeed at the programmed feed rate. If programmed, the plunging depth is decreased after each infeed by the decrement.
5. The TNC repeats this process (2 to 4) until the programmed total hole depth is reached.
6. The tool remains at the hole bottom—if programmed—for the entered dwell time to cut free, and then retracts to set-up clearance at the retraction feed rate. If programmed, the tool moves to the 2nd set-up clearance with FMAX.



Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.



- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth** Q201 (incremental value): Distance between workpiece surface and bottom of hole (tip of drill taper)
- **Feed rate for plunging** Q206: Traversing speed of the tool during drilling in mm/min
- **Plunging depth** Q202 (incremental value): Infeed per cut. The depth does not have to be a multiple of the plunging depth. The TNC will go to depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth
- **Dwell time at top** Q210: Time in seconds that the tool remains at set-up clearance after having been retracted from the hole for chip release.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.

Example: NC blocks

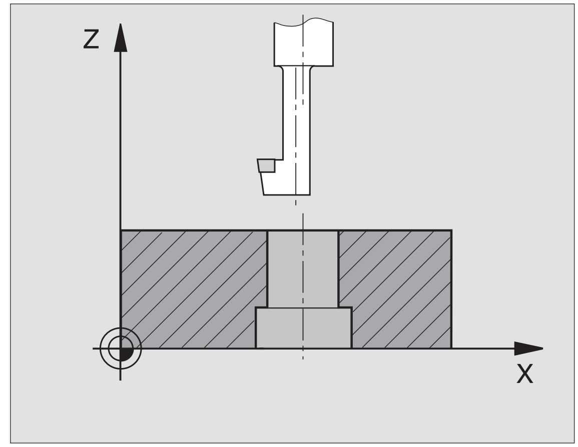
```
11 CYCL DEF 203 UNIVERSAL DRILLING
   Q200=2        ;SAFETY CLEARANCE
   Q201=-20      ;DEPTH
   Q206=150      ;FEED RATE FOR PLUNGING
   Q202=5        ;INFEED DEPTH
   Q210=0        ;DWELL TIME AT TOP
   Q203=+20      ;SURFACE COORDINATE
   Q204=50       ;2ND SAFETY CLEARANCE
   Q212=0.2      ;DECREMENT
   Q213=3        ;BREAKS
   Q205=3        ;MIN. INFEED DEPTH
   Q211=0.25     ;DWELL TIME AT DEPTH
   Q208=500      ;RETRACTION FEED RATE
   Q256=0.2      ;DIST. FOR CHIP BRKNG
```

- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Decrement** Q212 (incremental value): Value by which the TNC decreases the plunging depth Q202 after each infeed.
- **No. of breaks before retracting** Q213: Number of chip breaks after which the TNC is to withdraw the tool from the hole for chip release. For chip breaking, the TNC retracts the tool each time by the value Q256.
- **Minimum plunging depth** Q205 (incremental value): If you have entered a decrement, the TNC limits the plunging depth to the value entered with Q205.
- **Dwell time at depth** Q211: Time in seconds that the tool remains at the hole bottom
- **Retraction feed rate** Q208: Traversing speed of the tool in mm/min when retracting from the hole. If you enter Q208 = 0, the TNC retracts the tool at the feed rate in Q206.
- **Retraction rate for chip breaking** Q256 (incremental value): Value by which the TNC retracts the tool during chip breaking.

BACK BORING (Cycle 204)

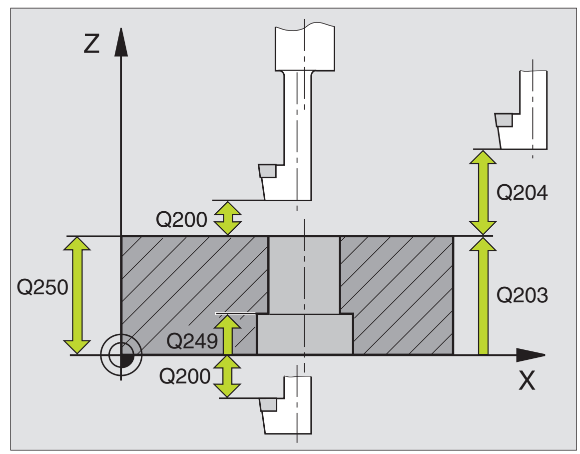
Machine and control must be specially prepared by the machine tool builder for use of this cycle.

Special boring bars for upward cutting are required for this cycle.



This cycle allows holes to be bored from the underside of the workpiece.

1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the set-up clearance above the workpiece surface.
2. The TNC then orients the spindle to the 0° position with an oriented spindle stop, and displaces the tool by the off-center distance.
3. The tool is then plunged into the already bored hole at the feed rate for pre-positioning until the tooth has reached set-up clearance on the underside of the workpiece.
4. The TNC then centers the tool again over the bore hole, switches on the spindle and the coolant and moves at the feed rate for boring to the depth of bore.
5. If a dwell time is entered, the tool will pause at the top of the bore hole and will then be retracted from the hole again. The TNC carries out another oriented spindle stop and the tool is once again displaced by the off-center distance.
6. The TNC moves the tool at the pre-positioning feed rate to the setup clearance and then, if entered, to the 2nd setup clearance with FMAX.



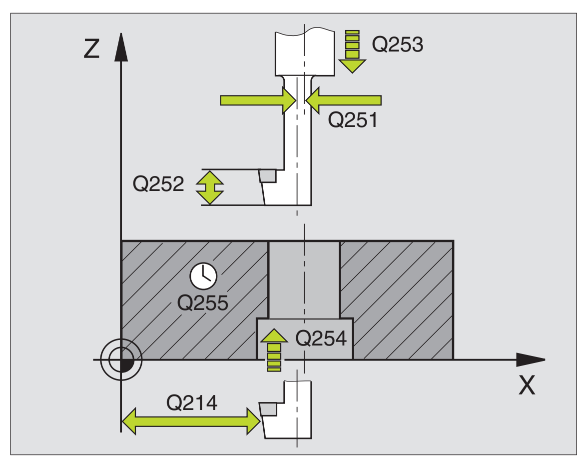
Before programming, note the following:

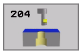
Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter depth determines the working direction. Note: A positive sign bores in the direction of the positive spindle axis.

The entered tool length is the total length to the underside of the boring bar and not just to the tooth.

When calculating the starting point for boring, the TNC considers the tooth length of the boring bar and the thickness of the material.





- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **`Depth of counterbore`** Q249 (incremental value): Distance between underside of workpiece and the top of the hole. A positive sign means the hole will be bored in the positive spindle axis direction.
- **`Material thickness`** Q250 (incremental value): Thickness of the workpiece
- **`Off-center distance`** Q251 (incremental value): Off-center distance for the boring bar; value from tool data sheet
- **`Tool edge height`** Q252 (incremental value): Distance between the underside of the boring bar and the main cutting tooth; value from tool data sheet
- **`Feed rate for pre-positioning`** Q253: Traversing speed of the tool when moving in and out of the workpiece, in mm/min
- **`Feed rate for counterboring`** Q254: Traversing speed of the tool during counterboring in mm/min
- **`Dwell time`** Q255: Dwell time in seconds at the top of the bore hole
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Disengaging direction (0/1/2/3/4)`** Q214: Determine the direction in which the TNC displaces the tool by the off-center distance (after spindle orientation).

  1 Retract tool in the negative ref. axis direction
  2 Retract tool in the neg. secondary axis direction
  3 Retract tool in the positive ref. axis direction
  4 Retract tool in the pos. secondary axis direction

Danger of collision

Check the position of the tool tip when you program a spindle orientation to the angle that you enter in Q336 (for example, in the Positioning with Manual Data Input mode of operation). Set the angle so that the tool tip is parallel to a coordinate axis. Select a disengaging direction in which the tool moves away from the edge of the hole.

- **`Angle for spindle orientation`** Q336 (absolute value): Angle at which the TNC positions the tool before it is plunged into or retracted from the bore hole.

Example: NC blocks

```
11 CYCL DEF 204 BACK BORING
    Q200=2        ;SAFETY CLEARANCE
    Q249=+5       ;DEPTH OF COUNTERBORE
    Q250=20       ;MATERIAL THICKNESS
    Q251=3.5      ;OFF-CENTER DISTANCE
    Q252=15       ;TOOL EDGE HEIGHT
    Q253=750      ;F PRE-POSITIONING
    Q254=200      ;F COUNTERBORING
    Q255=0        ;DWELL TIME
    Q203=+20      ;SURFACE COORDINATE
    Q204=50       ;2ND SAFETY CLEARANCE
    Q214=1        ;DISENGAGING DIRECTION
    Q336=0        ;ANGLE OF SPINDLE
```

UNIVERSAL PECKING (Cycle 205)

1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.
2. The tool drills to the first plunging depth at the programmed feed rate F.
3. If you have programmed chip breaking, the tool then retracts by the entered retraction value. If you are working without chip breaking, the tool is moved at rapid traverse to setup clearance and then at FMAX to the entered starting position above the first plunging depth.
4. The tool then advances with another infeed at the programmed feed rate. If programmed, the plunging depth is decreased after each infeed by the decrement.
5. The TNC repeats this process (2 to 4) until the programmed total hole depth is reached.
6. The tool remains at the hole bottom—if programmed—for the entered dwell time to cut free, and then retracts to set-up clearance at the retraction feed rate. If programmed, the tool moves to the 2nd set-up clearance with FMAX.

Before programming, note the following:

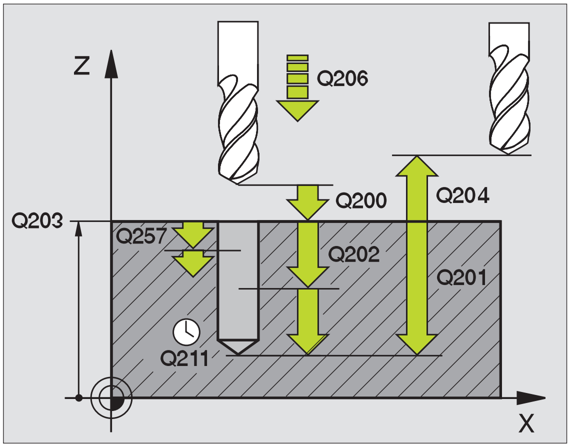
Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth** Q201 (incremental value): Distance between workpiece surface and bottom of hole (tip of drill taper)
- **Feed rate for plunging** Q206: Traversing speed of the tool during drilling in mm/min
- **Plunging depth** Q202 (incremental value): Infeed per cut. The depth does not have to be a multiple of the plunging depth. The TNC will go to depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Decrement** Q212 (incremental value): Value by which the TNC decreases the plunging depth Q202.
- **Minimum plunging depth** Q205 (incremental value): If you have entered a decrement, the TNC limits the plunging depth to the value entered with Q205.
- **Upper advanced stop distance** Q258 (incremental value): Set-up clearance for rapid traverse positioning when the TNC moves the tool again to the current plunging depth after retraction from the hole; value for the first plunging depth
- **Lower advanced stop distance** Q259 (incremental value): Set-up clearance for rapid traverse positioning when the TNC moves the tool again to the current plunging depth after retraction from the hole; value for the last plunging depth.

> If you enter Q258 not equal to Q259, the TNC will change the advance stop distances between the first and last plunging depths at the same rate.

- **Infeed depth for chip breaking** Q257 (incremental value): Depth at which the TNC carries out chip breaking. There is no chip breaking if 0 is entered.
- **Retraction rate for chip breaking** Q256 (incremental value): Value by which the TNC retracts the tool during chip breaking.
- **Dwell time at depth** Q211: Time in seconds that the tool remains at the hole bottom



Example: NC blocks

```
11 CYCL DEF 205 UNIVERSAL PECKING
   Q200=2      ;SAFETY CLEARANCE
   Q201=-80    ;DEPTH
   Q206=150    ;FEED RATE FOR PLUNGING
   Q202=15     ;INFEED DEPTH
   Q203=+100   ;SURFACE COORDINATE
   Q204=50     ;2ND SAFETY CLEARANCE
   Q212=0.5    ;DECREMENT
   Q205=3      ;MIN. INFEED DEPTH
   Q258=0.5    ;UPPER ADVANCED STOP DISTANCE
   Q259=1      ;LOWER ADV STOP DIST
   Q257=5      ;DEPTH FOR CHIP BRKNG
   Q256=0.2    ;DIST. FOR CHIP BRKNG
   Q211=0.25   ;DWELL TIME AT DEPTH
```

BORE MILLING (Cycle 208)

1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed set-up clearance above the workpiece surface and then moves the tool to the bore hole circumference on a rounded arc (if enough space is available).

2 The tool mills in a helix from the current position to the first plunging depth at the programmed feed rate.

3 When the drilling depth is reached, the TNC once again traverses a full circle to remove the material remaining after the initial plunge.

4 The TNC then positions the tool at the center of the hole again.

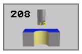
5 Finally the TNC returns to the setup clearance at FMAX. If programmed, the tool moves to the 2nd set-up clearance with FMAX.

Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

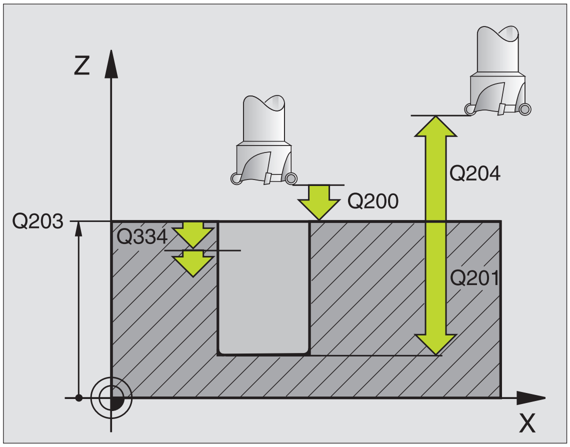
If you have entered the bore hole diameter to be the same as the tool diameter, the TNC will bore directly to the entered depth without any helical interpolation.

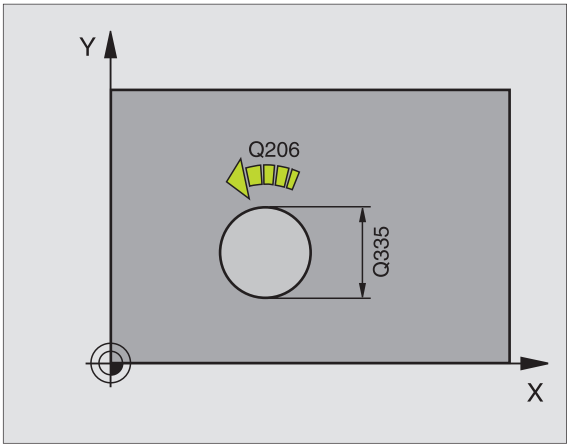


- **`Set-up clearance`** Q200 (incremental value): Distance between tool lower edge and workpiece surface.
- **`Depth`** Q201 (incremental value): Distance between workpiece surface and bottom of hole.
- **`Feed rate for plunging`** Q206: Traversing speed of the tool during helical drilling in mm/min.
- **`Infeed per helix`** Q334 (incremental value): Depth of the tool plunge with each helix (=360°).

> Note that if the infeed distance is too large, the tool or the workpiece may be damaged.
>
> To prevent the infeeds from being too large, enter the max. plunge angle of the tool in the tool table, column ANGLE (see “Tool Data,” page 102). The TNC then automatically calculates the max. infeed permitted and changes your entered value accordingly.

- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Nominal diameter`** Q335 (absolute value): Bore-hole diameter. If you have entered the nominal diameter to be the same as the tool diameter, the TNC will bore directly to the entered depth without any helical interpolation.
- **`Roughing diameter`** Q342 (absolute value): As soon as you enter a value greater than 0 in Q342, the TNC no longer checks the ratio between the nominal diameter and the tool diameter. This allows you to rough-mill holes whose diameter is more than twice as large as the tool diameter.



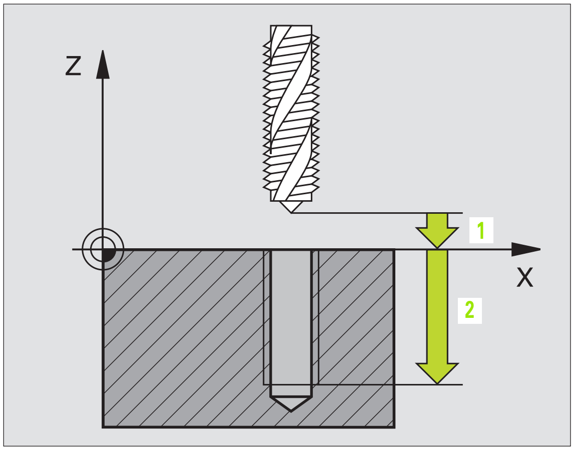


Example: NC blocks

```
12 CYCL DEF 208 BORE MILLING
   Q200=2        ;SAFETY CLEARANCE
   Q201=-80      ;DEPTH
   Q206=150      ;FEED RATE FOR PLUNGING
   Q334=1.5      ;INFEED DEPTH
   Q203=+100     ;SURFACE COORDINATE
   Q204=50       ;2ND SAFETY CLEARANCE
   Q335=25       ;NOMINAL DIAMETER
   Q342=0        ;ROUGHING DIAMETER
```

TAPPING with a floating tap holder (Cycle 2)

1. The tool drills to the total hole depth in one movement.
2. Once the tool has reached the total hole depth, the direction of spindle rotation is reversed and the tool is retracted to the starting position at the end of the dwell time.
3. At the starting position, the direction of spindle rotation reverses once again.



Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

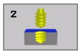
Program a positioning block for the starting point in the tool axis (set-up clearance above the workpiece surface).

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

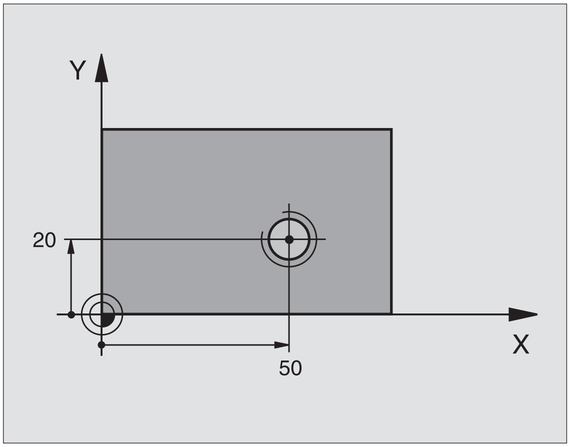
A floating tap holder is required for tapping. It must compensate the tolerances between feed rate and spindle speed during the tapping process.

When a cycle is being run, the spindle speed override knob is disabled. The feed rate override knob is active only within a limited range, which is defined by the machine tool builder (refer to your machine manual).

For tapping right-hand threads activate the spindle with M3, for left-hand threads use M4.



- **`Set-up clearance`** 1 (incremental value): Distance between tool tip (at starting position) and workpiece surface. Standard value: approx. 4 times the thread pitch
- **`Total hole depth`** 2 (thread length, incremental value): Distance between workpiece surface and end of thread
- **`Dwell time in seconds`**: Enter a value between 0 and 0.5 seconds to avoid wedging of the tool during retraction.
- **`Feed rate F`**: Traversing speed of the tool during tapping



Example: NC blocks

```
24 L Z+100 R0 FMAX
25 CYCL DEF 2.0 TAPPING
26 CYCL DEF 2.1 SETUP 3
27 CYCL DEF 2.2 DEPTH -20
28 CYCL DEF 2.3 DWELL 0.4
29 CYCL DEF 2.4 F100
30 L X+50 Y+20 FMAX M3
31 L Z+3 FMAX M99
```

The feed rate is calculated as follows: F = S x p

F Feed rate (mm/min)
S: Spindle speed (rpm)
p: Thread pitch (mm)

Retracting after a program interruption

If you interrupt program run during tapping with the machine stop button, the TNC will display a soft key with which you can retract the tool.

TAPPING NEW with floating tap holder (Cycle 206)

1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.
2. The tool drills to the total hole depth in one movement.
3. Once the tool has reached the total hole depth, the direction of spindle rotation is reversed and the tool is retracted to the set-up clearance at the end of the dwell time. If programmed, the tool moves to the 2nd set-up clearance with FMAX.
4. At the set-up clearance, the direction of spindle rotation reverses once again.

Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

A floating tap holder is required for tapping. It must compensate the tolerances between feed rate and spindle speed during the tapping process.

When a cycle is being run, the spindle speed override knob is disabled. The feed rate override knob is active only within a limited range, which is defined by the machine tool builder (refer to your machine manual).

For tapping right-hand threads activate the spindle with M3, for left-hand threads use M4.

- **Set-up clearance** Q200 (incremental value): Distance between tool tip (at starting position) and workpiece surface. Standard value: approx. 4 times the thread pitch
- **Total hole depth** Q201 (thread length, incremental value): Distance between workpiece surface and end of thread
- **Feed rate F** Q206: Traversing speed of the tool during tapping
- **Dwell time at bottom** Q211: Enter a value between 0 and 0.5 seconds to avoid wedging of the tool during retraction
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.

The feed rate is calculated as follows: F = S x p

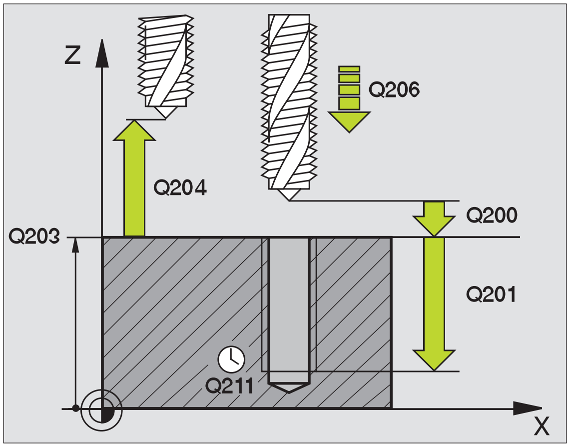
F   Feed rate (mm/min)

S: Spindle speed (rpm)

p: Thread pitch (mm)

Retracting after a program interruption

If you interrupt program run during tapping with the machine stop button, the TNC will display a soft key with which you can retract the tool.



Example: NC blocks

```
25 CYCL DEF 206 TAPPING NEW
    Q200=2          ;SAFETY CLEARANCE
    Q201=-20        ;DEPTH
    Q206=150        ;FEED RATE FOR PLUNGING
    Q211=0.25       ;DWELL TIME AT DEPTH
    Q203=+25        ;SURFACE COORDINATE
    Q204=50         ;2ND SAFETY CLEARANCE
```

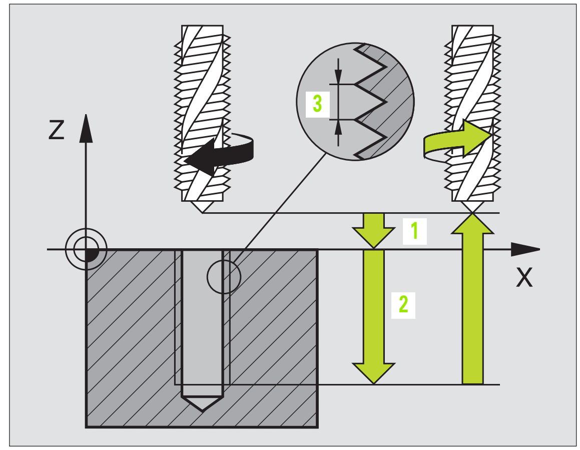
RIGID TAPPING (Cycle 17)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

The TNC cuts the thread without a floating tap holder in one or more passes.

Rigid tapping offers the following advantages over tapping with a floating tap holder

- Higher machining speeds possible
- Repeated tapping of the same thread is possible; repetitions are enabled via spindle orientation to the 0° position during cycle call (depending on machine parameter 7160).
- Increased traverse range of the spindle axis due to absence of a floating tap holder.



Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

Program a positioning block for the starting point in the tool axis (set-up clearance above the workpiece surface).

The algebraic sign for the parameter total hole depth determines the working direction.

The TNC calculates the feed rate from the spindle speed. If the spindle speed override is used during tapping, the feed rate is automatically adjusted.

The feed-rate override knob is disabled.

At the end of the cycle the spindle comes to a stop. Before the next operation, restart the spindle with M3 (or M4).

- **`Set-up clearance`** **1** (incremental value): Distance between tool tip (at starting position) and workpiece surface
- **`Total hole depth`** **2** (incremental value): Distance between workpiece surface (beginning of thread) and end of thread
- **`Pitch`** **3**:
  Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread

Example: NC blocks

```
18 CYCL DEF 17.0 RIGID TAPPING GS
19 CYCL DEF 17.1 SETUP 2
20 CYCL DEF 17.2 DEPTH -20
21 CYCL DEF 17.3 PITCH +1
```

Retracting after a program interruption

If you use the machine stop button to interrupt program run during tapping, the TNC will display the soft key MANUAL TRAVERSE. If you press the MANUAL TRAVERSE key, you can retract the tool under program control. Simply press the positive axis direction button of the active tool axis.

RIGID TAPPING (NEW) (Cycle 207)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

The TNC cuts the thread without a floating tap holder in one or more passes.

Rigid tapping offers the following advantages over tapping with a floating tap holder:See "RIGID TAPPING (Cycle 17)," page 235.

1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.
2. The tool drills to the total hole depth in one movement.
3. Once the tool has reached the total hole depth, the direction of spindle rotation is reversed and the tool is retracted to the set-up clearance at the end of the dwell time. If programmed, the tool moves to the 2nd set-up clearance with FMAX.
4. The TNC stops the spindle turning at set-up clearance.

Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

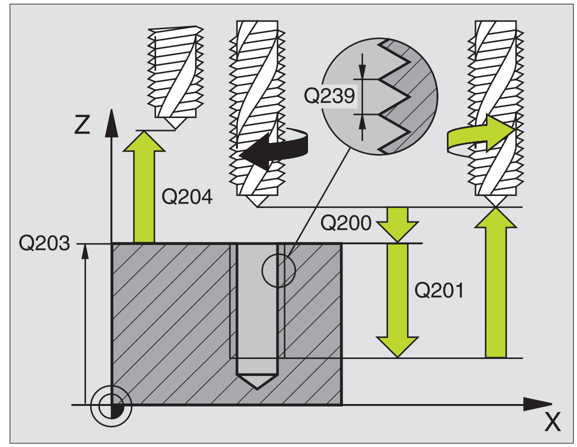
The algebraic sign for the parameter total hole depth determines the working direction.

The TNC calculates the feed rate from the spindle speed. If the spindle speed override is used during tapping, the feed rate is automatically adjusted.

The feed-rate override knob is disabled.

At the end of the cycle the spindle comes to a stop. Before the next operation, restart the spindle with M3 (or M4).

- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip (at starting position) and workpiece surface.
- **`Total hole depth`** Q201 (incremental value): Distance between workpiece surface and end of thread
- **`Pitch`** Q239
  Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.



Retracting after a program interruption

If you interrupt program run during thread cutting with the machine stop button, the TNC will display the soft key MANUAL OPERATION. If you press the MANUAL OPERATION key, you can retract the tool under program control. Simply press the positive axis direction button of the active tool axis.

Example: NC blocks

```
26 CYCL DEF 207 RIGID TAPPING NEW
    Q200=2        ;SAFETY CLEARANCE
    Q201=-20      ;DEPTH
    Q239=+1       ;THREAD PITCH
    Q203=+25      ;SURFACE COORDINATE
    Q204=50       ;2ND SAFETY CLEARANCE
```

THREAD CUTTING (Cycle 18)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

Cycle 18 THREAD CUTTING is performed by means of spindle control. The tool moves with the active spindle speed from its current position to the entered depth. As soon as it reaches the end of thread, spindle rotation is stopped. Tool approach and departure must be programmed separately. The most convenient way to do this is by using OEM cycles. The machine tool builder can give you further information.

Before programming, note the following:

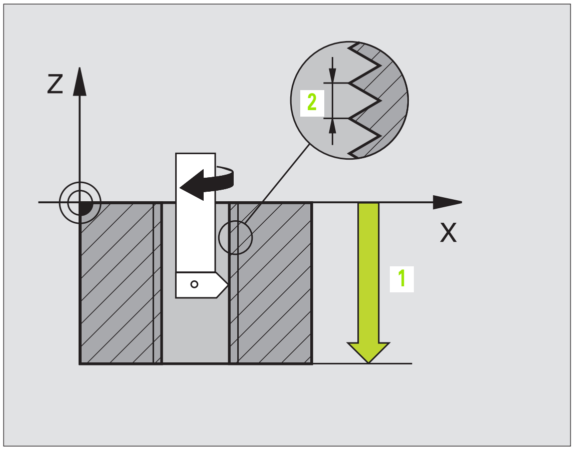
The TNC calculates the feed rate from the spindle speed. If the spindle speed override is used during thread cutting, the feed rate is automatically adjusted.

The feed-rate override knob is disabled.

The TNC automatically activates and deactivates spindle rotation. Do not program M3 or M4 before cycle call.

- **Total hole depth** 1: Distance between current tool position and end of thread

  The algebraic sign for the total hole depth determines the working direction (a negative value means a negative working direction in the tool axis)
- **Pitch** 2:
  Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  += right-hand thread (M3 with negative depth)
  – = left-hand thread (M4 with negative depth)



Example: NC blocks

```
22 CYCL DEF 18.0 THREAD CUTTING
23 CYCL DEF 18.1 DEPTH -20
24 CYCL DEF 18.2 PITCH +1
```

TAPPING WITH CHIP BREAKING (Cycle 209)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

The tool machines the thread in several passes until it reaches the programmed depth. You can define in a parameter whether the tool is to be retracted completely from the hole for chip breaking.

1. The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface. There it carries out an oriented spindle stop.
2. The tool moves to the programmed infeed depth, reverses the direction of spindle rotation and retracts by a specific distance or completely for chip release, depending on the definition.
3. It then reverses the direction of spindle rotation again and advances to the next infeed depth.
4. The TNC repeats this process (2 to 3) until the programmed thread depth is reached.
5. The tool is then retracted to set-up clearance. If programmed, the tool moves to the 2nd set-up clearance with FMAX.
6. The TNC stops the spindle turning at set-up clearance.

Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the parameter thread depth determines the working direction.

The TNC calculates the feed rate from the spindle speed. If the spindle speed override is used during tapping, the feed rate is automatically adjusted.

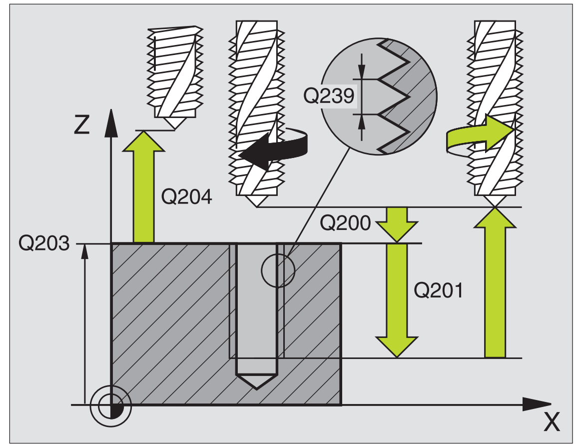
The feed-rate override knob is disabled.

At the end of the cycle the spindle comes to a stop. Before the next operation, restart the spindle with M3 (or M4).

- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip (at starting position) and workpiece surface.
- **`Thread depth`** Q201 (incremental value): Distance between workpiece surface and end of thread.
- **`Pitch`** Q239
  Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Infeed depth for chip breaking`** Q257 (incremental value): Depth at which TNC carries out chip breaking
- **`Retraction rate for chip breaking`** Q256: The TNC multiplies the pitch Q239 by the programmed value and retracts the tool by the calculated value during chip breaking. If you enter Q256 = 0, the TNC retracts the tool completely from the hole (to set-up clearance) for chip release.
- **`Angle for spindle orientation`** Q336 (absolute value): Angle at which the TNC positions the tool before machining the thread. This allows you to regroove the thread, if required.

Retracting after a program interruption

If you interrupt program run during thread cutting with the machine stop button, the TNC will display the soft key MANUAL OPERATION. If you press the MANUAL OPERATION key, you can retract the tool under program control. Simply press the positive axis direction button of the active tool axis.



Example: NC blocks

```
26 CYCL DEF 209 TAPPING W/ CHIP BRKG
     Q200=2          ;SAFETY CLEARANCE
     Q201=-20        ;DEPTH
     Q239=+1         ;THREAD PITCH
     Q203=+25        ;SURFACE COORDINATE
     Q204=50         ;2ND SAFETY CLEARANCE
     Q257=5          ;DEPTH FOR CHIP BRKNG
     Q256=+25        ;DIST. FOR CHIP BRKNG
     Q336=50         ;ANGLE OF SPINDLE
```

Fundamentals of thread milling

Prerequisites

- Your machine tool should feature internal spindle cooling (cooling lubricant min. 30 bar, compressed air supply min. 6 bar).
- Thread milling usually leads to distortions of the thread profile. To correct this effect, you need tool-specific compensation values which are given in the tool catalog or are available from the tool manufacturer. You program the compensation with the delta value for the tool radius DR in the tool call .
- The Cycles 262, 263, 264 and 267 can only be used with rightward rotating tools. For Cycle 265, you can use rightward and leftward rotating tools.
- The working direction is determined by the following input parameters: Algebraic sign Q239 (+ = right-hand thread /– = left-hand thread) and milling method Q351 (+1 = climb /–1 = up-cut). The table below illustrates the interrelation between the individual input parameters for rightward rotating tools.

Internal thread	Pitch	Climb/Up-cut	Work direction
Right-handed	+	+1(RL)	Z+
Left-handed	–	–1(RR)	Z+
Right-handed	+	–1(RR)	Z–
Left-handed	–	+1(RL)	Z–

External thread	Pitch	Climb/Up-cut	Work direction
Right-handed	+	+1(RL)	Z–
Left-handed	–	–1(RR)	Z–
Right-handed	+	–1(RR)	Z+
Left-handed	–	+1(RL)	Z+

Danger of collision

Always program the same algebraic sign for the infeeds: Cycles comprise several sequences of operation that are independent of each other. The order of precedence according to which the work direction is determined is described with the individual cycles. If you want to repeat specific machining operation of a cycle, for example with only the countersinking process, enter 0 for the thread depth. The work direction will then be determined from the countersinking depth.

Procedure in the case of a tool break!

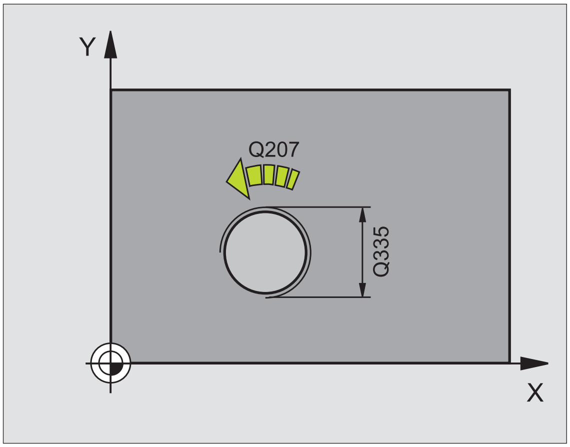
If a tool break occurs during thread cutting, stop the program run, change to the Positioning with MDI operating mode and move the tool in a linear path to the hole center. You can then retract the tool in the infeed axis and replace it.

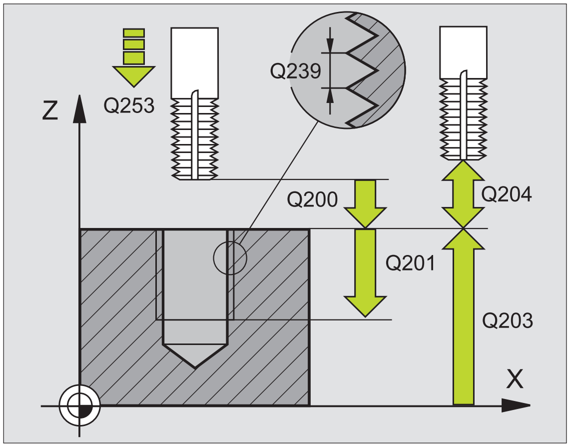
The TNC references the programmed feed rate during thread milling to the tool cutting edge. Since the TNC, however, always displays the feed rate relative to the path of the tool tip, the displayed value does not match the programmed value.

The machining direction of the thread changes if you execute a thread milling cycle in connection with Cycle 8 MIRRORING with only one axis.

THREAD MILLING (Cycle 262)

1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.
2 The tool moves at the programmed feed rate for pre-positioning to the starting plane. The starting plane is derived from the algebraic sign of the thread pitch, the milling method (climb or up-cut milling) and the number of threads per step.
3 The tool then approaches the nominal thread diameter tangentially in a helical movement. Before the helical approach, a compensating motion of the tool axis is carried out in order to begin at the programmed starting plane for the thread path.
4 Depending on the setting of the parameter for the number of threads, the tool mills the thread in one, in several spaced or in one continuous helical movement.
5 After this, the tool departs the contour tangentially and returns to the starting point in the working plane.
6 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance or, if programmed, to the 2nd set-up clearance





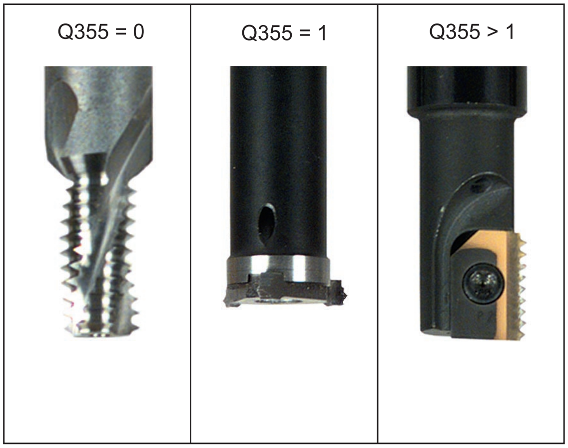
Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

The algebraic sign for the cycle parameter thread depth determines the working direction. If you program the thread depth = 0, the cycle will not be executed.

The thread diameter is approached in a semi-circle from the center. A pre-positioning movement to the side is carried out if the pitch of the tool diameter is four times smaller than the thread diameter.

Note that the TNC makes a compensating movement in the tool axis before the approach movement. The length of the compensating movement depends on the thread pitch. Ensure sufficient space in the hole!



- **Nominal diameter** Q335: Nominal thread diameter
- **Thread pitch** Q239: Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **Thread depth** Q201 (incremental value): Distance between workpiece surface and root of thread
- **Threads per step** Q355: Number of thread revolutions by which the tool is offset, see figure at lower right **:**
  0 = one 360° helical line to the thread depth
  1 = continuous helical path over the entire length of the thread
  >1 = several helical paths with approach and departure; between them, the TNC offsets the tool by Q355, multiplied by the pitch
- **Feed rate for pre-positioning** Q253: Traversing speed of the tool when moving in and out of the workpiece, in mm/min
- **Climb or up-cut** Q351: Type of milling operation with M03
  +1 = climb milling
  –1 = up-cut milling
- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.

Example: NC blocks

```
25 CYCL DEF 262 THREAD MILLING
     Q335=10        ;NOMINAL DIAMETER
     Q239=+1.5      ;PITCH
     Q201=-20       ;THREAD DEPTH
     Q355=0         ;THREADS PER STEP
     Q253=750       ;F PRE-POSITIONING
     Q351=+1        ;CLIMB OR UP-CUT
     Q200=2         ;SAFETY CLEARANCE
     Q203=+30       ;SURFACE COORDINATE
     Q204=50        ;2ND SAFETY CLEARANCE
     Q207=500       ;FEED RATE FOR MILLING
```

THREAD MILLING/COUNTERSINKING (Cycle 263)

1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.

Countersinking

2 The tool moves at the feed rate for pre-positioning to the countersinking depth minus the setup clearance, and then at the feed rate for countersinking to the countersinking depth.
3 If a safety clearance to the side has been entered, the TNC immediately positions the tool at the feed rate for pre-positioning to the countersinking depth
4 Then, depending on the available space, the TNC makes a tangential approach to the core diameter, either tangentially from the center or with a pre-positioning move to the side, and follows a circular path.

Countersinking at front

5 The tool moves at the feed rate for pre-positioning to the sinking depth at front.
6 The TNC positions the tool without compensation from the center on a semicircle to the offset at front, and then follows a circular path at the feed rate for countersinking.
7 The tool then moves in a semicircle to the hole center.

Thread milling

8 The TNC moves the tool at the programmed feed rate for pre-positioning to the starting plane for the thread. The starting plane is determined from the thread pitch and the type of milling (climb or up-cut).
9 Then the tool moves tangentially on a helical path to the thread diameter and mills the thread with a 360° helical motion.
10 After this, the tool departs the contour tangentially and returns to the starting point in the working plane.

11 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance or, if programmed, to the 2nd set-up clearance

Before programming, note the following:

Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

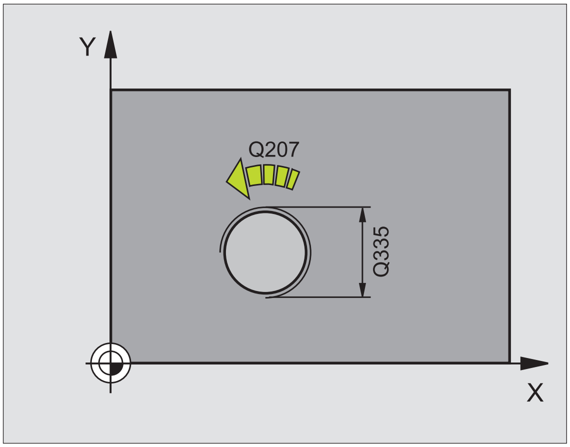
The algebraic sign of the cycle parameters depth of thread, countersinking depth or sinking depth at front determines the working direction. The working direction is defined in the following sequence:
1st: Depth of thread
2nd: Countersinking depth
3rd: Depth at front

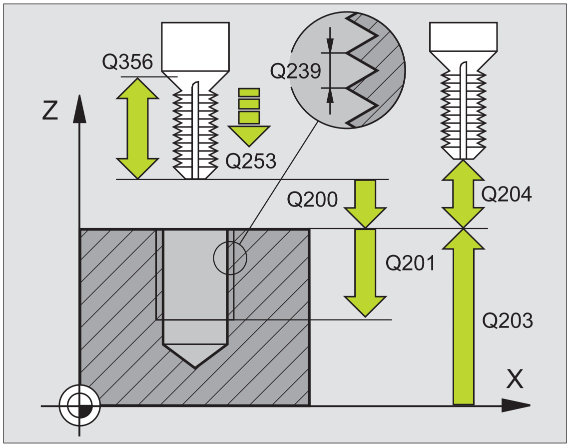
If you program a depth parameter to be 0, the TNC does not execute that step.

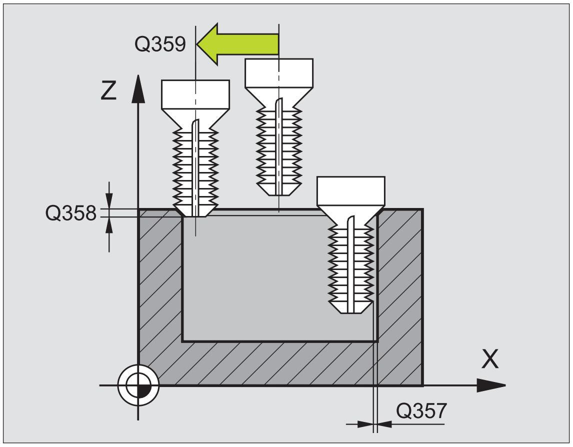
if you wish to countersink with the front of the tool, define the countersinking depth as 0.

Program the thread depth as a value smaller than the countersinking depth by at least one-third the thread pitch.

- **`Nominal diameter`** Q335: Nominal thread diameter
- **`Thread pitch`** Q239: Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **`Thread depth`** Q201 (incremental value): Distance between workpiece surface and root of thread
- **`Countersinking depth`** Q356 (incremental value): Distance between tool point and the top surface of the workpiece
- **`Feed rate for pre-positioning`** Q253: Traversing speed of the tool when moving in and out of the workpiece, in mm/min
- **`Climb or up-cut`** Q351: Type of milling operation with M03
  +1 = climb milling
  –1 = up-cut milling
- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **`Set-up clearance to the side`** Q357 (incremental value): Distance between tool tooth and the wall
- **`Depth at front`** Q358 (incremental value): Distance between tool point and the top surface of the workpiece for countersinking at the front of the tool
- **`Countersinking offset at front`** Q359 (incremental value): Distance by which the TNC moves the tool center away from the hole center







- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Feed rate for counterboring** Q254: Traversing speed of the tool during counterboring in mm/min
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.

Example: NC blocks

```
25 CYCL DEF 263 THREAD MILLING/
COUNTERSINKING
     Q335=10        ;NOMINAL DIAMETER
     Q239=+1.5      ;PITCH
     Q201=-16       ;THREAD DEPTH
     Q356=-20       ;COUNTERSINKING DEPTH
     Q253=750       ;F PRE-POSITIONING
     Q351=+1        ;CLIMB OR UP-CUT
     Q200=2         ;SAFETY CLEARANCE
     Q357=0.2       ;CLEARANCE TO SIDE
     Q358=+0        ;DEPTH AT FRONT
     Q359=+0        ;OFFSET AT FRONT
     Q203=+30       ;SURFACE COORDINATE
     Q204=50        ;2ND SAFETY CLEARANCE
     Q254=150       ;F COUNTERBORING
     Q207=500       ;FEED RATE FOR MILLING
```

THREAD DRILLING/MILLING (Cycle 264)

1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.

Drilling

2 The tool drills to the first plunging depth at the programmed feed rate for plunging.
3 If you have programmed chip breaking, the tool then retracts by the entered retraction value. If you are working without chip breaking, the tool is moved at rapid traverse to setup clearance and then at FMAX to the entered starting position above the first plunging depth.
4 The tool then advances with another infeed at the programmed feed rate.
5 The TNC repeats this process (2 to 4) until the programmed total hole depth is reached.

Countersinking at front

6 The tool moves at the feed rate for pre-positioning to the sinking depth at front.
7 The TNC positions the tool without compensation from the center on a semicircle to the offset at front, and then follows a circular path at the feed rate for countersinking.
8 The tool then moves in a semicircle to the hole center.

Thread milling

9 The TNC moves the tool at the programmed feed rate for pre-positioning to the starting plane for the thread. The starting plane is determined from the thread pitch and the type of milling (climb or up-cut).
10 Then the tool moves tangentially on a helical path to the thread diameter and mills the thread with a 360° helical motion.
11 After this, the tool departs the contour tangentially and returns to the starting point in the working plane.
12 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance or, if programmed, to the 2nd set-up clearance

Before programming, note the following:

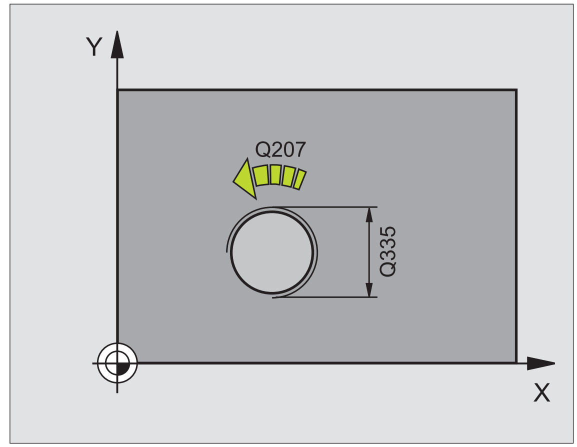
Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

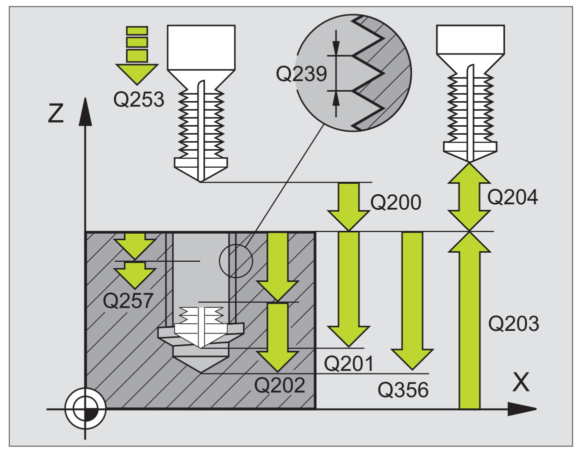
The algebraic sign of the cycle parameters depth of thread, countersinking depth or sinking depth at front determines the working direction. The working direction is defined in the following sequence:
1st: Depth of thread
2nd: Total hole depth
3rd: Depth at front

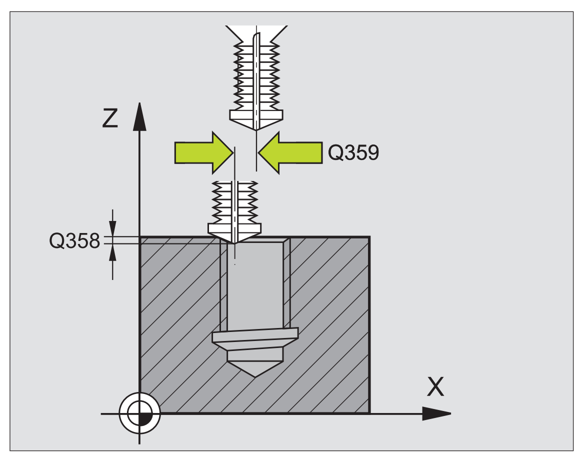
If you program a depth parameter to be 0, the TNC does not execute that step.

Program the thread depth as a value smaller than the total hole depth by at least one-third the thread pitch.

- **Nominal diameter** Q335: Nominal thread diameter
- **Thread pitch** Q239: Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **Thread depth** Q201 (incremental value): Distance between workpiece surface and root of thread
- **Total hole depth** Q356 (incremental value): Distance between workpiece surface and bottom of hole
- **Feed rate for pre-positioning** Q253: Traversing speed of the tool when moving in and out of the workpiece, in mm/min
- **Climb or up-cut** Q351: Type of milling operation with M03
  +1 = climb milling
  –1 = up-cut milling
- **Plunging depth** Q202 (incremental value): Infeed per cut. The depth does not have to be a multiple of the plunging depth. The TNC will go to depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth
- **Upper advanced stop distance** Q258 (incremental value): Set-up clearance for rapid traverse positioning when the TNC moves the tool again to the current plunging depth after retraction from the hole
- **Infeed depth for chip breaking** Q257 (incremental value): Depth at which TNC carries out chip breaking. There is no chip breaking if 0 is entered.
- **Retraction rate for chip breaking** Q256 (incremental value): Value by which the TNC retracts the tool during chip breaking.
- **Depth at front** Q358 (incremental value): Distance between tool point and the top surface of the workpiece for countersinking at the front of the tool
- **Countersinking offset at front** Q359 (incremental value): Distance by which the TNC moves the tool center away from the hole center







- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Feed rate for plunging** Q206: Traversing speed of the tool during drilling in mm/min
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.

Example: NC blocks

```
25 CYCL DEF 264 THREAD DRILLING/MILLING
    Q335=10        ;NOMINAL DIAMETER
    Q239=+1.5      ;PITCH
    Q201=-16       ;THREAD DEPTH
    Q356=-20       ;TOTAL HOLE DEPTH
    Q253=750       ;F PREPOSITIONING
    Q351=+1        ;CLIMB OR UP-CUT
    Q202=5         ;INFEED DEPTH
    Q258=0.2       ;ADVANCED STOP DISTANCE
    Q257=5         ;DEPTH FOR CHIP BRKNG
    Q256=0.2       ;DIST. FOR CHIP BRKNG
    Q358=+0        ;DEPTH AT FRONT
    Q359=+0        ;OFFSET AT FRONT
    Q200=2         ;SAFETY CLEARANCE
    Q203=+30       ;SURFACE COORDINATE
    Q204=50        ;2ND SAFETY CLEARANCE
    Q206=150       ;FEED RATE FOR PLUNGING
    Q207=500       ;FEED RATE FOR MILLING
```

HELICAL THREAD DRILLING/MILLING (Cycle 265)

1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.

Countersinking at front

2 If countersinking is before thread milling, the tool moves at the feed rate for countersinking to the sinking depth at front. If countersinking is after thread milling, the tool moves at the feed rate for pre-positioning to the countersinking depth.

3 The TNC positions the tool without compensation from the center on a semicircle to the offset at front, and then follows a circular path at the feed rate for countersinking.

4 The tool then moves in a semicircle to the hole center.

Thread milling

5 The tool moves at the programmed feed rate for pre-positioning to the starting plane for the thread.

6 The tool then approaches the thread diameter tangentially in a helical movement.

7 The tool moves on a continuous helical downward path until it reaches the thread depth.

8 After this, the tool departs the contour tangentially and returns to the starting point in the working plane.

9 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance, or—if programmed—to the 2nd set-up clearance.

Before programming, note the following:

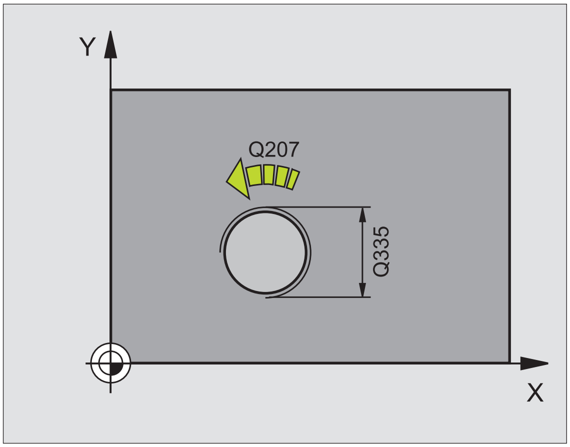
Program a positioning block for the starting point (hole center) in the working plane with radius compensation R0.

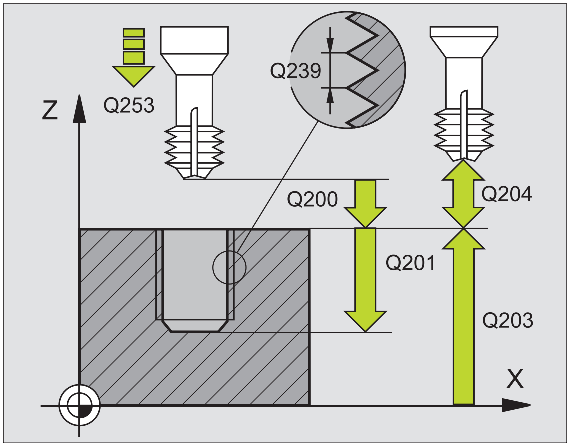
The algebraic sign of the cycle parameters depth of thread or sinking depth at front determines the working direction. The working direction is defined in the following sequence:
1st: Depth of thread
2nd: Depth at front

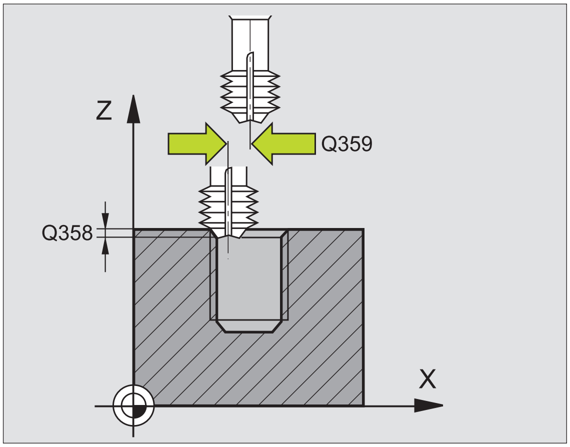
If you program a depth parameter to be 0, the TNC does not execute that step.

The type of milling (up-cut/climb) is determined by the thread (right-hand/left-hand) and the direction of tool rotation, since it is only possible to work in the direction of the tool.

- **`Nominal diameter`** Q335: Nominal thread diameter
- **`Thread pitch`** Q239: Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **`Thread depth`** Q201 (incremental value): Distance between workpiece surface and root of thread
- **`Feed rate for pre-positioning`** Q253: Traversing speed of the tool when moving in and out of the workpiece, in mm/min
- **`Depth at front`** Q358 (incremental value): Distance between tool point and the top surface of the workpiece for countersinking at the front of the tool
- **`Countersinking offset at front`** Q359 (incremental value): Distance by which the TNC moves the tool center away from the hole center
- **`Countersink`** Q360: Execution of the chamfer
  0 = before thread machining
  1 = after thread machining
- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.







- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Feed rate for counterboring** Q254: Traversing speed of the tool during counterboring in mm/min
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.

Example: NC blocks

```
25 CYCL DEF 265 HEL. THREAD DRLG/MLG
    Q335=10        ;NOMINAL DIAMETER
    Q239=+1.5      ;PITCH
    Q201=-16       ;THREAD DEPTH
    Q253=750       ;F PREPOSITIONING
    Q358=+0        ;DEPTH AT FRONT
    Q359=+0        ;OFFSET AT FRONT
    Q360=0         ;COUNTERSINKING
    Q200=2         ;SAFETY CLEARANCE
    Q203=+30       ;SURFACE COORDINATE
    Q204=50        ;2ND SAFETY CLEARANCE
    Q254=150       ;F COUNTERBORING
    Q207=500       ;FEED RATE FOR MILLING
```

OUTSIDE THREAD MILLING (Cycle 267)

1 The TNC positions the tool in the tool axis at rapid traverse FMAX to the programmed setup clearance above the workpiece surface.

Countersinking at front

2 The TNC moves on the reference axis of the working plane from the center of the stud to the starting point for countersinking at front. The position of the starting point is determined by the thread radius, tool radius and pitch.
3 The tool moves at the feed rate for pre-positioning to the sinking depth at front.
4 The TNC positions the tool without compensation from the center on a semicircle to the offset at front, and then follows a circular path at the feed rate for countersinking.
5 The tool then moves in a semicircle to the starting point.

Thread milling

6 The TNC positions the tool to the starting point if there has been no previous countersinking at front. Starting point for thread milling = starting point for countersinking at front.
7 The tool moves at the programmed feed rate for pre-positioning to the starting plane. The starting plane is derived from the algebraic sign of the thread pitch, the milling method (climb or up-cut milling) and the number of threads per step.
8 The tool then approaches the thread diameter tangentially in a helical movement.
9 Depending on the setting of the parameter for the number of threads, the tool mills the thread in one, in several spaced or in one continuous helical movement.
10 After this, the tool departs the contour tangentially and returns to the starting point in the working plane.

11 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance or, if programmed, to the 2nd set-up clearance

Before programming, note the following:

Program a positioning block for the starting point (stud center) in the working plane with radius compensation R0.

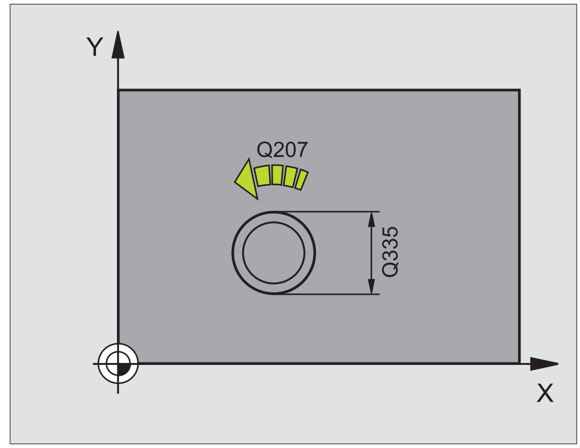
The offset required before countersinking at the front should be determined ahead of time. You must enter the value from the center of the stud to the center of the tool (uncorrected value).

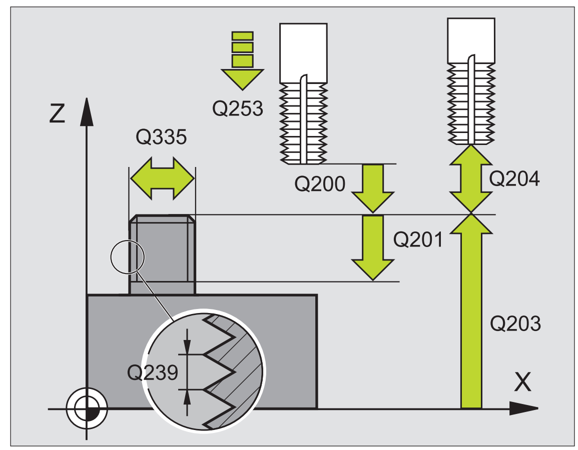
The algebraic sign of the cycle parameters depth of thread or sinking depth at front determines the working direction. The working direction is defined in the following sequence:
1st: Depth of thread
2nd: Depth at front

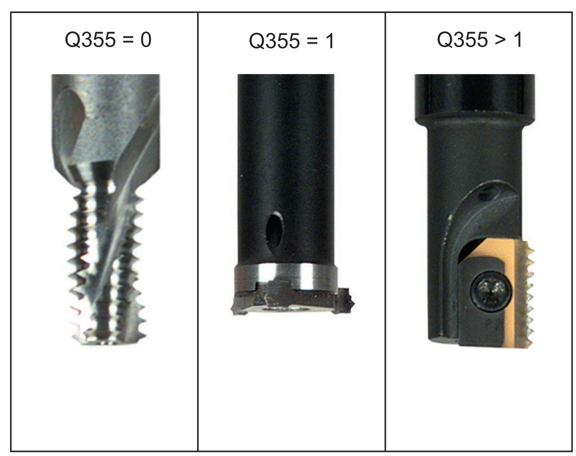
If you program a depth parameter to be 0, the TNC does not execute that step.

The algebraic sign for the cycle parameter thread depth determines the working direction.

- **Nominal diameter** Q335: Nominal thread diameter
- **Thread pitch** Q239: Pitch of the thread. The algebraic sign differentiates between right-hand and left-hand threads:
  + = right-hand thread
  – = left-hand thread
- **Thread depth** Q201 (incremental value): Distance between workpiece surface and root of thread
- **Threads per step** Q355: Number of thread revolutions by which the tool is offset, see figure at lower right:
  0 = one helical line to the thread depth
  1 = continuous helical path over the entire length of the thread
  >1 = several helical paths with approach and departure; between them, the TNC offsets the tool by Q355, multiplied by the pitch
- **Feed rate for pre-positioning** Q253: Traversing speed of the tool when moving in and out of the workpiece, in mm/min
- **Climb or up-cut** Q351: Type of milling operation with M03
  +1 = climb milling
  –1 = up-cut milling





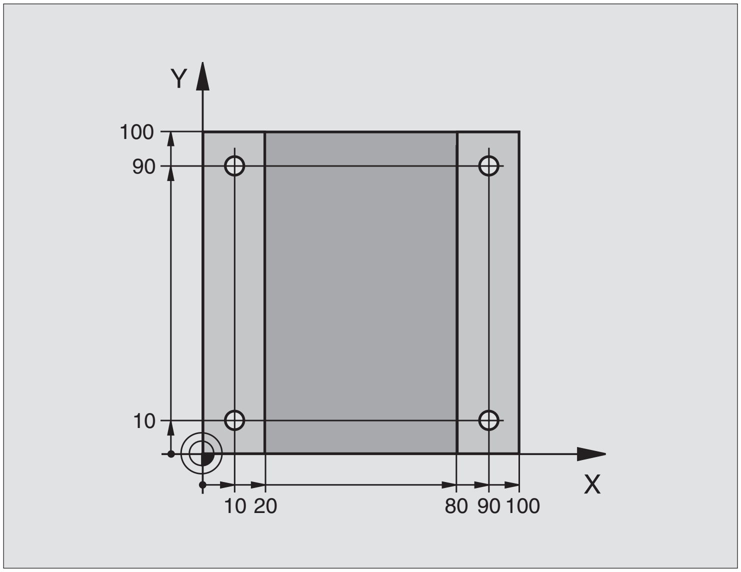


- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth at front** Q358 (incremental value): Distance between tool point and the top surface of the workpiece for countersinking at the front of the tool
- **Countersinking offset at front** Q359 (incremental value): Distance by which the TNC moves the tool center away from the stud center
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Feed rate for counterboring** Q254: Traversing speed of the tool during counterboring in mm/min
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.

Example: NC blocks

```
25 CYCL DEF 267 OUTSIDE THREAD MLLNG
     Q335=10       ;NOMINAL DIAMETER
     Q239=+1.5     ;PITCH
     Q201=-20      ;THREAD DEPTH
     Q355=0        ;THREADS PER STEP
     Q253=750      ;F PREPOSITIONING
     Q351=+1       ;CLIMB OR UP-CUT
     Q200=2        ;SAFETY CLEARANCE
     Q358=+0       ;DEPTH AT FRONT
     Q359=+0       ;OFFSET AT FRONT
     Q203=+30      ;SURFACE COORDINATE
     Q204=50       ;2ND SAFETY CLEARANCE
     Q254=150      ;F COUNTERBORING
     Q207=500      ;FEED RATE FOR MILLING
```

Example: Drilling cycles



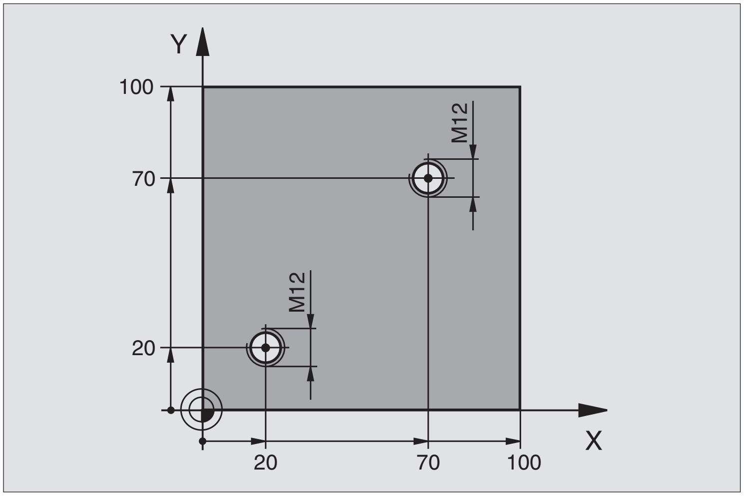
0 BEGIN PGM C200 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+3	Define the tool
4 TOOL CALL 1 Z S4500	Tool call
5 L Z+250 R0 FMAX	Retract the tool
6 CYCL DEF 200 DRILLING	Define cycle
Q200=2 ;SAFETY CLEARANCE	
Q201=-15 ;DEPTH	
Q206=250 ;F FEED RATE FOR PLUNGING	
Q202=5 ;INFEED DEPTH	
Q210=0 ;DWELL TIME AT TOP	
Q203=-10 ;SURFACE COORDINATE	
Q204=20 ;SECOND SET-UP CLEARANCE	
Q211=0.2 ;DWELL TIME AT DEPTH	

7 L X+10 Y+10 R0 FMAX M3	Approach hole 1, spindle ON
8 CYCL CALL	Call the cycle
9 L Y+90 R0 FMAX M99	Approach hole 2, call cycle
10 L X+90 R0 FMAX M99	Approach hole 3, call cycle
11 L Y+10 R0 FMAX M99	Approach hole 4, call cycle
12 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
13 END PGM C200 MM	

Example: Drilling cycles

Program sequence

- Program the drilling cycle in the main program
- Program machining within a subprogram, see "Subprograms," page 363



`0 BEGIN PGM C18 MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-20`	Define the workpiece blank
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	
`3 TOOL DEF 1 L+0 R+6`	Define the tool
`4 TOOL CALL 1 Z S100`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 CYCL DEF 18.0 THREAD CUTTING`	Define THREAD CUTTING cycle
`7 CYCL DEF 18.1 DEPTH +30`	
`8 CYCL DEF 18.2 PITCH +1.75`	
`9 L X+20 Y+20 R0 FMAX`	Approach hole 1
`10 CALL LBL 1`	Call subprogram 1
`11 L X+70 Y+70 R0 FMAX`	Approach hole 2
`12 CALL LBL 1`	Call subprogram 1
`13 L Z+250 R0 FMAX M2`	Retract tool, end of main program

`14 LBL 1`	Subprogram 1: Thread cutting
`15 CYCL DEF 13.0 ORIENTATION`	Define the spindle angle (makes it possible to cut repeatedly)
`16 CYCL DEF 13.1 ANGLE 0`	
`17 L M19`	Orient the spindle (machine-specific M function)
`18 L IX-2 R0 F1000`	Tool offset to prevent collision during tool infeed (dependent
	on core diameter and tool)
`19 L Z+5 R0 FMAX`	Pre-position in rapid traverse
`20 L Z-30 R0 F1000`	Move to starting depth
`21 L IX+2`	Reset the tool to hole center
`22 CYCL CALL`	Call Cycle 18
`23 L Z+5 R0 FMAX`	Retract tool
`24 LBL 0`	End of subprogram 1
`25 END PGM C18 MM`	

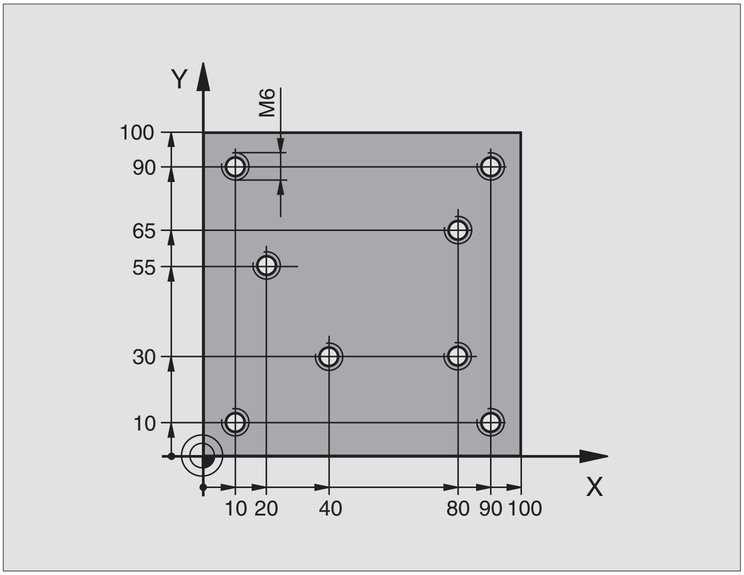
Example: Calling drilling cycles in connection with point tables

The drill hole coordinates are stored in the point table TAB1.PNT and are called by the TNC with **CYCL CALL PAT**.

The tool radii are selected so that all work steps can be seen in the test graphics.

Program sequence

- Centering
- Drilling
- Tapping



0 BEGIN PGM 1 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Y+0	
3 TOOL DEF 1 L+0 R+4	Tool definition of center drill
4 TOOL DEF 2 L+0 2.4	Define tool: drill
5 TOOL DEF 3 L+0 R+3	Tool definition of tap
6 TOOL CALL 1 Z S5000	Tool call of centering drill
7 L Z+10 R0 F5000	Move tool to clearance height (Enter a value for F.
	The TNC positions to the clearance height after every cycle
8 SEL PATTERN "TAB1"	Defining point tables
9 CYCL DEF 200 DRILLING	Cycle definition: Centering
Q200=2 ;SAFETY CLEARANCE	
Q201=-2 ;DEPTH	
Q206=150 ;F FEED RATE FOR PLUNGING	
Q202=2 ;INFEED DEPTH	
Q210=0 ;DWELL TIME AT TOP	
Q203=+0 ;SURFACE COORDINATE	0 must be entered here, effective as defined in point table
Q204=0 ;SECOND SET-UP CLEARANCE	0 must be entered here, effective as defined in point table
Q211=0.2 ;DWELL TIME AT DEPTH	

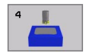
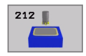
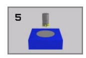
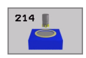
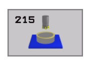
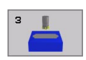
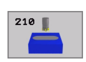
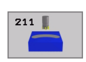
`10 CYCL CALL PAT F5000 M3`	Cycle call in connection with point table TAB1.PNT
	Feed rate between points: 5000 mm/min
`11 L Z+100 R0 FMAX M6`	Retract the tool, change the tool
`12 TOOL CALL 2 Z S5000`	Call the drilling tool
`13 L Z+10 R0 F5000`	Move tool to clearance height (enter a value for F)
`14 CYCL DEF 200 DRILLING`	Cycle definition: drilling
`Q200=2 ;SAFETY CLEARANCE`	
`Q201=-25 ;DEPTH`	
`Q206=150 ;FEED RATE FOR PECKING`	
`Q202=5 ;INFEED DEPTH`	
`Q210=0 ;DWELL TIME AT TOP`	
`Q203=+0 ;SURFACE COORDINATE`	0 must be entered here, effective as defined in point table
`Q204=0 ;2ND SET-UP CLEARANCE`	0 must be entered here, effective as defined in point table
`Q211=0.2 ;DWELL TIME AT DEPTH`	
`15 CYCL CALL PAT F5000 M3`	Cycle call in connection with point table TAB1.PNT
`16 L Z+100 R0 FMAX M6`	Retract the tool, change the tool
`17 TOOL CALL 3 Z S200`	Tool call for tap
`18 L Z+50 R0 FMAX`	Move tool to clearance height
`19 CYCL DEF 206 TAPPING NEW`	Cycle definition for tapping
`Q200=2 ;SAFETY CLEARANCE`	
`Q201=-25 ;THREAD DEPTH`	
`Q206=150 ;FEED RATE FOR PECKING`	
`Q211=0 ;DWELL TIME AT DEPTH`	
`Q203=+0 ;SURFACE COORDINATE`	0 must be entered here, effective as defined in point table
`Q204=0 ;2ND SET-UP CLEARANCE`	0 must be entered here, effective as defined in point table
`20 CYCL CALL PAT F5000 M3`	Cycle call in connection with point table TAB1.PNT
`21 L Z+100 R0 FMAX M2`	Retract in the tool axis, end program
`22 END PGM 1 MM`	

Point table TAB1.PNT

TAB1. PNT MM			
NR	X	Y	Z
0	+10	+10	+0
1	+40	+30	+0
2	+90	+10	+0
3	+80	+30	+0
4	+80	+65	+0
5	+90	+90	+0
6	+10	+90	+0
7	+20	+55	+0
[END]			

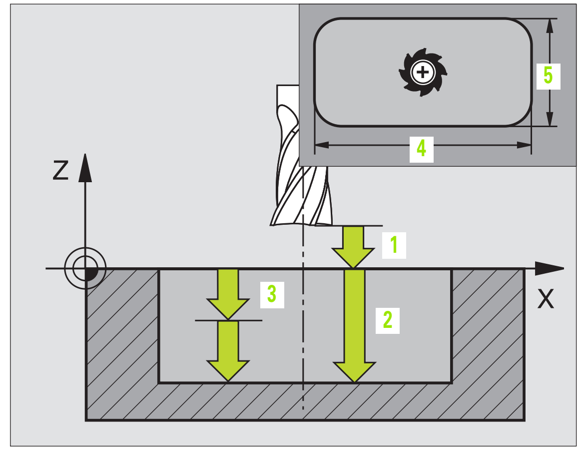
8.4 Cycles for Milling Pockets, Studs and Slots

Overview

Cycle	Soft key
4 POCKET MILLING (rectangular) Roughing cycle without automatic pre-positioning	
212 POCKET FINISHING (rectangular) Finishing cycle with automatic pre-positioning, 2nd set-up clearance	
213 STUD FINISHING (rectangular) Finishing cycle with automatic pre-positioning, 2nd set-up clearance	
5 CIRCULAR POCKET Roughing cycle without automatic pre-positioning	
214 CIRCULAR POCKET FINISHING Finishing cycle with automatic pre-positioning, 2nd set-up clearance	
215 CIRCULAR STUD FINISHING Finishing cycle with automatic pre-positioning, 2nd set-up clearance	
3 SLOT MILLING Roughing/finishing cycle without automatic pre-positioning, vertical depth infeed	
210 SLOT RECIP. PLNG Roughing/finishing cycle with automatic pre-positioning, with reciprocating plunge infeed	
211 CIRCULAR SLOT Roughing/finishing cycle with automatic pre-positioning, with reciprocating plunge infeed	

POCKET MILLING (Cycle 4)

1. The tool penetrates the workpiece at the starting position (pocket center) and advances to the first plunging depth.
2. The cutter begins milling in the positive axis direction of the longer side (on square pockets, always starting in the positive Y direction) and then roughs out the pocket from the inside out.
3. This process (1 to 2) is repeated until the depth is reached.
4. At the end of the cycle, the TNC retracts the tool to the starting position.



Before programming, note the following:

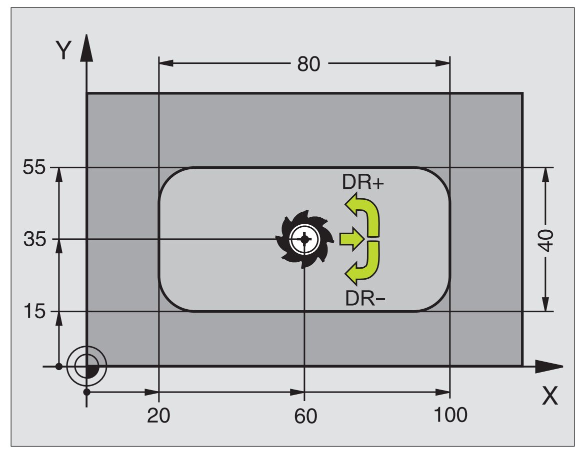
This cycle requires a center-cut end mill (ISO 1641), or pilot drilling at the pocket center.

Pre-position over the pocket center with radius compensation R0.

Program a positioning block for the starting point in the tool axis (set-up clearance above the workpiece surface).

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

The following prerequisite applies for the 2nd side length: 2nd side length greater than [(2 x rounding radius) + stepover factor k].



- **Set-up clearance 1** (incremental value): Distance between tool tip (at starting position) and workpiece surface
- **Depth 2** (incremental value): Distance between workpiece surface and bottom of pocket
- **Plunging depth 3** (incremental value): Infeed per cut The TNC will go to depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth
- **Feed rate for plunging**: Traversing speed of the tool during penetration
- **First side length 4** (incremental value): Pocket length, parallel to the reference axis of the working plane
- **2nd side length 5**: Pocket width
- Feed rate F: Traversing speed of the tool in the working plane
- **Clockwise**
  DR **+**: Climb milling with M3
  DR **–**: Up-cut milling with M3

Example: NC blocks

```
11 L Z+100 R0 FMAX
12 CYCL DEF 4.0 POCKET MILLING
13 CYCL DEF 2.1 SETUP 2
14 CYCL DEF 4.2 DEPTH -10
15 CYCL DEF 4.3 PECKG 4 F80
16 CYCL DEF 4.4 X80
17 CYCL DEF 4.5 Y40
18 CYCL DEF 4.6 F100 DR+ RADIUS 10
19 L X+60 Y+35 FMAX M3
20 L Z+2 FMAX M99
```

- **`Rounding off radius`**: Radius for the pocket corners. If Radius = 0 is entered, the pocket corners will be rounded with the radius of the cutter.

Calculations:
Stepover factor k = K x R

K: is the overlap factor, preset in machine parameter 7430, and
R is the cutter radius

POCKET FINISHING (Cycle 212)

1 The TNC automatically moves the tool in the tool axis to set-up clearance, or—if programmed—to the 2nd set-up clearance, and subsequently to the center of the pocket.

2 From the pocket center, the tool moves in the working plane to the starting point for machining. The TNC takes the allowance and tool radius into account for calculating the starting point. If necessary, the TNC penetrates at the pocket center.

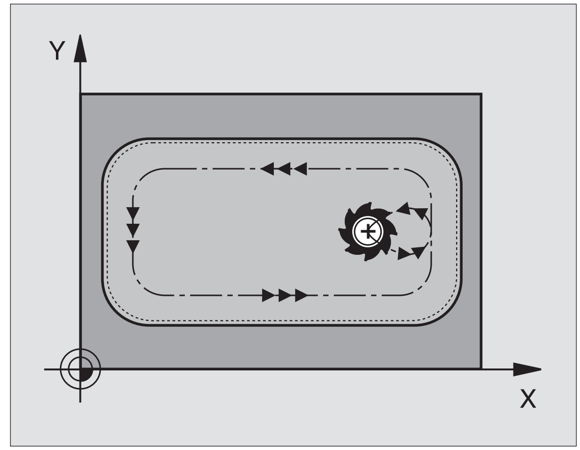
3 If the tool is at the 2nd set-up clearance, it moves in rapid traverse FMAX to set-up clearance, and from there advances to the first plunging depth at the feed rate for plunging.

4 The tool then moves tangentially to the contour of the finished part and, using climb milling, machines one revolution.

5 The tool then departs the contour on a tangential path and returns to the starting point in the working plane.

6 This process (3 to 5) is repeated until the programmed depth is reached.

7 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance, or—if programmed—to the 2nd set-up clearance, and finally to the center of the pocket (end position = starting position).



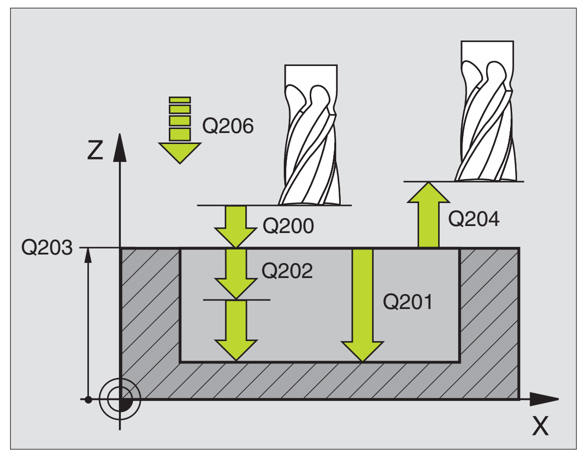
Before programming, note the following:

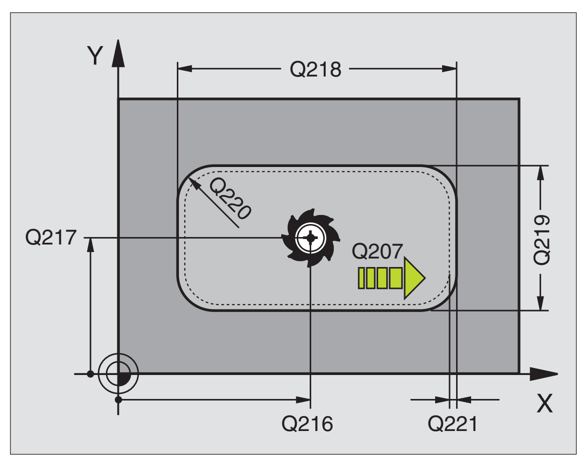
The TNC automatically pre-positions the tool in the tool axis and working plane.

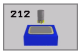
The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

If you want to clear and finish the pocket with the same tool, use a center-cut end mill (ISO 1641) and enter a low feed rate for plunging.

Minimum size of the pocket: 3 times the tool radius.





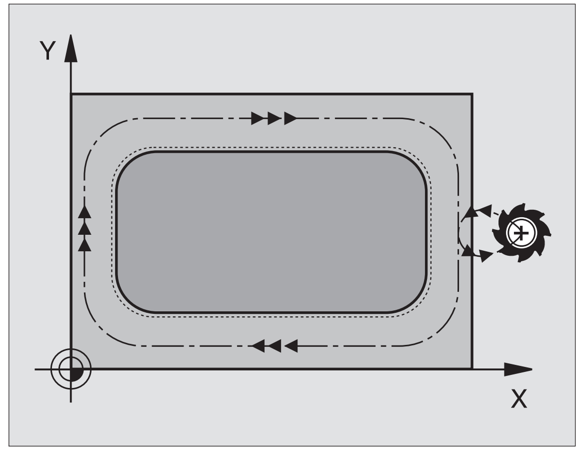


- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth** Q201 (incremental value): Distance between workpiece surface and bottom of pocket
- **Feed rate for plunging** Q206: Traversing speed of the tool in mm/min when moving to depth. If you are plunge-cutting into the material, enter a value lower than that defined in Q207
- **Plunging depth** Q202 (incremental value): Infeed per cut. Enter a value greater than 0.
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Center in 1st axis** Q216 (absolute value): Center of the pocket in the reference axis of the working plane
- **Center in 2nd axis** Q217 (absolute value): Center of the pocket in the minor axis of the working plane
- **First side length** Q218 (incremental value): Pocket length, parallel to the reference axis of the working plane.
- **Second side length** Q219 (incremental value): Pocket length, parallel to the minor axis of the working plane
- **Corner radius** Q220: Radius of the pocket corner: If you make no entry here, the TNC assumes that the corner radius is equal to the tool radius.
- **Allowance in 1st axis** Q221 (incremental value): Allowance for pre-positioning in the reference axis of the working plane referenced to the length of the pocket.

Example: NC blocks

```
354 CYCL DEF 212 POCKET FINISHING
    Q200=2          ;SAFETY CLEARANCE
    Q201=-20        ;DEPTH
    Q206=150        ;FEED RATE FOR PLUNGING
    Q202=5          ;INFEED DEPTH
    Q207=500        ;FEED RATE FOR MILLING
    Q203=+30        ;SURFACE COORDINATE
    Q204=50         ;2ND SAFETY CLEARANCE
    Q216=+50        ;CENTER IN 1ST AXIS
    Q217=+50        ;CENTER IN 2ND AXIS
    Q218=80         ;FIRST SIDE LENGTH
    Q219=60         ;SECOND SIDE LENGTH
    Q220=5          ;CORNER RADIUS
    Q221=0          ;OVERSIZE
```

STUD FINISHING (Cycle 213)



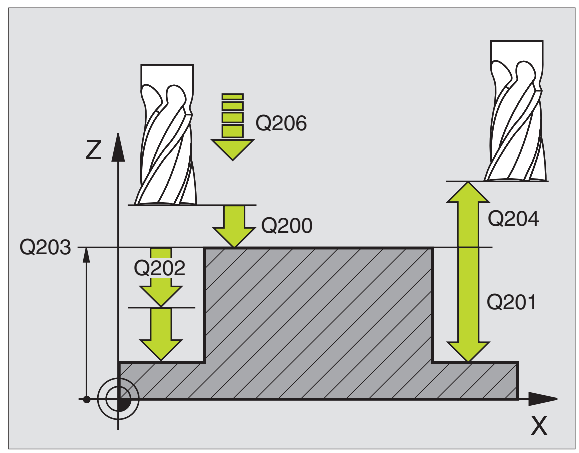
1. The TNC moves the tool in the tool axis to set-up clearance, or—if programmed—to the 2nd set-up clearance, and subsequently to the center of the stud.
2. From the stud center, the tool moves in the working plane to the starting point for machining. The starting point lies to the right of the stud by a distance approx. 3.5 times the tool radius.
3. If the tool is at the 2nd set-up clearance, it moves in rapid traverse FMAX to set-up clearance, and from there advances to the first plunging depth at the feed rate for plunging.
4. The tool then moves tangentially to the contour of the finished part and, using climb milling, machines one revolution.
5. The tool then departs the contour on a tangential path and returns to the starting point in the working plane.
6. This process (3 to 5) is repeated until the programmed depth is reached.
7. At the end of the cycle, the TNC retracts the tool in FMAX to set-up clearance, or—if programmed—to the 2nd set-up clearance, and finally to the center of the stud (end position = starting position).

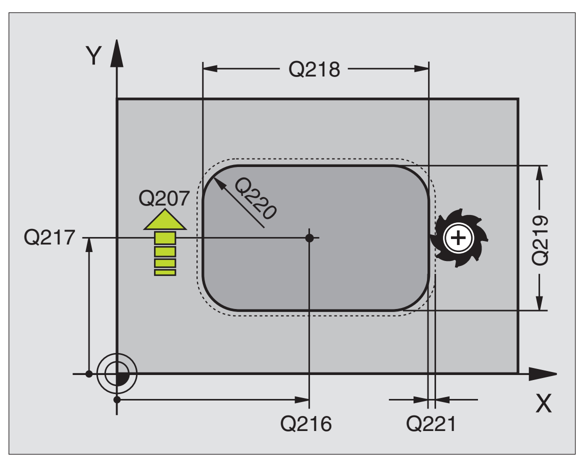
Before programming, note the following:

The TNC automatically pre-positions the tool in the tool axis and working plane.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

If you want to clear and finish the stud with the same tool, use a center-cut end mill (ISO 1641) and enter a low feed rate for plunging.



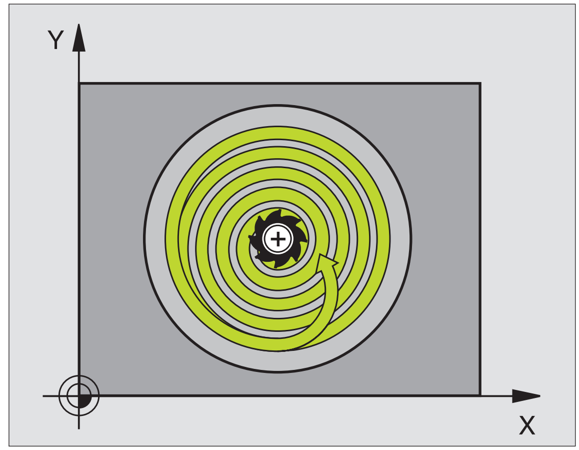


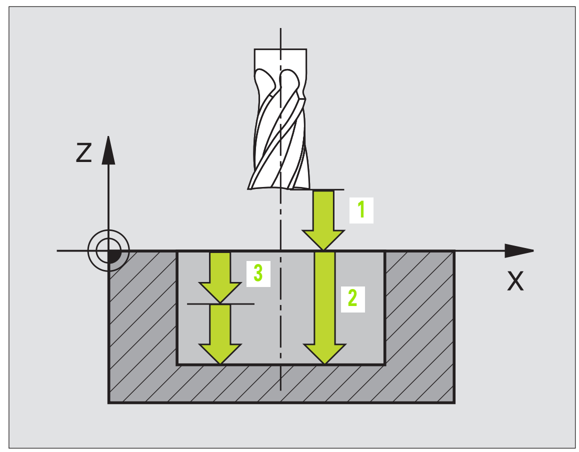
- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **`Depth`** Q201 (incremental value): Distance between workpiece surface and bottom of stud
- **`Feed rate for plunging`** Q206: Traversing speed of the tool in mm/min when moving to depth. If you are plunge-cutting into the material, enter a low value; if you have already cleared the stud, enter a higher feed rate.
- **`Plunging depth`** Q202 (incremental value): Infeed per cut. Enter a value greater than 0.
- **`Feed rate for milling`** Q207: Traversing speed of the tool in mm/min while milling.
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Center in 1st axis`** Q216 (absolute value): Center of the stud in the reference axis of the working plane
- **`Center in 2nd axis`** Q217 (absolute value): Center of the stud in the minor axis of the working plane.
- **`First side length`** Q218 (incremental value): Length of stud parallel to the reference axis of the working plane
- **`Second side length`** Q219 (incremental value): Length of stud parallel to the secondary axis of the working plane
- **`Corner radius`** Q220: Radius of the stud corner
- **`Allowance in 1st axis`** Q221 (incremental value): Allowance for pre-positioning in the reference axis of the working plane referenced to the length of the stud

Example: NC blocks

```
35 CYCL DEF 213 STUD FINISHING
     Q200=2         ;SAFETY CLEARANCE
     Q291=-20       ;DEPTH
     Q206=150       ;FEED RATE FOR PLUNGING
     Q202=5         ;INFEED DEPTH
     Q207=500       ;FEED RATE FOR MILLING
     Q203=+30       ;SURFACE COORDINATE
     Q294=50        ;2ND SAFETY CLEARANCE
     Q216=+50       ;CENTER IN 1ST AXIS
     Q217=+50       ;CENTER IN 2ND AXIS
     Q218=80        ;FIRST SIDE LENGTH
     Q219=60        ;SECOND SIDE LENGTH
     Q220=5         ;CORNER RADIUS
     Q221=0         ;OVERSIZE
```

CIRCULAR POCKET MILLING (Cycle 5)





1 The tool penetrates the workpiece at the starting position (pocket center) and advances to the first plunging depth.

2 The tool subsequently follows a spiral path at the feed rate F - see figure at right. For calculating the stepover factor k, see Cycle 4 POCKET MILLING.see "POCKET MILLING (Cycle 4)," page 267

3 This process is repeated until the depth is reached.

4 At the end of the cycle, the TNC retracts the tool to the starting position.

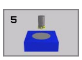
Before programming, note the following:

This cycle requires a center-cut end mill (ISO 1641), or pilot drilling at the pocket center.

Pre-position over the pocket center with radius compensation R0.

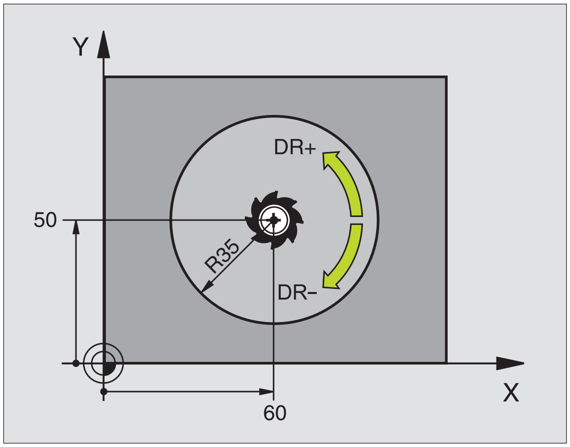
Program a positioning block for the starting point in the tool axis (set-up clearance above the workpiece surface).

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.



- **`Set-up clearance`** 1 (incremental value): Distance between tool tip (at starting position) and workpiece surface
- **`Milling depth`** 2: Distance between workpiece surface and bottom of pocket
- **`Plunging depth`** 3 (incremental value): Infeed per cut The TNC will go to depth in one movement if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth

- **Feed rate for plunging**: Traversing speed of the tool during penetration
- **Circular radius**: Radius of the circular pocket
- **Feed rate F**: Traversing speed of the tool in the working plane
- **Clockwise**
  DR **+**: Climb milling with M3
  DR **–**: Up-cut milling with M3

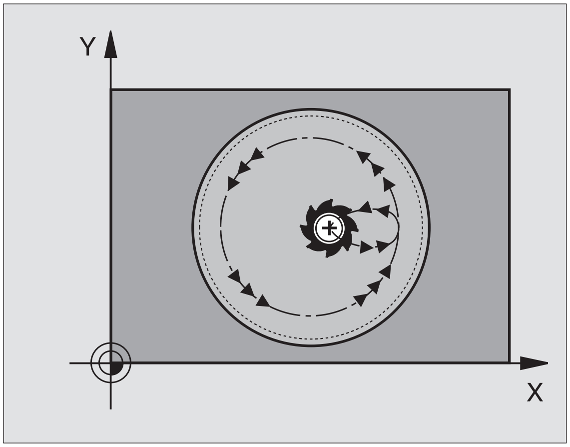


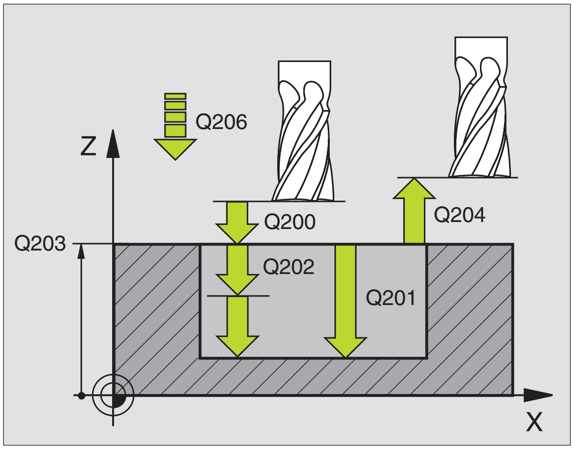
Example: NC blocks

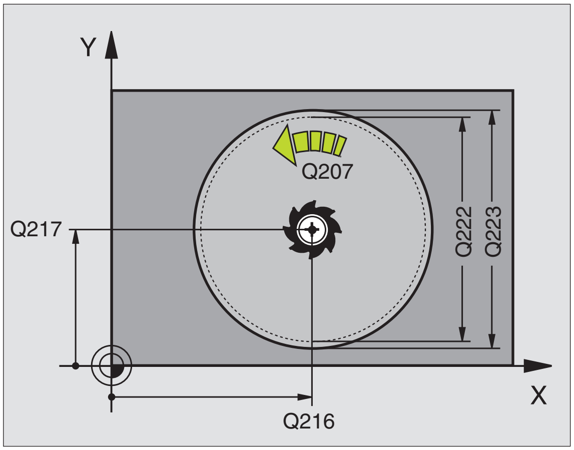
```
16 L Z+100 R0 FMAX
17 CYCL DEF 5.0 CIRCULAR POCKET
18 CYCL DEF 5.1 SETUP 2
19 CYCL DEF 5.2 DEPTH -12
20 CYCL DEF 5.3 PECKG 6 F80
21 CYCL DEF 5.4 RADIUS 35
22 CYCL DEF 5.5 F100 DR+
23 L X+60 Y+50 FMAX M3
24 L Z+2 FMAX M99
```

CIRCULAR POCKET FINISHING (Cycle 214)

1 The TNC automatically moves the tool in the tool axis to set-up clearance, or—if programmed—to the 2nd set-up clearance, and subsequently to the center of the pocket.
2 From the pocket center, the tool moves in the working plane to the starting point for machining. The TNC takes the workpiece blank diameter and tool radius into account for calculating the starting point. If you enter a workpiece blank diameter of 0, the TNC plunge-cuts into the pocket center.
3 If the tool is at the 2nd set-up clearance, it moves in rapid traverse FMAX to set-up clearance, and from there advances to the first plunging depth at the feed rate for plunging.
4 The tool then moves tangentially to the contour of the finished part and, using climb milling, machines one revolution.
5 After this, the tool departs the contour tangentially and returns to the starting point in the working plane.
6 This process (3 to 5) is repeated until the programmed depth is reached.
7 At the end of the cycle, the TNC retracts the tool in rapid traverse to set-up clearance, or, if programmed, to the 2nd set-up clearance and then to the center of the pocket (end position = starting position)







Before programming, note the following:

The TNC automatically pre-positions the tool in the tool axis and working plane.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

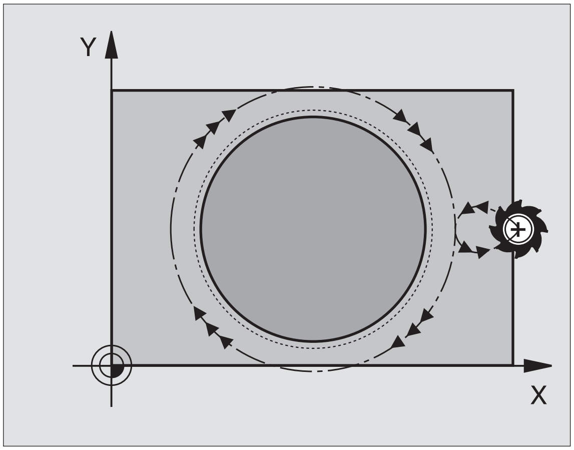
If you want to clear and finish the pocket with the same tool, use a center-cut end mill (ISO 1641) and enter a low feed rate for plunging.

- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth** Q201 (incremental value): Distance between workpiece surface and bottom of pocket
- **Feed rate for plunging** Q206: Traversing speed of the tool in mm/min when moving to depth. If you are plunge-cutting into the material, enter a value lower than that defined in Q207
- **Plunging depth** Q202 (incremental value): Infeed per cut.
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Center in 1st axis** Q216 (absolute value): Center of the pocket in the reference axis of the working plane
- **Center in 2nd axis** Q217 (absolute value): Center of the pocket in the minor axis of the working plane
- **Workpiece blank diameter** Q222: Diameter of the premachined pocket for calculating the pre-position. Enter the workpiece blank diameter to be less than the diameter of the finished part
- **Finished part diameter** Q223: Diameter of the finished pocket. Enter the diameter of the finished part to be greater than the workpiece blank diameter.

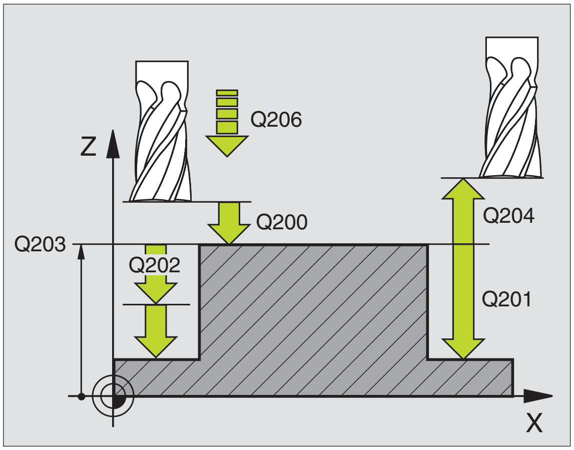
Example: NC blocks

```
42 CYCL DEF 214 CIRCULAR POCKET FINISHING
      Q200=2        ;SAFETY CLEARANCE
      Q201=-20      ;DEPTH
      Q206=150      ;FEED RATE FOR PLUNGING
      Q202=5        ;INFEED DEPTH
      Q207=500      ;FEED RATE FOR MILLING
      Q203=+30      ;SURFACE COORDINATE
      Q204=50       ;2ND SAFETY CLEARANCE
      Q216=+50      ;CENTER IN 1ST AXIS
      Q217=+50      ;CENTER IN 2ND AXIS
      Q222=79       ;WORKPIECE BLANK DIA.
      Q223=80       ;FINISHED PART DIA.
```

CIRCULAR STUD FINISHING (Cycle 215)



1. The TNC automatically moves the tool in the tool axis to set-up clearance, or—if programmed—to the 2nd set-up clearance, and subsequently to the center of the stud.
2. From the stud center, the tool moves in the working plane to the starting point for machining. The starting point lies to the right of the stud by a distance approx. 2 times the tool radius.
3. If the tool is at the 2nd set-up clearance, it moves in rapid traverse FMAX to set-up clearance, and from there advances to the first plunging depth at the feed rate for plunging.
4. The tool then moves tangentially to the contour of the finished part and, using climb milling, machines one revolution.
5. The tool then departs the contour on a tangential path and returns to the starting point in the working plane.
6. This process (3 to 5) is repeated until the programmed depth is reached.
7. At the end of the cycle, the TNC retracts the tool in FMAX to set-up clearance, or—if programmed—to the 2nd set-up clearance, and finally to the center of the pocket (end position = starting position).

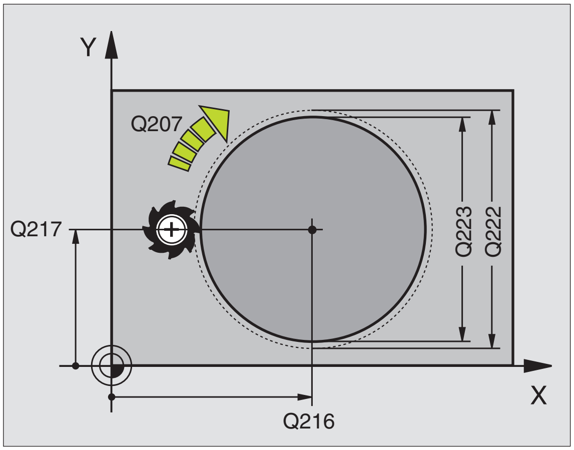


Before programming, note the following:

The TNC automatically pre-positions the tool in the tool axis and working plane.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

If you want to clear and finish the stud with the same tool, use a center-cut end mill (ISO 1641) and enter a low feed rate for plunging.

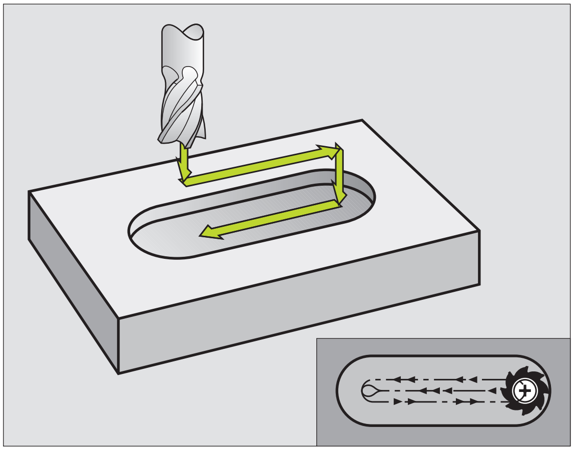


- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth** Q201 (incremental value): Distance between workpiece surface and bottom of stud
- **Feed rate for plunging** Q206: Traversing speed of the tool in mm/min when moving to depth. If you are plunge-cutting into the material, enter a low value; if you have already cleared the stud, enter a higher feed rate.
- **Plunging depth** Q202 (incremental value): Infeed per cut. Enter a value greater than 0.
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Center in 1st axis** Q216 (absolute value): Center of the stud in the reference axis of the working plane
- **Center in 2nd axis** Q217 (absolute value): Center of the stud in the minor axis of the working plane.
- **Workpiece blank diameter** Q222: Diameter of the premachined stud for calculating the pre-position. Enter the workpiece blank diameter to be greater than the diameter of the finished part
- **Diameter of finished part** Q223: Diameter of the finished stud. Enter the diameter of the finished part to be less than the workpiece blank diameter.

Example: NC blocks

```
43 CYCL DEF 215 CIRCULAR FINISHING
    Q200=2         ;SAFETY CLEARANCE
    Q201=-20       ;DEPTH
    Q206=150       ;FEED RATE FOR PLUNGING
    Q202=5         ;INFEED DEPTH
    Q207=500       ;FEED RATE FOR MILLING
    Q203=+30       ;SURFACE COORDINATE
    Q204=50        ;2ND SAFETY CLEARANCE
    Q216=+50       ;CENTER IN 1ST AXIS
    Q217=+50       ;CENTER IN 2ND AXIS
    Q222=81        ;WORKPIECE BLANK DIA.
    Q223=80        ;FINISHED PART DIA.
```

SLOT MILLING (Cycle 3)



Roughing process

1. The TNC moves the tool inward by the milling allowance (half the difference between the slot width and the tool diameter). From there it plunge-cuts into the workpiece and mills in the longitudinal direction of the slot.
2. After downfeed at the end of the slot, milling is performed in the opposite direction. This process is repeated until the programmed milling depth is reached.

Finishing process

3. The TNC advances the tool at the slot bottom on a tangential arc to the outside contour. The tool subsequently climb mills the contour (with M3).
4. At the end of the cycle, the tool is retracted in rapid traverse FMAX to set-up clearance. If the number of infeeds was odd, the tool returns to the starting position at the level of the set-up clearance.

Before programming, note the following:

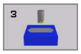
This cycle requires a center-cut end mill (ISO 1641), or pilot drilling at the starting point.

Pre-position to the center of the slot and offset by the tool radius into the slot with radius compensation R0.

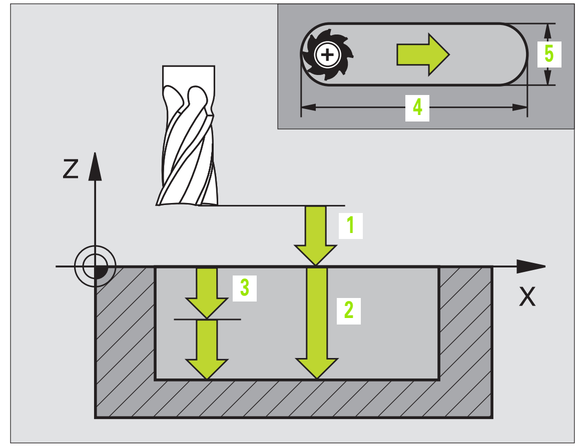
The cutter diameter must be not be larger than the slot width and not smaller than half the slot width.

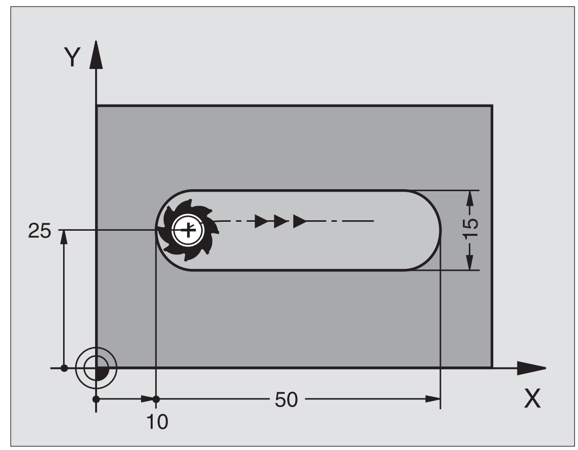
Program a positioning block for the starting point in the tool axis (set-up clearance above the workpiece surface).

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.



- **`Set-up clearance`** 1 (incremental value): Distance between tool tip (at starting position) and workpiece surface
- **`Milling depth`** 2 (incremental value): Distance between workpiece surface and bottom of pocket
- **`Plunging depth`** 3 (incremental value): Infeed per cut. The tool will drill to the depth in one operation if:
  - the plunging depth is equal to the depth
  - the plunging depth is greater than the depth
- **`Feed rate for plunging`**: Traversing speed during penetration
- **`1st side length`** 4: Slot length; specify the sign to determine the first milling direction
- **`2nd side length`** 5: Slot width
- **`Feed rate F`**: Traversing speed of the tool in the working plane





Example: NC blocks

```
9 L Z+100 R0 FMAX
10 TOOL DEF 1 L+0 R+6
11 TOOL CALL 1 Z S1500
12 CYCL DEF 3.0 SLOT MILLING
13 CYCL DEF 3.1 SETUP 2
14 CYCL DEF 3.2 DEPTH -15
15 CYCL DEF 3.3 PECKG 5 F80
16 CYCL DEF 3.4 X50
17 CYCL DEF 3.5 Y15
18 CYCL DEF 3.6 F120
19 L X+16 Y+25 R0 FMAX M3
20 L Z+2 M99
```

SLOT (oblong hole) with reciprocating plunge-cut (Cycle 210)

Before programming, note the following:

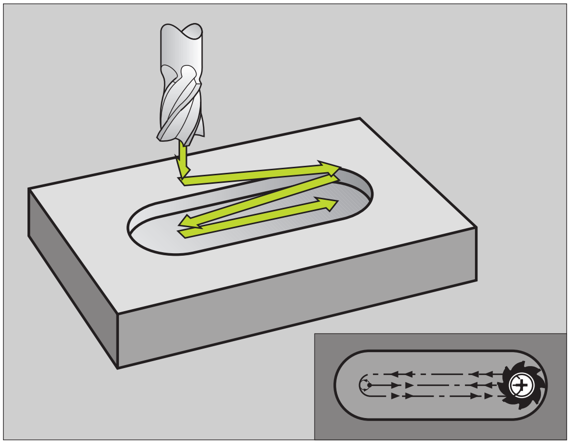
The TNC automatically pre-positions the tool in the tool axis and working plane.

During roughing the tool plunges into the material with a sideward reciprocating motion from one end of the slot to the other. Pilot drilling is therefore unnecessary.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

The cutter diameter must not be larger than the slot width and not smaller than a third of the slot width.

The cutter diameter must be smaller than half the slot length. The TNC otherwise cannot execute this cycle.



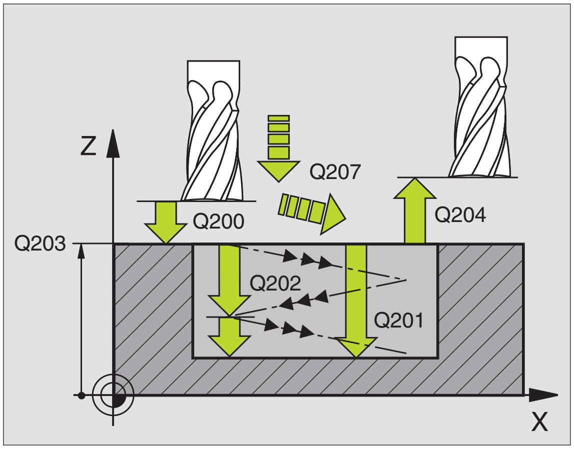
Roughing process

1 At rapid traverse, the TNC positions the tool in the tool axis to the 2nd set-up clearance and subsequently to the center of the left circle. From there, the TNC positions the tool to set-up clearance above the workpiece surface.

2 The tool moves at the feed rate for milling to the workpiece surface. From there, the cutter advances in the longitudinal direction of the slot—plunge-cutting obliquely into the material—until it reaches the center of the right circle.

3 The tool then moves back to the center of the left circle, again with oblique plunge-cutting. This process is repeated until the programmed milling depth is reached.

4 At the milling depth, the TNC moves the tool for the purpose of face milling to the other end of the slot and then back to the center of the slot.

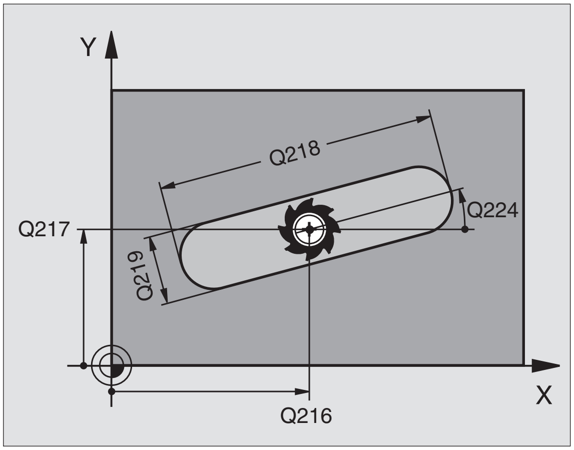


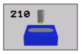
Finishing process

5 The TNC positions the tool in the center of the left circle of the rounded slot and then moves it tangentially to the left slot end. The tool subsequently climb mills the contour (with M3), and if so entered, in more than one infeed.

6 When the tool reaches the end of the contour, it departs the contour tangentially and returns to the center of the left circle of the rounded slot.

7 At the end of the cycle, the tool is retracted at rapid traverse FMAX to set-up clearance and—if programmed—to the 2nd set-up clearance.





- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Depth** Q201 (incremental value): Distance between workpiece surface and bottom of slot.
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.
- **Plunging depth** Q202 (incremental value): Total extent by which the tool is fed in the tool axis during a reciprocating movement.
- **Machining operation (0/1/2)** Q215: Define the machining operation:
  0: Roughing and finishing
  1: Only roughing
  2: Only finishing
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Z coordinate at which no collision between tool and workpiece (clamping devices) can occur.
- **Center in 1st axis** Q216 (absolute value): Center of the slot in the reference axis of the working plane.
- **Center in 2nd axis** Q217 (absolute value): Center of the slot in the minor axis of the working plane.
- **First side length** Q218 (value parallel to the reference axis of the working plane): Enter the length of the slot.
- **Second side length** Q219 (value parallel to the secondary axis of the working plane): Enter the slot width. If you enter a slot width that equals the tool diameter, the TNC will carry out the roughing process only (slot milling).
- **Angle of rotation** Q224 (absolute value): Angle by which the entire slot is rotated. The center of rotation lies in the center of the slot.
- **Infeed for finishing** Q338 (incremental value): Infeed per cut. Q338=0: Finishing in one infeed.
- **Feed rate for plunging** Q206: Traversing speed of the tool while moving to depth in mm/min. Effective only during finishing if infeed for finishing is entered.

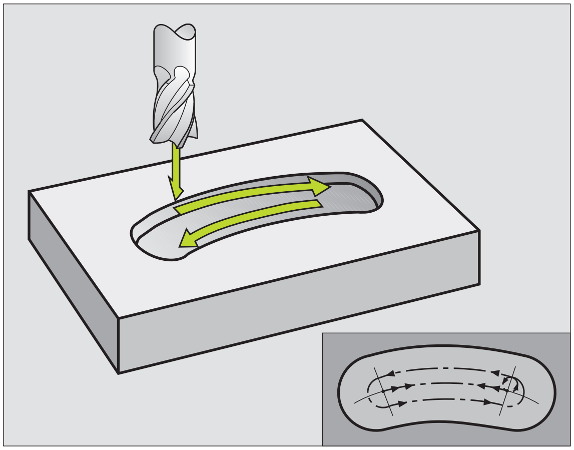
Example: NC blocks

```
51 CYCL DEF 210 SLOT RECIP. PLNG
      Q200=2          ;SET-UP CLEARANCE
      Q201=-20        ;DEPTH
      Q207=500        ;FEED RATE FOR MILLING
      Q202=5          ;PLUNGING DEPTH
      Q215=0          ;MACHINING OPERATION
      Q203=+30        ;SURFACE COORDINATE
      Q204=50         ;2ND SET-UP CLEARANCE
      Q216=+50        ;CENTER IN 1ST AXIS
      Q217=+50        ;CENTER IN 2ND AXIS
      Q218=80         ;FIRST SIDE LENGTH
      Q219=12         ;SECOND SIDE LENGTH
      Q224=+15        ;ANGLE OF ROTATION
      Q338=5          ;INFEED FOR FINISHING
      Q206=150        ;FEED RATE FOR PLNGNG
```

CIRCULAR SLOT (oblong hole) with reciprocating plunge-cut (Cycle 211)

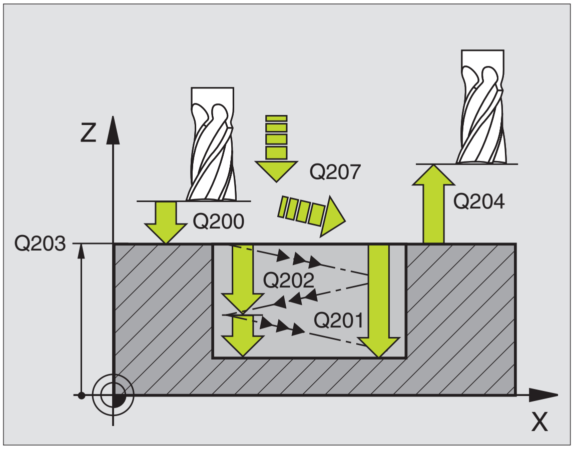
Roughing process

1. At rapid traverse, the TNC positions the tool in the tool axis to the 2nd set-up clearance and subsequently to the center of the right circle. From there, the tool is positioned to the programmed set-up clearance above the workpiece surface.
2. The tool moves at the milling feed rate to the workpiece surface. From there, the cutter advances—plunge-cutting obliquely into the material—to the other end of the slot.
3. The tool then moves at a downward angle back to the starting point, again with oblique plunge-cutting. This process (2 to 3) is repeated until the programmed milling depth is reached.
4. At the milling depth, the TNC moves the tool for the purpose of face milling to the other end of the slot.



Finishing process

5. The TNC advances the tool from the slot center tangentially to the contour of the finished part. The tool subsequently climb mills the contour (with M3), and if so entered, in more than one infeed. The starting point for the finishing process is the center of the right circle.
6. When the tool reaches the end of the contour, it departs the contour tangentially.
7. At the end of the cycle, the tool is retracted at rapid traverse FMAX to set-up clearance and—if programmed—to the 2nd set-up clearance.



Before programming, note the following:

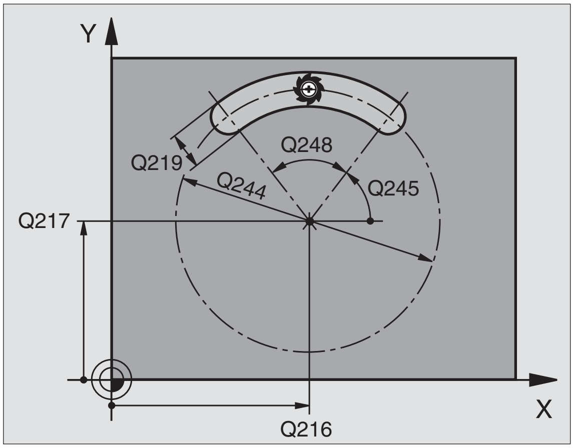
The TNC automatically pre-positions the tool in the tool axis and working plane.

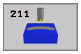
During roughing the tool plunges into the material with a helical sideward reciprocating motion from one end of the slot to the other. Pilot drilling is therefore unnecessary.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

The cutter diameter must not be larger than the slot width and not smaller than a third of the slot width.

The cutter diameter must be smaller than half the slot length. The TNC otherwise cannot execute this cycle.



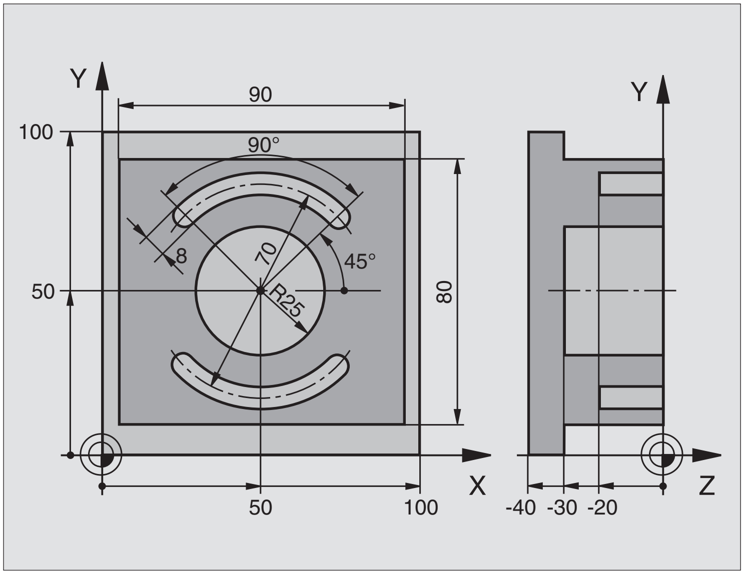


- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **`Depth`** Q201 (incremental value): Distance between workpiece surface and bottom of slot.
- **`Feed rate for milling`** Q207: Traversing speed of the tool in mm/min while milling.
- **`Plunging depth`** Q202 (incremental value): Total extent by which the tool is fed in the tool axis during a reciprocating movement.
- **`Machining operation (0/1/2)`** Q215: Define the machining operation:
  0: Roughing and finishing
  1: Only roughing
  2: Only finishing
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Z coordinate at which no collision between tool and workpiece (clamping devices) can occur.
- **`Center in 1st axis`** Q216 (absolute value): Center of the slot in the reference axis of the working plane.
- **`Center in 2nd axis`** Q217 (absolute value): Center of the slot in the minor axis of the working plane.
- **`Pitch circle diameter`** Q244: Enter the diameter of the pitch circle.
- **`Second side length`** Q219: Enter the slot width. If you enter a slot width that equals the tool diameter, the TNC will carry out the roughing process only (slot milling).
- **`Starting angle`** Q245 (absolute value): Enter the polar angle of the starting point.
- **`Angular length`** Q248 (incremental value): Enter the angular length of the slot.
- **`Infeed for finishing`** Q338 (incremental value): Infeed per cut. Q338=0: Finishing in one infeed.
- **`Feed rate for plunging`** Q206: Traversing speed of the tool while moving to depth in mm/min. Effective only during finishing if infeed for finishing is entered.

Example: NC blocks

```
52 CYCL DEF 211 CIRCULAR SLOT
     Q200=2        ;SET-UP CLEARANCE
     Q201=-20      ;DEPTH
     Q207=500      ;FEED RATE FOR MILLING
     Q202=5        ;PLUNGING DEPTH
     Q215=0        ;MACHINING OPERATION
     Q203=+30      ;SURFACE COORDINATE
     Q204=50       ;2ND SET-UP CLEARANCE
     Q216=+50      ;CENTER IN 1ST AXIS
     Q217=+50      ;CENTER IN 2ND AXIS
     Q244=80       ;PITCH CIRCLE DIA.
     Q219=12       ;SECOND SIDE LENGTH
     Q245=+45      ;STARTING ANGLE
     Q248=90       ;ANGULAR LENGTH
     Q338=5        ;INFEED FOR FINISHING
     Q206=150      ;FEED RATE FOR PLNGNG
```

Example: Milling pockets, studs and slots



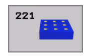
0 BEGIN PGM C210 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-40	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+6	Define the tool for roughing/finishing
4 TOOL DEF 2 L+0 R+3	Define slotting mill
5 TOOL CALL 1 Z S3500	Call the tool for roughing/finishing
6 L Z+250 R0 FMAX	Retract the tool
7 CYCL DEF 213 STUD FINISHING	Define cycle for machining the contour outside
Q200=2 ;SAFETY CLEARANCE	
Q201=-30 ;DEPTH	
Q206=250 ;F FEED RATE FOR PLUNGING	
Q202=5 ;INFEED DEPTH	
Q207=250 ;FEED RATE FOR MILLING	
Q203=+0 ;SURFACE COORDINATE	
Q204=20 ;SECOND SET-UP CLEARANCE	
Q216=+50 ;CENTER IN 1ST AXIS	
Q217=+50 ;CENTER IN 2ND AXIS	
Q218=90 ;FIRST SIDE LENGTH	
Q219=80 ;SECOND SIDE LENGTH	

Q220=0 ;CORNER RADIUS	
Q221=5 ;OVERSIZE	
8 CYCL CALL M3	Call cycle for machining the contour outside
9 CYCL DEF 5.0 CIRCULAR POCKET	Define CIRCULAR POCKET MILLING cycle
10 CYCL DEF 5.1 SETUP 2	
11 CYCL DEF 5.2 DEPTH -30	
12 CYCL DEF 5.3 PECKG 5 F250	
13 CYCL DEF 5.4 RADIUS 25	
14 CYCL DEF 5.5 F400 DR+	
15 L Z+2 R0 FMAX M99	Call CIRCULAR POCKET MILLING cycle
16 L Z+250 R0 FMAX M6	Tool change
17 TOLL CALL 2 Z S5000	Call slotting mill
18 CYCL DEF 211 CIRCULAR SLOT	Cycle definition for slot 1
Q200=2 ;SET-UP CLEARANCE	
Q201=-20 ;DEPTH	
Q207=250 ;FEED RATE FOR MILLING	
Q202=5 ;INFEED DEPTH	
Q215=0 ;MACHINING OPERATION	
Q203=+0 ;SURFACE COORDINATE	
Q204=100 ;SECOND SET-UP CLEARANCE	
Q216=+50 ;CENTER IN 1ST AXIS	
Q217=+50 ;CENTER IN 2ND AXIS	
Q244=70 ;PITCH CIRCLE DIA.	
Q219=8 ;SECOND SIDE LENGTH	
Q245=+45 ;STARTING ANGLE	
Q248=90 ;ANGULAR LENGTH	
Q338=5 ;INFEED FOR FINISHING	
19 CYCL CALL M3	Call cycle for slot 1
20 FN 0: Q245 0 +225	New starting angle for slot 2
21 CYCL CALL	Call cycle for slot 2
22 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
23 END PGM C210 MM	

8.5 Cycles for Machining Hole Patterns

Overview

The TNC provides two cycles for machining hole patterns directly:

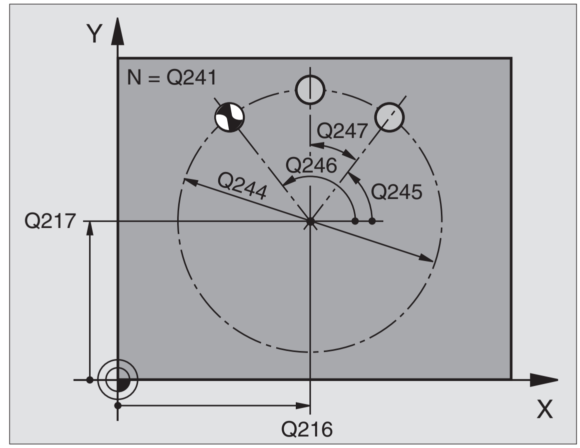
Cycle	Soft key
220 CIRCULAR PATTERN	
221 LINEAR PATTERN	

You can combine Cycle 220 and Cycle 221 with the following fixed cycles:

If you have to machine irregular hole patterns, use **CYCL CALL PAT** (see "Point Tables" on page 212) to develop point tables.

Cycle 1	PECKING
Cycle 2	TAPPING with a floating tap holder
Cycle 3	SLOT MILLING
Cycle 4	POCKET MILLING
Cycle 5	CIRCULAR POCKET MILLING
Cycle 17	RIGID TAPPING without a floating tap holder
Cycle 18	THREAD CUTTING
Cycle 200	DRILLING
Cycle 201	REAMING
Cycle 202	BORING
Cycle 203	UNIVERSAL DRILLING
Cycle 204	BACK BORING
Cycle 205	UNIVERSAL PECKING
Cycle 206	TAPPING NEW with a floating tap holder
Cycle 207	RIGID TAPPING NEW without a floating tap holder
Cycle 208	BORE MILLING
Cycle 209	TAPPING WITH CHIP BREAKING
Cycle 212	POCKET FINISHING
Cycle 213	STUD FINISHING
Cycle 214	CIRCULAR POCKET FINISHING
Cycle 215	CIRCULAR STUD FINISHING
Cycle 262	THREAD MILLING
Cycle 263	THREAD MILLING/COUNTERSINKING
Cycle 264	THREAD DRILLING/MILLING
Cycle 265	HELICAL THREAD DRILLING/MILLING
Cycle 267	OUTSIDE THREAD MILLING

CIRCULAR PATTERN (Cycle 220)



1 At rapid traverse, the TNC moves the tool from its current position to the starting point for the first machining operation.

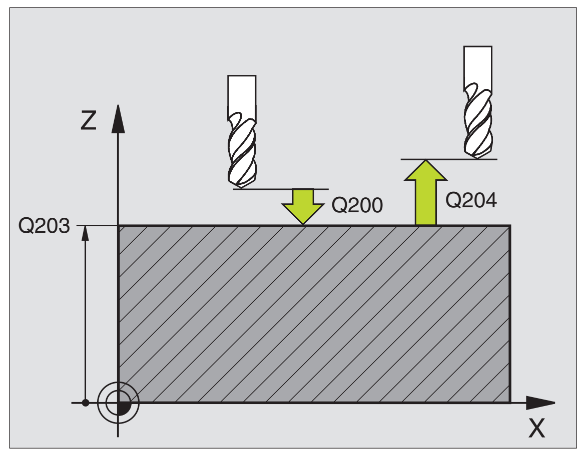
Sequence:

- Move to 2nd set-up clearance (spindle axis)
- Approach the starting point in the spindle axis
- Move to set-up clearance above the workpiece surface (spindle axis)

2 From this position, the TNC executes the last defined fixed cycle.

3 The tool then approaches the starting point for the next machining operation on a straight line at set-up clearance (or 2nd set-up clearance).

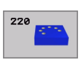
4 This process (1 to 3) is repeated until all machining operations have been executed.



Before programming, note the following:

Cycle 220 is DEF active, which means that Cycle 220 automatically calls the last defined fixed cycle.

If you combine Cycle 220 with one of the fixed cycles 200 to 209, 212 to 215, 262 to 265 or 267, the set-up clearance, workpiece surface and 2nd set-up clearance that you defined in Cycle 220 will be effective for the selected fixed cycle.



- ▶ **`Center in 1st axis`** Q216 (absolute value): Center of the pitch circle in the reference axis of the working plane
- ▶ **`Center in 2nd axis`** Q217 (absolute value): Center of the pitch circle in the minor axis of the working plane
- ▶ **`Pitch circle diameter`** Q244: Diameter of the pitch circle
- ▶ **`Starting angle`** Q245 (absolute value): Angle between the reference axis of the working plane and the starting point for the first machining operation on the pitch circle
- ▶ **`Stopping angle`** Q246 (absolute value): Angle between the reference axis of the working plane and the starting point for the last machining operation on the pitch circle (does not apply to complete circles). Do not enter the same value for the stopping angle and starting angle. If you enter the stopping angle greater than the starting angle, machining will be carried out counterclockwise; otherwise, machining will be clockwise.

Example: NC blocks

```
53 CYCL DEF 220 POLAR PATTERN
    Q216=+50    ;CENTER IN 1ST AXIS
    Q217=+50    ;CENTER IN 2ND AXIS
    Q244=80     ;PITCH CIRCLE DIA.
    Q245=+0     ;STARTING ANGLE
    Q246=+360   ;END ANGLE
    Q247=+0     ;STEPPING ANGLE
    Q241=8      ;NUMBER OF REPETITIONS
    Q200=2      ;SAFETY CLEARANCE
    Q203=+30    ;SURFACE COORDINATE
    Q204=50     ;2ND SAFETY CLEARANCE
    Q203=1      ;TRAVERSE TO CLEARANCE HEIGHT
```

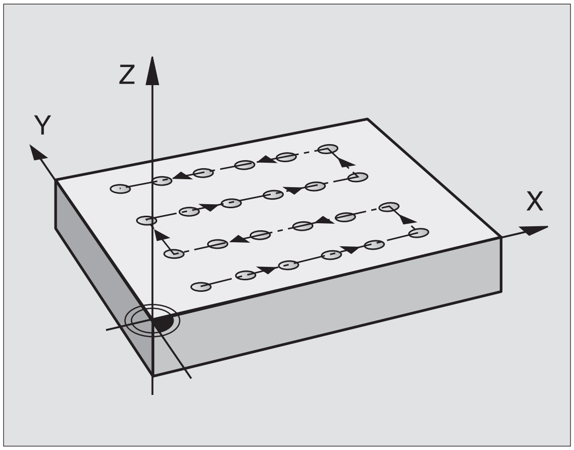
- **`Stepping angle`** Q247 (incremental value): Angle between two machining operations on a pitch circle. If you enter an angle step of 0, the TNC will calculate the angle step from the starting and stopping angles and the number of pattern repetitions. If you enter a value other than 0, the TNC will not take the stopping angle into account. The sign for the angle step determines the working direction (– = clockwise).
- **`Number of repetitions`** Q241: Number of machining operations on a pitch circle.
- **`Set-up clearance`** Q200 (incremental value): Distance between tool tip and workpiece surface. Enter a positive value.
- **`Workpiece surface coordinate`** Q203 (absolute value): Coordinate of the workpiece surface.
- **`2nd set-up clearance`** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **`Traversing to clearance height`** Q301: Definition of how the tool is to move between machining processes:
  0: Move between operations to the set-up clearance
  1: Move between operations to 2nd set-up clearance

LINEAR PATTERN (Cycle 221)

Before programming, note the following:

Cycle 221 is DEF active, which means that Cycle 221 calls the last defined fixed cycle automatically.

If you combine Cycle 221 with one of the fixed cycles 200 to 209, 212 to 215, 262 to 265 or 267, the set-up clearance, workpiece surface and 2nd set-up clearance that you defined in Cycle 221 will be effective for the selected fixed cycle.



1 The TNC automatically moves the tool from its current position to the starting point for the first machining operation.

Sequence:

- Move to 2nd set-up clearance (spindle axis)
- Approach the starting point in the spindle axis
- Move to set-up clearance above the workpiece surface (spindle axis)

2 From this position, the TNC executes the last defined fixed cycle.

3 The tool then approaches the starting point for the next machining operation in the positive reference axis direction at set-up clearance (or 2nd set-up clearance).

4 This process (1 to 3) is repeated until all machining operations on the first line have been executed. The tool is located above the last point on the first line.

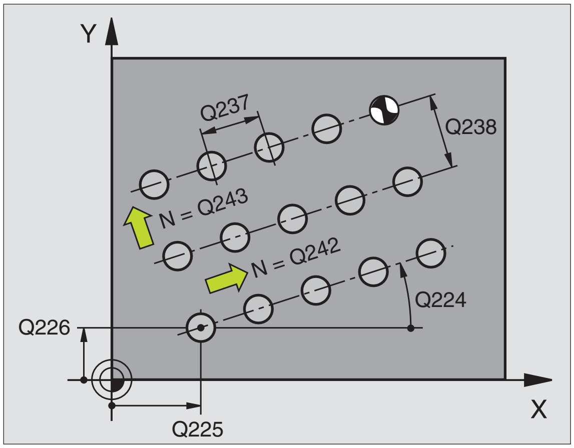
5 The tool subsequently moves to the last point on the second line where it carries out the machining operation.

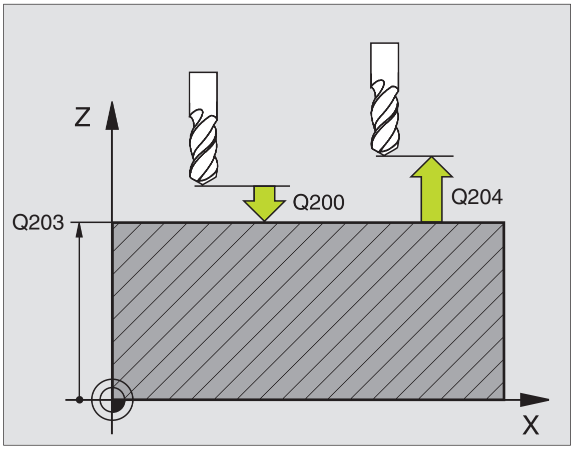
6 From this position, the tool approaches the starting point for the next machining operation in the negative reference axis direction.

7 This process (6) is repeated until all machining operations in the second line have been executed.

8 The tool then moves to the starting point of the next line.

9 All subsequent lines are processed in a reciprocating movement.



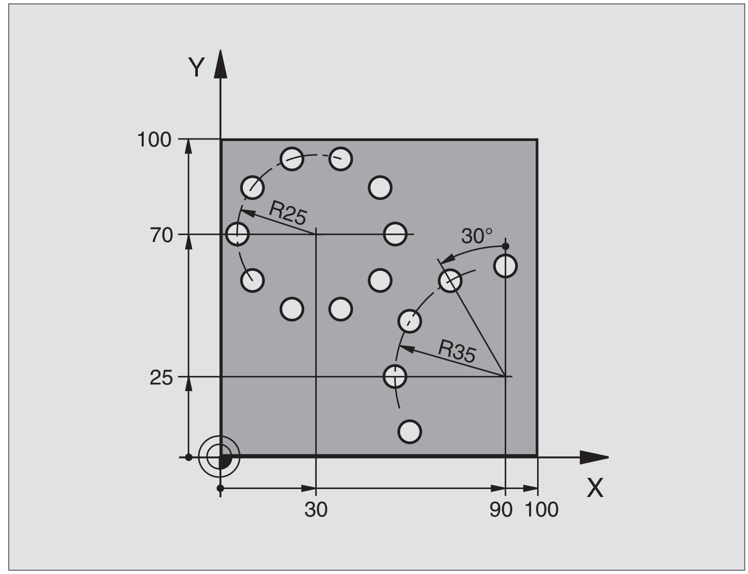


- **Starting point 1st axis** Q225 (absolute value): Coordinate of the starting point in the reference axis of the working plane
- **Starting point 2nd axis** Q226 (absolute value): Coordinate of the starting point in the minor axis of the working plane
- **Spacing in 1st axis** Q237 (incremental value): Spacing between the individual points on a line
- **Spacing in 2nd axis** Q238 (incremental value): Spacing between the individual lines
- **Number of columns** Q242: Number of machining operations on a line
- **Number of lines** Q243: Number of passes
- **Angle of rotation** Q224 (absolute value): Angle by which the entire pattern is rotated. The center of rotation lies in the starting point.
- **Set-up clearance** Q200 (incremental value): Distance between tool tip and workpiece surface.
- **Workpiece surface coordinate** Q203 (absolute value): Coordinate of the workpiece surface.
- **2nd set-up clearance** Q204 (incremental value): Coordinate in the tool axis at which no collision between tool and workpiece (clamping devices) can occur.
- **Traversing to clearance height** Q301: Definition of how the tool is to move between machining processes:
  0: Move to set-up clearance
  1: Move to 2nd set-up clearance between the measuring points.

Example: NC blocks

```
54 CYCL DEF 221 CARTESIAN PATTRN
    Q225=+15  ;STARTING PNT 1ST AXIS
    Q226=+15  ;STARTING PNT 2ND AXIS
    Q237=+10  ;SPACING 1ST AXIS
    Q238=+8   ;SPACING 2ND AXIS
    Q242=6    ;NUMBER OF COLUMNS
    Q243=4    ;NUMBER OF LINES
    Q224=+15  ;ANGLE OF ROTATION
    Q200=2    ;SAFETY CLEARANCE
    Q203=+30  ;SURFACE COORDINATE
    Q204=50   ;2ND SAFETY CLEARANCE
    Q301=1    ;TRAVERSE TO CLEARANCE HEIGHT
```

Example: Circular hole patterns



0 BEGIN PGM PATTERN MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-40	Define the workpiece blank
2 BLK FORM 0.2 Y+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+3	Define the tool
4 TOOL CALL 1 Z S3500	Tool call
5 L Z+250 R0 FMAX M3	Retract the tool
6 CYCL DEF 200 DRILLING	Cycle definition: drilling
Q200=2 ;SAFETY CLEARANCE	
Q201=-15 ;DEPTH	
Q206=250 ;F FEED RATE FOR PLUNGING	
Q202=4 ;INFEED DEPTH	
Q210=0 ;DWELL TIME	
Q203=+0 ;SURFACE COORDINATE	
Q204=0 ;SECOND SET-UP CLEARANCE	
Q211=0.25 ;DWELL TIME AT DEPTH	

7 CYCL DEF 220 POLAR PATTERN	Define cycle for circular pattern 1, CYCL 200 is called automatically,
Q216=+30 ;CENTER IN 1ST AXIS	Q200, Q203 and Q204 are effective as defined in Cycle 220.
Q217=+70 ;CENTER IN 2ND AXIS	
Q244=50 ;PITCH CIRCLE DIA.	
Q245=+0 ;STARTING ANGLE	
Q246=+360 ;END ANGLE	
Q247=+0 ;STEPPING ANGLE	
Q241=10 ;NR. OF REPETITIONS	
Q200=2 ;SAFETY CLEARANCE	
Q203=+0 ;SURFACE COORDINATE	
Q204=100 ;SECOND SET-UP CLEARANCE	
Q301=1 ;TRAVERSE TO CLEARANCE HEIGHT	
8 CYCL DEF 220 POLAR PATTERN	Define cycle for circular pattern 2, CYCL 200 is called automatically,
Q216=+90 ;CENTER IN 1ST AXIS	Q200, Q203 and Q204 are effective as defined in Cycle 220.
Q217=+25 ;CENTER IN 2ND AXIS	
Q244=70 ;PITCH CIRCLE DIA.	
Q245=+90 ;STARTING ANGLE	
Q246=+360 ;END ANGLE	
Q247=30 ;STEPPING ANGLE	
Q241=5 ;NR. OF REPETITIONS	
Q200=2 ;SET-UP CLEARANCE	
Q203=+0 ;SURFACE COORDINATE	
Q204=100 ;SECOND SET-UP CLEARANCE	
Q301=1 ;TRAVERSE TO CLEARANCE HEIGHT	
9 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
10 END PGM PATTERN MM	

8.6 SL Cycles

Fundamentals

SL cycles enable you to form complex contours by combining up to 12 subcontours (pockets or islands). You define the individual subcontours in subprograms. The TNC calculates the total contour from the subcontours (subprogram numbers) that you enter in Cycle 14 CONTOUR GEOMETRY.

> The memory capacity for programming an SL cycle (all contour subprograms) is limited. The number of possible contour elements depends on the type of contour (inside or outside contour) and the number of subcontours. For example, you can program up to approx. 1024 line blocks.

Characteristics of the subprograms

- Coordinate transformations are allowed. If they are programmed within the subcontour they are also effective in the following subprograms, but they need not be reset after the cycle call.
- The TNC ignores feed rates F and miscellaneous functions M.
- The TNC recognizes a pocket if the tool path lies inside the contour, for example if you machine the contour clockwise with radius compensation RR.
- The TNC recognizes an island if the tool path lies outside the contour, for example if you machine the contour clockwise with radius compensation RL.
- The subprograms must not contain tool axis coordinates.
- The working plane is defined in the first coordinate block of the subprogram. The secondary axes U,V,W are permitted.

Characteristics of the fixed cycles

- The TNC automatically positions the tool to set-up clearance before a cycle.
- Each level of infeed depth is milled without interruptions since the cutter traverses around islands instead of over them.
- The radius of "inside corners" can be programmed—the tool keeps moving to prevent surface blemishes at inside corners (this applies for the outermost pass in the Rough-out and Side-Finishing cycles).
- The contour is approached in a tangential arc for side finishing.
- For floor finishing, the tool again approaches the workpiece in a tangential arc (for tool axis Z, for example, the arc may be in the Z/X plane).
- The contour is machined throughout in either climb or up-cut milling.

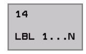
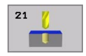
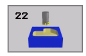
> With MP7420 you can determine where the tool is positioned at the end of Cycles 21 to 24.

The machining data (such as milling depth, finishing allowance and setup clearance) are entered as CONTOUR DATA in Cycle 20.

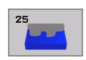
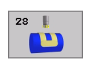
Example: Program structure: Machining with SL cycles

```
0 BEGIN PGM SL2 MM
...
12 CYCL DEF 140 CONTOUR GEOMETRY ...
13 CYCL DEF 20.0 CONTOUR DATA ...
...
16 CYCL DEF 21.0 PILOT DRILLING ...
17 CYCL CALL
...
18 CYCL DEF 22.0 ROUGH-OUT ...
19 CYCL CALL
...
22 CYCL DEF 23.0 FLOOR FINISHING ...
23 CYCL CALL
...
26 CYCL DEF 24.04 SIDE FINISHING ...
27 CYCL CALL
...
50 L Z+250 R0 FMAX M2
51 LBL 1
...
55 LBL 0
56 LBL 2
...
60 LBL 0
...
99 END PGM SL2 MM
```

Overview of SL cycles

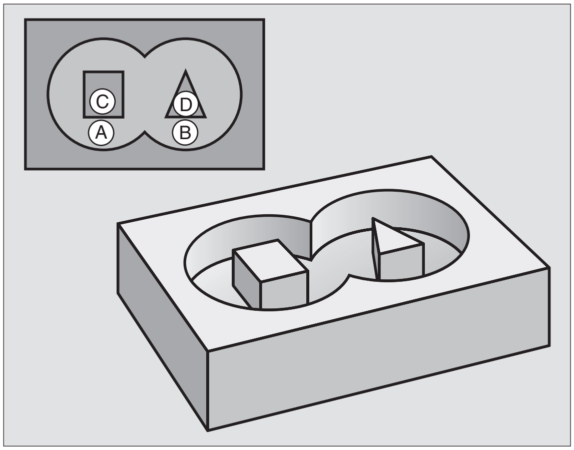
Cycle	Soft key
14 CONTOUR GEOMETRY (essential)	
20 CONTOUR DATA (essential)	
21 PILOT DRILLING (optional)	
22 ROUGH-OUT (essential)	
23 FLOOR FINISHING (optional)	
24 SIDE FINISHING (optional)	

Enhanced cycles:

Cycle	Soft key
25 CONTOUR TRAIN	
27 CYLINDER SURFACE	
28 CYLINDER SURFACE slot milling	

CONTOUR GEOMETRY (Cycle 14)

All subprograms that are superimposed to define the contour are listed in Cycle 14 CONTOUR GEOMETRY.



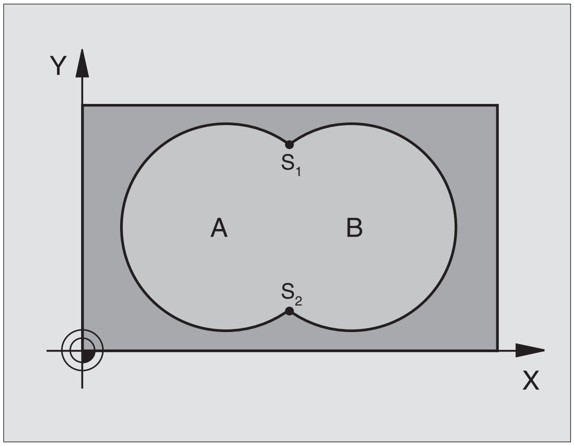
Before programming, note the following:

Cycle 14 is DEF active, which means that it becomes effective as soon as it is defined in the part program.

You can list up to 12 subprograms (subcontours) in Cycle 14.

14
LBL 1...N

▶ **`Label numbers for the contour`**: Enter all label numbers for the individual subprograms that are to be superimposed to define the contour. Confirm every label number with the ENT key. When you have entered all numbers, conclude entry with the END key.



Example: NC blocks

```
12 CYCL DEF 14.0 CONTOUR GEOMETRY
13 CYCL DEF 14.1 CONTOUR LABEL 1/2/3/4
```

Overlapping contours

Pockets and islands can be overlapped to form a new contour. You can thus enlarge the area of a pocket by another pocket or reduce it by an island.

Subprograms: Overlapping pockets

The subsequent programming examples are contour subprograms that are called by Cycle 14 CONTOUR GEOMETRY in a main program.

Pockets A and B overlap.

The TNC calculates the points of intersection S1 and S2 (they do not have to be programmed).

The pockets are programmed as full circles.

Subprogram 1: Pocket A

```
51 LBL 1
52 L X+10 Y+50 RR
53 CC X+35 Y+50
54 C X+10 Y+50 DR-
55 LBL 0
```

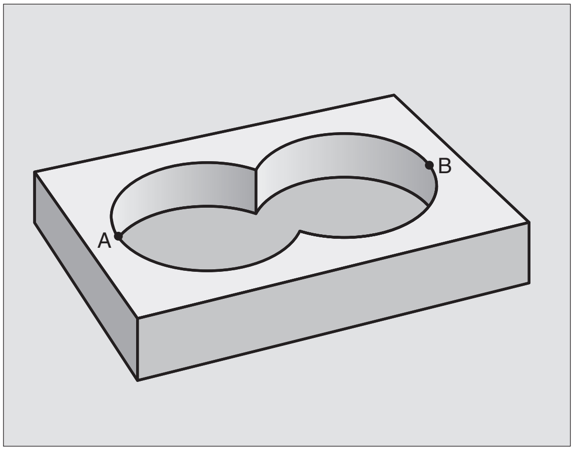
Subprogram 2: Pocket B

```
56 LBL 2
57 L X+90 Y+50 RR
58 CC X+65 Y+50
59 C X+90 Y+50 DR-
60 LBL 0
```

Area of inclusion

Both surfaces A and B are to be machined, including the mutually overlapped area:

- The surfaces A and B must be pockets.
- The first pocket (in Cycle 14) must start outside the second pocket.



Surface A:

```
51 LBL 1
52 L X+10 Y+50 RR
53 CC X+35 Y+50
54 C X+10 Y+50 DR-
55 LBL 0
```

Surface B:

```
56 LBL 2
57 L X+90 Y+50 RR
58 CC X+65 Y+50
59 C X+90 Y+50 DR-
60 LBL 0
```

Area of exclusion

Surface A is to be machined without the portion overlapped by B

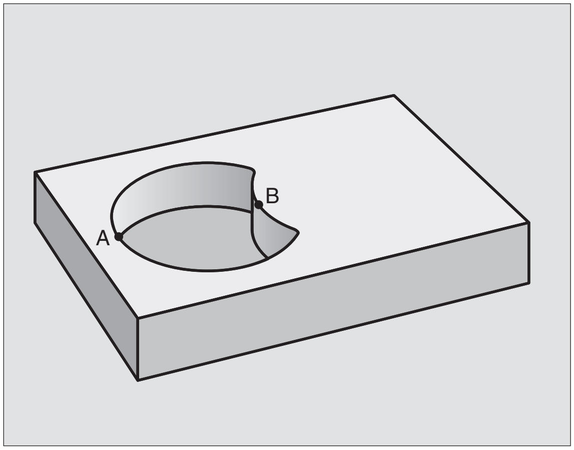
- Surface A must be a pocket and B an island.
- A must start outside of B.

Surface A:

```
51 LBL 1
52 L X+10 Y+50 RR
53 CC X+35 Y+50
54 C X+10 Y+50 DR-
55 LBL 0
```

Surface B:

```
56 LBL 2
57 L X+90 Y+50 RL
58 CC X+65 Y+50
59 C X+90 Y+50 DR-
60 LBL 0
```



Area of intersection

Only the area overlapped by both A and B is to be machined. (The areas covered by A or B alone are to be left unmachined.)

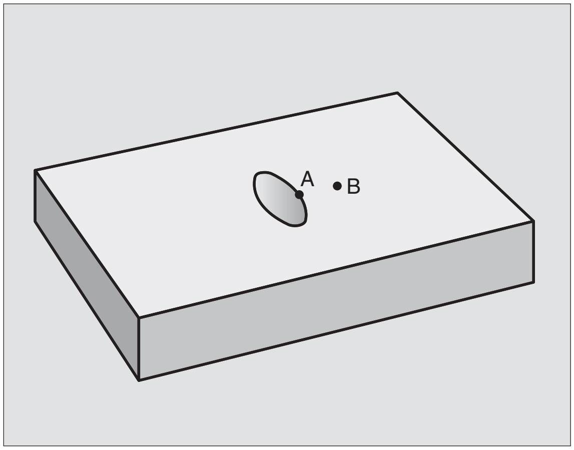
- A and B must be pockets.
- A must start inside of B.

Surface A:

```
51 LBL 1
52 L X+60 Y+50 RR
53 CC X+35 Y+50
54 C X+60 Y+50 DR-
55 LBL 0
```

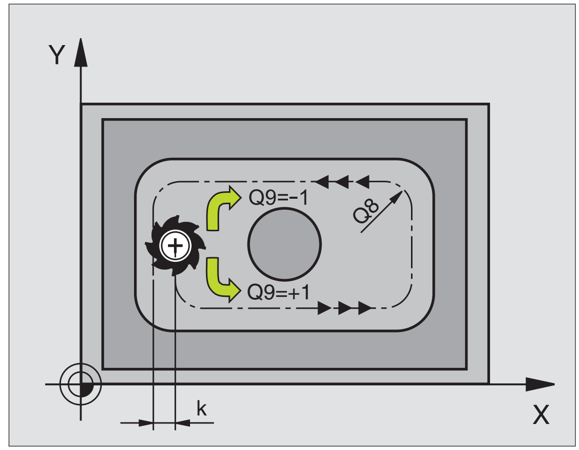
Surface B:

```
56 LBL 2
57 L X+90 Y+50 RR
58 CC X+65 Y+50
59 C X+90 Y+50 DR-
60 LBL 0
```



CONTOUR DATA (Cycle 20)

Machining data for the subprograms describing the subcontours are entered in Cycle 20.



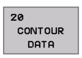
Before programming, note the following:

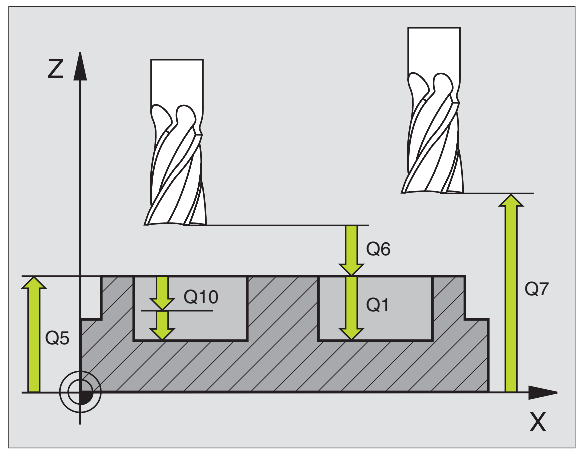
Cycle 20 is DEF active which means that it becomes effective as soon as it is defined in the part program.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program depth = 0, the TNC does not execute that next cycle.

The machining data entered in Cycle 20 are valid for Cycles 21 to 24.

If you are using the SL cycles in Q parameter programs, the cycle parameters Q1 to Q19 cannot be used as program parameters.





- **`Milling depth`** Q1 (incremental value): Distance between workpiece surface and bottom of pocket
- **`Path overlap`** factor Q2: Q2 x tool radius = stepover factor k
- **`Finishing allowance for side`** Q3 (incremental value): Finishing allowance in the working plane
- **`Finishing allowance for floor`** Q4 (incremental value): Finishing allowance in the tool axis
- **`Workpiece surface coordinate`** Q5 (absolute value): Absolute coordinate of the workpiece surface
- **`Set-up clearance`** Q6 (incremental value): Distance between tool tip and workpiece surface
- **`Clearance height`** Q7 (absolute value): Absolute height at which the tool cannot collide with the workpiece (for intermediate positioning and retraction at the end of the cycle)
- **`Inside corner radius`** Q8: Inside "corner" rounding radius; entered value is referenced to the tool midpoint path.
- **`Direction of rotation ? Clockwise = -1`** Q9: Machining direction for pockets
  - Clockwise (Q9 = –1 up-cut milling for pocket and island)
  - Counterclockwise (Q9 = +1 climb milling for pocket and island)

You can check the machining parameters during a program interruption and overwrite them if required.

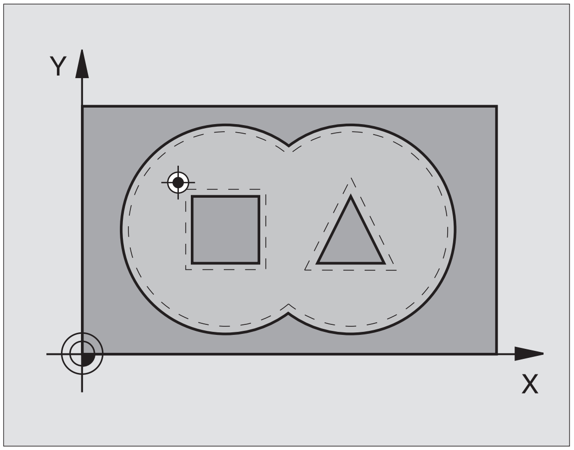
Example: NC blocks

```
57 CYCL DEF 20.0 CONTOUR DATA
     Q1=-20          ;MILLING DEPTH
     Q2=1            ;TOOL PATH OVERLAP
     Q3=+0.2         ;ALLOWANCE FOR SIDE
     Q4=+0.1         ;ALLOWANCE FOR FLOOR
     Q5=+30          ;SURFACE COORDINATE
     Q6=2            ;SAFETY CLEARANCE
     Q7=+80          ;CLEARANCE HEIGHT
     Q8=0.5          ;ROUNDING RADIUS
     Q9=+1           ;DIRECTION OF ROTATION
```

REAMING (Cycle 21)

When calculating the infeed points, the TNC does not account for the delta value DR programmed in a TOOL CALL block.

In narrow areas, the TNC may not be able to carry out pilot drilling with a tool that is larger than the rough-out tool.

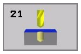


Process

Same as Cycle 1, Pecking; see "Cycles for Drilling, Tapping and Thread Milling," page 215.

Application

Cycle 21 is for PILOT DRILLING of the cutter infeed points. It accounts for the allowance for side and the allowance for floor as well as the radius of the rough-out tool. The cutter infeed points also serve as starting points for roughing.



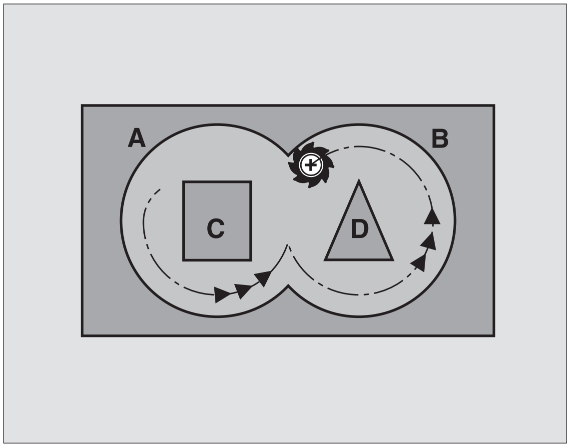
- **`Plunging depth`** Q10 (incremental value): Dimension by which the tool drills in each infeed (negative sign for negative working direction)
- **`Feed rate for plunging`** Q11: Traversing speed in mm/min during drilling
- **`Rough-out tool number`** Q13: Tool number of the roughing mill

Example: NC blocks

```
58 CYCL DEF 21.0 PILOT DRILLING
    Q10=+5          ;INFEED DEPTH
    Q11=100         ;FEED RATE FOR PLUNGING
    Q13=1           ;ROUGH-OUT TOOL
```

ROUGH-OUT (Cycle 22)

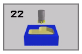
1. The TNC positions the tool over the cutter infeed point, taking the allowance for side into account.
2. In the first plunging depth, the tool mills the contour from inside outward at the milling feed rate Q12.
3. The island contours (here: C/D) are cleared out with an approach toward the pocket contour (here: A/B).
4. Then the TNC rough-mills the pocket contour retracts the tool to the clearance height.



Before programming, note the following:

This cycle requires a center-cut end mill (ISO 1641) or pilot drilling with Cycle 21.

If you define a plunge angle in the ANGLE column of the tool table for the roughing tool, the TNC moves on a helical path to the respective roughing depth (see “Tool table: Standard tool data” on page 104).



- **Plunging depth** Q10 (incremental value): Dimension by which the tool plunges in each infeed
- **Feed rate for plunging** Q11: Traversing speed of the tool in mm/min during penetration
- **Feed rate for milling** Q12: Traversing speed for milling in mm/min
- **Coarse roughing tool number** Q18: Number of the tool with which the TNC has already coarse-roughed the contour. If there was no coarse roughing, enter “0”; if you enter a value other than zero, the TNC will only rough-out the portion that could not be machined with the coarse roughing tool.
  If the portion that is to be roughed cannot be approached from the side, the TNC will mill in a reciprocating plunge-cut; For this purpose you must enter the tool length LCUTS in the tool table TOOL.T, see “Tool Data,” page 102 and define the maximum plunging ANGLE of the tool. The TNC will otherwise generate an error message.
- **Reciprocation feed rate** Q19: Traversing speed of the tool in mm/min during reciprocating plunge-cut

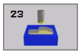
Example: NC blocks

```
59 CYCL DEF 22.0 ROUGH-OUT
    Q10=+5          ;INFEED DEPTH
    Q11=100         ;FEED RATE FOR PLUNGING
    Q12=350         ;FEED RATE FOR MILLING
    Q18=1           ;COARSE ROUGHING TOOL
    Q19=150         ;RECIPROCATION FEED RATE
```

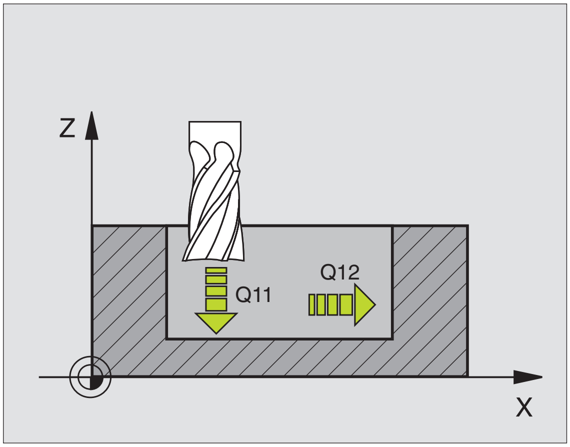
FLOOR FINISHING (Cycle 23)

The TNC automatically calculates the starting point for finishing. The starting point depends on the available space in the pocket.

The tool approaches the machining plane smoothly (in a vertically tangential arc). The tool then clears the finishing allowance remaining from rough-out.



- **Feed rate for plunging** Q11: Traversing speed of the tool during penetration
- **Feed rate for milling** Q12: Traversing speed for milling



Example: NC blocks

```
60 CYCL DEF 23.0 FLOOR FINISHING
   Q11=100      ;FEED RATE FOR PLUNGING
   Q12=350      ;FEED RATE FOR MILLING
```

SIDE FINISHING (Cycle 24)

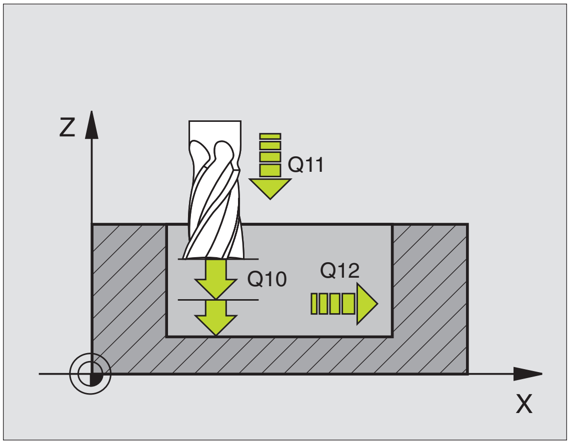
The subcontours are approached and departed on a tangential arc. Each subcontour is finish-milled separately.

Before programming, note the following:

The sum of allowance for side (Q14) and the radius of the finish mill must be smaller than the sum of allowance for side (Q3, Cycle 20) and the radius of the rough mill.

This calculation also holds if you run Cycle 24 without having roughed out with Cycle 22; in this case, enter "0" for the radius of the rough mill.

The TNC automatically calculates the starting point for finishing. The starting point depends on the available space in the pocket.



- **Direction of rotation ? Clockwise = -1** Q9: Machining direction:
  +1:Counterclockwise
  -1:Clockwise
- **Plunging depth** Q10 (incremental value): Dimension by which the tool plunges in each infeed
- **Feed rate for plunging** Q11: Traversing speed of the tool during penetration
- **Feed rate for milling** Q12: Traversing speed for milling
- **Finishing allowance for side** Q14 (incremental value): Enter the allowed material for several finish-milling operations. If you enter Q14 = 0, the remaining finishing allowance will be cleared.

Example: NC blocks

```
61 CYCL DEF 24.0 SIDE FINISHING
    Q9=+1        ;DIRECTION OF ROTATION
    Q10=+5       ;INFEED DEPTH
    Q11=100      ;FEED RATE FOR PLUNGING
    Q12=350      ;FEED RATE FOR MILLING
    Q14=+0       ;ALLOWANCE FOR SIDE
```

CONTOUR TRAIN (Cycle 25)

In conjunction with Cycle 14 CONTOUR GEOMETRY, this cycle facilitates the machining of open contours (i.e. where the starting point of the contour is not the same as its end point).

Cycle 25 CONTOUR TRAIN offers considerable advantages over machining an open contour using positioning blocks:

- The TNC monitors the operation to prevent undercuts and surface blemishes. It is recommended that you run a graphic simulation of the contour before execution.
- If the radius of the selected tool is too large, the corners of the contour may have to be reworked.
- The contour can be machined throughout by up-cut or by climb milling. The type of milling even remains effective when the contours are mirrored.
- The tool can traverse back and forth for milling in several infeeds: This results in faster machining.
- Allowance values can be entered in order to perform repeated rough-milling and finish-milling operations.

Before programming, note the following:

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

The TNC takes only the first label of Cycle 14 CONTOUR GEOMETRY into account.

The memory capacity for programming an SL cycle is limited. For example, you can program up to 1024 straight-line blocks in one SL cycle.

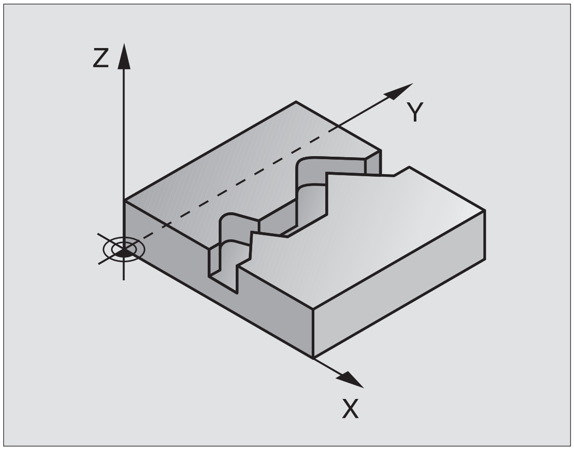
Cycle 20 CONTOUR DATA is not required.

Positions that are programmed in incremental dimensions immediately after Cycle 25 are referenced to the position of the tool at the end of the cycle.

Danger of collision!

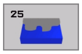
To avoid collisions,

- Do not program positions in incremental dimensions immediately after Cycle **125** since they are referenced to the position of the tool at the end of the cycle.
- Move the tool to defined (absolute) positions in all main axes, since the position of the tool at the end of the cycle is not identical to the position of the tool at the start of the cycle.



Example: NC blocks

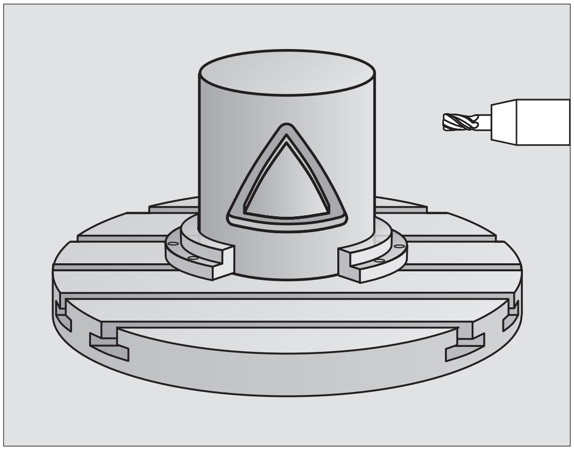
```
62 CYCL DEF 25.0 CONTOUR TRAIN
    Q1=-20          ;MILLING DEPTH
    Q3=+0           ;ALLOWANCE FOR SIDE
    Q5=+0           ;SURFACE COORDINATE
    Q7=+50          ;CLEARANCE HEIGHT
    Q10=+5          ;INFEED DEPTH
    Q11=100         ;FEED RATE FOR PLUNGING
    Q12=350         ;FEED RATE FOR MILLING
    Q15=-1          ;CLIMB OR UP-CUT
```



- **Milling depth** Q1 (incremental value): Distance between workpiece surface and contour floor
- **Finishing allowance for side** Q3 (incremental value): Finishing allowance in the working plane
- **Workpiece surface coordinate** Q5 (absolute value): Absolute coordinate of the workpiece surface referenced to the workpiece datum
- **Clearance height** Q7 (absolute value): Absolute height at which the tool cannot collide with the workpiece. Position for tool retraction at the end of the cycle.
- **Plunging depth** Q10 (incremental value): Dimension by which the tool plunges in each infeed
- **Feed rate for plunging** Q11: Traversing speed of the tool in the tool axis
- **Feed rate for milling** Q12: Traversing speed of the tool in the working plane
- **Climb or up-cut ? Up-cut = –1** Q15:
  Climb milling: Input value = +1
  Up-cut milling: Input value = –1
  To enable climb milling and up-cut milling alternately in several infeeds:Input value = 0

CYLINDER SURFACE (Cycle 27)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

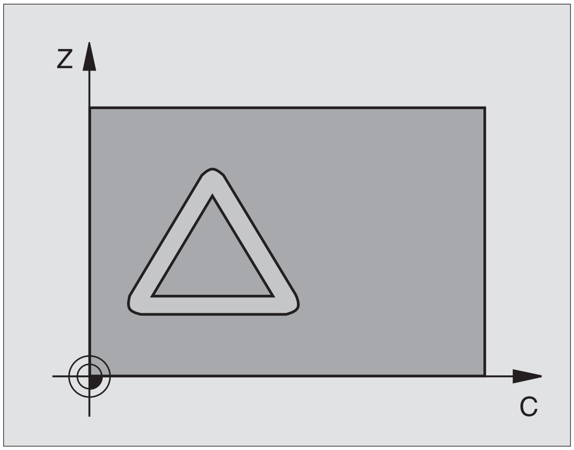


This cycle enables you to program a contour in two dimensions and then roll it onto a cylindrical surface for 3-D machining. Use Cycle 28 if you wish to mill guide notches onto the cylinder surface.

The contour is described in a subprogram identified in Cycle 14 CONTOUR GEOMETRY.

The subprogram contains coordinates in a rotary axis and in its parallel axis. The rotary axis C, for example, is parallel to the Z axis. The path functions L, CHF, CR, RND APPR (except APPR LCT) and DEP are available.

The dimensions in the rotary axis can be entered as desired either in degrees or in mm (or inches). You can select the desired dimension type in the cycle definition.



1 The TNC positions the tool over the cutter infeed point, taking the allowance for side into account.

2 At the first plunging depth, the tool mills along the programmed contour at the milling feed rate Q12.

3 At the end of the contour, the TNC returns the tool to the setup clearance and returns to the point of penetration;

4 Steps 1 to 3 are repeated until the programmed milling depth Q1 is reached.

5 Then the tool moves to the setup clearance.

Before programming, note the following:

The memory capacity for programming an SL cycle is limited. For example, you can program up to 1024 straight-line blocks in one SL cycle.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

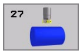
This cycle requires a center-cut end mill (ISO 1641).

The cylinder must be set up centered on the rotary table.

The tool axis must be perpendicular to the rotary table. If this is not the case, the TNC will generate an error message.

This cycle can also be used in a tilted working plane.

The TNC checks whether the compensated and non-compensated tool paths lie within the display range of the rotary axis, which is defined in Machine Parameter 810.x. If the error message “Contour programming error” is output, set MP 810.x = 0.



- **Milling depth** Q1 (incremental value): Distance between the cylindrical surface and the floor of the contour
- **Finishing allowance for side** Q3 (incremental value): Finishing allowance in the plane of the unrolled cylindrical surface. This allowance is effective in the direction of the radius compensation
- **Set-up clearance** Q6 (incremental value): Distance between the tool tip and the cylinder surface
- **Plunging depth** Q10 (incremental value): Dimension by which the tool plunges in each infeed
- **Feed rate for plunging** Q11: Traversing speed of the tool in the tool axis
- **Feed rate for milling** Q12: Traversing speed of the tool in the working plane
- **Cylinder radius** Q16: Radius of the cylinder on which the contour is to be machined
- **Dimension type ? ang./lin.** Q17: The dimensions for the rotary axis of the subprogram are given either in degrees (0) or in mm/inches (1)

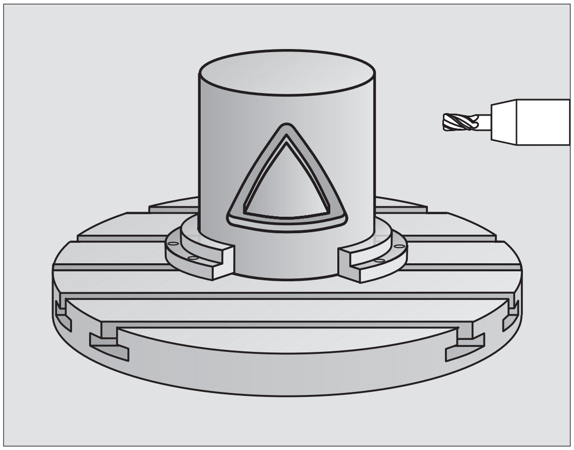
Example: NC blocks

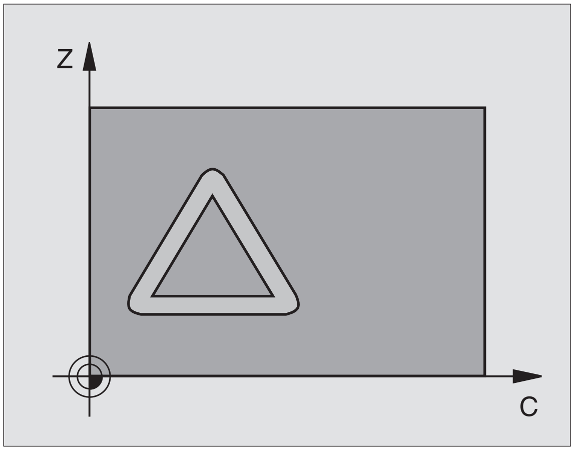
```
63 CYCL DEF 27.0 CYLINDER SURFACE
   Q1=-8        ;MILLING DEPTH
   Q3=+0        ;ALLOWANCE FOR SIDE
   Q6=+0        ;SAFETY CLEARANCE
   Q10=+3       ;INFEED DEPTH
   Q11=100      ;FEED RATE FOR PLUNGING
   Q12=350      ;FEED RATE FOR MILLING
   Q16=25       ;RADIUS
   Q17=0        ;DIMENSION TYPE
```

CYLINDER SURFACE slot milling (Cycle 28)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

This cycle enables you to program a guide notch in two dimensions and then transfer it onto a cylindrical surface. Unlike Cycle 27, with this cycle the TNC adjusts the tool so that, with radius compensation active, the walls of the slot are always parallel. Program the midpoint path of the contour together with the tool radius compensation. With the radius compensation you specify whether the TNC cuts the slot with climb milling or up-cut milling.





1. The TNC positions the tool over the cutter infeed point.
2. At the first plunging depth, the tool mills along the programmed slot wall at the milling feed rate Q12 while respecting the finishing allowance for the side.
3. At the end of the contour, the TNC moves the tool to the opposite wall and returns to the infeed point.
4. Steps 2 and 3 are repeated until the programmed milling depth Q1 is reached.
5. Then the tool moves to the setup clearance.

Before programming, note the following:

The memory capacity for programming an SL cycle is limited. For example, you can program up to 1024 straight-line blocks in one SL cycle.

The algebraic sign for the cycle parameter DEPTH determines the working direction. If you program DEPTH = 0, the cycle will not be executed.

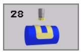
This cycle requires a center-cut end mill (ISO 1641).

The cylinder must be set up centered on the rotary table.

The tool axis must be perpendicular to the rotary table. If this is not the case, the TNC will generate an error message.

This cycle can also be used in a tilted working plane.

The TNC checks whether the compensated and non-compensated tool paths lie within the display range of the rotary axis, which is defined in Machine Parameter 810.x. If the error message “Contour programming error” is output, set MP 810.x = 0.

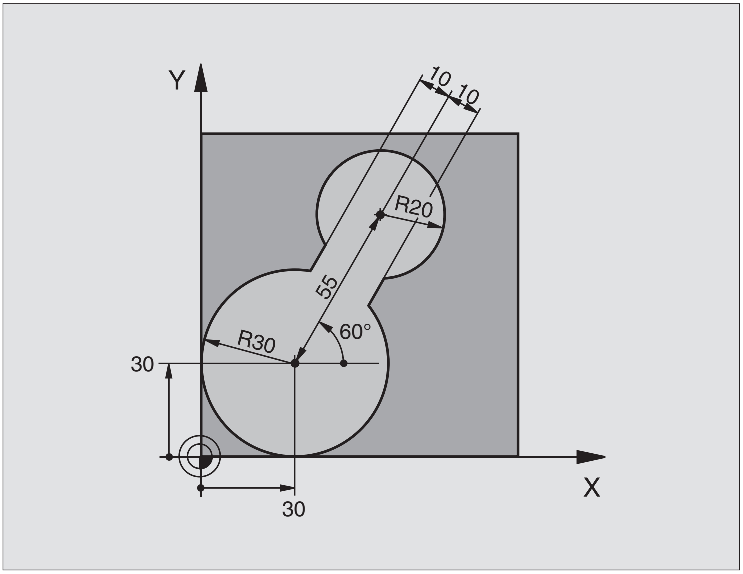


- **Milling depth** Q1 (incremental value): Distance between the cylindrical surface and the floor of the contour
- **Finishing allowance for side** Q3 (incremental value): Finishing allowance on the slot wall. The finishing allowance reduces the slot width by twice the entered value.
- **Set-up clearance** Q6 (incremental value): Distance between the tool tip and the cylinder surface
- **Plunging depth** Q10 (incremental value): Dimension by which the tool plunges in each infeed
- **Feed rate for plunging** Q11: Traversing speed of the tool in the tool axis
- **Feed rate for milling** Q12: Traversing speed of the tool in the working plane
- **Cylinder radius** Q16: Radius of the cylinder on which the contour is to be machined
- **Dimension type ? ang./lin.** Q17: The dimensions for the rotary axis of the subprogram are given either in degrees (0) or in mm/inches (1)
- **Slot width** Q20: Width of the slot to be machined

Example: NC blocks

```
63 CYCL DEF 28.0 CYLINDER SURFACE
     Q1=-8           ;MILLING DEPTH
     Q3=+0           ;ALLOWANCE FOR SIDE
     Q6=+0           ;SAFETY CLEARANCE
     Q10=+3          ;INFEED DEPTH
     Q11=100         ;FEED RATE FOR PLUNGING
     Q12=350         ;FEED RATE FOR MILLING
     Q16=25          ;RADIUS
     Q17=0           ;DIMENSION TYPE
     Q20=12          ;SLOT WIDTH
```

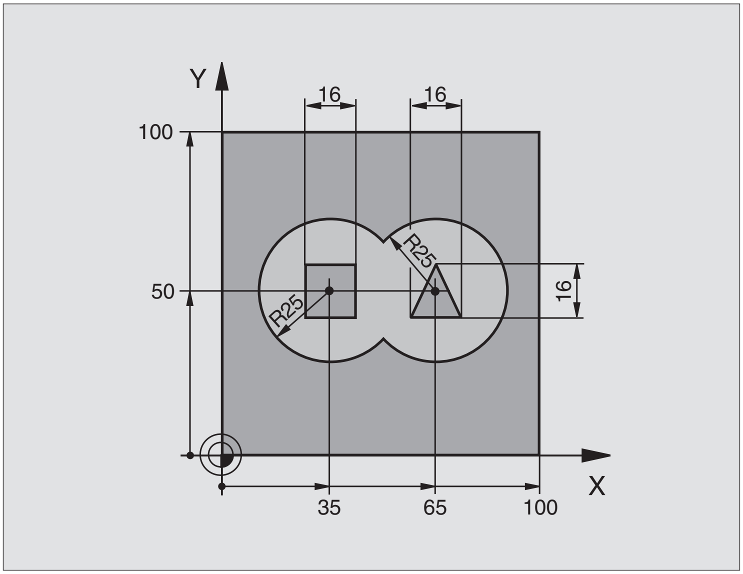
Example: Roughing-out and fine-roughing a pocket



0 BEGIN PGM C20 MM	
1 BLK FORM 0.1 Z X-10 Y-10 Z-40	
2 BLK FORM 0.2 X+100 Y+100 Z+0	Define the workpiece blank
3 TOOL DEF 1 L+0 R+15	Tool definition: coarse roughing tool
4 TOOL DEF 2 L+0 R+7.5	Tool definition: fine roughing tool
5 TOOL CALL 1 Z S2500	Tool call: coarse roughing tool
6 L Z+250 R0 FMAX	Retract the tool
7 CYCL DEF 14.0 CONTOUR GEOMETRY	Define contour subprogram
8 CYCL DEF 14.1 CONTOUR LABEL 1	
9 CYCL DEF 20.0 CONTOUR DATA	Define general machining parameters
Q1=-20 ;MILLING DEPTH	
Q2=1 ;TOOL PATH OVERLAP	
Q3=+0 ;ALLOWANCE FOR SIDE	
Q4=+0 ;ALLOWANCE FOR FLOOR	
Q5=+0 ;SURFACE COORDINATE	
Q6=2 ;SAFETY CLEARANCE	
Q7=+100 ;CLEARANCE HEIGHT	
Q8=0.1 ;ROUNDING RADIUS	
Q9=-1 ;DIRECTION OF ROTATION	

10 CYCL DEF 22.0 ROUGH-OUT	Cycle definition: Coarse roughing
Q10=5 ;INFEED DEPTH	
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=350 ;FEED RATE FOR MILLING	
Q18=0 ;COARSE ROUGHING TOOL	
Q19=150 ;RECIPROCATION FEED RATE	
11 CYCL CALL M3	Cycle call: Coarse roughing
12 L Z+250 R0 FMAX M6	Tool change
13 TOOL CALL 2 Z S3000	Tool call: fine roughing tool
14 CYCL DEF 22.0 ROUGH-OUT	Define the fine roughing cycle
Q10=5 ;INFEED DEPTH	
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=350 ;FEED RATE FOR MILLING	
Q18=1 ;COARSE ROUGHING TOOL	
Q19=150 ;RECIPROCATION FEED RATE	
15 CYCL CALL M3	Cycle call: Fine roughing
16 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
17 LBL 1	Contour subprogram
18 L X+0 Y+30 RR	see “Example: FK programming 2,” page 175
19 FC DR- R30 CCX+30 CCY+30	
20 FL AN+60 PDX+30 PDY+30 D10	
21 FSELECT 3	
22 FPOL X+30 Y+30	
23 FC DR- R20 CCPR+55 CCPA+60	
24 FSELECT 2	
25 FL AN-120 PDX+30 PDY+30 D10	
26 FSELECT 3	
27 FC X+0 DR- R30 CCX+30 CCY+30	
28 FSELECT 2	
29 LBL 0	
30 END PGM C20 MM	

Example: Pilot drilling, roughing-out and finishing overlapping contours

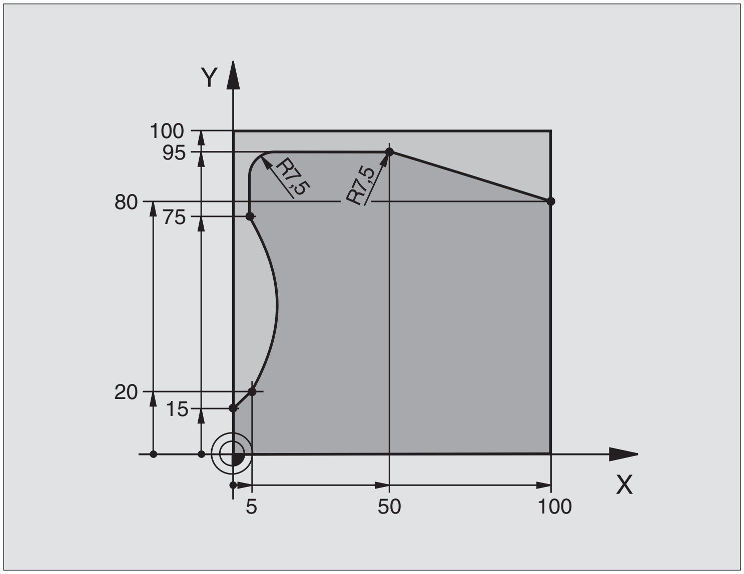


0 BEGIN PGM C21 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-40	Define the workpiece blank
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+6	Define tool: drill
4 TOOL DEF 2 L+0 R+6	Define the tool for roughing/finishing
5 TOOL CALL 1 Z S2500	Call the drilling tool
6 L Z+250 R0 FMAX	Retract the tool
7 CYCL DEF 14.0 CONTOUR GEOMETRY	Define contour subprogram
8 CYCL DEF 14.1 CONTOUR LABEL 1/2/3/4	
9 CYCL DEF 20.0 CONTOUR DATA	Define general machining parameters
Q1=-20 ;MILLING DEPTH	
Q2=1 ;TOOL PATH OVERLAP	
Q3=+0.5 ;ALLOWANCE FOR SIDE	
Q4=+0.5 ;ALLOWANCE FOR FLOOR	
Q5=+0 ;SURFACE COORDINATE	
Q6=2 ;SAFETY CLEARANCE	
Q7=+100 ;CLEARANCE HEIGHT	
Q8=0.1 ;ROUNDING RADIUS	
Q9=-1 ;DIRECTION OF ROTATION	

10 CYCL DEF 21.0 PILOT DRILLING	Cycle definition: Pilot drilling
Q10=5 ;INFEED DEPTH	
Q11=250 ;FEED RATE FOR PLUNGING	
Q13=2 ;ROUGH-OUT TOOL	
11 CYCL CALL M3	Cycle call: Pilot drilling
12 L T+250 R0 FMAX M6	Tool change
13 TOOL CALL 2 Z S3000	Call the tool for roughing/finishing
14 CYCL DEF 22.0 ROUGH-OUT	Cycle definition: Rough-out
Q10=5 ;INFEED DEPTH	
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=350 ;FEED RATE FOR MILLING	
Q18=0 ;COARSE ROUGHING TOOL	
Q19=150 ;RECIPROCATION FEED RATE	
15 CYCL CALL M3	Cycle call: Rough-out
16 CYCL DEF 23.0 FLOOR FINISHING	Cycle definition: Floor finishing
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=200 ;FEED RATE FOR MILLING	
17 CYCL CALL	Cycle call: Floor finishing
18 CYCL DEF 24.0 SIDE FINISHING	Cycle definition: Side finishing
Q9=+1 ;DIRECTION OF ROTATION	
Q10=5 ;INFEED DEPTH	
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=400 ;FEED RATE FOR MILLING	
Q14=+0 ;ALLOWANCE FOR SIDE	
19 CYCL CALL	Cycle call: Side finishing
20 L Z+250 R0 FMAX M2	Retract in the tool axis, end program

21 LBL 1	Contour subprogram 1: left pocket
22 CC X+35 Y+50	
23 L X+10 Y+50 RR	
24 C X+10 DR-	
25 LBL 0	
26 LBL 2	Contour subprogram 2: right pocket
27 CC X+65 Y+50	
28 L X+90 Y+50 RR	
29 C X+90 DR-	
30 LBL 0	
31 LBL 3	Contour subprogram 3: square left island
32 L X+27 Y+50 RL	
33 L Y+58	
34 L X+43	
35 L Y+42	
36 L X+27	
37 LBL 0	
38 LBL 4	Contour subprogram 4: triangular right island
39 L X+65 Y+42 RL	
40 L X+57	
41 L X+65 Y+58	
42 L X+73 Y+42	
43 LBL 0	
44 END PGM C21 MM	

Example: Contour train



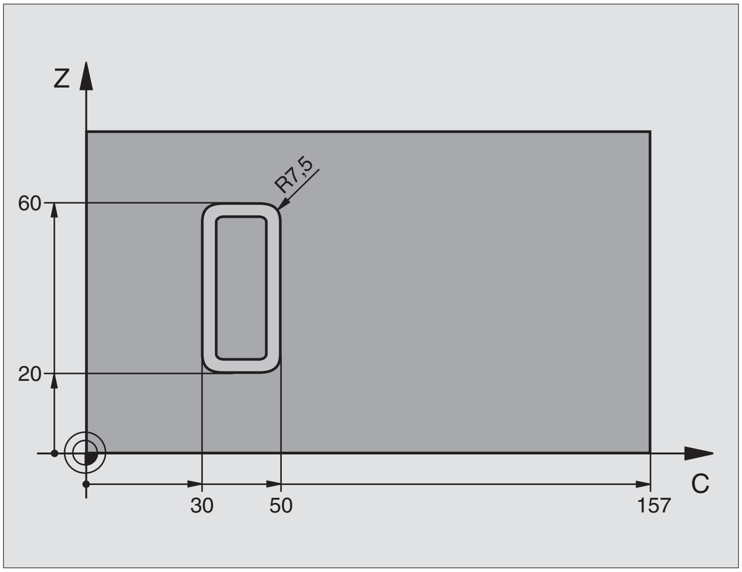
`0 BEGIN PGM C25 MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-40`	Define the workpiece blank
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	
`3 TOOL DEF 1 L+0 R+10`	Define the tool
`4 TOOL CALL 1 Z S2000`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 CYCL DEF 14.0 CONTOUR GEOMETRY`	Define contour subprogram
`7 CYCL DEF 14.1 CONTOUR LABEL 1`	
`8 CYCL DEF 25.0 CONTOUR TRAIN`	Define machining parameters
`Q1=-20 ;MILLING DEPTH`	
`Q3=+0 ;ALLOWANCE FOR SIDE`	
`Q5=+0 ;SURFACE COORDINATE`	
`Q7=+250 ;CLEARANCE HEIGHT`	
`Q10=5 ;INFEED DEPTH`	
`Q11=100 ;FEED RATE FOR PLUNGING`	
`Q12=200 ;FEEED RATE FOR MILLING`	
`Q15=+1 ;CLIMB OR UP-CUT`	
`9 CYCL CALL M3`	Call the cycle
`10 L Z+250 R0 FMAX M2`	Retract in the tool axis, end program

`11 LBL 1`	Contour subprogram
`12 L X+0 Y+15 RL`	
`13 L X+5 Y+20`	
`14 CT X+5 Y+75`	
`15 L Y+95`	
`16 RND R7.5`	
`17 L X+50`	
`18 RND R7.5`	
`19 L X+100 Y+80`	
`20 LBL 0`	
`21 END PGM C25 MM`	

Example: Cylinder surface with Cycle 27

Note:

- Cylinder centered on rotary table
- Datum at center of rotary table



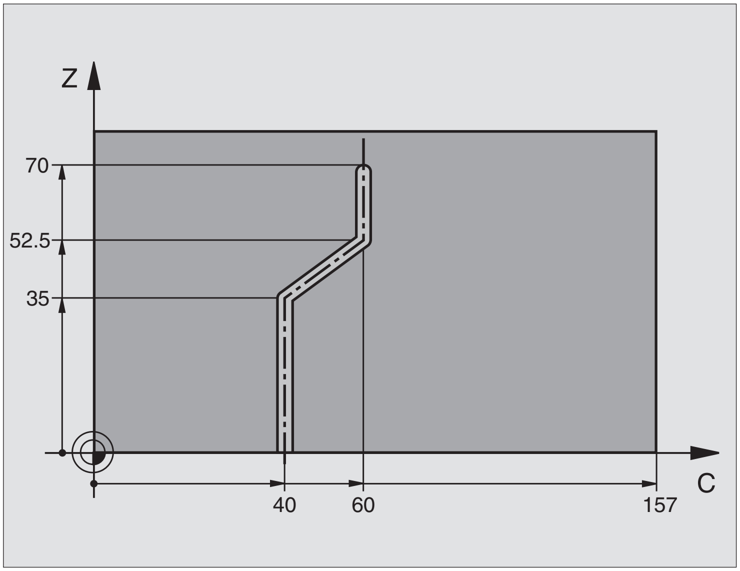
0 BEGIN PGM C27 MM	
1 TOOL DEF 1 L+0 R+3.5	Define the tool
2 TOOL CALL 1 Y S2000	Call tool, tool axis is Y
3 L X+250 R0 FMAX	Retract the tool
4 L X+0 R0 FMAX	Position tool on rotary table center
5 CYCL DEF 14.0 CONTOUR GEOMETRY	Define contour subprogram
6 CYCL DEF 14.1 CONTOUR LABEL 1	
7 CYCL DEF 27.0 CYLINDER SURFACE	Define machining parameters
Q1=-7 ;MILLING DEPTH	
Q3=+0 ;ALLOWANCE FOR SIDE	
Q6=2 ;SAFETY CLEARANCE	
Q10=4 ;INFEED DEPTH	
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=250 ;FEEED RATE FOR MILLING	
Q16=25 ;RADIUS	
Q17=1 ;DIMENSION TYPE	
8 L C+0 R0 FMAX M3	Pre-position rotary table
9 CYCL CALL	Call the cycle
10 L Y+250 R0 FMAX M2	Retract in the tool axis, end program

`11 LBL 1`	Contour subprogram
`12 L C+40 Z+20 RL`	Data for the rotary axis are entered in mm (Q17=1)
`13 L C+50`	
`14 RND R7.5`	
`15 L Z+60`	
`16 RND R7.5`	
`17 L IC-20`	
`18 RND R7.5`	
`19 L Z+20`	
`20 RND R7.5`	
`21 L C+40`	
`22 LBL 0`	
`23 END PGM C27 MM`	

Example: Cylinder surface with Cycle 28

Notes:

- Cylinder centered on rotary table
- Datum at center of rotary table
- Description of the midpoint path in the contour subprogram



`0 BEGIN PGM C28 MM`	
`1 TOOL DEF 1 L+0 R+3.5`	Define the tool
`2 TOOL CALL 1 Y S2000`	Call tool, tool axis is Y
`3 L Y+250 R0 FMAX`	Retract the tool
`4 L X+0 R0 FMAX`	Position tool on rotary table center
`5 CYCL DEF 14.0 CONTOUR GEOMETRY`	Define contour subprogram
`6 CYCL DEF 14.1 CONTOUR LABEL 1`	
`7 CYCL DEF 28.0 CYLINDER SURFACE`	Define machining parameters
`Q1=-7 ;MILLING DEPTH`	
`Q3=+0 ;ALLOWANCE FOR SIDE`	
`Q6=2 ;SAFETY CLEARANCE`	
`Q10=-4 ;INFEED DEPTH`	
`Q11=100 ;FEED RATE FOR PLUNGING`	
`Q12=250 ;FEEED RATE FOR MILLING`	
`Q16=25 ;RADIUS`	
`Q17=1 ;DIMENSION TYPE`	
`Q20=10 ;SLOT WIDTH`	
`8 L C+0 R0 FMAX M3`	Pre-position rotary table
`9 CYCL CALL`	Call the cycle
`10 L Y+250 R0 FMAX M2`	Retract in the tool axis, end program

`11 LBL 1`	Contour subprogram, description of the midpoint path
`12 L C+40 Z+0 RL`	Data for the rotary axis are entered in mm (Q17=1)
`13 L Z+35`	
`14 L C+60 Z+52.5`	
`15 L Z+70`	
`16 LBL 0`	
`17 END PGM C28 MM`	

8.7 SL Cycles with Contour Formula

Fundamentals

SL cycles and the contour formula enable you to form complex contours by combining subcontours (pockets or islands). You define the individual subcontours (geometry data) as separate programs. In this way, any subcontour can be used any number of times. The TNC calculates the complete contour from the selected subcontours, which you link together through a contour formula.

> The memory capacity for programming an SL cycle (all contour description programs) is limited to 32 contours. The number of possible contour elements depends on the type of contour (inside or outside contour) and the number of contour descriptions. For example, you can program up to approx. 1024 line blocks.
>
> The SL cycles with contour formula presuppose a structured program layout and enable you to save frequently used contours in individual programs. Using the contour formula, you can connect the subcontours to a complete contour and define whether it applies to a pocket or island.
>
> In its present form, the "SL cycles with contour formula" function requires input from several areas in the TNC's user interface. This form is to serve as a basis for further development.

Properties of the subcontours

- By default, the TNC assumes that the contour is a pocket. Do not program a radius compensation. In the contour formula you can convert a pocket to an island by making it negative.
- The TNC ignores feed rates F and miscellaneous functions M.
- Coordinate transformations are allowed. If they are programmed within the subcontour they are also effective in the following subprograms, but they need not be reset after the cycle call.
- Although the subprograms can contain coordinates in the spindle axis, such coordinates are ignored.
- The working plane is defined in the first coordinate block of the subprogram. The secondary axes U,V,W are permitted.

Characteristics of the fixed cycles

- The TNC automatically positions the tool to set-up clearance before a cycle.
- Each level of infeed depth is milled without interruptions since the cutter traverses around islands instead of over them.
- The radius of “inside corners” can be programmed—the tool keeps moving to prevent surface blemishes at inside corners (this applies for the outermost pass in the Rough-out and Side-Finishing cycles).
- The contour is approached in a tangential arc for side finishing.

Example: Program structure: Machining with SL cycles and contour formula

```
0 BEGIN PGM CONTOUR MM
...
5 SEL CONTOUR "MODEL"
6 CYCL DEF 20.0 CONTOUR DATA ...
8 CYCL DEF 22.0 ROUGH-OUT...
9 CYCL CALL
...
12 CYCL DEF 23.0 FLOOR FINISHING ...
13 CYCL CALL
...
16 CYCL DEF 24.0 SIDE FINISHING ...
17 CYCL CALL
63 L Z+250 R0 FMAX M2
64 END PGM CONTOUR MM
```

Example: Program structure: Calculation of the subcontours with contour formula

```
0 BEGIN PGM MODEL MM
1 DECLARE CONTOUR QC1 = "CIRCLE1"
2 DECLARE CONTOUR QC2 = "CIRCLE31XY"
3 DECLARE CONTOUR QC1 = "TRIANGLE"
4 DECLARE CONTOUR QC1 = "SQUARE"
5 QC10 = ( QC1 | QC3 | QC4 ) \ QC2
6 END PGM MODEL MM

0 BEGIN PGM CIRCLE1 MM
1 CC X+75 Y+50
2 LP PR+45 PA+0 R0
3 CP IPA+360 DR+
4 END PGM CIRCLE1 MM

0 BEGIN PGM CIRCLE31XY MM
...
...
```

- For floor finishing, the tool again approaches the workpiece in a tangential arc (for tool axis Z, for example, the arc may be in the Z/X plane).
- The contour is machined throughout in either climb or up-cut milling.

> With MP7420 you can determine where the tool is positioned at the end of Cycles 21 to 24.

The machining data (such as milling depth, finishing allowance and setup clearance) are entered as CONTOUR DATA in Cycle 20.

Selecting a program with contour definitions

With the **SEL CONTOUR** function you select a program with contour definitions, from which the TNC takes the contour descriptions:

PGM CALL

- To select the functions for program call, press the PGM CALL key.

SELECT CONTOUR

- press the SELECT KONTUR soft key.
- Enter the full name of the program with the contour definition and confirm with the END key.

> Program a SEL CONTOUR block before the SL cycles. Cycle 14 CONTOUR GEOMETRY is no longer necessary if you use SEL CONTUR.

Defining contour descriptions

With the **DECLARE CONTOUR** function you enter in a program the path for programs from which the TNC draws the contour descriptions:

DECLARE

- Press the DECLARE soft key.

CONTOUR

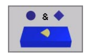
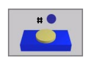
- Press the CONTOUR soft key.
- Enter the number for the contour designator **QC,** and confirm with the ENT key.
- Enter the full name of the program with the contour description and confirm with the END key.

> With the given contour designators QC you can include the various contours in the contour formula.
>
> With the **DECLARE STRING** function you define a text. For the time being, this function is not evaluated.

Entering a contour formula

You can use soft keys to interlink various contours in a mathematical formula.

- Select a Q parameter function: Press the Q key (in the numerical keypad at right). The Q parameter functions are displayed in a soft-key row.
- To select the function for entering the contour formula, press the CONTOUR FORMULA soft key. The TNC then shows the following soft keys:

Logic command	Soft key
Intersection with e.g. **`QC10 = QC1 & QC5`**	
Union with e.g. **`QC25 = QC7 | QC18`**	
Union without intersection e.g. **`QC12 = QC5 ^ QC25`**	
Intersection with complement of e.g. **`QC25 = QC1 \ QC2`**	
Complement of contour area e.g. **`Q12 = #Q11`**	
Opening parenthesis e.g. **`QC12 = QC1 * (QC2 + QC3)`**	(
Closing parenthesis e.g. **`QC12 = QC1 * (QC2 + QC3)`**	)

Overlapping contours

By default, the TNC considers a programmed contour to be a pocket. With the functions of the contour formula, you can convert a contour from a pocket to an island.

Pockets and islands can be overlapped to form a new contour. You can thus enlarge the area of a pocket by another pocket or reduce it by an island.

Subprograms: Overlapping pockets

> The following program examples are contour description programs that are defined in a contour definition program. The contour definition program is called through the **`SEL CONTOUR`** function in the actual main program.

Pockets A and B overlap.

The TNC calculates the points of intersection S1 and S2 (they do not have to be programmed).

The pockets are programmed as full circles.

Contour description program 1: Pocket A

```
0 BEGIN PGM POCKET_A MM
1 L X+10 Y+50 R0
2 CC X+35 Y+50
3 C X+10 Y+50 DR-
4 END PGM POCKET_A MM
```

Contour description program 2: Pocket B

```
0 BEGIN PGM POCKET_B MM
1 L X+90 Y+50 R0
2 CC X+65 Y+50
3 C X+90 Y+50 DR-
4 END PGM POCKET_B MM
```

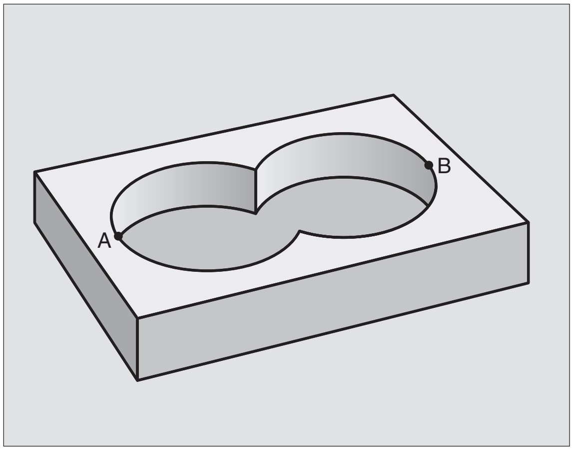
Area of inclusion

Both surfaces A and B are to be machined, including the mutually overlapped area:

- The surfaces A and B must be programmed in separate programs without radius compensation.
- In the contour formula, the surfaces A and B are processed with the "union with" function.

Contour definition program:

```
50 ...
51 ...
52 DECLARE CONTOUR QC1 = "POCKET_A.H"
53 DECLARE CONTOUR QC2 = "POCKET_B.H"
54 QC10 = QC1 | QC2
55 ...
56 ...
```



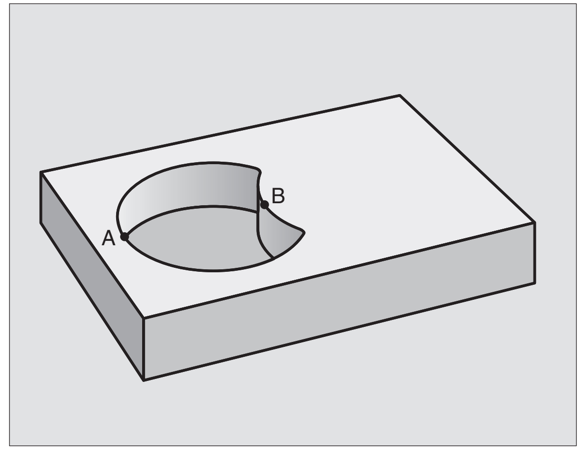
Area of exclusion

Surface A is to be machined without the portion overlapped by B

- The surfaces A and B must be entered in separate programs without radius compensation.
- In the contour formula, the surface B is subtracted from the surface A with the "intersection with complement of" function.

Contour definition program:

```
50 ...
51 ...
52 DECLARE CONTOUR QC1 = "POCKET_A.H"
53 DECLARE CONTOUR QC2 = "POCKET_B.H"
54 QC10 = QC1 \ QC2
55 ...
56 ...
```



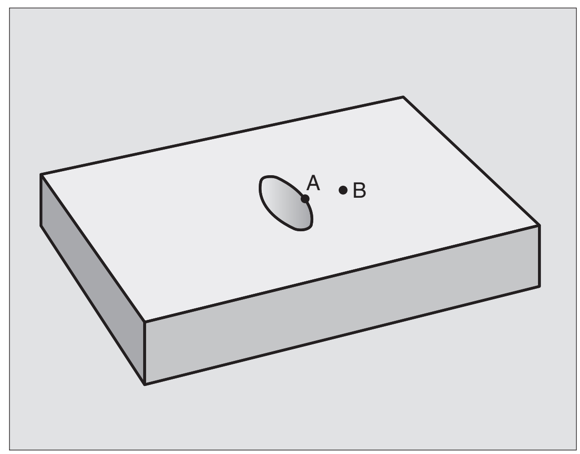
Area of intersection

Only the area overlapped by both A and B is to be machined. (The areas covered by A or B alone are to be left unmachined.)

- The surfaces A and B must be entered in separate programs without radius compensation.
- In the contour formula, the surfaces A and B are processed with the "intersection with" function.

Contour definition program:

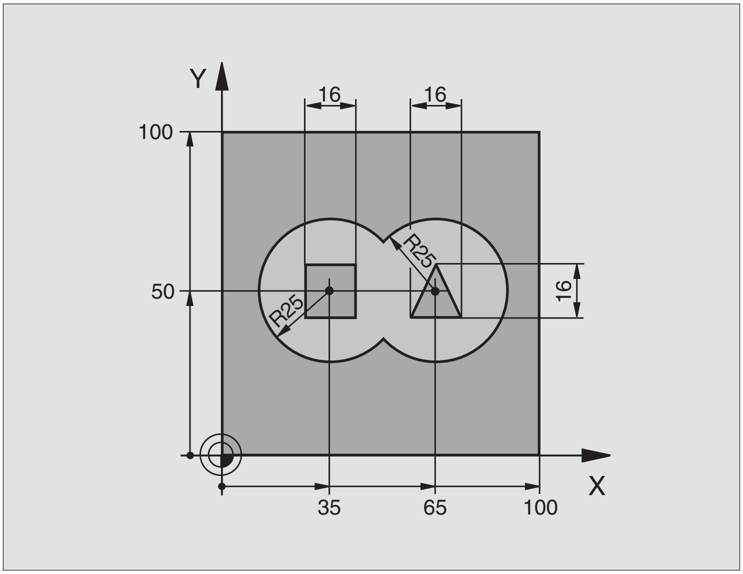
```
50 ...
51 ...
52 DECLARE CONTOUR QC1 = "POCKET_A.H"
53 DECLARE CONTOUR QC2 = "POCKET_B.H"
54 QC10 = QC1 \ QC2
55 ...
56 ...
```



Contour machining with SL cycles

The complete contour is machined with the SL Cycles 20 – 24 (see “SL Cycles” on page 294)

Example: Roughing and finishing superimposed contours with the contour formula



`0 BEGIN PGM CONTOUR MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-40`	Define the workpiece blank
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	
`3 TOOL DEF 1 L+0 R+2.5`	Tool definition of roughing cutter
`4 TOOL DEF 2 L+0 R+3`	Tool definition of finishing cutter
`5 TOOL CALL 1 Z S2500`	Tool call of roughing cutter
`6 L Z+250 R0 FMAX`	Retract the tool
`7 SEL CONTOUR "MODEL"`	Specify contour definition program
`8 CYCL DEF 20.0 CONTOUR DATA`	Define general machining parameters
`Q1=-20 ;MILLING DEPTH`	
`Q2=1 ;TOOL PATH OVERLAP`	
`Q3=+0.5 ;ALLOWANCE FOR SIDE`	
`Q4=+0.5 ;ALLOWANCE FOR FLOOR`	
`Q5=+0 ;SURFACE COORDINATE`	
`Q6=2 ;SAFETY CLEARANCE`	
`Q7=+100 ;CLEARANCE HEIGHT`	
`Q8=0.1 ;ROUNDING RADIUS`	
`Q9=-1 ;DIRECTION OF ROTATION`	
`9 CYCL DEF 22.0 ROUGH-OUT`	Cycle definition: Rough-out
`Q10=5 ;INFEED DEPTH`	

Q11=100 ;FEED RATE FOR PLUNGING	
Q12=350 ;FEED RATE FOR MILLING	
Q18=0 ;COARSE ROUGHING TOOL	
Q19=150 ;RECIPROCATION FEED RATE	
10 CYCL CALL M3	Cycle call: Rough-out
11 TOOL CALL 2 Z S5000	Tool call of finishing cutter
12 CYCL DEF 23.0 FLOOR FINISHING	Cycle definition: Floor finishing
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=200 ;FEED RATE FOR MILLING	
13 CYCL CALL M3	Cycle call: Floor finishing
14 CYCL DEF 24.0 SIDE FINISHING	Cycle definition: Side finishing
Q9=+1 ;DIRECTION OF ROTATION	
Q10=5 ;INFEED DEPTH	
Q11=100 ;FEED RATE FOR PLUNGING	
Q12=400 ;FEED RATE FOR MILLING	
Q14=+0 ;ALLOWANCE FOR SIDE	
15 CYCL CALL M3	Cycle call: Side finishing
16 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
17 END PGM CONTOUR MM	

Contour definition program with contour formula:

0 BEGIN PGM MODEL MM	Contour definition program
1 DECLARE CONTOUR QC1 = "CIRCLE1"	Definition of the contour designator for the program "CIRCLE1"
2 FN 0: Q1 =+35	Assignment of values for parameters used in PGM "CIRCLE31XY"
3 FN 0: Q2 =+50	
4 FN 0: Q3 =+25	
5 DECLARE CONTOUR QC2 = "CIRCLE31XY"	Definition of the contour designator for the program "CIRCLE31XY"
6 DECLARE CONTOUR QC3 = "TRIANGLE"	Definition of the contour designator for the program "TRIANGLE"
7 DECLARE CONTOUR QC4 = "SQUARE"	Definition of the contour designator for the program "SQUARE"
8 QC10 = (QC 1 | QC 2) \ QC 3 \ QC 4	Contour formula
9 END PGM MODEL MM	

Contour description programs:

0 BEGIN PGM CIRCLE1 MM	Contour description program: circle at right
1 CC X+65 Y+50	
2 L PR+25 PA+0 R0	
3 CP IPA+360 DR+	
4 END PGM CIRCLE1 MM	

0 BEGIN PGM CIRCLE31XY MM	Contour description program: circle at left
1 CC X+Q1 Y+Q2	
2 LP PR+Q3 PA+0 R0	
3 CP IPA+360 DR+	
4 END PGM CIRCLE31XY MM	

0 BEGIN PGM TRIANGLE MM	Contour description program: triangle at right
1 L X+73 Y+42 R0	
2 L X+65 Y+58	
3 L X+42 Y+42	
4 L X+73	
5 END PGM TRIANGLE MM	

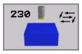
0 BEGIN PGM SQUARE MM	Contour description program: square at left
1 L X+27 Y+58 R0	
2 L X+43	
3 L Y+42	
4 L X+27	
5 L Y+58	
6 END PGM SQUARE MM	

8.8 Cycles for Multipass Milling

Overview

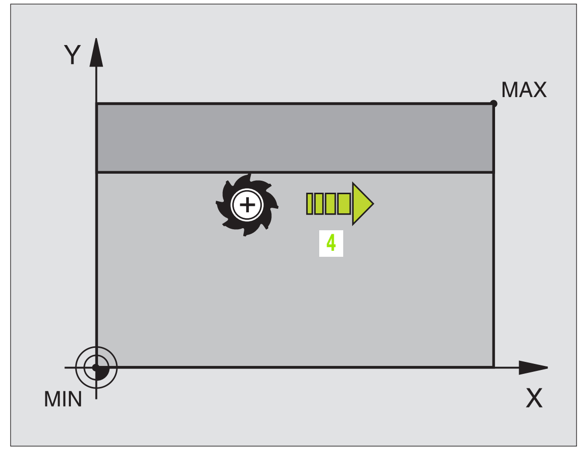
The TNC offers three cycles for machining the following surface types:

- Created with a CAD/CAM system
- Flat, rectangular surfaces
- Flat, oblique-angled surfaces
- Surfaces that are inclined in any way
- Twisted surfaces

Cycle	Soft key
60 RUN 3-D DATA For multipass milling of 3-D data in several infeeds	
230 MULTIPASS MILLING For flat rectangular surfaces	
231 RULED SURFACE For oblique, inclined or twisted surfaces	

RUN 3-D DATA (Cycle 30)

1 From the current position, the TNC positions the tool in rapid traverse FMAX in the tool axis to the set-up clearance above the MAX point that you have programmed in the cycle.
2 The tool then moves in FMAX in the working plane to the MIN point you have programmed in the cycle.
3 From this point, the tool advances to the first contour point at the feed rate for plunging.
4 The TNC subsequently processes all points that are stored in the digitizing data file at the feed rate for milling. If necessary, the TNC retracts the tool between machining operations to set-up clearance if specific areas are to be left unmachined.
5 At the end of the cycle, the tool is retracted in FMAX to set-up clearance.

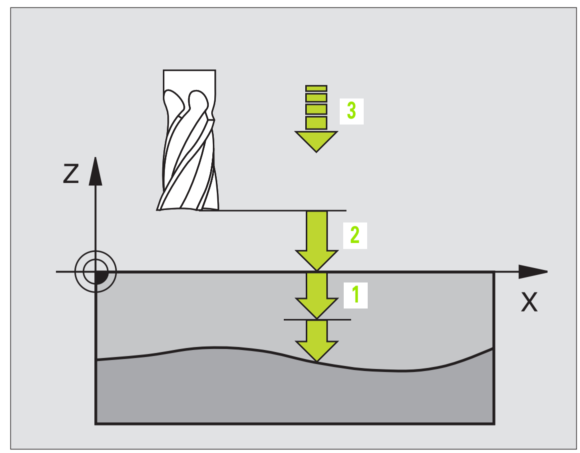


Before programming, note the following:

You can use Cycle 30 to run conversational programs and PNT files.

If you want to run PNT files in which no tool axis coordinate is programmed, the milling depth is derived from the programmed MIN point in the tool axis.

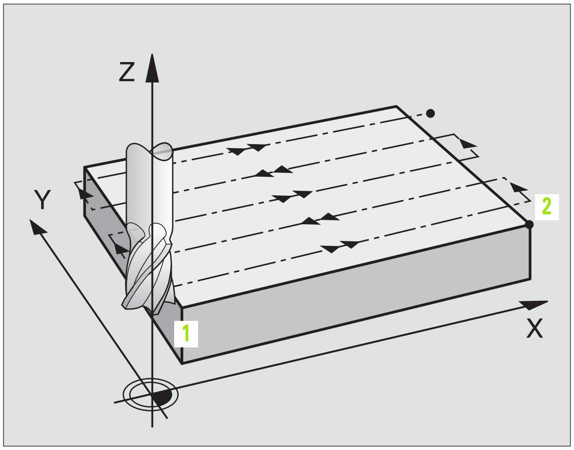
- **PGM Name 3-D data**: Enter the name of the file in which the data is stored. If the file is not stored in the current directory, enter the complete path.
- **Min. point of range**: Lowest coordinates (X, Y and Z coordinates) in the range to be milled
- **Max. point of range**: Highest coordinates (X, Y and Z coordinates) in the range to be milled
- **Set-up clearance** 1 (incremental value): Distance between tool tip and workpiece surface for tool movements in rapid traverse
- **Plunging depth** 2 (incremental value): Infeed per cut
- **Feed rate for plunging** 3: Traversing speed of the tool in mm/min during penetration
- **Feed rate for milling** 4: Traversing speed of the tool in mm/min while milling.
- **Miscellaneous function M**: Optional entry of a miscellaneous function, for example M13



Example: NC blocks

```
64 CYCL DEF 30.0 RUN 3-D DATA
65 CYCL DEF 30.1 PGM DIGIT.: BSP.H
66 CYCL DEF 30.2 X+0 Y+0 Z-20
67 CYCL DEF 30.3 X+100 Y+100 Z+0
68 CYCL DEF 30.4 SETUP 2
69 CYCL DEF 30.5 PECKG +5 F100
70 CYCL DEF 30.6 F350 M8
```

MULTIPASS MILLING (Cycle 230)

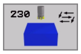


1. From the current position in the working plane, the TNC positions the tool in rapid traverse FMAX to the starting point **1**; the TNC moves the tool by its radius to the left and upward.
2. The tool then moves at FMAX in the tool axis to set-up clearance. From there it approaches the programmed starting position in the tool axis at the feed rate for plunging.
3. The tool then moves as the programmed feed rate for milling to the end point **2**. The TNC calculates the end point from the programmed starting point, the program length, and the tool radius.
4. The TNC offsets the tool to the starting point in the next pass at the stepover feed rate. The offset is calculated from the programmed width and the number of cuts.
5. The tool then returns in the negative direction of the first axis.
6. Multipass milling is repeated until the programmed surface has been completed.
7. At the end of the cycle, the tool is retracted in FMAX to set-up clearance.

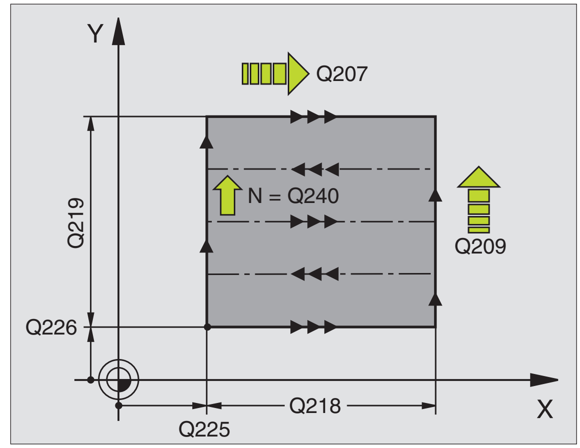
Before programming, note the following:

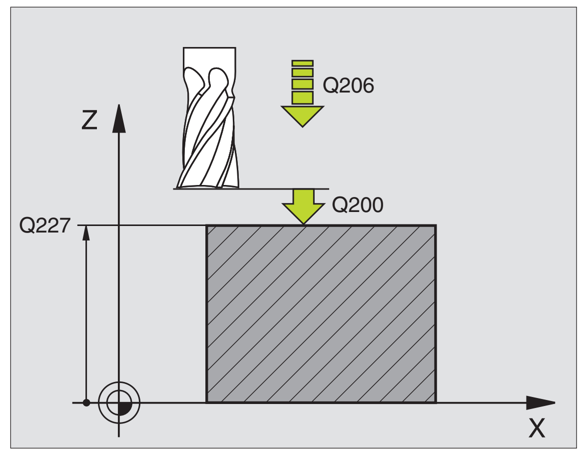
From the current position, the TNC positions the tool at the starting point 1, first in the working plane and then in the tool axis.

Pre-position the tool in such a way that no collision between tool and clamping devices can occur.



- **Starting point in 1st axis** Q225 (absolute value): Minimum point coordinate of the surface to be multipass-milled in the reference axis of the working plane
- **Starting point in 2nd axis** Q226 (absolute value): Minimum-point coordinate of the surface to be multipass-milled in the minor axis of the working plane
- **Starting point in 3rd axis** Q227 (absolute value): Height in the spindle axis at which multipass-milling is carried out
- **First side length** Q218 (incremental value): Length of the surface to be multipass-milled in the reference axis of the working plane, referenced to the starting point in 1st axis
- **Second side length** Q219 (incremental value): Length of the surface to be multipass-milled in the minor axis of the working plane, referenced to the starting point in 2nd axis
- **Number of cuts** Q240: Number of passes to be made over the width
- **Feed rate for plunging** 206: Traversing speed of the tool in mm/min when moving from set-up clearance to the milling depth
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling.
- **Stepover feed rate** Q209: Traversing speed of the tool in mm/min when moving to the next pass. If you are moving the tool transversely in the material, enter Q209 to be smaller than Q207. If you are moving it transversely in the open, Q209 may be greater than Q207.
- **Set-up clearance** Q200 (incremental value): Distance between tool tip and milling depth for positioning at the start and end of the cycle.



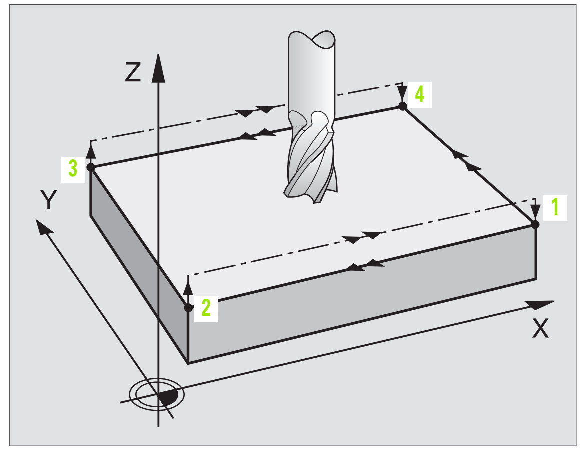


Example: NC blocks

```
71 CYCL DEF 230 MULTIPASS MILLING
    Q225=+10        ;STARTING PNT 1ST AXIS
    Q226=+12        ;STARTING PNT 2ND AXIS
    Q227=+2.5       ;STARTING PNT 3RD AXIS
    Q218=150        ;FIRST SIDE LENGTH
    Q219=75         ;SECOND SIDE LENGTH
    Q240=25         ;NUMBER OF CUTS
    Q206=150        ;FEED RATE FOR PLUNGING
    Q207=500        ;FEEED RATE FOR MILLING
    Q209=200        ;STEPOVER FEED RATE
    Q200=2          ;SAFETY CLEARANCE
```

RULED SURFACE (Cycle 231)

1 From the current position, the TNC positions the tool in a linear 3-D movement to the starting point **1**.
2 The tool subsequently advances to the stopping point **2** at the feed rate for milling.
3 From this point, the tool moves in rapid traverse FMAX by the tool diameter in the positive tool axis direction, and then back to starting point **1**.
4 At the starting point **1** the TNC moves the tool back to the last traversed Z value.
5 Then the TNC moves the tool in all three axes from point **1** in the direction of point **4** to the next line.
6 From this point, the tool moves to the stopping point on this pass. The TNC calculates the end point from point **2** and a movement in the direction of point **3**.
7 Multipass milling is repeated until the programmed surface has been completed.
8 At the end of the cycle, the tool is positioned above the highest programmed point in the tool axis, offset by the tool diameter.

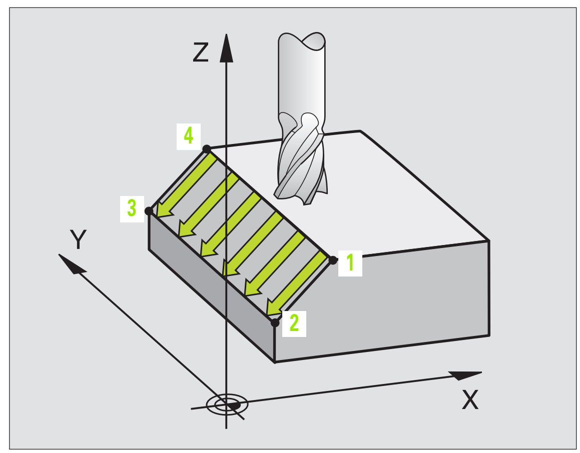


Cutting motion

The starting point, and therefore the milling direction, is selectable because the TNC always moves from point **1** to point **2** and in the total movement from point **1** / **2** to point **3** / **4**. You can program point **1** at any corner of the surface to be machined.

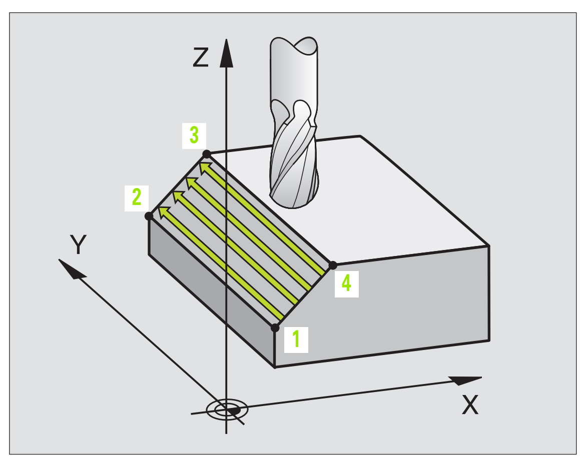
If you are using an end mill for the machining operation, you can optimize the surface finish in the following ways

- A shaping cut (spindle axis coordinate of point **1** greater than spindle-axis coordinate of point **2**) for slightly inclined surfaces.
- A drawing cut (spindle axis coordinate of point **1** smaller than spindle-axis coordinate of point **2**) for steep surfaces.
- When milling twisted surfaces, program the main cutting direction (from point **1** to point **2**) parallel to the direction of the steeper inclination.



If you are using a spherical cutter for the machining operation, you can optimize the surface finish in the following way:

- When milling twisted surfaces, program the main cutting direction (from point **1** to point **2**) perpendicular to the direction of the steepest inclination.

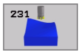


Before programming, note the following:

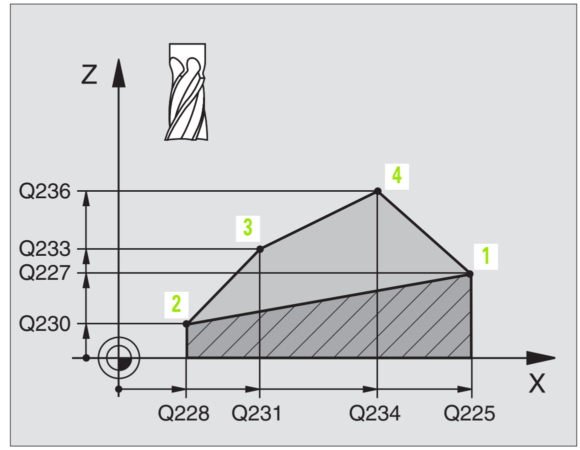
The TNC positions the tool from the current position in a linear 3-D movement to the starting point **1**. Pre-position the tool in such a way that no collision between tool and clamping devices can occur.

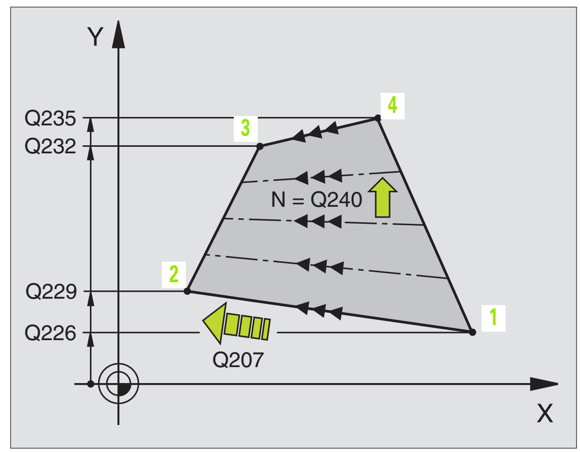
The TNC moves the tool with radius compensation R0 to the programmed positions.

If required, use a center-cut end mill (ISO 1641).



- **Starting point in 1st axis** Q225 (absolute value): Starting point coordinate of the surface to be multipass-milled in the reference axis of the working plane
- **Starting point in 2nd axis** Q226 (absolute value): Starting point coordinate of the surface to be multipass-milled in the minor axis of the working plane
- **Starting point in 3rd axis** Q227 (absolute value): Starting point coordinate of the surface to be multipass-milled in the tool axis
- **2nd point in 1st axis** Q228 (absolute value): Stopping point coordinate of the surface to be multipass milled in the reference axis of the working plane
- **2nd point in 2nd axis** Q229 (absolute value): Stopping point coordinate of the surface to be multipass milled in the minor axis of the working plane
- **2nd point in 3rd axis** Q230 (absolute value): Stopping point coordinate of the surface to be multipass milled in the tool axis
- **3rd point in 1st axis** Q231 (absolute value): Coordinate of point **3** in the reference axis of the working plane
- **3rd point in 2nd axis** Q232 (absolute value): Coordinate of point **3** in the minor axis of the working plane
- **3rd point in 3rd axis** Q233 (absolute value): Coordinate of point **3** in the tool axis



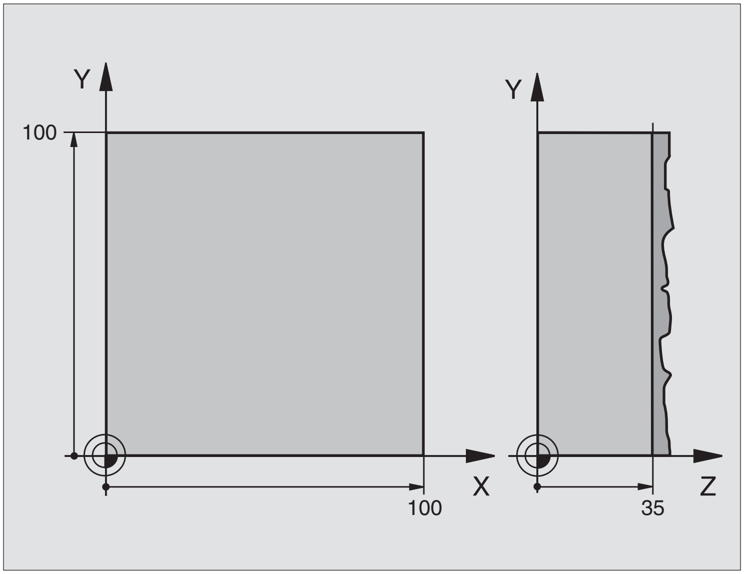


- **4th point in 1st axis** Q234 (absolute value): Coordinate of point **4** in the reference axis of the working plane
- **4th point in 2nd axis** Q235 (absolute value): Coordinate of point **4** in the minor axis of the working plane
- **4th point in 3rd axis** Q236 (absolute value): Coordinate of point **4** in the tool axis
- **Number of cuts** Q240: Number of passes to be made between points **1** and **4**, **2** and **3**.
- **Feed rate for milling** Q207: Traversing speed of the tool in mm/min while milling. The TNC performs the first step at half the programmed feed rate.

Example: NC blocks

```
72 CYCL DEF 231 RULED SURFACE
    Q225=+0         ;STARTING PNT 1ST AXIS
    Q226=+5         ;STARTING PNT 2ND AXIS
    Q227=-2         ;STARTING PNT 3RD AXIS
    Q228=+100       ;2ND POINT 1ST AXIS
    Q229=+15        ;2ND POINT 2ND AXIS
    Q230=+5         ;2ND POINT 3RD AXIS
    Q231=+15        ;3RD POINT 1ST AXIS
    Q232=+125       ;3RD POINT 2ND AXIS
    Q233=+25        ;3RD POINT 3RD AXIS
    Q234=+15        ;4TH POINT 1ST AXIS
    Q235=+125       ;4TH POINT 2ND AXIS
    Q236=+25        ;4TH POINT 3RD AXIS
    Q240=40         ;NUMBER OF CUTS
    Q207=500        ;FEEED RATE FOR MILLING
```

Example: Multipass milling



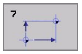
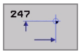
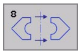
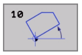
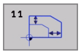
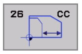
`0 BEGIN PGM C230 MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z+0`	Define the workpiece blank
`2 BLK FORM 0.2 X+100 Y+100 Z+40`	
`3 TOOL DEF 1 L+0 R+5`	Define the tool
`4 TOOL CALL 1 Z S3500`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 CYCL DEF 230 MULTIPASS MILLING`	Cycle definition: MULTIPASS MILLING
`Q225=+0 ;START IN 1ST AXIS`	
`Q226=+0 ;START IN 2ND AXIS`	
`Q227=+35 ;START IN 3RD AXIS`	
`Q218=100 ;FIRST SIDE LENGTH`	
`Q219=100 ;SECOND SIDE LENGTH`	
`Q240=25 ;NUMBER OF CUTS`	
`Q206=250 ;FEED RATE FOR PLNGNG`	
`Q207=400 ;FEED RATE FOR MILLING`	
`Q209=150 ;STEPOVER FEED RATE`	
`Q200=2 ;SET-UP CLEARANCE`	

7 L X+-25 Y+0 R0 FMAX M3	Pre-position near the starting point
8 CYCL CALL	Call the cycle
9 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
10 END PGM C230 MM	

8.9 Coordinate Transformation Cycles

Overview

Once a contour has been programmed, you can position it on the workpiece at various locations and in different sizes through the use of coordinate transformations. The TNC provides the following coordinate transformation cycles:

Cycle	Soft key
7 DATUM SHIFT For shifting contours directly within the program or from datum tables	
247 DATUM SETTING Datum setting during program run	
8 MIRROR IMAGE Mirroring contours	
10 ROTATION For rotating contours in the working plane	
11 SCALING FACTOR For increasing or reducing the size of contours	
26 AXIS-SPECIFIC SCALING FACTOR For increasing or reducing the size of contours with scaling factors for each axis	
19 WORKING PLANE Machining in tilted coordinate system on machines with swivel heads and/or tilting tables	

Effect of coordinate transformations

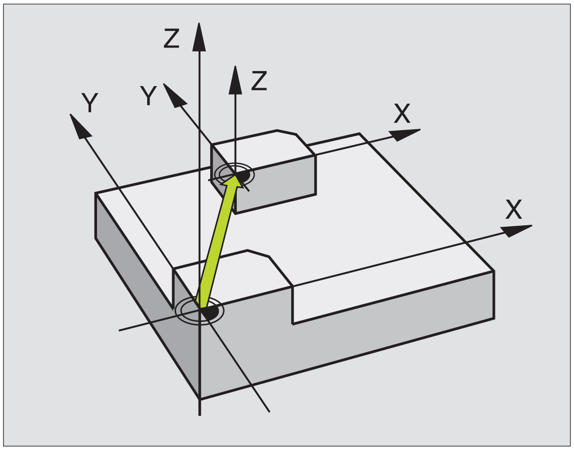
Beginning of effect: A coordinate transformation becomes effective as soon as it is defined—it is not called. It remains in effect until it is changed or canceled.

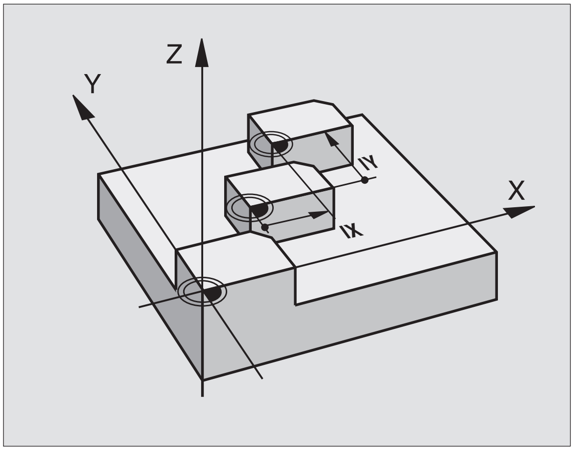
To cancel coordinate transformations:

- Define cycles for basic behavior with a new value, such as scaling factor 1.0
- Execute a miscellaneous function M02, M30, or an END PGM block (depending on machine parameter 7300)
- Select a new program
- Program miscellaneous function M142 Erasing modal program information

DATUM SHIFT (Cycle 7)

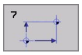
A DATUM SHIFT allows machining operations to be repeated at various locations on the workpiece.





Effect

When the DATUM SHIFT cycle is defined, all coordinate data is based on the new datum. The TNC displays the datum shift in each axis in the additional status display. Input of rotary axes is also permitted.



- **`Datum shift:`** Enter the coordinates of the new datum. Absolute values are referenced to the manually set workpiece datum. Incremental values are always referenced to the datum which was last valid—this can be a datum which has already been shifted.

Cancellation

A datum shift is canceled by entering the datum shift coordinates X=0, Y=0 and Z=0.

Graphics

If you program a new BLK FORM after a datum shift, you can use machine parameter 7310 to determine whether the BLK FORM is referenced to the current datum or to the original datum. Referencing a new BLK FORM to the current datum enables you to display each part in a program in which several pallets are machined.

Status Displays

- The actual position values are referenced to the active (shifted) datum.
- All of the position values shown in the additional status display are referenced to the manually set datum.

Example: NC blocks

```
13 CYCL DEF 7.0 DATUM SHIFT
14 CYCL DEF 7.1 X+60
16 CYCL DEF 7.3 Z-5
15 CYCL DEF 7.2 Y+40
```

DATUM SHIFT with datum tables (Cycle 7)

If you are using datum shifts with datum tables, then use the SEL TABLE function to activate the desired datum table from the NC program.

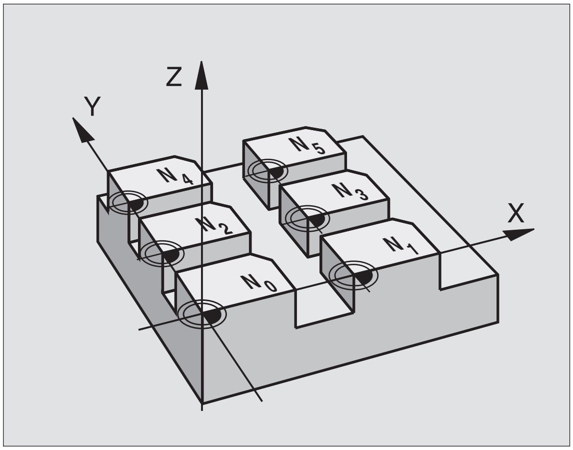
If you work without SEL-TABLE, then you must activate the desired datum table before the test run or the program run. (This applies also for the programming graphics).

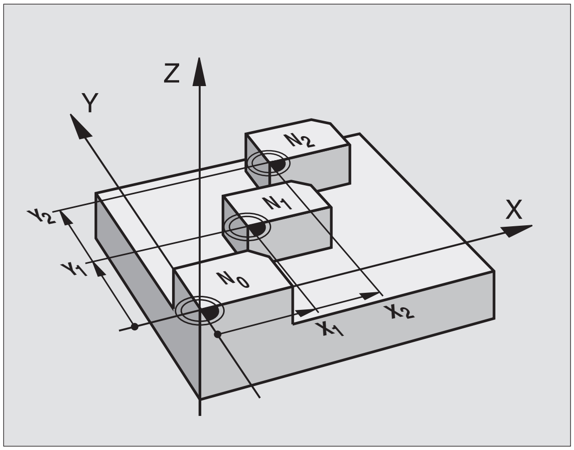
- Use the file management to select the desired table for a test run in the **`Test Run`** operating mode: The table receives the status S.
- Use the file management in a program run mode to select the desired table for a program run: The table receives the status M.

Datums from a datum table can be referenced either to the current datum or to the machine datum (depending on machine parameter 7475).

The coordinate values from datum tables are only effective with absolute coordinate values.

New lines can only be inserted at the end of the table.



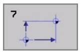


Function

Datum tables are used for

- frequently recurring machining sequences at various locations on the workpiece
- frequent use of the same datum shift

Within a program, you can either program datum points directly in the cycle definition or call them from a datum table.



- **`Datum shift:`** Enter the number of the datum from the datum table or a Q parameter. If you enter a Q parameter, the TNC activates the datum number found in the Q parameter.

Cancellation

- Call a datum shift to the coordinates X=0; Y=0 etc. from the datum table.
- Execute a datum shift to the coordinates X=0; Y=0 etc. directly with a cycle definition.

Example: NC blocks

```
77 CYCL DEF 7.0 DATUM SHIFT
78 CYCL DEF 7.1 #5
```

Selecting a datum table in the part program

With the **SEL TABLE** function you select the table from which the TNC takes the datums:

PGM CALL

- To select the functions for program call, press the PGM CALL key.

DATUM TABLE

- Press the TOOL TABLE soft key.
- Enter the complete path name of the datum table and confirm your entry with the END key.

> Program a SEL TABLE block before Cycle 7 Datum Shift.
>
> A datum table selected with SEL TABLE remains active until you select another datum table with SEL TABLE or through PGM MGT.

Editing a datum table

Select the datum table in the **Programming and Editing** mode of operation.

PGM MGT

- To call the file manager, press the PGM MGT key; see "File Management: Fundamentals," page 39.
- Display the datum tables: Press the soft keys SELECT TYPE and SHOW .D.
- Select the desired table or enter a new file name.
- Edit the file. The soft-key row comprises the following functions for editing:

Function	Soft key
Select beginning of table	BEGIN ↑
Select end of table	END ↓
Go to previous page	PAGE ↑
Go to next page	PAGE ↓
Insert line (only possible at end of table)	INSERT LINE
Delete line	DELETE LINE
Confirm entered line and go to beginning of next line	NEXT LINE
Add the entered number of lines (reference points) to the end of the table	APPEND N LINES

Edit a pocket table in a Program Run operating mode.

In a program run mode you can select the active datum table. Press the DATUM TABLE soft key. You can then use the same editing functions as in the `Programming and Editing` mode of operation.

Transferring the actual values into the datum table

You can enter the current tool position or the last probed position in the datum table by pressing the "actual-position-capture" key:

- Place the text box on the line of the column in which you want to enter the position.

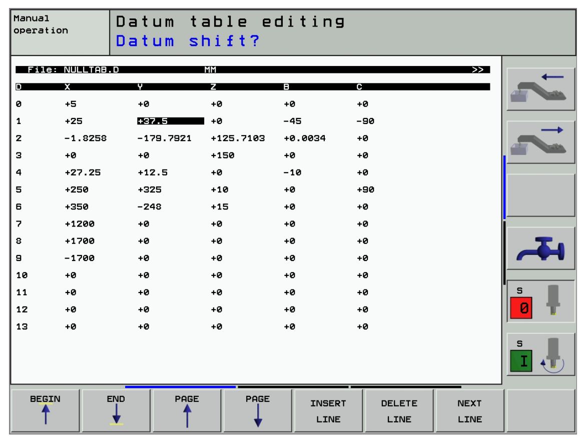
- Select the actual-position-capture function: The TNC opens a pop-up window that asks whether you want to enter the current tool position or the last probed values.
- Select the desired function with the arrow keys and confirm your selection with the ENT key.

- To enter the values in all axes, press the ALL VALUES soft key.

- To enter the value in the axis where the text box is located, press the CURRENT VALUE soft key.

Configuring the datum table

On the second and third soft-key rows you can define for each datum table the axes for which you wish to set the datums. In the standard setting all of the axes are active. If you wish to exclude an axis, set the corresponding soft key to OFF. The TNC then deletes that column from the datum table.



If you do not wish to define a datum table for an active axis, press the NO ENT key. The TNC then enters a dash in the corresponding column.

To leave a datum table

Select a different type of file in file management and choose the desired file.

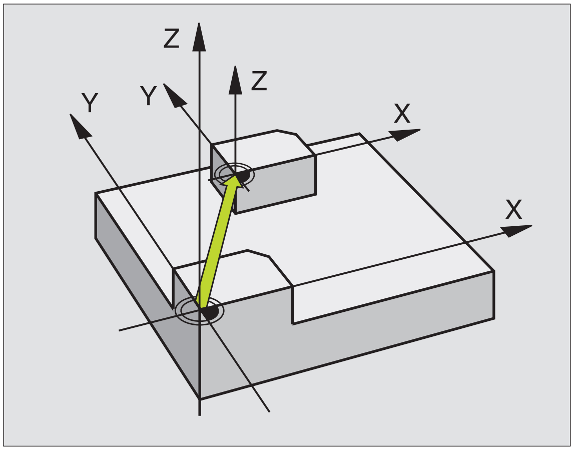
Status Displays

If datums in the table are referenced to the machine datum, then:

- The actual position values are referenced to the active (shifted) datum.
- All of the position values shown in the additional status display are referenced to the machine datum, whereby the TNC accounts for the manually set datum.

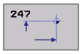
DATUM SETTING (Cycle 247)

With the cycle DATUM SETTING, you can activate a datum defined in a datum table as the new datum.



Effect

After a DATUM SETTING cycle definition, all of the coordinate inputs and datum shifts (absolute and incremental) are referenced to the new datum. Setting datums for rotary axes is also possible.



- **`Number for datum?`**: Enter the number of the datum in the datum table.

Cancellation

You can reactivate the last datum set in the Manual mode by entering the miscellaneous function M104.

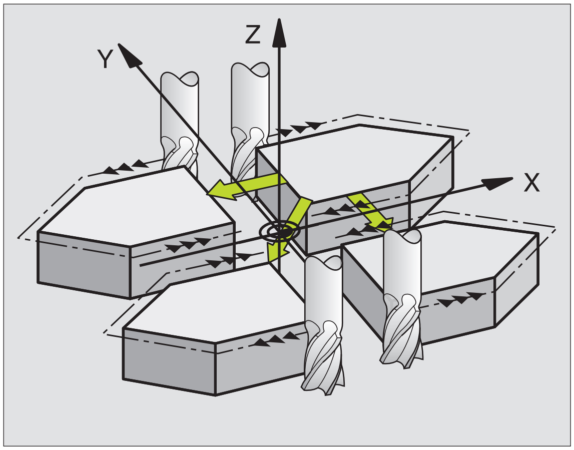
> The TNC only sets the datum for those axes which are active in the datum table. An axis displayed as a column in the datum table, but not existing on the TNC, will cause an error message.
>
> Cycle 247 always interprets the values saved in the datum table as coordinates referenced to the machine datum. Machine parameter 7475 has no influence on this.
>
> When using Cycle 247, you cannot use the block scan function for mid-program startup.
>
> Cycle G247 is not functional in Test Run mode.

Example: NC blocks

```
13 CYCL DEF 247 DATUM SETTING
    Q339=4          ;DATUM NUMBER
```

MIRROR IMAGE (Cycle 8)

The TNC can machine the mirror image of a contour in the working plane.



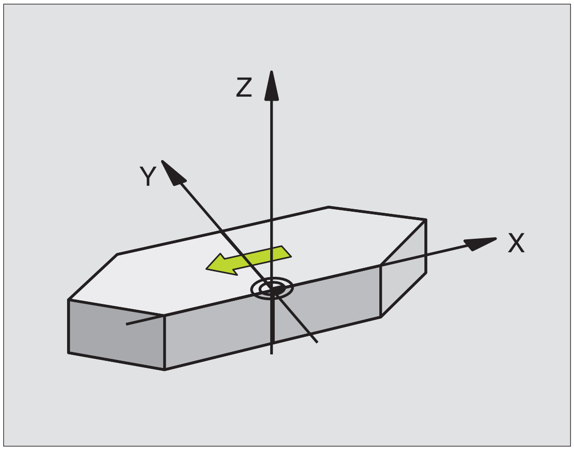
Effect

The mirror image cycle becomes effective as soon as it is defined in the program. It is also effective in the Positioning with MDI mode of operation. The active mirrored axes are shown in the additional status display.

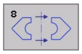
- If you mirror only one axis, the machining direction of the tool is reversed (except in fixed cycles).
- If you mirror two axes, the machining direction remains the same.

The result of the mirror image depends on the location of the datum:

- If the datum lies on the contour to be mirrored, the element simply flips over.
- If the datum lies outside the contour to be mirrored, the element also “jumps” to another location.



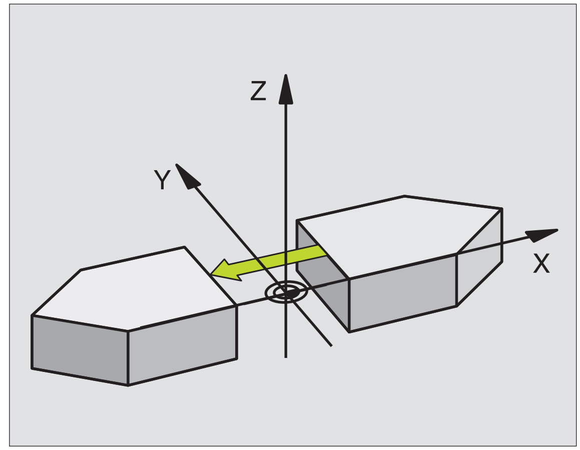
> If you mirror only one axis, the machining direction is reversed for the new machining cycles (cycles 2xx). The machining direction remains the same for older machining cycles, such as Cycle 4 POCKET MILLING.



- **Mirrored axis?**: Enter the axis to be mirrored. You can mirror all axes, including rotary axes, except for the spindle axis and its auxiliary axes. You can enter up to three axes.

Reset

Program the MIRROR IMAGE cycle once again with NO ENT.



Example: NC blocks

```
79 CYCL DEF 8.0 MIRROR IMAGE
80 CYCL DEF 8.1 X Y U
```

ROTATION (Cycle 10)

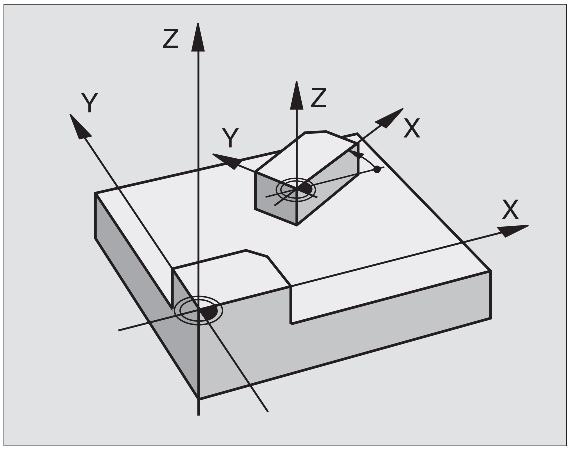
The TNC can rotate the coordinate system about the active datum in the working plane within a program.

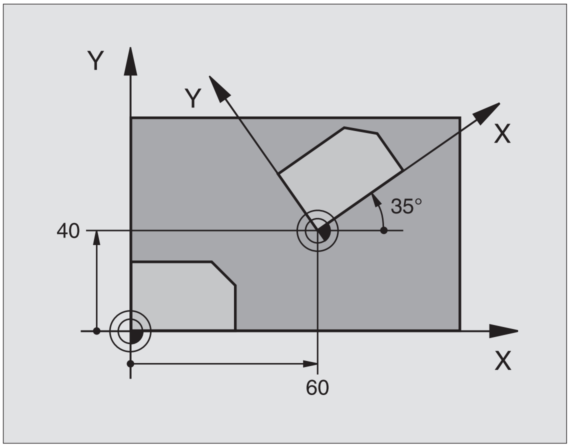
Effect

The ROTATION cycle becomes effective as soon as it is defined in the program. It is also effective in the Positioning with MDI mode of operation. The active rotation angle is shown in the additional status display.

Reference axis for the rotation angle:

- X/Y plane X axis
- Y/Z plane Y axis
- Z/X plane Z axis

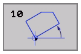




Before programming, note the following:

An active radius compensation is canceled by defining Cycle 10 and must therefore be reprogrammed, if necessary.

After defining Cycle 10, you must move both axes of the working plane to activate rotation for all axes.



- **Rotation:** Enter the rotation angle in degrees (°). Input range: –360° to +360° (absolute or incremental).

Cancellation

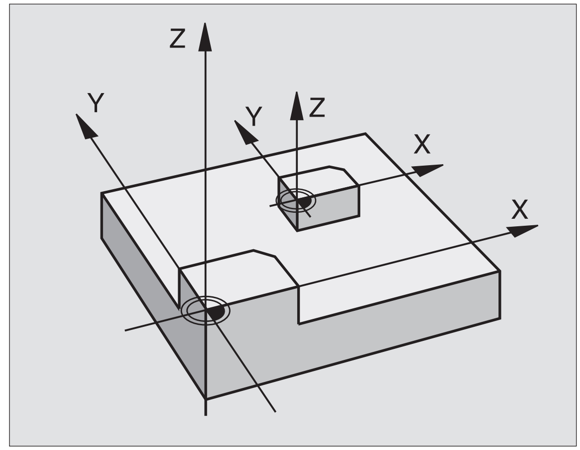
Program the ROTATION cycle once again with a rotation angle of 0°.

Example: NC blocks

```
12 CALL LBL 1
13 CYCL DEF 7.0 DATUM SHIFT
14 CYCL DEF 7.1 X+60
15 CYCL DEF 7.2 Y+40
16 CYCL DEF 10.0 ROTATION
17 CYCL DEF 10.1 ROT+35
18 CALL LBL 1
```

SCALING FACTOR (Cycle 11)

The TNC can increase or reduce the size of contours within a program, enabling you to program shrinkage and oversize allowances.



Effect

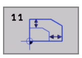
The SCALING FACTOR becomes effective as soon as it is defined in the program. It is also effective in the Positioning with MDI mode of operation. The active scaling factor is shown in the additional status display.

The scaling factor affects

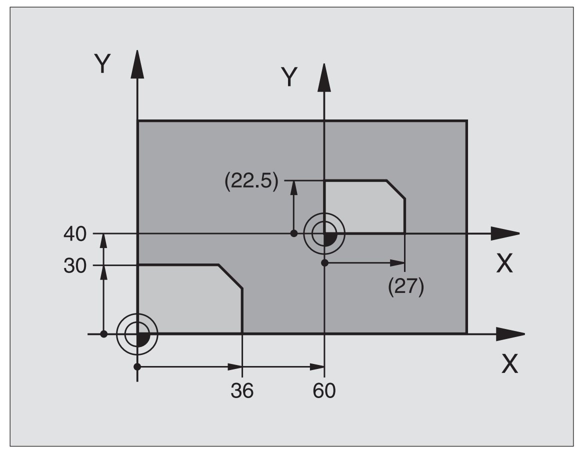
- in the working plane, or on all three coordinate axes at the same time (depending on machine parameter 7410)
- dimensions in cycles
- to the parallel axes U,V,W

Prerequisite

It is advisable to set the datum to an edge or a corner of the contour before enlarging or reducing the contour.



- **`Scaling factor ?:`** Enter the scaling factor SCL. The TNC multiplies the coordinates and radii by the SCL factor (as described under "Effect" above)



Enlargement: SCL greater than 1 (up to 99.999 999)

Reduction: SCL less than 1 (down to 0.000 001)

Cancellation

Program the SCALING FACTOR cycle once again with a scaling factor of 1.

Example: NC blocks

```
11 CALL LBL 1
12 CYCL DEF 7.0 DATUM SHIFT
13 CYCL DEF 7.1 X+60
14 CYCL DEF 7.2 Y+40
15 CYCL DEF 11.0 SCALING
16 CYCL DEF 11.1 SCL 0.75
17 CALL LBL 1
```

AXIS-SPECIFIC SCALING (Cycle 26)

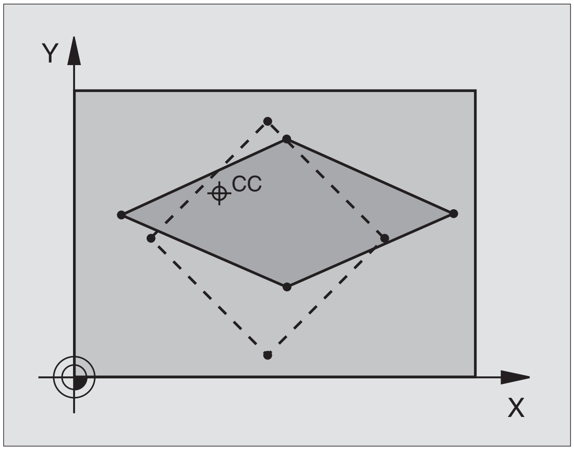
Before programming, note the following:

Coordinate axes sharing coordinates for arcs must be enlarged or reduced by the same factor.

You can program each coordinate axis with its own axis-specific scaling factor.

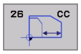
In addition, you can enter the coordinates of a center for all scaling factors.

The size of the contour is enlarged or reduced with reference to the center, and not necessarily (as in Cycle 11 SCALING FACTOR) with reference to the active datum.



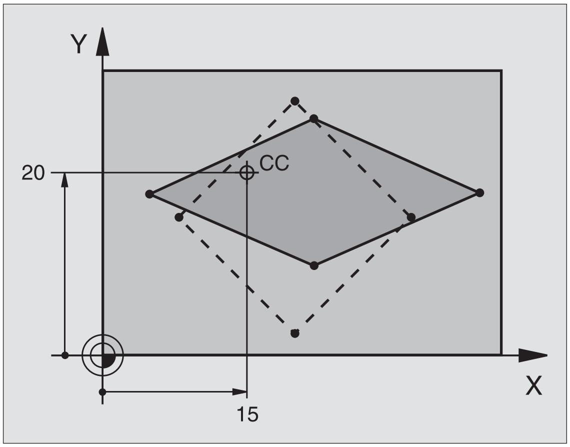
Effect

The SCALING FACTOR becomes effective as soon as it is defined in the program. It is also effective in the Positioning with MDI mode of operation. The active scaling factor is shown in the additional status display.



- **`Axis and scaling factor:`** Enter the coordinate axis/axes as well as the factor(s) involved in enlarging or reducing. Enter a positive value up to 99.999 999.
- **`Center coordinates:`** Enter the center of the axis-specific enlargement or reduction.

The coordinate axes are selected with soft keys.



Cancellation

Program the SCALING FACTOR cycle once again with a scaling factor of 1 for the same axis.

Example: NC blocks

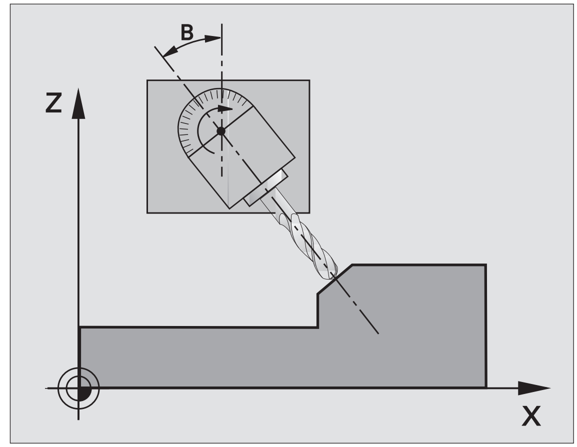
```
25 CALL LBL 1
26 CYCL DEF 26.0 AXIS-SPECIFIC SCALING
27 CYCL DEF 26.1 X 1.4 Y 0.6 CCX+15 CCY+20
28 CALL LBL 1
```

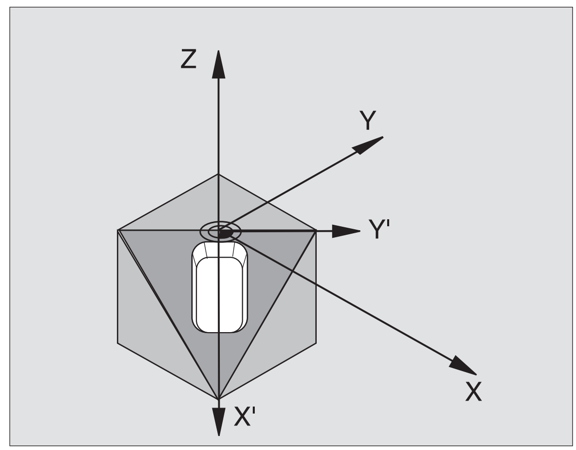
WORKING PLANE (Cycle 19)

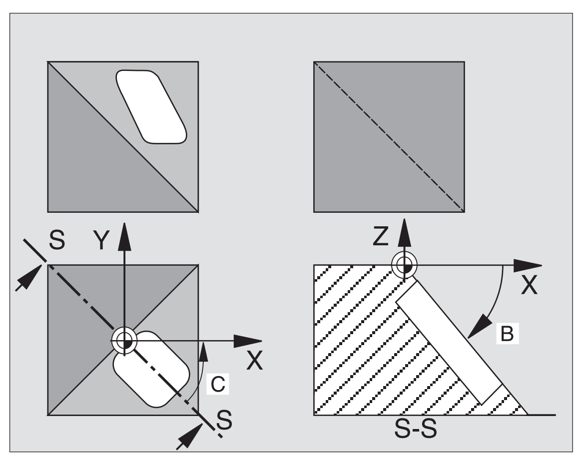
The functions for tilting the working plane are interfaced to the TNC and the machine tool by the machine tool builder. With some swivel heads and tilting tables, the machine tool builder determines whether the entered angles are interpreted as coordinates of the tilt axes or as mathematical angles of a tilted plane. Refer to your machine manual.

The working plane is always tilted around the active datum.

For fundamentals, see "Tilting the Working Plane," page 24: Please read this seciton completely.







Effect

In Cycle 19 you define the position of the working plane—i.e. the position of the tool axis referenced to the machine coordinate system—by entering tilt angles. There are two ways to determine the position of the working plane:

- Enter the position of the tilting axes directly.
- Describe the position of the working plane using up to 3 rotations (spatial angle) of the **machine-referenced** coordinate system. The required spatial angle can be calculated by cutting a perpendicular line through the tilted working plane and considering it from the axis around which you wish to tilt. With two spatial angles, every tool position in space can be defined exactly.

Note that the position of the tilted coordinate system, and therefore also all movement in the tilted system, are dependent on your description of the tilted plane.

If you program the position of the working plane via spatial angles, the TNC will calculate the required angle positions of the tilted axes automatically and will store these in the parameters Q120 (A axis) to Q122 (C axis). If two solutions are possible, the TNC will choose the shorter path from the zero position of the rotary axes.

The axes are always rotated in the same sequence for calculating the tilt of the plane: The TNC first rotates the A axis, then the B axis, and finally the C axis.

Cycle 19 becomes effective as soon as it is defined in the program. As soon as you move an axis in the tilted system, the compensation for this specific axis is activated. You have to move all axes to activate compensation for all axes.

If you set the function TILTING program run to ACTIVE in the Manual Operation mode see “Tilting the Working Plane,” page 24, the angular value entered in this menu is overwritten by Cycle 19 WORKING PLANE.

- **Tilt axis and tilt angle?**: The axes of rotation together with the associated tilt angles. The rotary axes A, B and C are programmed using soft keys.

If the TNC automatically positions the rotary axes, you can enter the following parameters

- **Feed rate ?   F=**: Traverse speed of the rotary axis during automatic positioning
- **Set-up clearance ?**(incremental value): The TNC positions the tilting head so that the position that results from the extension of the tool by the set-up clearance does not change relative to the workpiece.

Cancellation

To cancel the tilt angle, redefine the WORKING PLANE cycle and enter an angular value of 0° for all axes of rotation. You must then program the WORKING PLANE cycle once again by answering the dialog question with the NO ENT key to disable the function.

Position the axis of rotation

> The machine tool builder determines whether Cycle 19 positions the axes of rotation automatically or whether they must be pre-positioned in the program. Refer to your machine manual.

If the rotary axes are positioned automatically in Cycle 19:

- The TNC can position only controlled axes
- In order for the tilted axes to be positioned, you must enter a feed rate and a set-up clearance in addition to the tilting angles, during cycle definition.
- You can use only preset tools (with the full tool length defined in the TOOL DEF block or in the tool table).
- The position of the tool tip as referenced to the workpiece surface remains nearly unchanged after tilting
- The TNC tilts the working plane at the last programmed feed rate. The maximum feed rate that can be reached depends on the complexity of the swivel head or tilting table.

If the axes are not positioned automatically in Cycle 19, position them before defining the cycle, for example with an L block.

Example NC blocks:

10 L Z+100 R0 FMAX	
11 L X+25 Y+10 R0 FMAX	
12 L B+15 R0 F1000	Position the axis of rotation
13 CYCL DEF 19.0 WORKING PLANE	Define the angle for calculation of the compensation
14 CYCL DEF 19.1 B+15	

`15 L Z+80 R0 FMAX`	Activate compensation for the tool axis
`16 L X-8.5 Y-10 R0 FMAX`	Activate compensation for the working plane

Position display in the tilted system

On activation of Cycle 19, the displayed positions (**ACTL** and **NOML**) and the datum indicated in the additional status display are referenced to the tilted coordinate system. The positions displayed immediately after cycle definition may not be the same as the coordinates of the last programmed position before Cycle 19.

Workspace monitoring

The TNC monitors only those axes in the tilted coordinate system that are moved. If necessary, the TNC outputs an error message.

Positioning in a tilted coordinate system

With the miscellaneous function M130 you can move the tool, while the coordinate system is tilted, to positions that are referenced to the non-tilted coordinate system see "Miscellaneous Functions for Coordinate Data," page 184.

Positioning movements with straight lines that are referenced to the machine coordinate system (blocks with M91 or M92), can also be executed in a tilted working plane. Constraints:

- Positioning is without length compensation.
- Positioning is without machine geometry compensation.
- Tool radius compensation is not permitted.

Combining coordinate transformation cycles

When combining coordinate transformation cycles, always make sure the working plane is swiveled around the active datum. You can program a datum shift before activating Cycle 19. In this case, you are shifting the "machine-based coordinate system."

If you program a datum shift after having activated Cycle 19, you are shifting the "tilted coordinate system."

Important: When resetting the cycles, use the reverse sequence used for defining the them:

1. Activate datum shift
2nd: Activate tilting function.
3rd: Activate rotation.
...
Machining
...
1st: Reset the rotation.
2nd: Reset the tilting function.
3rd: Reset the datum shift.

Automatic workpiece measurement in the tilted system

The TNC measuring cycles enable you to have the TNC measure a workpiece in a tilted system automatically. The TNC stores the measured data in Q parameters for further processing (for example, for printout).

Procedure for working with Cycle 19 WORKING PLANE

1 Write the program

- Define the tool (not required, when TOOL.T is active), and enter the full tool length.
- Call the tool.
- Retract the tool in the tool axis to a position where there is no danger of collision with the workpiece (clamping devices) during tilting.
- If required, position the tilt axis or axes with an L block to the appropriate angular value(s) (depending on a machine parameter).
- Activate datum shift if required.
- Define Cycle 19 WORKING PLANE; enter the angular values for the tilt axes.
- Traverse all main axes (X, Y, Z) to activate compensation.
- Write the program as if the machining process were to be executed in a non-tilted plane.
- If required, define Cycle 19 WORKING PLANE with other angular values to execute machining in a different axis position. In this case, it is not necessary to reset Cycle 19. You can define the new angular values directly.
- Reset Cycle 19 WORKING PLANE; program 0° for all tilt axes.
- Disable the WORKING PLANE function; redefine Cycle 19 and answer the dialog question with NO ENT.
- Reset datum shift if required.
- Position the tilt axes to the 0° position, if required.

2 Clamp the workpiece

3 Preparations in the operating mode
Positioning with Manual Data Input (MDI)

Pre-position the tilt axis/axes to the corresponding angular value(s) for setting the datum. The angular value depends on the selected reference plane on the workpiece.

4 Preparations in the operating mode
Manual Operation

Use the 3D-ROT soft key to set the function TILT WORKING PLANE to ACTIVE in the Manual Operation mode. Enter the angular values for the tilt axes into the menu if the axes are not controlled.

If the axes are not controlled, the angular values entered in the menu must correspond to the actual position(s) of the tilted axis or axes, respectively. The TNC will otherwise calculate a wrong datum.

5 Set the datum

- Manually by touching the workpiece with the tool in the untilted coordinate system see "Datum Setting (Without a 3-D Touch Probe)," page 22
- Automatically by using a HEIDENHAIN 3-D touch probe (see the new Touch Probe Cycles Manual, chapter 2)
- Automatically by using a HEIDENHAIN 3-D touch probe (see the new Touch Probe Cycles Manual, chapter 3)

6 Start the part program in the operating mode Program Run, Full Sequence

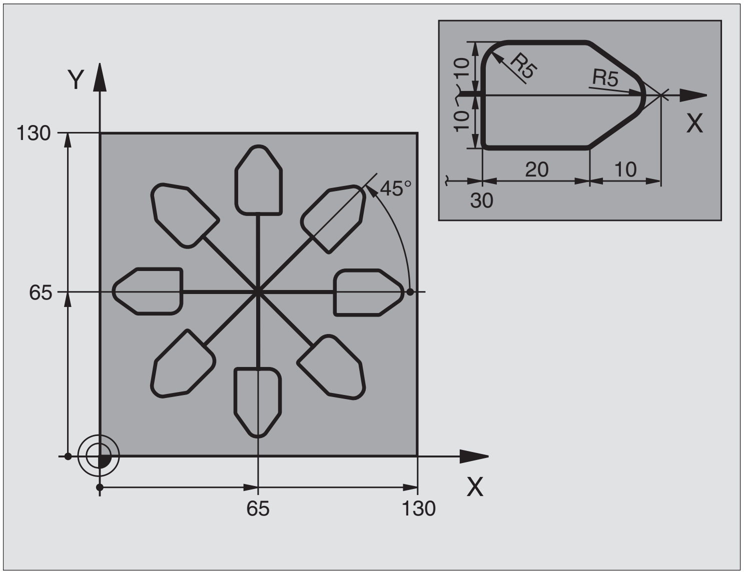
7 Manual Operation mode

Use the 3D-ROT soft key to set the function TILT WORKING PLANE to INACTIVE. Enter an angular value of 0° for each axis in the menu see "To activate manual tilting:," page 27.

Example: Coordinate transformation cycles

Program sequence

- Program the coordinate transformations in the main program
- For subprograms within a subprogram, see “Subprograms,” page 363



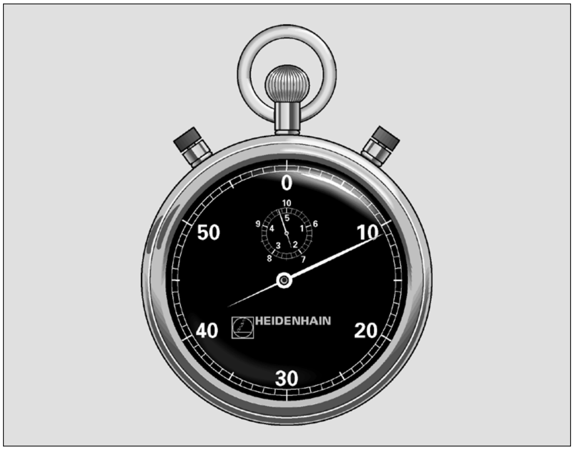
`0 BEGIN PGM KOUMR MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-20`	Define the workpiece blank
`2 BLK FORM 0.2 X+130 Y+130 Z+0`	
`3 TOOL DEF 1 L+0 R+1`	Define the tool
`4 TOOL CALL 1 Z S4500`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 CYCL DEF 7.0 DATUM SHIFT`	Shift datum to center
`7 CYCL DEF 7.1 X+65`	
`8 CYCL DEF 7.2 Y+65`	
`9 CALL LBL 1`	Call milling operation
`10 LBL 10`	Set label for program section repeat
`11 CYCL DEF 10.0 ROTATION`	Rotate by 45° (incremental)
`12 CYCL DEF 10.1 IROT+45`	
`13 CALL LBL 1`	Call milling operation
`14 CALL LBL 10 REP 6/6`	Return jump to LBL 10; execute the milling operation six times
`15 CYCL DEF 10.0 ROTATION`	Reset the rotation
`16 CYCL DEF 10.1 ROT+0`	
`17 CYCL DEF 7.0 DATUM SHIFT`	Reset the datum shift
`18 CYCL DEF 7.1 X+0`	
`19 CYCL DEF 7.2 Y+0`	

20 L Z+250 R0 FMAX M2	Retract in the tool axis, end program
21 LBL 1	Subprogram 1:
22 L X+0 Y+0 R0 FMAX	Define milling operation
23 L Z+2 R0 FMAX M3	
24 L Z-5 R0 F200	
25 L X+30 RL	
26 L IY+10	
27 RND R5	
28 L IX+20	
29 L IX+10 IY-10	
30 RND R5	
31 L IX-10 IY-10	
32 L IX-20	
33 L IY+10	
34 L X+0 Y+0 R0 F5000	
35 L Z+20 R0 FMAX	
36 LBL 0	
37 END PGM KOUMR MM	

8.10 Special Cycles

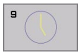
DWELL TIME (Cycle 9)

This causes the execution of the next block within a running program to be delayed by the programmed dwell time. A dwell time can be used for such purposes as chip breaking.



Effect

Cycle 9 becomes effective as soon as it is defined in the program. Modal conditions such as spindle rotation are not affected.



- **`Dwell time in seconds:`** Enter the dwell time in seconds.

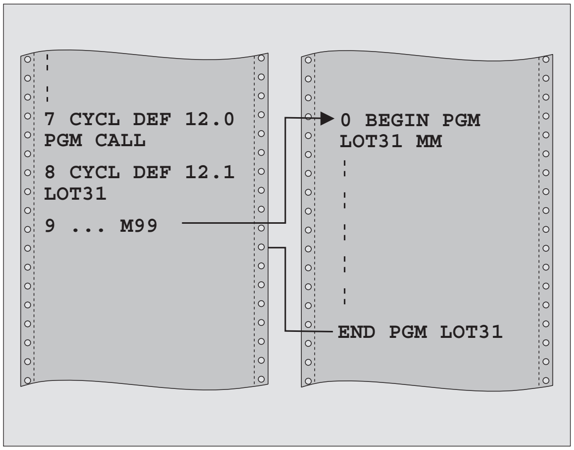
Input range 0 to 3600 s (1 hour) in 0.001 s steps

Example: NC blocks

```
89 CYCL DEF 9.0 DWELL TIME
90 CYCL DEF 9.1 DWELL 1.5
```

PROGRAM CALL (Cycle 12)

Routines that you have programmed (such as special drilling cycles or geometrical modules) can be written as main programs and then called like fixed cycles.



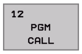
Before programming, note the following:

The program you are calling must be stored on the hard disk of your TNC.

If the program you are defining to be a cycle is located in the same directory as the program you are calling it from, you need only to enter the program name.

If the program you are defining to be a cycle is not located in the same directory as the program you are calling it from, you must enter the complete path (for example TNC:\KLAR35\FK1\50.H.

If you want to define an ISO program to be a cycle, enter the file type .I behind the program name.



- **Program name:** Enter the name of the program you want to call and, if necessary, the directory it is located in.

Call the program with

- CYCL CALL (separate block) or
- M99 (blockwise) or
- M89 (executed after every positioning block)

Example: Program call

A callable program 50 is to be called into a program via a cycle call.

Example: NC blocks

```
55 CYCL DEF 12.0 PGM CALL
56 CYCL DEF 12.1 PGM TNC:\KLAR35\FK1\50.H
57 L X+20 Y+50 FMAX M99
```

ORIENTED SPINDLE STOP (Cycle 13)

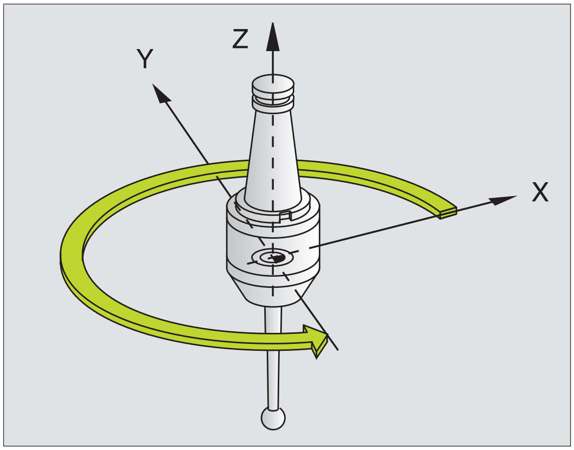
Machine and control must be specially prepared by the machine tool builder for use of this cycle.

Cycle 13 is used internally for machining cycles 202, 204 and 209. Please note that, if required, you must program Cycle 13 again in your NC program after one of the machining cycles mentioned above.

The TNC can control the machine tool spindle and rotate it to a given angular position.

Oriented spindle stops are required for

- Tool changing systems with a defined tool change position
- Orientation of the transmitter/receiver window of HEIDENHAIN 3-D touch probes with infrared transmission



Example: NC blocks

```
93 CYCL DEF 13.0 ORIENTATION
94 CYCL DEF 13.1 ANGLE 180
```

Effect

The angle of orientation defined in the cycle is positioned to by entering M19 or M20 (depending on the machine).

If you program M19 or M20 without having defined Cycle 13, the TNC positions the machine tool spindle to an angle that has been set by the machine manufacturer (see your machine manual).

- **`Angle of orientation:`** Enter the angle according to the reference axis of the working plane.

  Input range: 0 to 360°

  Input resolution: 0.1°

TOLERANCE (Cycle 32)

Machine and control must be specially prepared by the machine tool builder for use of this cycle.

The input parameters **FINISHING/ROUGHING** and **TOLERANCE FOR ROTARY AXES** are effective only if the HSC filter (software option 2) is active on your machine. The TNC will otherwise display an error message. If necessary, contact your machine tool builder.

The TNC automatically smoothes the contour between two path elements (whether compensated or not). The tool has constant contact with the workpiece surface. If necessary, the TNC automatically reduces the programmed feed rate so that the program can be machined at the fastest possible speed without short pauses for computing time. As a result the surface quality is improved and the machine is protected.

A contour deviation results from the smoothing. The size of this deviation **(tolerance value)** is set in a machine parameter by the machine manufacturer. With Cycle **32,** you can change the pre-set tolerance value and select different filter settings.

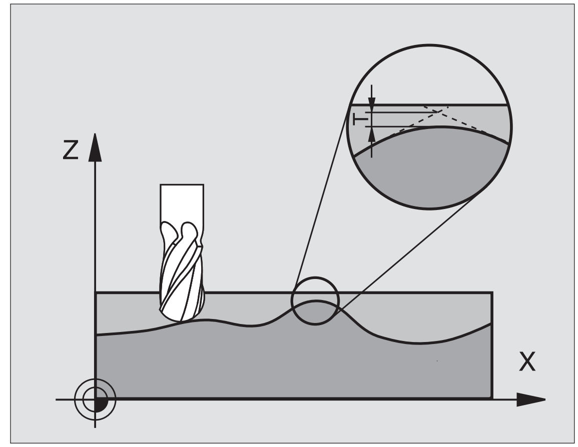
Before programming, note the following:

Cycle 32 is DEF active which means that it becomes effective as soon as it is defined in the part program.

You can reset Cycle 32 by defining it again and confirming the dialog question after the **tolerance value** with NO ENT. Resetting reactivates the pre-set tolerance.

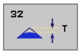
In a program with millimeters set as unit of measure, the TNC interprets the entered tolerance value in millimeters. In an inch program it interprets them as inches.

The input parameters for finishing/roughing and the tolerance for rotary axes are effective only if the HSC filter is active on your machine. If necessary, contact your machine tool builder.

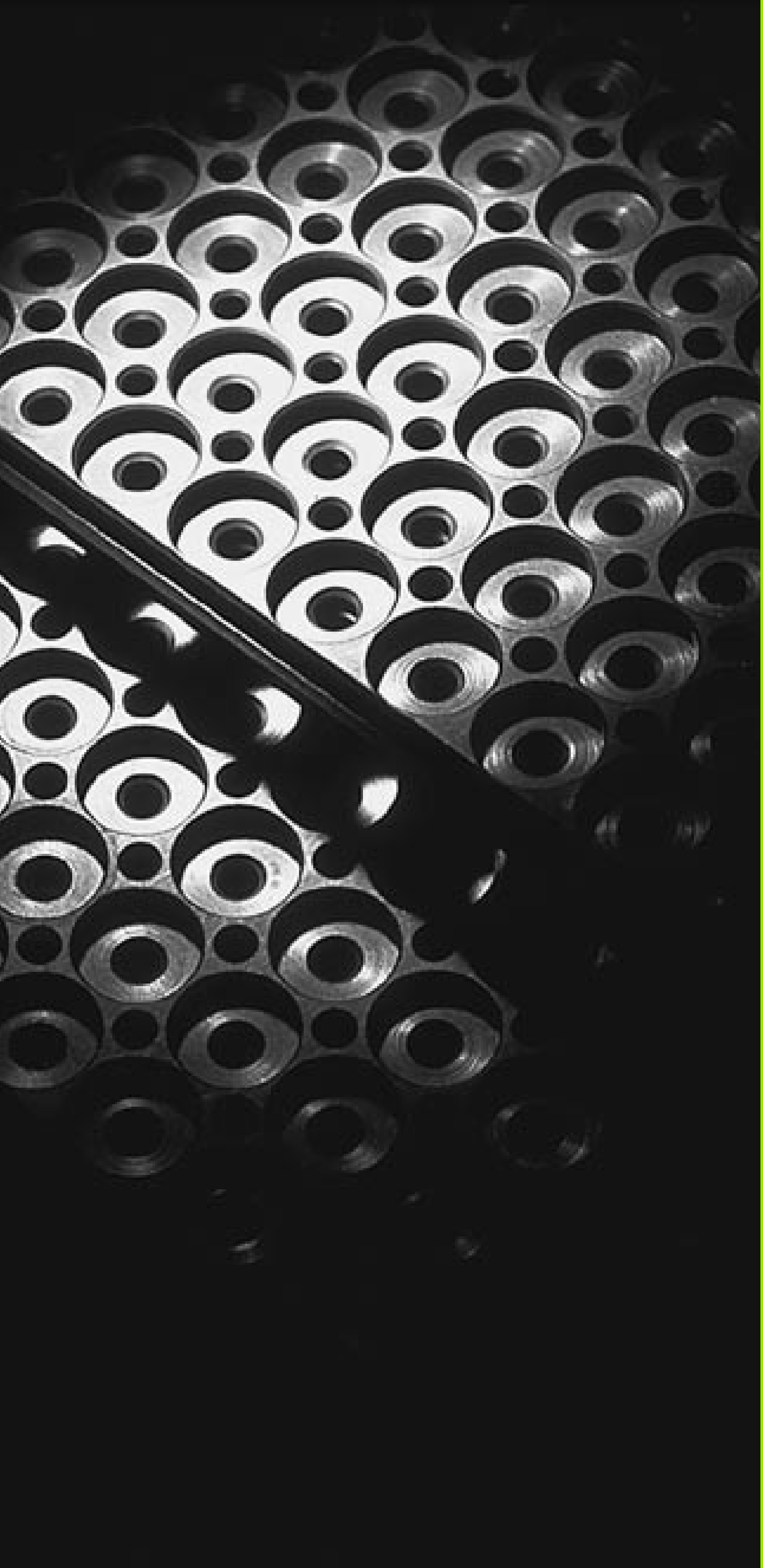


Example: NC blocks

```
95 CYCL DEF 32.0 TOLERANCE
96 CYCL DEF 32.1 T0.05
97 CYCL DEF 32.2 HSC-MODE:1 TA5
```



- **`Tolerance value`**: Permissible contour deviation in mm (inches)
- **`Finishing=0, Roughing=1:`** Activate filter:
  - Input value 0:
    Milling with increased contour accuracy. The TNC uses the filter settings that your machine tool builder has defined for finishing operations.
  - Input value 1:
    Milling at an increased feed rate. The TNC uses the filter settings that your machine tool builder has defined for roughing operations.
- **`Tolerance for rotary axes:`** Permissible position error of rotary axes in degrees when M128 is active. The TNC always reduces the feed rate in such a way that—if more than one axis is traversed—the slowest axis moves at its maximum feed rate. Rotary axes are usually much slower than linear axes. You can significantly reduce the machining time for programs for more than one axis by entering a large tolerance value (e.g. 10°), since the TNC does not always have to move the rotary axis to the given nominal position. The contour will not be damaged by entering a tolerance value. Only the position of the rotary axis with respect to the workpiece surface will change.



9

Programming: Subprograms and Program Section Repeats

9.1 Labeling Subprograms and Program Section Repeats

Subprograms and program section repeats enable you to program a machining sequence once and then run it as often as desired.

Labels

The beginnings of subprograms and program section repeats are marked in a part program by labels.

A label is identified by a number between 1 and 254. Each label can be set only once with LABEL SET in a program.

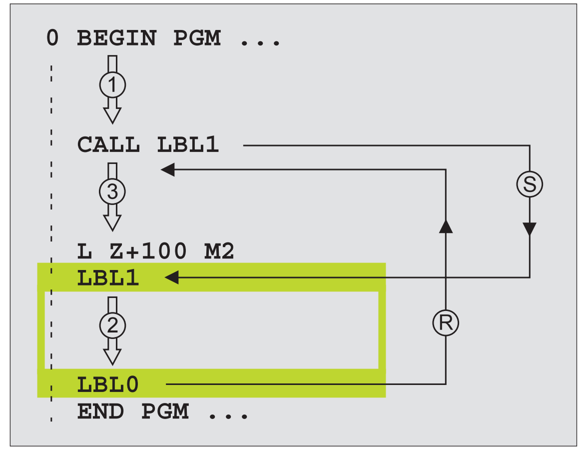
> If a label is set more than once, the TNC sends an error message at the end of the LBL SET block. With very long programs, you can limit the number of blocks to be checked for repeated labels with MP7229.

LABEL 0 (LBL 0) is used exclusively to mark the end of a subprogram and can therefore be used as often as desired.

9.2 Subprograms

Operating sequence

1. The TNC executes the part program up to the block in which a subprogram is called with CALL LBL.
2. The subprogram is then executed from beginning to end. The subprogram end is marked LBL 0.
3. The TNC then resumes the part program from the block after the subprogram call.



Programming notes

- A main program can contain up to 254 subprograms.
- You can call subprograms in any sequence and as often as desired.
- A subprogram cannot call itself.
- Write subprograms at the end of the main program (behind the block with M2 or M30).
- If subprograms are located before the block with M02 or M30, they will be executed at least once even if they are not called.

Programming a subprogram

LBL SET

- To mark the beginning, press the LBL SET key.
- Enter the subprogram number.
- To mark the end, press the LBL SET key and enter the label number "0".

Calling a subprogram

LBL CALL

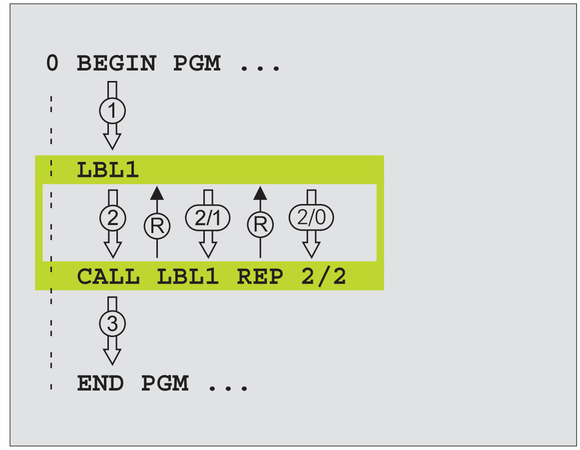
- To call a subprogram, press the LBL CALL key.
- **Label number:** Enter the label number of the subprogram you wish to call.
- **Repeat REP:** Ignore the dialog question with the NO ENT key. Repeat REP is used only for program section repeats.

> CALL LBL 0 is not permitted (Label 0 is only used to mark the end of a subprogram).

9.3 Program Section Repeats

Label LBL

The beginning of a program section repeat is marked by the label LBL. The end of a program section repeat is identified by CALL LBL /REP.



Operating sequence

1. The TNC executes the part program up to the end of the program section (CALL LBL /REP).
2. Then the program section between the called LBL and the label call is repeated the number of times entered after REP.
3. The TNC then resumes the part program after the last repetition.

Programming notes

- You can repeat a program section up to 65 534 times in succession.
- The number behind the slash after REP indicates the number of repetitions remaining to be run.
- The TNC always executes the program section once more than the programmed number of repeats.

Programming a program section repeat

LBL SET

- ▶ To mark the beginning, press the LBL SET key and enter a LABEL NUMBER for the program section you wish to repeat.
- ▶ Enter the program section.

Calling a program section repeat

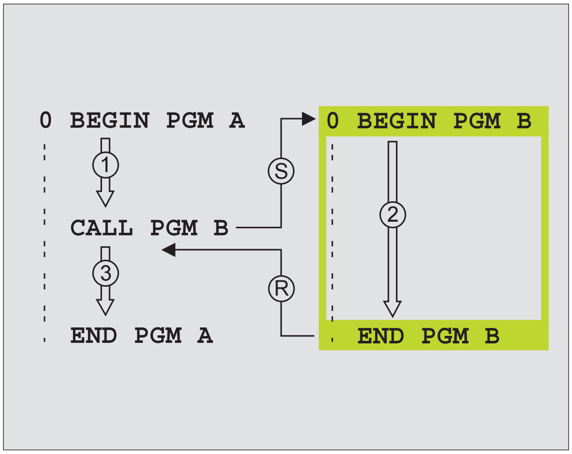
LBL CALL

- ▶ Press the LBL CALL key and enter the label number of the program section you want to repeat as well as the number of repeats (with Repeat REP).

9.4 Separate Program as Subprogram

Operating sequence

1 The TNC executes the part program up to the block in which another program is called with CALL PGM.
2 Then the other program is run from beginning to end.
3 The TNC then resumes the first (calling) part program with the block behind the program call.



Programming notes

- No labels are needed to call any program as a subprogram.
- The called program must not contain the miscellaneous functions M2 or M30.
- The called program must not contain a program call into the calling program, otherwise an infinite loop will result.

Calling any program as a subprogram

PGM CALL

▶ To select the functions for program call, press the PGM CALL key.

PROGRAM

▶ Press the PROGRAM soft key.

▶ Enter the complete path name of the program you want to call and confirm your entry with the END key.

> The program you are calling must be stored on the hard disk of your TNC.
>
> You need only enter the program name if the program you want to call is located in the same directory as the program you are calling it from.
>
> If the called program is not located in the same directory as the program you are calling it from, you must enter the complete path, e.g. TNC:\ZW35\ROUGH\PGM1.H
>
> If you want to call an ISO program, enter the file type .I after the program name.
>
> You can also call a program with Cycle 12 PGM CALL.

9.5 Nesting

Types of nesting

- Subprograms within a subprogram
- Program section repeats within a program section repeat
- Subprograms repeated
- Program section repeats within a subprogram

Nesting depth

The nesting depth is the number of successive levels in which program sections or subprograms can call further program sections or subprograms.

- Maximum nesting depth for subprograms: 8
- Maximum nesting depth for main program calls: 6, where a CYCL CALL acts like a main program call.
- You can nest program section repeats as often as desired.

Subprogram within a subprogram

Example NC blocks

0 BEGIN PGM UPGMS MM	
...	
17 CALL LBL 1	Call the subprogram marked with LBL 1
...	
35 L Z+100 R0 FMAX M2	Last program block of the
	main program (with M2)
36 LBL 1	Beginning of subprogram 1
...	
39 CALL LBL 2	Call the subprogram marked with LBL2
...	
45 LBL 0	End of subprogram 1
46 LBL 2	Beginning of subprogram 2
...	
62 LBL 0	End of subprogram 2
63 END PGM UPGMS MM	

Program execution

1. Main program UPGMS is executed up to block 17.
2. Subprogram 1 is called, and executed up to block 39.
3. Subprogram 2 is called, and executed up to block 62. End of subprogram 2 and return jump to the subprogram from which it was called.
4. Subprogram 1 is executed from block 40 up to block 45. End of subprogram 1 and return jump to the main program SUBPGMS.
5. Main program SUBPGMS is executed from block 18 up to block 35. Return jump to block 1 and end of program.

Repeating program section repeats

Example NC blocks

0 BEGIN PGM REPS MM	
...	
15 LBL 1	Beginning of program section repeat 1
...	
20 LBL 2	Beginning of program section repeat 2
...	
27 CALL LBL 2 REP 2/2	The program section between this block and LBL 2
...	(block 20) is repeated twice
35 CALL LBL 1 REP 1/1	The program section between this block and LBL 1
...	(block 15) is repeated once.
50 END PGM REPS MM	

Program execution

1. Main program REPS is executed up to block 27.
2. Program section between block 27 and block 20 is repeated twice.
3. Main program REPS is executed from block 28 to block 35.
4. Program section between block 35 and block 15 is repeated once (including the program section repeat between 20 and block 27).
5. Main program REPS is executed from block 36 to block 50 (end of program).

Repeating a subprogram

Example NC blocks

0 BEGIN PGM EPGREP MM	
...	
10 LBL 1	Beginning of program section repeat 1
11 CALL LBL 2	Subprogram call
12 CALL LBL 1 REP 2/2	The program section between this block and LBL1
...	(block 10) is repeated twice
19 L Z+100 R0 FMAX M2	Last block of the main program with M2
20 LBL 2	Beginning of subprogram
...	
28 LBL 0	End of subprogram
29 END PGM UPGREP MM	

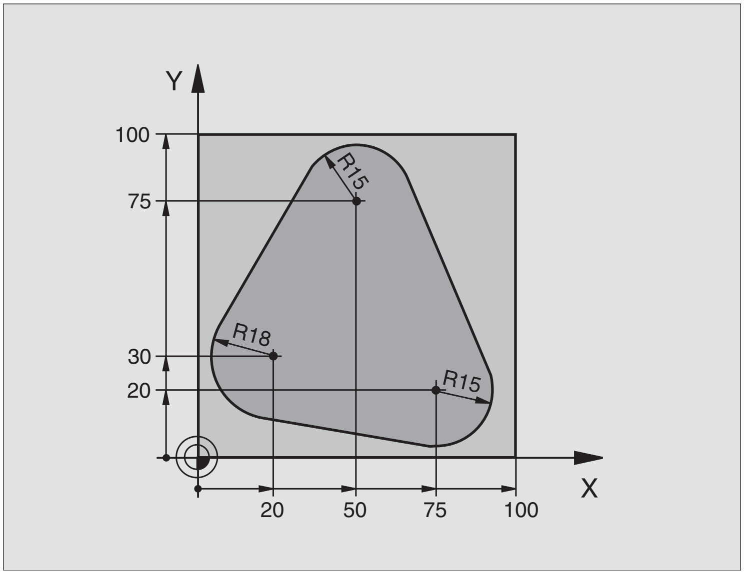
Program execution

1. Main program UPGREP is executed up to block 11.
2. Subprogram 2 is called and executed.
3. Program section between block 12 and block 10 is repeated twice. This means that subprogram 2 is repeated twice.
4. Main program UPGREP is executed from block 13 to block 19. End of program.

Example: Milling a contour in several infeeds

Program sequence

- Pre-position the tool to the workpiece surface
- Enter the infeed depth in incremental values
- Mill the contour
- Repeat downfeed and contour-milling



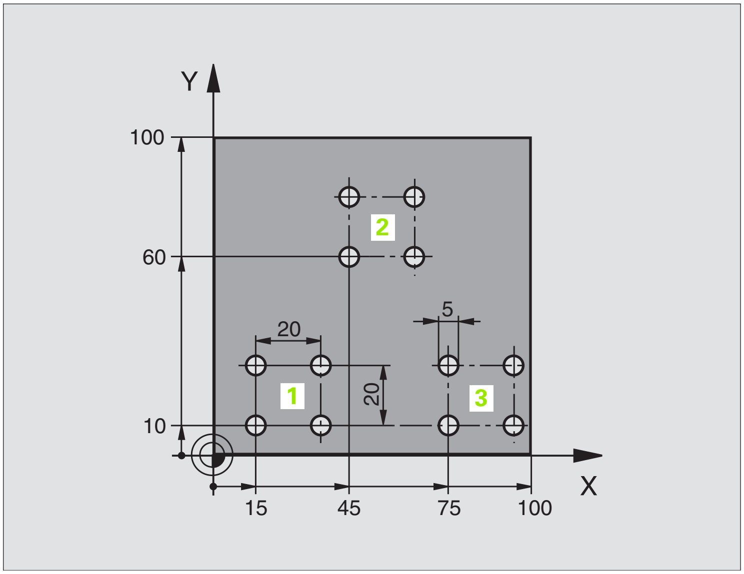
`0 BEGIN PGM PGMWDH MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-40`	
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	
`3 TOOL DEF 1 L+0 R+10`	Define the tool
`4 TOOL CALL 1 Z S500`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 L X-20 Y+30 R0 FMAX`	Pre-position in the working plane
`7 L Z+0 R0 FMAX M3`	Pre-position to the workpiece surface

`8 LBL 1`	Set label for program section repeat
`9 L IZ-4 R0 FMAX`	Infeed depth in incremental values (in the open)
`10 APPR CT X+2 Y+30 CCA90 R+5 RL F250`	Approach contour
`11 FC DR- R18 CLSD+ CCX+20 CCY+30`	Contour
`12 FLT`	
`13 FCT DR- R15 CCX+50 CCY+75`	
`14 FLT`	
`15 FCT DR- R15 CCX+75 CCY+20`	
`16 FLT`	
`17 FC DR- R18 CLSD+ CCX+20 CCY+30`	
`18 DEP CT CCA90 R+5 F1000`	Depart contour
`19 L X-20 Y+0 R0 FMAX`	Retract tool
`20 CALL LBL 1 REP 4/4`	Return jump to LBL 1; section is repeated a total of 4 times.
`21 L Z+250 R0 FMAX M2`	Retract in the tool axis, end program
`22 END PGM PGMWDH MM`	

Example: Groups of holes

Program sequence

- Approach the groups of holes in the main program
- Call the group of holes (subprogram 1)
- Program the group of holes only once in subprogram 1



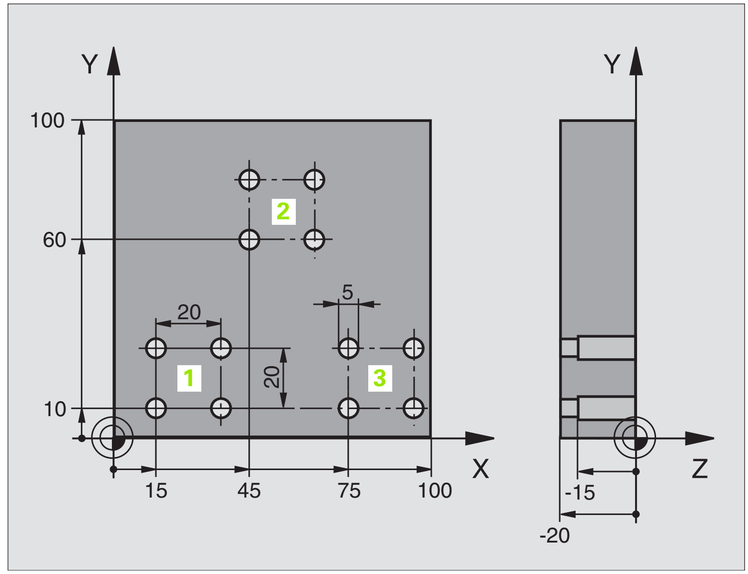
`0 BEGIN PGM UP1 MM`	
`1 BLK FORM 0.1 Z X+0 Y+0 Z-20`	
`2 BLK FORM 0.2 X+100 Y+100 Z+0`	
`3 TOOL DEF 1 L+0 R+2.5`	Define the tool
`4 TOOL CALL 1 Z S5000`	Tool call
`5 L Z+250 R0 FMAX`	Retract the tool
`6 CYCL DEF 200 DRILLING`	Cycle definition: drilling
`Q200=2 ;SAFETY CLEARANCE`	
`Q201=-10 ;DEPTH`	
`Q206=250 ;FEED RATE FOR PLNGNG`	
`Q202=5 ;INFEED DEPTH`	
`Q210=0 ;DWELL TIME AT TOP`	
`Q203=+0 ;SURFACE COORDINATE`	
`Q204=10 ;2. SET-UP CLEARANCE`	
`Q211=0.25 ;DWELL TIME AT DEPTH`	

`7 L X+15 Y+10 R0 FMAX M3`	Move to starting point for group 1
`8 CALL LBL 1`	Call the subprogram for the group
`9 L X+45 Y+60 R0 FMAX`	Move to starting point for group 2
`10 CALL LBL 1`	Call the subprogram for the group
`11 L X+75 Y+10 R0 FMAX`	Move to starting point for group 3
`12 CALL LBL 1`	Call the subprogram for the group
`13 L Z+250 R0 FMAX M2`	End of main program
`14 LBL 1`	Beginning of subprogram 1: Group of holes
`15 CYCL CALL`	Hole 1
`16 L IX.20 R0 FMAX M99`	Move to 2nd hole, call cycle
`17 L IY+20 R0 FMAX M99`	Move to 3rd hole, call cycle
`18 L IX-20 R0 FMAX M99`	Move to 4th hole, call cycle
`19 LBL 0`	End of subprogram 1
`20 END PGM UP1 MM`	

Example: Group of holes with several tools

Program sequence

- Program the fixed cycles in the main program
- Call the entire hole pattern (subprogram 1)
- Approach the groups of holes in subprogram 1, call group of holes (subprogram 2)
- Program the group of holes only once in subprogram 2



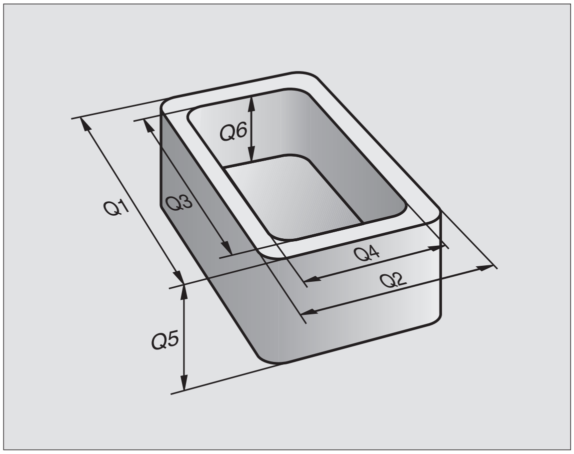
0 BEGIN PGM UP2 MM	
1 BLK FORM 0.1 Z X+0 Y+0 Z-20	
2 BLK FORM 0.2 X+100 Y+100 Z+0	
3 TOOL DEF 1 L+0 R+4	Define tool: center drill
4 TOOL DEF 2 L+0 R+3	Define tool: drill
5 TOOL DEF 2 L+0 R+3.5	Define tool: reamer
6 TOOL CALL 1 Z S5000	Call tool: center drill
7 L Z+250 R0 FMAX	Retract the tool
8 CYCL DEF 200 DRILLING	Cycle definition: Centering
Q200=2 ;SAFETY CLEARANCE	
Q202=-3 ;DEPTH	
Q206=250 ;FEED RATE FOR PLNGNG	
Q202=3 ;INFEED DEPTH	
Q210=0 ;DWELL TIME AT TOP	
Q203=+0 ;SURFACE COORDINATE	
Q204=10 ;2. SET-UP CLEARANCE	
Q211=0.25 ;DWELL TIME AT DEPTH	
9 CALL LBL 1	Call subprogram 1 for the entire hole pattern

10 L Z+250 R0 FMAX M6	Tool change
11 TOOL CALL 2 Z S4000	Call the drilling tool
12 FN 0: Q201 = -25	New depth for drilling
13 FN 0: Q202 = +5	New plunging depth for drilling
14 CALL LBL 1	Call subprogram 1 for the entire hole pattern
15 L Z+250 R0 FMAX M6	Tool change
16 TOOL CALL 3 Z S500	Tool call: reamer
17 CYCL DEF 201 REAMING	Cycle definition: REAMING
Q200=2 ;SAFETY CLEARANCE	
Q201=-15 ;DEPTH	
Q206=250 ;FEED RATE FOR PLNGNG	
Q211=0.5 ;DWELL TIME AT DEPTH	
Q208=400 ;RETRACTION FEED RATE	
Q203=+0 ;SURFACE COORDINATE	
Q204=10 ;2. SET-UP CLEARANCE	
18 CALL LBL 1	Call subprogram 1 for the entire hole pattern
19 L Z+250 R0 FMAX M2	End of main program
20 LBL 1	Beginning of subprogram 1: Entire hole pattern
21 L X+15 Y+10 R0 FMAX M3	Move to starting point for group 1
22 CALL LBL 2	Call subprogram 2 for the group
23 L X+45 Y+60 R0 FMAX	Move to starting point for group 2
24 CALL LBL 2	Call subprogram 2 for the group
25 L X+75 Y+10 R0 FMAX	Move to starting point for group 3
26 CALL LBL 2	Call subprogram 2 for the group
27 LBL 0	End of subprogram 1
28 LBL 2	Beginning of subprogram 2: Group of holes
29 CYCL CALL	1st hole with active fixed cycle
30 L 9X+20 R0 FMAX M99	Move to 2nd hole, call cycle
31 L IY+20 R0 FMAX M99	Move to 3rd hole, call cycle
32 L IX-20 R0 FMAX M99	Move to 4th hole, call cycle
33 LBL 0	End of subprogram 2
34 END PGM UP2 MM	

10

Programming: Q Parameters

10.1 Principle and Overview



You can program an entire family of parts in a single part program. You do this by entering variables called Q parameters instead of fixed numerical values.

Q parameters can represent information such as:

- Coordinate values
- Feed rates
- RPM
- Cycle data

Q parameters also enable you to program contours that are defined through mathematical functions. You can also use Q parameters to make the execution of machining steps depend on logical conditions. In conjunction with FK programming you can also combine contours that do not have NC-compatible dimensions with Q parameters.

Q parameters are designated by the letter Q and a number between 0 and 299. They are grouped according to three ranges:

Meaning	Range
Freely applicable parameter, globally effective for all programs stored in the TNC memory	Q0 to Q99
Parameters for special TNC functions	Q100 to Q199
Parameters that are primarily used for cycles, globally effective for all programs that are stored in the TNC memory	Q200 to Q399

Programming notes

You can mix Q parameters and fixed numerical values within a program.

Q parameters can be assigned numerical values between -99 999.9999 and +99 999.9999. Internally, the TNC can calculate up to a width of 57 bits before and 7 bits after the decimal point (32-bit data width corresponds to a decimal value of 4 294 967 296).

Some Q parameters are always assigned the same data by the TNC. For example, Q108 is always assigned the current tool radius; see "Preassigned Q Parameters," page 408. If you are using the parameters Q60 to Q99 in OEM cycles, define via MP7251 whether the parameters are only to be used locally in the OEM cycles, or may be used globally.

Calling Q parameter functions

When you are writing a part program, press the “Q” key (in the numeric keypad for numerical input and axis selection, below the +/– key). The TNC then displays the following soft keys:

Function group	Soft key
Basic arithmetic (assign, add, subtract, multiply, divide, square root)	BASIC ARITHM.
Trigonometric functions	TRIGO-NOMETRY
Function for calculating circles	CIRCLE CALCU-LATION
If/then conditions, jumps	JUMP
Other functions	DIVERSE FUNCTION
Entering formulas directly	FORMULA
Function for machining complex contours	CONTOUR FORMULA

10.2 Part Families—Q Parameters in Place of Numerical Values

The Q parameter function FN0: ASSIGN assigns numerical values to Q parameters. This enables you to use variables in the program instead of fixed numerical values.

Example NC blocks

`15 FN0: Q10=25`	Assign
`...`	Q10 contains the value 25
`25  L X +Q10`	Means L X +25

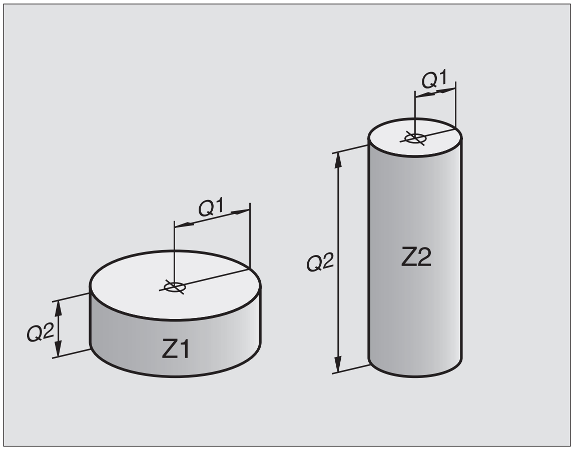
You need write only one program for a whole family of parts, entering the characteristic dimensions as Q parameters.

To program a particular part, you then assign the appropriate values to the individual Q parameters.

Example

Cylinder with Q parameters

Cylinder radius	R = Q1
Cylinder height	H = Q2
Cylinder Z1	Q1 = +30 Q2 = +10
Cylinder Z2	Q1 = +10 Q2 = +50



10.3 Describing Contours through Mathematical Operations

Function

The Q parameters listed below enable you to program basic mathematical functions in a part program:

- Select a Q parameter function: Press the Q key (in the numerical keypad at right). The Q parameter functions are displayed in a soft-key row.
- To select the mathematical functions: Press the BASIC ARITHMETIC soft key. The TNC then displays the following soft keys:

Overview

Function	Soft key
FN0: ASSIGN Example: **`FN0: Q5 = +60`** Assigns a numerical value.	FN0 X = Y
FN1: ADDITION Example: **`FN1: Q1 = –Q2 + –5`** Calculates and assigns the sum of two values.	FN1 X + Y
FN2: SUBTRACTION Example: **`FN2: Q1 = +10 – +5`** Calculates and assigns the difference of two values.	FN2 X - Y
FN3: MULTIPLICATION Example: **`FN3: Q2 = +3 * +3`** Calculates and assigns the product of two values.	FN3 X * Y
FN4: DIVISION Example: **`FN4: Q4 = +8 DIV +Q2`** Calculates and assigns the quotient of two values. Not permitted: division by 0	FN4 X / Y
FN5: SQUARE ROOT Example: **`FN5: Q20 = SQRT 4`** Calculates and assigns the square root of a number. **Not permitted:** Square root of a negative number	FN5 SQRT

To the right of the "=" character you can enter the following:

- Two numbers
- Two Q parameters
- A number and a Q parameter

The Q parameters and numerical values in the equations can be entered with positive or negative signs.

Programming fundamental operations

Example:

Q Call the Q parameter functions by pressing the Q key.

BASIC ARITHM. To select the mathematical functions: Press the BASIC ARITHMETIC soft key.

FN0 X = Y To select the Q parameter function ASSIGN, press the FN0 X = Y soft key.

PARAMETER NO. FOR RESULT?

5 ENT Enter the number of the Q parameter, e.g. 5.

1. VALUE OR PARAMETER ?

10 ENT Assign the value 10 to Q5.

Q Call the Q parameter functions by pressing the Q key.

BASIC ARITHM. To select the mathematical functions: Press the BASIC ARITHMETIC soft key.

FN3 X * Y To select the Q parameter function MULTIPLICATION, press the FN3 X * Y soft key.

PARAMETER NO. FOR RESULT?

12 ENT Enter the number of the Q parameter, e.g. 12.

1. VALUE OR PARAMETER ?

Q5 ENT Enter Q5 for the first value.

2. VALUE OR PARAMETER ?

7 ENT Enter 7 for the second value.

Example: Program blocks in the TNC

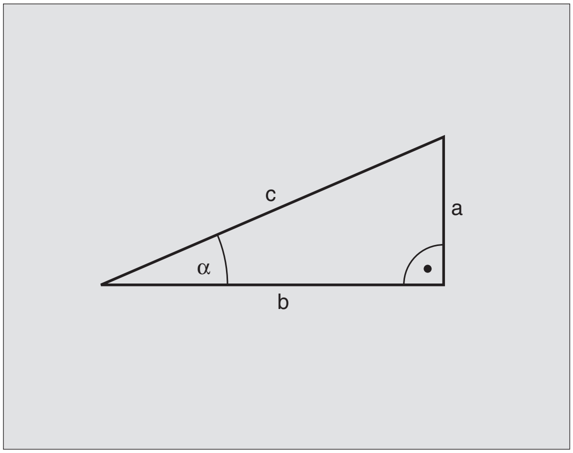
```
16 FN0: Q5 = +10
17 FN3: Q12 = +Q5 * +7
```

10.4 Trigonometric Functions

Definitions

Sine, cosine and tangent are terms designating the ratios of sides of right triangles. For a right triangle, the trigonometric functions of the angle a are defined by the following equations:

Sine: sin a = a / c
Cosine: cos a = b / c
Tangent: tan a = a / b = sin a / cos a



where

- c is the side opposite the right angle
- a is the side opposite the angle *a*
- b is the third side.

The TNC can find the angle from the tangent

a = arctan (a / b) = arctan (sin a / cos a)

Example:

a = 25 mm

b = 50 mm

a = arctan (a / b) = arctan 0.5 = 26.57°

Furthermore:

$a^2 + b^2 = c^2$ (where $a^2 = a \times a$)

$$c = \sqrt{(a^2 + b^2)}$$

Programming trigonometric functions

Press the ANGLE FUNCTION soft key to call the angle functions. The TNC then displays the following soft keys:

Programming: Compare "Example: Programming fundamental operations."

Function	Soft key
FN6: SINE Example: **`FN6: Q20 = SIN–Q5`** Calculate the sine of an angle in degrees (°) and assign it to a parameter.	FN6 SIN(X)
FN7: COSINE Example: **`FN7: Q21 = COS–Q5`** Calculate the cosine of an angle in degrees (°) and assign it to a parameter.	FN7 COS(X)
FN8: ROOT SUM OF SQUARES Example: **`FN8: Q10 = +5 LEN +4`** Calculate and assign length from two values.	FN8 X LEN Y
FN13: ANGLE Example: **`FN13: Q20 = +25 ANG–Q1`** Calculate the angle from the arc tangent of two sides or from the sine and cosine of the angle (0 < angle < 360°) and assign it to a parameter.	FN13 X ANG Y

10.5 Calculating Circles

Function

The TNC can use the functions for calculating circles to calculate the circle center and the circle radius from three or four given points on the circle. The calculation is more accurate if four points are used.

Application: These functions can be used if you wish to determine the location and size of a bore hole or a pitch circle using the programmable probing function.

Function	Soft key
FN23: Determining the CIRCLE DATA from three points Example: **FN23: Q20 = CDATA Q30**	FN23 3 POINTS OF CIRCLE

The coordinate pairs for three points of the circle must be stored in Parameter Q30 and in the following five parameters – here to Q35.

The TNC then stores the circle center of the reference axis (X with spindle axis Z) in Parameter Q20, the circle center of the minor axis (Y with spindle axis Z) in Parameter Q21 and the circle radius in Parameter Q22.

Function	Soft key
FN24: Determining the CIRCLE DATA from four points Example: **FN24: Q20 = CDATA Q30**	FN24 4 POINTS OF CIRCLE

The coordinate pairs for four points of the circle must be stored in Parameter Q30 and in the following seven parameters – here to Q37.

The TNC then stores the circle center of the reference axis (X with spindle axis Z) in Parameter Q20, the circle center of the minor axis (Y with spindle axis Z) in Parameter Q21 and the circle radius in Parameter Q22.

Note that FN23 and FN24 beside the resulting parameter also overwrite the two following parameters.

10.6 If-Then Decisions with Q Parameters

Function

The TNC can make logical If-Then decisions by comparing a Q parameter with another Q parameter or with a numerical value. If the condition is fulfilled, the TNC continues the program at the label that is programmed after the condition (for information on labels, see "Labeling Subprograms and Program Section Repeats," page 362). If it is not fulfilled, the TNC continues with the next block.

To call another program as a subprogram, enter PGM CALL after the block with the target label.

Unconditional jumps

An unconditional jump is programmed by entering a conditional jump whose condition is always true. Example:

FN9: IF+10 EQU+10 GOTO LBL1

Programming If-Then decisions

Press the SPRÜNGE soft key to call the if-then conditions. The TNC then displays the following soft keys:

Function	Soft key
FN9: IF EQUAL, JUMP Example: **`FN9: IF +Q1 EQU +Q3 GOTO LBL 5`** If the two values or parameters are equal, jump to the given label.	FN9 IF X EQ Y GOTO
FN10: IF NOT EQUAL, JUMP Example: **`FN10: IF +10 NE –Q5 GOTO LBL 10`** If the two values or parameters are not equal, jump to the given label.	FN10 IF X NE Y GOTO
FN11: IF GREATER THAN, JUMP Example: **`FN11: IF+Q1 GT+10 GOTO LBL 5`** If the first parameter or value is greater than the second value or parameter, jump to the given label.	FN11 IF X GT Y GOTO
FN12: IF LESS THAN, JUMP Example: **`FN12: IF+Q5 LT+0 GOTO LBL 1`** If the first value or parameter is less than the second value or parameter, jump to the given label.	FN12 IF X LT Y GOTO

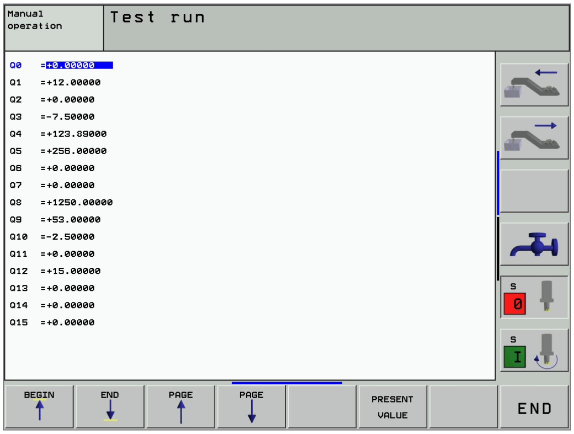
Abbreviations used:

IF	:	If
EQU	:	Equals
NE	:	Not equal
GT	:	Greater than
LT	:	Less than
GOTO	:	Go to

10.7 Checking and Changing Q Parameters

Procedure

You can check and edit Q parameters when writing, testing and running programs in the Programming and Editing, Test Run, Program Run Full Sequence, and Program Run Single Block modes.



- If you are in a program run, interrupt it if required (for example by pressing the machine STOP button and the INTERNAL STOP soft key). If you are doing a test run, interrupt it.

Q

- To call Q parameter functions: Press the Q key or the Q INFO soft key in the Programming and Editing mode of operation.
- The TNC lists all parameters and their current values. With the arrow keys or the soft keys, go pagewise to the desired parameters.
- If you would like to change the value, enter a new value and confirm with the ENT key.
- To leave the value unchanged, press the PRESENT VALUE soft key or end the dialog with the END key.

The parameters (parameter numbers > 100) used by the TNC are provided with comments.

10.8 Additional Functions

Overview

Press the DIVERSE FUNCTION soft key to call the additional functions. The TNC then displays the following soft keys:

Function	Soft key
FN14:ERROR Output error messages	FN14 ERROR=
FN15:PRINT Unformatted output of texts or Q parameter values	FN15 PRINT
FN16:F-PRINT Formatted output of texts or Q parameter values	FN16 F-PRINT
FN18:SYS-DATUM READ Read system data	FN18 SYS-DATUM READ
FN19:PLC Transfer values to the PLC	FN19 PLC=
FN20:WAIT FOR Synchronize NC and PLC	FN20 WAIT FOR
FN25:PRESET Set datum during program run	FN25 SET DATUM
FN26:TABOPEN Open a freely definable table	FN26 OPEN TABLE
FN27:TABWRITE Write to a freely definable table	FN27 WRITE TO TABLE
FN28:TABREAD Read from a freely definable table	FN28 READ FROM TABLE

FN14: ERROR: Displaying error messages

With the function FN14: ERROR you can call messages under program control. The messages were programmed by the machine tool builder or by HEIDENHAIN. Whenever the TNC comes to a block with FN 14 in the Program Run or Test Run mode, the interrupts the program run and displays a message. The program must then be restarted. The error numbers are listed in the table below.

Range of error numbers	Standard dialog text
0 ... 299	FN 14: Error code 0 299
300 ... 999	Machine-dependent dialog
1000 ... 1099	Internal error messages (see table at right)

Example NC block

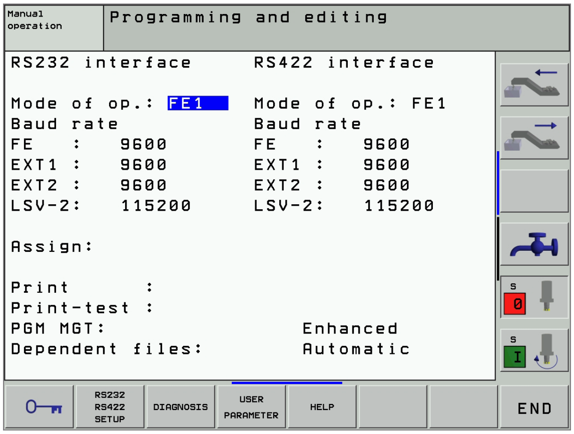
The TNC is to display the text stored under error number 254:

```
180 FN14: ERROR = 254
```

Error number	Text
1000	Spindle ?
1001	Tool axis is missing
1002	Slot width too large
1003	Tool radius too large
1004	Range exceeded
1005	Start position incorrect
1006	ROTATION not permitted
1007	SCALING FACTOR not permitted
1008	MIRRORING not permitted
1009	Datum shift not permitted
1010	Feed rate is missing
1011	Entry value incorrect
1012	Wrong sign programmed
1013	Entered angle not permitted
1014	Touch point inaccessible
1015	Too many points
1016	Contradictory entry
1017	CYCL incomplete
1018	Plane wrongly defined
1019	Wrong axis programmed
1020	Wrong RPM
1021	Radius comp. undefined
1022	Rounding-off undefined
1023	Rounding radius too large
1024	Program start undefined
1025	Excessive subprogramming
1026	Angle reference missing
1027	No fixed cycle defined
1028	Slot width too small
1029	Pocket too small
1030	Q202 not defined
1031	Q205 not defined
1032	Enter Q218 greater than Q219
1033	CYCL 210 not permitted
1034	CYCL 211 not permitted
1035	Q220 too large
1036	Enter Q222 greater than Q223
1037	Q244 must be greater than 0
1038	Q245 must not equal Q246
1039	Angle range must be < 360°
1040	Enter Q223 greater than Q222
1041	Q214: 0 not permitted

Error number	Text
1042	Traverse direction not defined
1043	No datum table active
1044	Position error: center in axis 1
1045	Position error: center in axis 2
1046	Hole diameter too small
1047	Hole diameter too large
1048	Stud diameter too small
1049	Stud diameter too large
1050	Pocket too small: rework axis 1
1051	Pocket too small: rework axis 2
1052	Pocket too large: scrap axis 1
1053	Pocket too large: scrap axis 2
1054	Stud too small: scrap axis 1
1055	Stud too small: scrap axis 2
1056	Stud too large: rework axis 1
1057	Stud too large: rework axis 2
1058	TCHPROBE 425: length exceeds max
1059	TCHPROBE 425: length below min
1060	TCHPROBE 426: length exceeds max
1061	TCHPROBE 426: length below min
1062	TCHPROBE 430: diameter too large
1063	TCHPROBE 430: diameter too small
1064	No measuring axis defined
1065	Tool breakage tolerance exceeded
1066	Enter Q247 unequal 0
1067	Enter Q247 greater than 5
1068	Datum table?
1069	Enter direction Q351 unequal 0
1070	Thread depth too large
1071	Missing calibration data
1072	Tolerance exceeded
1073	Block scan active
1074	ORIENTATION not permitted
1075	3DROT not permitted
1076	Activate 3DROT
1077	Enter depth as a negative value
1078	Q303 not defined in measuring cycle
1079	Tool axis not allowed
1080	Calculated values incorrect
1081	Contradictory measuring points

FN15: PRINT: Output of texts or Q parameter values



> Setting the data interface: In the menu option PRINT or PRINT-TEST, you must enter the path for storing the texts or Q parameters. See "Assign," page 447.

The function FN15: PRINT transfers Q parameter values and error messages through the data interface, for example to a printer. When you save the data in the TNC memory or transfer them to a PC, the TNC stores the data in the file %FN 15RUN.A (output in program run mode) or in the file %FN15SIM.A (output in test run mode).

The data are transmitted from a buffer. Data output begins at the latest by program end or when you stop the program. In the Single Block mode of operation, data transfer begins at block end.

To output dialog texts and error messages with FN 15: PRINT "numerical value"

Numerical values from 0 to 99:	Dialog texts for OEM cycles
Numerical values exceeding 100:	PLC Error Messages

Example: Output of dialog text 20

```
67 FN15: PRINT 20
```

Outputting dialog texts and Q parameters with FN15: PRINT "Q parameter"

Application example: Recording workpiece measurement.

You can transfer up to six Q parameters and numerical values simultaneously. The TNC separates them with slashes.

Example: Output of dialog text 1 and numerical value for Q1

```
70 FN15: PRINT1/Q1
```

FN16: F-PRINT: Formatted output of texts or Q parameter values

Setting the data interface: In the menu option PRINT or PRINT-TEST, you must enter the path for storing the text file. See “Assign,” page 447.

The function FN16: F-PRINT transfers Q parameter values and texts in a selectable format through the data interface, for example to a printer. If you save the values internally or send them to a computer, the TNC saves the data in the file that you defined in the FN 16 block.

To output the formatted texts and Q parameter values, create a text file with the TNC’s text editor. In this file, you then define the output format and Q parameters you want to output.

Example of a text file to define the output format:

“TEST RECORD IMPELLER CENTER OF GRAVITY”;

```
"DATE: %02.2d-%02.2d-%4d",DAY,MONTH,YEAR4;

"TIME: %2d:%02.2d:%02.2d",HOUR,MIN,SEC;"

"________________________"

"NO. OF MEASURED VALUES : = 1";

"*******************************************";#

"X1 = %5.3LF", Q31;

"Y1 = %5.3LF", Q32;
```

“Z1 = %5.3LF”, Q33;

```
"*******************************************";
```

When you create a text file, use the following formatting functions:

Special character	Function
“...........“	Define output format for texts and variables between the quotation marks
%5.3LF	Define format for Q parameter: 5 places before and 4 places behind the decimal point; long, floating (decimal number)
%S	Format for text variable
,	Separation character between output format and parameter
;	End of block character

The following functions allow you to include the following additional information in the protocol log file:

Code word	Function
CALL_PATH	Gives the path for the NC program where you will find the FN16 function. Example: "Measuring program: %S",CALL_PATH;
M_CLOSE	Closes the file to which you are writing with FN16. Example: M_CLOSE;
L_ENGLISH	Display the text only in English conversational language
L_GERMAN	Display the text only in German conversational language
L_CZECH	Display text only in Czech conversational language
L_FRENCH	Display text only in French conversational language
L_ITALIAN	Display text only in Italian conversational language
L_SPANISH	Display text only in Spanish conversational language
L_SWEDISH	Output text only in Swedish conversational language
L_DANISH	Display text only in Danish conversational language
L_FINNISH	Display text only in Finnish conversational language
L_DUTCH	Display the text only in Dutch conversational language
L_POLISH	Display text only in Polish conversational language
L_HUNGARIA	Display text only in Hungarian conversational language
L_ALL	Display the text independent of the conversational language
HOUR	Number of hours from the real-time clock
MIN	Number of minutes from the real-time clock
SEC	Number of seconds from the real-time clock
DAY	Day from the real-time clock
MONTH	Month as a number from the real-time clock
STR_MONTH	Month as a string abbreviation from the real-time clock
YEAR2	Two-digit year from the real-time clock
YEAR4	Four-digit year from the real-time clock

In the part program, program FN 16: F-PRINT, to activate the output:

```
96 FN16: F-PRINT TNC:\MASKE\MASKE1.A/RS232:\PROT1.TXT
```

The TNC then outputs the file PROT1.TXT through the serial interface:

CALIBRAT. CHART IMPELLER CENTER GRAVITY

DATE: 27:11:2001

TIME: 8:56:34

NO. OF MEASURED VALUES : = 1

****

X1 = 149.360

Y1 = 25.509

Z1 = 37.000

****

If you use FN 16 several times in the program, the TNC saves all texts in the file that you have defined with the first FN 16 function. The file is not output until the TNC reads the END PGM block, or you press the NC stop button, or you close the file with M_CLOSE.

In the FN16 block, program the format file and the log file with their respective extensions.

FN18: SYS-DATUM READ Read system data

With the function FN 18: SYS-DATUM READ you can read system data and store them in Q parameters. You select the system data through a group number (ID number), and additionally through a number and an index.

Group name, ID No.	Number	Index	Meaning
Program information, 10	1	-	MM/inch condition
	2	-	Overlap factor for pocket milling
	3	-	Number of active fixed cycle
Machine status, 20	1	-	Active tool number
	2	-	Prepared tool number
	3	-	Active tool axis 0=X, 1=Y, 2=Z, 6=U, 7=V, 8=W
	4	-	Programmed spindle rpm
	5	-	Active spindle status: -1=undefined, 0=M3 active, 1=M4 active, 2=M5 after M3, 3=M5 after M4

Group name, ID No.	Number	Index	Meaning
	8	-	Coolant status: 0=off, 1=on
	9	-	Active feed rate
	10	-	Index of the prepared tool
	11	-	Index of the active tool
Cycle parameter, 30	1	-	Setup clearance of active fixed cycle
	2	-	Drilling depth / milling depth of active fixed cycle
	3	-	Plunging depth of active fixed cycle
	4	-	Feed rate for pecking in active fixed cycle
	5	-	1. side length for rectangular pocket cycle
	6	-	2. side length for rectangular pocket cycle
	7	-	1. side length for slot cycle
	8	-	2. side length for slot cycle
	9	-	Radius for circular pocket cycle
	10	-	Feed rate for milling in active fixed cycle
	11	-	Direction of rotation for active fixed cycle
	12	-	Dwell time for active fixed cycle
	13	-	Thread pitch for Cycles 17, 18
	14	-	Milling allowance for active fixed cycle
	15	-	Direction angle for rough out in active fixed cycle
Data from the tool table, 50	1	Tool no.	Tool length
	2	Tool no.	Tool radius
	3	Tool no.	Tool radius R2
	4	Tool no.	Oversize for tool length DL
	5	Tool no.	Oversize for tool radius DR
	6	Tool no.	Oversize for tool radius DR2
	7	Tool no.	Tool inhibited (0 or 1)
	8	Tool no.	Number of replacement tool
	9	Tool no.	Maximum tool age TIME1
	10	Tool no.	Maximum tool age TIME2

Group name, ID No.	Number	Index	Meaning
	11	Tool no.	Current tool age CUR. TIME
	12	Tool no.	PLC status
	13	Tool no.	Maximum tooth length LCUTS
	14	Tool no.	Maximum plunge angle ANGLE
	15	Tool no.	TT: Number of teeth CUT
	16	Tool no.	TT: Wear tolerance for length LTOL
	17	Tool no.	TT: Wear tolerance for radius RTOL
	18	Tool no.	TT: Rotational direction DIRECT (0=positive/-1=negative)
	19	Tool no.	TT: Offset for radius R-OFFS
	20	Tool no.	TT: Offset for length L-OFFS
	21	Tool no.	TT: Breakage tolerance in length LBREAK
	22	Tool no.	TT: Breakage tolerance in radius RBREAK
	No index: Data of the currently active tool		
Pocket table data, 51	1	Pocket number	Tool number
	2	Pocket number	Special tool: 0=no, 1=yes
	3	Pocket number	Fixed pocket: 0=no, 1=yes
	4	Pocket number	Locked pocket: 0=no, 1=yes
	5	Pocket number	PLC status
Pocket number of a tool in the tool-pocket table, 52	1	Tool no.	Pocket number
Immediately after TOOL CALL programmed position, 70	1	-	Position valid / invalid (1/0)
	2	1	X axis
	2	2	Y axis
	2	3	Z axis
	3	-	Programmed feed rate (-1: no feed rate programmed)
Active tool compensation, 200	1	-	Tool radius (including delta values)
	2	-	Tool length (including delta values)

Group name, ID No.	Number	Index	Meaning
Active transformations, 210	1	-	Basic rotation in MANUAL OPERATION mode
	2	-	Programmed rotation with Cycle 10
	3	-	Active mirror axis
			0: mirroring not active
			+1: X axis mirrored
			+2: Y axis mirrored
			+4: Z axis mirrored
			+64: U axis mirrored
			+128: V axis mirrored
			+256: W axis mirrored
			Combinations = sum of individual axes
	4	1	Active scaling factor in X axis
	4	2	Active scaling factor in Y axis
	4	3	Active scaling factor in Z axis
	4	7	Active scaling factor in U axis
	4	8	Active scaling factor in V axis
	4	9	Active scaling factor in W axis
	5	1	3D ROT A axis
	5	2	3D ROT B axis
	5	3	3D ROT C axis
	6	-	Tilted working plane active / inactive (-1/0) in a program run operating mode
	7	-	Tilted working plane active / inactive (-1/0) in a manual operating mode
Active datum shift, 220	2	1	X axis
		2	Y axis
		3	Z axis
		4	A axis
		5	B axis
		6	C axis

Group name, ID No.	Number	Index	Meaning
		7	U axis
		8	V axis
		9	W axis
Traverse range, 230	2	1 to 9	Negative software limit switch in axes 1 to 9
	3	1 to 9	Positive software limit switch in axes 1 to 9
Nominal position in the REF system, 240	1	1	X axis
		2	Y axis
		3	Z axis
		4	A axis
		5	B axis
		6	C axis
		7	U axis
		8	V axis
		9	W axis
Nominal positions in the input system, 270	1	1	X axis
		2	Y axis
		3	Z axis
		4	A axis
		5	B axis
		6	C axis
		7	U axis
		8	V axis
		9	W axis
Status of M128, 280	1	-	0: M128 inactive, -1: M128 active
	2	-	Feed rate that was programmed with M128
Triggering touch probe, 350	10	-	Touch probe axis
	11	-	Effective ball radius
	12	-	Effective length
	13	-	Radius setting ring

Group name, ID No.	Number	Index	Meaning
	14	1	Center misalignment in ref. axis
		2	Center misalignment in minor axis
	15	-	Direction of center misalignment compared with 0° position
Tool touch probe 130	20	1	Center point X-axis (REF system)
		2	Center point Y-axis (REF system)
		3	Center point Z axis (REF system)
	21	-	Probe contact radius
Measuring touch probe, 350	30	-	Calibrated stylus length
	31	-	Stylus radius 1
	32	-	Stylus radius 2
	33	-	Setting ring diameter
	34	1	Center misalignment in ref. axis
		2	Center misalignment in minor axis
	35	1	Compensation factor for 1st axis
		2	Compensation factor for 2nd axis
		3	Compensation factor for 3rd axis
	36	1	Power ratio for 1st axis
		2	Power ratio for 2nd axis
		3	Power ratio for 3rd axis
Last touch point in TCH PROBE Cycle 0 or last touch point from manual operating mode, 360	1	1 to 9	Position in the active coordinate system in axes 1 to 9
	2	1 to 9	Position in the REF system in axes 1 to 9
Value from the active datum table in the active coordinate system, 500	Datum number	1 to 9	X axis to W axis
REF value from the active datum table, 501	Datum number	1 to 9	X axis to W axis
Datum table selected, 505	1	-	Acknowledgement value = 0: No datum table active Return code = 1: Datum table active
Data from the active pallet table, 510	1	-	Active line
	2	-	Palette number from PAL/PGM field

Group name, ID No.	Number	Index	Meaning
Machine parameter exists, 1010	MP number	MP index	Acknowledgement value = 0: MP does not exist Return code = 1: MP exists

Example: Assign the value of the active scaling factor for the Z axis to Q25

```
55 FN18: SYSREAD Q25 = ID210 NR4 IDX3
```

FN19: PLC: Transferring values to the PLC

The function FN 19: PLC transfers up to two numerical values or Q parameters to the PLC.

Increments and units: 0.1 µm or 0.0001°

Example: Transfer the numerical value 10 (which means 1 µm or 0.001°) to the PLC

```
56 FN19: PLC=+10/+Q3
```

FN20: WAIT FOR: NC and PLC synchronization

This function may only be used with the permission of your machine tool builder.

With function FN 20: WAIT FOR you can synchronize the NC and PLC with each other during a program run. The NC stops machining until the condition that you have programmed in the FN 20 block is fulfilled. With FN20 the TNC can check the following operands:

PLC Operand	Abbreviation	Address range
Marker	M	0 to 4999
Input	I	0 to 31, 128 to 152 64 to 126 (first PL 401 B) 192 to 254 (second PL 401 B)
Output	O	0 to 30 32 to 62 (first PL 401 B) 64 to 94 (second PL 401 B)
Counter	C	48 to 79
Timer	T	0 to 95
Byte	B	0 to 4095
Word	W	0 to 2047
Double word	D	2048 to 4095

The following conditions are permitted in the FN 20 block:

Condition	Abbreviation
Equals	==
Less than	<
Greater than	>
Less than or equal	<=
Greater than or equal	>=

Example: Stop program run until the PLC sets marker 4095 to 1

```
32 FN20: WAIT FOR M4095==1
```

FN25: PRESET: Setting a new datum

> This function can only be programmed if you have entered the code number 555343, see "Code Numbers," page 445.

With the function FN 25: PRESET, it is possible to set a new datum in an axis of choice during program run.

- Select a Q parameter function: Press the Q key (in the numerical keypad at right). The Q parameter functions are displayed in a soft-key row.
- To select the additional functions, press the DIVERSE FUNCTIONS soft key.
- Select FN25: Switch the soft-key row to the second level, press the FN25 DATUM SET soft key
- **Axis?:** Enter the axis where you wish to set the new datum and confirm with ENT
- **Value to be calculated?:** Enter the coordinate for the new datum point in the active coordinate system
- **New datum?:** Enter the value that the new datum point will have in the new coordinate system

Example: Set a new datum at the current coordinate X+100

```
56 FN25: PRESET = X/+100/+0
```

Example: The current coordinate Z+50 will have the value -20 in the new coordinate system

```
56 FN25: PRESET = Z/+50/-20
```

FN26: TABOPEN: Opening a Freely Definable Table

With FN 26: TABOPEN you can define a table to be written with FN27, or to be read from with FN28.

> Only one table can be open in an NC program. A new block with TABOPEN automatically closes the last opened table.
>
> The table to be opened must have the file name extension .TAB.

.Example: Open the table TAB1.TAB, which is save in the directory TNC:\DIR1.

```
56 FN26: TABOPEN TNC:\DIR1\TAB1.TAB
```

FN27: TABWRITE: writing to a freely definable table

After you have opened a table with FN 26 TABOPEN, you can use function FN 27: TABWRITE to write to it.

You can define and write up to 8 column names in a TABWRITE block. The column names must be written between quotation marks and separated by a comma. You define the values that the TNC is to write to the respective column with Q parameters.

> You can write only to numerical table fields.
>
> If you wish to write to more than one column in a block, you must save the values under successive Q parameter numbers.

Example:

You wish to write to the columns “Radius,” “Depth” and “D” in line 5 of the presently opened table. The values to be written in the table must be saved in the Q parameters Q5, Q6 and Q7.

```
53 FN0: Q5 = 3.75
54 FN0: Q6 = -5
55 FN0: Q7 = 7.5
56 FN27: TABWRITE 5/"RADIUS,DEPTH,D" = Q5
```

FN28: TABREAD: Reading a Freely Definable Table

After you have opened a table with FN 26 TABOPEN, you can use function FN 28: TABREAD to read from it.

You can define, i.e. read in, up to 8 column names in a TABREAD block. The column names must be written between quotation marks and separated by a comma. In the FN 28 block you can define the Q parameter number in which the TNC is to write the value that is first read.

You can read only numerical table fields.

If you wish to read from more than one column in a block, the TNC will save the values under successive Q parameter numbers.

Example:

You wish to read the values of the columns "Radius," "Depth" and "D" from line 6 of the presently opened table. Save the first value in Q parameter Q10 (second value in Q11, third value in Q12).

```
56 FN28: TABREAD Q10 = 6/"RADIUS,DEPTH,D"
```

10.9 Entering Formulas Directly

Entering formulas

You can enter mathematical formulas that include several operations directly into the part program by soft key.

Press the FORMULA soft key to call the formula functions. The TNC displays the following soft keys in several soft-key rows:

Logic command	Soft key
Addition Example: **Q10 = Q1 + Q5**	+
Subtraction Example: **Q25 = Q7 – Q108**	-
Multiplication Example: **Q12 = 5 * Q5**	*
Division Example: **Q25 = Q1 / Q2**	/
Opening parenthesis Example: **Q12 = Q1 * (Q2 + Q3)**	(
Closing parenthesis Example: **Q12 = Q1 * (Q2 + Q3)**	)
Square of a value Example: **Q15 = SQ 5**	SQ
Square root Example: **Q22 = SQRT 25**	SQRT
Sine of an angle Example: **Q44 = SIN 45**	SIN
Cosine of an angle Example: **Q45 = COS 45**	COS
Tangent of an angle Example: **Q46 = TAN 45**	TAN
Arc sine Inverse of the sine. Determine the angle from the ratio of the opposite side to the hypotenuse. Example: **Q10 = ASIN 0.75**	ASIN
Arc cosine Inverse of the cosine. Determine the angle from the ratio of the adjacent side to the hypotenuse. Example: **Q11 = ACOS Q40**	ACOS

Logic command	Soft key
Arc tangent Inverse of the tangent. Determine the angle from the ratio of the opposite to the adjacent side. Example: **`Q12 = ATAN Q50`**	ATAN
Powers of values Example: **`Q15 = 3^3`**	^
Constant "pi" (3.14159) Example: **`Q15 = PI`**	PI
Natural logarithm (LN) of a number Base 2.7183 Example: **`Q15 = LN Q11`**	LN
Logarithm of a number, base 10 Example: **`Q33 = LOG Q22`**	LOG
Exponential function, 2.7183 to the power of n Example: **`Q1 = EXP Q12`**	EXP
Negate (multiplication by -1) Example: **`Q2 = NEG Q1`**	NEG
Truncate decimal places (form an integer) Example: **`Q3 = INT Q42`**	INT
Absolute value of a number Example: **`Q4 = ABS Q22`**	ABS
Truncate places before the decimal point (form a fraction) Example: **`Q5 = FRAC Q23`**	FRAC
Check algebraic sign of a number Example: **`Q12 = SGN Q50`** If result for Q12 = 1: Q50 >= 0 If result for Q12 = 0: Q50 < 0	SGN
Calculate modulo value Example: **`Q12 = 400 % 360`** Result: Q12 = 40	%

Rules for formulas

Mathematical formulas are programmed according to the following rules:

Higher-level operations are performed first (multiplication and division before addition and subtraction)

```
12  Q1 = 5 * 3 + 2 * 10 = 35
```

1st step 5 * 3 = 15
2nd step 2 * 10 = 20
3rd step 15 +20 = 35

or

```
13  Q2 = SQ 10 - 3^3 = 73
```

1st step 10 squared = 100
2nd step 3 to the power of 3 = 27
3rd step 100 – 27 = 73

Distributive law
for calculating with parentheses

a * (b + c) = a * b + a * c

Programming example

Calculate an angle with the arc tangent from the opposite side (Q12) and adjacent side (Q13); then store in Q25.

Q FORMULA To select the formula entering function, press the Q key and FORMULA soft key.

PARAMETER NO. FOR RESULT?

ENT 25 Enter the parameter number.

▷ ATAN Shift the soft-key row and select the arc tangent function.

◁ (Shift the soft-key row and open the parentheses.

Q 12 Enter Q parameter number 12.

/ Select division.

Q 13 Enter Q parameter number 13.

) END Close parentheses and conclude formula entry.

Example NC block

```
37  Q25 = ATAN (Q12/Q13)
```

10.10 Preassigned Q Parameters

The Q parameters Q100 to Q122 are assigned values by the TNC. These values include:

- Values from the PLC
- Tool and spindle data
- Data on operating status, etc.

Values from the PLC: Q100 to Q107

The TNC uses the parameters Q100 to Q107 to transfer values from the PLC to an NC program.

Active tool radius: Q108

The active value of the tool radius is assigned to Q108. Q108 is calculated from:

- Tool radius R (Tool table or TOOL DEF block)
- Delta value DR from the tool table
- Delta value DR from the TOOL CALL block

Tool axis: Q109

The value of Q109 depends on the current tool axis:

Tool axis	Parameter value
No tool axis defined	Q109 = -1
X axis	Q109 = 0
Y axis	Q109 = 1
Z axis	Q109 = 2
U axis	Q109 = 6
V axis	Q109 = 7
W axis	Q109 = 8

Spindle status: Q110

The value of Q110 depends on which M function was last programmed for the spindle:

M Function	Parameter value
No spindle status defined	Q110 = -1
M03: Spindle ON, clockwise	Q110 = 0
M04: Spindle ON, counterclockwise	Q110 = 1
M05 after M03	Q110 = 2
M05 after M04	Q110 = 3

Coolant on/off: Q111

M Function	Parameter value
M08: Coolant ON	Q111 = 1
M09: Coolant OFF	Q111 = 0

Overlap factor: Q112

The overlap factor for pocket milling (MP7430) is assigned to Q112.

Unit of measurement for dimensions in the program: Q113

The value of parameter Q113 specifies whether the highest-level NC program (for nesting with PGM CALL) is programmed in millimeters or inches.

Dimensions of the main program	Parameter value
Metric system (mm)	Q113 = 0
Inch system (inches)	Q113 = 1

Tool length: Q114

The current value for the tool length is assigned to Q114.

Coordinates after probing during program run

The parameters Q115 to Q119 contain the coordinates of the spindle position at the moment of contact during programmed measurement with the 3-D touch probe. The coordinates are referenced to the datum that is currently active in the Manual operating mode.

The length and radius of the probe tip are not compensated in these coordinates.

Coordinate axis	Parameter value
X axis	Q115
Y axis	Q116
Z axis	Q117
IVth axis dependent on MP100	Q118
Vth axis dependent on MP100	Q119

Deviation between actual value and nominal value during automatic tool measurement with the TT 130

Actual-nominal deviation	Parameter value
Tool length	Q115
Tool radius	Q116

Tilting the working plane with mathematical angles: Rotary axis coordinates calculated by the TNC

coordinates	Parameter value
A axis	Q120
B axis	Q121
C axis	Q122

Measurement results from touch probe cycles (see also User's Manual for Touch Probe Cycles)

Measured actual values	Parameter value
Angle of a straight line	Q150
Center in reference axis	Q151
Center in minor axis	Q152
Diameter	Q153
Length of pocket	Q154
Width of pocket	Q155
Length in the axis selected in the cycle	Q156
Position of the center line	Q157
Angle of the A axis	Q158
Angle of the B axis	Q159
Coordinate of the axis selected in the cycle	Q160

Measured deviation	Parameter value
Center in reference axis	Q161
Center in minor axis	Q162
Diameter	Q163
Length of pocket	Q164
Width of pocket	Q165
Measured length	Q166
Position of the center line	Q167

Measured solid angle	Parameter value
Rotation about the A axis	Q170
Rotation about the B axis	Q171
Rotation about the C axis	Q172

Workpiece status	Parameter value
Good	Q180
Re-work	Q181
Scrap	Q182

Measured deviation with cycle 440	Parameter value
X axis	Q185
Y axis	Q186
Z axis	Q187

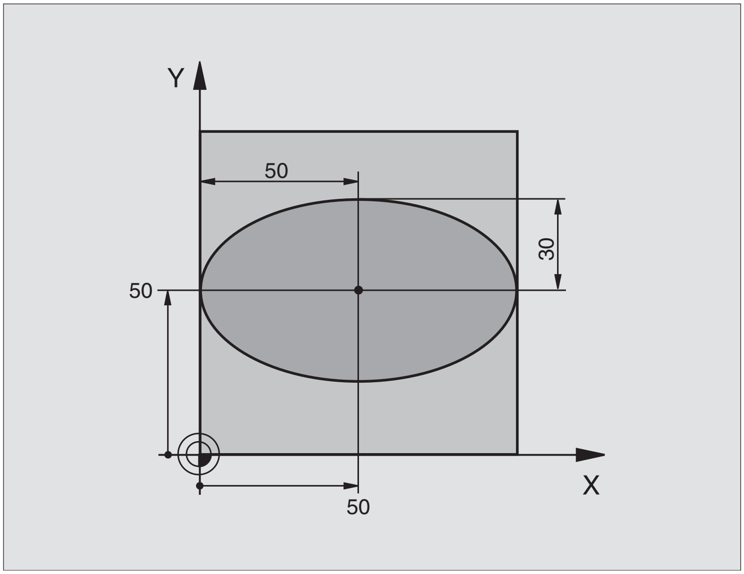
Reserved for internal use	Parameter value
Markers for cycles (point patterns)	Q197
Number of the last active measuring cycle	Q198

Status during tool measurement with TT	Parameter value
Tool within tolerance	Q199 = 0.0
Tool is worn (LTOL/RTOL exceeded)	Q199 = 1.0
Tool is broken (LBREAK/RBREAK exceeded)	Q199 = 2.0

Example: Ellipse

Program sequence

- The contour of the ellipse is approximated by many short lines (defined in Q7). The more calculating steps you define for the lines, the smoother the curve becomes.
- The machining direction can be altered by changing the entries for the starting and end angles in the plane:
  Clockwise machining direction:
  starting angle > end angle
  Counterclockwise machining direction:
  starting angle < end angle
- The tool radius is not taken into account.



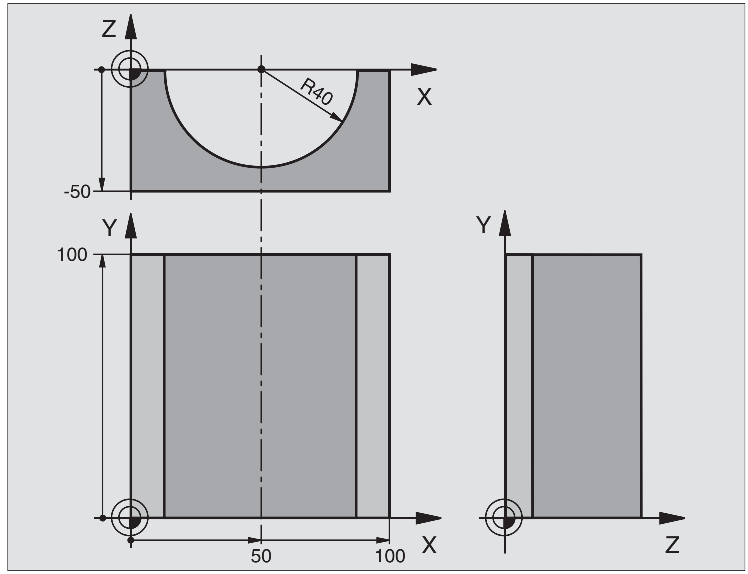
0 BEGIN PGM ELLIPSE MM	
1 FN 0: Q1 = +50	Center in X axis
2 FN 0: Q2 =+50	Center in Y axis
3 FN 0: Q3 = +50	Semiaxis in X
4 FN 0: Q4 = +30	Semiaxis in Y
5 FN 0: Q5 = +0	Starting angle in the plane
6 FN 0: Q6 = +360	End angle in the plane
7 FN 0: Q7 = +40	Number of calculating steps
8 FN 0: Q8 = +0	Rotational position of the ellipse
9 FN 0: Q9 = +5	Milling depth
10 FN 0: Q10 = +100	Feed rate for plunging
11 FN 0: Q11 = +350	Feed rate for milling
12 FN 0: Q12 = +2	Set-up clearance for pre-positioning
13 BLK FORM 0.1 Z X+0 Y+0 Z-20	Define the workpiece blank
14 BLK FORM 0.2 X+100 Y+100 Z+0	
15 TOOL DEF 1 L+0 R+2.5	Define the tool
16 TOOL CALL 1 Z S4000	Tool call
17 L Z+250 R0 FMAX	Retract the tool
18 CALL LBL 10	Call machining operation
19 L Z+100 R0 FMAX M2	Retract in the tool axis, end program

`20 LBL 10`	Subprogram 10: Machining operation
`21 CYCL DEF 7.0 DATUM SHIFT`	Shift datum to center of ellipse
`22 CYCL DEF 7.1 X+Q1`	
`23 CYCL DEF 7.2 Y+Q2`	
`24 CYCL DEF 10.0 ROTATION`	Account for rotational position in the plane
`25 CYCL DEF 10.1 ROT+Q8`	
`26 Q35 = (Q6 - Q5) / Q7`	Calculate angle increment
`27 Q36 = Q5`	Copy starting angle
`28 Q37 = 0`	Set counter
`29 Q21 = Q3 * COS Q36`	Calculate X coordinate for starting point
`30 Q22 = Q4 * SIN Q36`	Calculate Y coordinate for starting point
`31 L X+Q21 Y+Q22 R0 FMAX M3`	Move to starting point in the plane
`32 L Z+Q12 R0 FMAX`	Pre-position in tool axis to setup clearance
`33 L Z-Q9 R0 FQ10`	Move to working depth
`34 LBL 1`	
`35 Q36 = Q36 + Q35`	Update the angle
`36 Q37 = Q37 + 1`	Update the counter
`37 Q21 = Q3 * COS Q36`	Calculate the current X coordinate
`38 Q22 = Q4 * SIN Q36`	Calculate the current Y coordinate
`39 L X+Q21 Y+Q22 R0 FQ11`	Move to next point
`40 FN 12: IF +Q37 LT +Q7 GOTO LBL 1`	Unfinished? If not finished, return to LBL 1
`41 CYCL DEF 10.0 ROTATION`	Reset the rotation
`42 CYCL DEF 10.1 ROT+0`	
`43 CYCL DEF 7.0 DATUM SHIFT`	Reset the datum shift
`44 CYCL DEF 7.1 X+0`	
`45 CYCL DEF 7.2 Y+0`	
`46 L Z+Q12 F0 FMAX`	Move to setup clearance
`47 LBL 0`	End of subprogram
`48 END PGM ELLIPSE MM`	

Example: Concave cylinder machined with spherical cutter

Program sequence

- Program functions only with a spherical cutter. The tool length refers to the sphere center.
- The contour of the cylinder is approximated by many short line segments (defined in Q13). The more line segments you define, the smoother the curve becomes.
- The cylinder is milled in longitudinal cuts (here: parallel to the Y axis).
- The machining direction can be altered by changing the entries for the starting and end angles in space:
  Clockwise machining direction:
  starting angle > end angle
  Counterclockwise machining direction:
  starting angle < end angle
- The tool radius is compensated automatically.



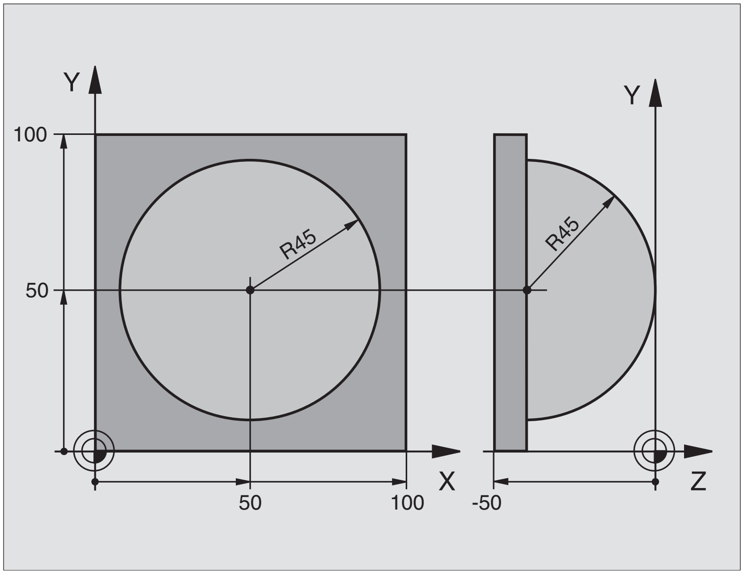
`0 BEGIN PGM CYLIN MM`	
`1 FN 0: Q1 = +50`	Center in X axis
`2 FN 0: Q2 =+0`	Center in Y axis
`3 FN 0: Q3 = +0`	Center in Z axis
`4 FN 0: Q4 = +90`	Starting angle in space (Z/X plane)
`5 FN 0: Q5 = +270`	End angle in space (Z/X plane)
`6 FN 0: Q6 = +40`	Radius of the cylinder
`7 FN 0: Q7 = +100`	Length of the cylinder
`8 FN 0: Q8 = +0`	Rotational position in the X/Y plane
`9 FN 0: Q10 = +5`	Allowance for cylinder radius
`10 FN 0: Q11 = +250`	Feed rate for plunging
`11 FN 0: Q12 = +400`	Feed rate for milling
`12 FN 0: Q13 = +90`	Number of cuts
`13 BLK FORM 0.1 Z X+0 Y+0 Z-50`	Define the workpiece blank
`15 BLK FORM 0.2 X+100 Y+100 Z+0`	
`15 TOOL DEF 1 L+0 R+3`	Define the tool
`16 TOOL CALL 1 Z S4000`	Tool call
`17 L Z+250 R0 FMAX`	Retract the tool
`18 CALL LBL 10`	Call machining operation
`19 FN 0: Q10 = +0`	Reset allowance

20 CALL LBL 10	Call machining operation
21 L Z+100 R0 FMAX M2	Retract in the tool axis, end program
22 LBL 10	Subprogram 10: Machining operation
23 Q16 = Q6 - Q10 - Q108	Account for allowance and tool, based on the cylinder radius
24 FN 0: Q20 = +1	Set counter
25 FN 0: Q24 = +Q4	Copy starting angle in space (Z/X plane)
26 Q25 = (Q5 - Q4) / Q13	Calculate angle increment
27 CYCL DEF 7.0 DATUM SHIFT	Shift datum to center of cylinder (X axis)
28 CYCL DEF 7.1 X+Q1	
29 CYCL DEF 7.2 Y+Q2	
30 CYCL DEF 7.3 Z+Q3	
31 CYCL DEF 10.0 ROTATION	Account for rotational position in the plane
32 CYCL DEF 10.1 ROT+Q8	
33 L X+0 Y+0 R0 FMAX	Pre-position in the plane to the cylinder center
34 L Z+5 R0 F1000 M3	Pre-position in the tool axis
35 LBL 1	
36 CC Z+0 X+0	Set pole in the Z/X plane
37 LP PR+Q16 PA+Q24 FQ11	Move to starting position on cylinder, oblique plunge-cutting
38 L Y+Q7 R0 FQ12	Longitudinal cut in Y+ direction
39 FN 1: Q20 = +Q20 + +1	Update the counter
40 FN 1: Q24 = +Q24 + +Q25	Update solid angle
41 FN 11: IF +Q20 GT +Q13 GOTO LBL 99	Finished? If finished, jump to end.
42 LP PR+Q16 PA+Q24 FQ11	Move in an approximated “arc” for the next longitudinal cut.
43 L Q+0 F0 FQ12	Longitudinal cut in Y– direction
44 FN 1: Q20 = +Q20 + +1	Update the counter
45 FN 1: Q24 = +Q24 + +Q25	Update solid angle
46 FN 12: IF +Q20 LT +Q13 GOTO LBL 1	Unfinished? If not finished, return to LBL 1
47 LBL 99	
48 CYCL DEF 10.0 ROTATION	Reset the rotation
49 CYCL DEF 10.1 ROT+0	
50 CYCL DEF 7.0 DATUM SHIFT	Reset the datum shift
51 CYCL DEF 7.1 X+0	
52 CYCL DEF 7.2 Y+0	
53 CYCL DEF 7.3 Z+0	
54 LBL 0	End of subprogram
55 END PGM CYLIN	

Example: Convex sphere machined with end mill

Program sequence

- This program requires an end mill.
- The contour of the sphere is approximated by many short lines (in the Z/X plane, defined in Q14). The smaller you define the angle increment, the smoother the curve becomes.
- You can determine the number of contour cuts through the angle increment in the plane (defined in Q18).
- The tool moves upward in three-dimensional cuts.
- The tool radius is compensated automatically.



`0 BEGIN PGM SPHERE MM`	
`1 FN 0: Q1 = +50`	Center in X axis
`2 FN 0: Q2 =+50`	Center in Y axis
`3 FN 0: Q4 = +90`	Starting angle in space (Z/X plane)
`4 FN 0: Q5 = +0`	End angle in space (Z/X plane)
`5 FN 0: Q14 = +5`	Angle increment in space
`6 FN 0: Q6 = +45`	Radius of the sphere
`7 FN 0: Q8 = +0`	Starting angle of rotational position in the X/Y plane
`8 FN 0: Q9 = +360`	End angle of rotational position in the X/Y plane
`9 FN 0: Q18 = +10`	Angle increment in the X/Y plane for roughing
`10 FN 0: Q10 = +5`	Allowance in sphere radius for roughing
`11 FN 0: Q11 = +2`	Setup clearance for pre-positioning in the tool axis
`12 FN 0: Q12 = +350`	Feed rate for milling
`13 BLK FORM 0.1 Z X+0 Y+0 Z-50`	Define the workpiece blank
`14 BLK FORM 0.2 X+100 Y+100 Z+0`	
`15 TOOL DEF 1 L+0 R+7.5`	Define the tool
`16 TOOL CALL 1 Z S4000`	Tool call
`17 L Z+250 R0 FMAX`	Retract the tool

`18 CALL LBL 10`	Call machining operation
`19 FN 0: Q10 = +0`	Reset allowance
`20 FN 0: Q18 = +5`	Angle increment in the X/Y plane for finishing
`21 CALL LBL 10`	Call machining operation
`22 L Z+100 R0 FMAX M2`	Retract in the tool axis, end program
`23 LBL 10`	Subprogram 10: Machining operation
`24 FN 1: Q23 = +Q11 + +Q6`	Calculate Z coordinate for pre-positioning
`25 FN 0: Q24 = +Q4`	Copy starting angle in space (Z/X plane)
`26 FN 1: Q26 = +Q6 + +Q108`	Compensate sphere radius for pre-positioning
`27 FN 0: Q28 = +Q8`	Copy rotational position in the plane
`28 FN 1: Q16 = +Q6 + -Q10`	Account for allowance in the sphere radius
`29 CYCL DEF 7.0 DATUM SHIFT`	Shift datum to center of sphere
`30 CYCL DEF 7.1 X+Q1`	
`31 CYCL DEF 7.2 Y+Q2`	
`32 CYCL DEF 7.3 Z-Q16`	
`33 CYCL DEF 10.0 ROTATION`	Account for starting angle of rotational position in the plane
`34 CYCL DEF 10.1 ROT+Q8`	
`35 LBL 1`	Pre-position in the tool axis
`36 CC X+0 Y+0`	Set pole in the X/Y plane for pre-positioning
`37 LP PR+Q26 PA+Q8 R0 FQ12`	Pre-position in the plane
`38 CC Z+0 X+Q108`	Set pole in the Z/X plane, offset by the tool radius
`39 L Y+0 Z+0 FQ12`	Move to working depth

40 LBL 2	
41 LP PR+Q6 PA+Q24 R9 FQ12	Move upward in an approximated "arc"
42 FN 2: Q24 = +Q24 - +Q14	Update solid angle
43 FN 11: IF +Q24 GT +Q5 GOTO LBL 2	Inquire whether an arc is finished. If not finished, return to LBL 2.
44 LP PR+Q6 PA+Q5	Move to the end angle in space
45 L Z+Q23 R0 F1000	Retract in the tool axis
46 L X+Q26 R0 FMAX	Pre-position for next arc
47 FN 1: Q28 = +Q28 + +Q18	Update rotational position in the plane
48 FN 0: Q24 = +Q4	Reset solid angle
49 CYCL DEF 10.0 ROTATION	Activate new rotational position
50 CYCL DEF 10.0 ROT+Q28	
51 FN 12: IF +Q28 LT +Q9 GOTO LBL 1	
52 FN 9: IF +Q28 EQU +Q9 GOTO LBL 1	Unfinished? If not finished, return to label 1
53 CYCL DEF 10.0 ROTATION	Reset the rotation
54 CYCL DEF 10.1 ROT+0	
55 CYCL DEF 7.0 DATUM SHIFT	Reset the datum shift
56 CYCL DEF 7.1 X+0	
57 CYCL DEF 7.2 Y+0	
58 CYCL DEF 7.3 Z+0	
59 LBL 0	End of subprogram
60 END PGM SPHERE MM	

11

Test Run and Program Run

11.1 Graphics

Function

In the Program Run modes of operation as well as in the Test Run mode, the TNC provides the following display modes. Using soft keys, select whether you desire:

- Plan view
- Projection in 3 planes
- 3-D view

The TNC graphic depicts the workpiece as if it were being machined with a cylindrical end mill. If a tool table is active, you can also simulate the machining operation with a spherical cutter. For this purpose, enter R2 = R in the tool table.

The TNC will not show a graphic if

- the current program has no valid blank form definition
- no program is selected

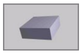
With Machine Parameters 7315 to 7317 you can have the TNC display a graphic even if no tool axis is defined or moved.

A graphic simulation is not possible for program sections or programs in which rotary axis movements or a tilted working plane are defined. In this case, the TNC will display an error message.

The TNC graphic does not show a radius oversize DR that has been programmed in the TOOL CALL block.

Overview of display modes

The control displays the following soft keys in the Program Run and Test Run modes of operation:

Display mode	Soft key
Plan view	
Projection in 3 planes	
3-D view	

Limitations during program run

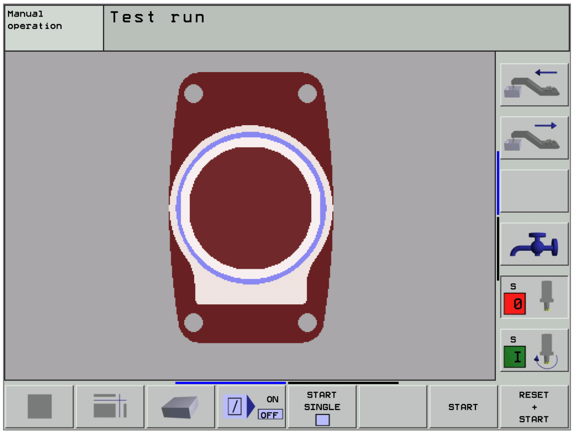
A graphical representation of a running program is not possible if the microprocessor of the TNC is already occupied with complicated machining tasks or if large areas are being machined. Example: Multipass milling over the entire blank form with a large tool. The TNC interrupts the graphics and displays the text **ERROR** in the graphics window. The machining process is continued, however.

Plan view

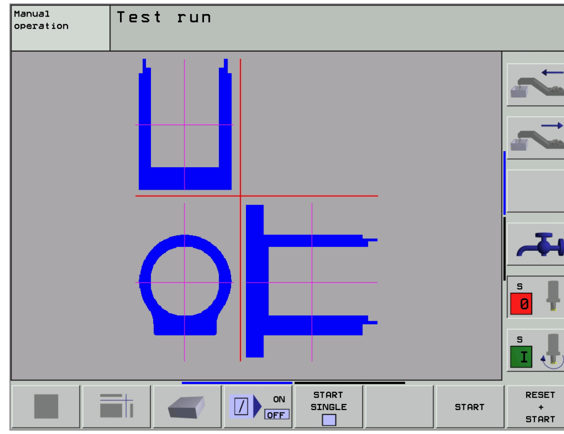
This is the fastest of the three graphic display modes.

- Press the soft key for plan view.
- Regarding depth display, remember:

  The deeper the surface, the darker the shade.



Projection in 3 planes

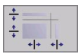


Similar to a workpiece drawing, the part is displayed with a plan view and two sectional planes. A symbol to the lower left indicates whether the display is in first angle or third angle projection according to ISO 6433 (selected with MP7310).

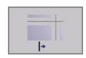
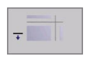
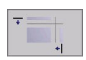
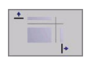
Details can be isolated in this display mode for magnification (see "Magnifying details," page 426).

In addition, you can shift the sectional planes with the corresponding soft keys:

- Select the soft key for projection in three planes.



- Shift the soft-key row and select the soft key for sectional planes.
- The TNC then displays the following soft keys:

Function	Soft keys	
Shift the vertical sectional plane to the right or left		
Shift the vertical sectional plane forward or backward		
Shift the horizontal sectional plane upwards or downwards		

The positions of the sectional planes are visible during shifting.

Coordinates of the line of intersection

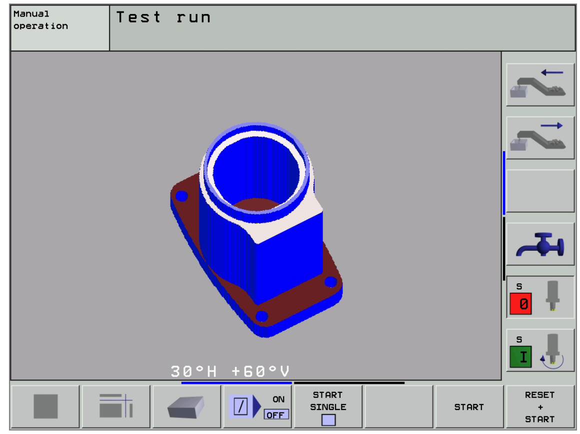
At the bottom of the graphics window, the TNC displays the coordinates of the line of intersection, referenced to the workpiece datum. Only the coordinates of the working plane are shown. This function is activated with MP7310.

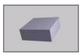
3-D view

The workpiece is displayed in three dimensions, and can be rotated about the vertical axis.

You can rotate the 3-D display about the vertical and horizontal axes. The shape of the workpiece blank can be depicted by a frame overlay at the beginning of the graphic simulation.

In the Test Run mode of operation you can isolate details for magnification, see “Magnifying details,” page 426.

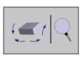




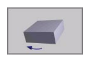
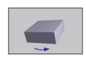
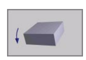
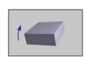
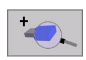
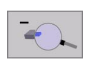
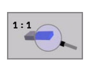
▶ Press the soft key for 3-D view.

Rotating and magnifying/reducing the 3-D view

▶ Shift the soft-key row until the soft key for the rotating and magnification/reduction appears.

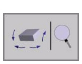


▶ Select functions for rotating and magnifying/reducing:

Function	Soft keys	
Rotate in 5° steps about the vertical axis		
Rotate in 5° steps about the horizontal axis		
Magnify the graphic stepwise. If the view is magnified, the TNC shows the letter **Z** in the footer of the graphic window.		
Reduce the graphic stepwise. . If the view is magnified, the TNC shows the letter **Z** in the footer of the graphic window.		
Reset image to programmed size		

Switch the frame overlay display for the workpiece blank on/off:

▶ Shift the soft-key row until the soft key for the rotating and magnification/reduction appears.

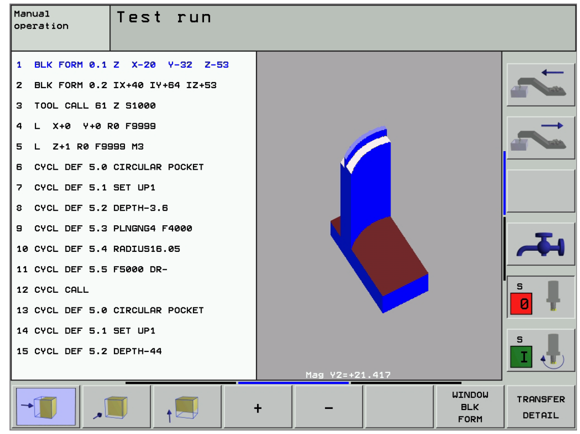


▶ Select functions for rotating and magnifying/reducing:

▶ Show the frame for the BLK FORM: Set the highlight in the soft key to SHOW

▶ Hide the frame for the BLK FORM: Set the highlight in the soft key to OMIT

Magnifying details



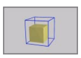
You can magnify details in all display modes in the Test Run mode and a program run mode.

The graphic simulation or the program run, respectively, must first have been stopped. A detail magnification is always effective in all display modes.

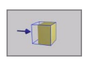
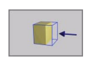
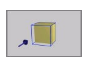
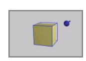
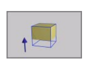
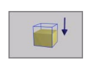
Changing the detail magnification

The soft keys are listed in the table.

- Interrupt the graphic simulation, if necessary.
- Shift the soft-key row in the Test Run mode, or in a program run mode, respectively, until the soft key for detail enlargement appears.



- Select the functions for section magnification.
- Press the corresponding soft key to select the workpiece surface (see table below).
- To reduce or magnify the blank form, press and hold the MINUS or PLUS soft key, respectively.
- Restart the test run or program run by pressing the START soft key (RESET + START returns the workpiece blank to its original state).

Function	Soft keys	
Select the left/right workpiece surface		
Select the front/back workpiece surface		
Select the top/bottom workpiece surface		
Shift the sectional plane to reduce or magnify the blank form	–	+
Select the isolated detail	TRANSFER DETAIL	

Cursor position during detail magnification

During detail magnification, the TNC displays the coordinates of the axis that is currently being isolated. The coordinates describe the area determined for magnification. To the left of the slash is the smallest coordinate of the detail (MIN point), to the left is the largest (MAX point).

If a graphic display is magnified, this is indicated with **MAGN** at the lower right of the graphics window.

If the workpiece blank cannot be further enlarged or reduced, the TNC displays an error message in the graphics window. To clear the error message, reduce or enlarge the workpiece blank.

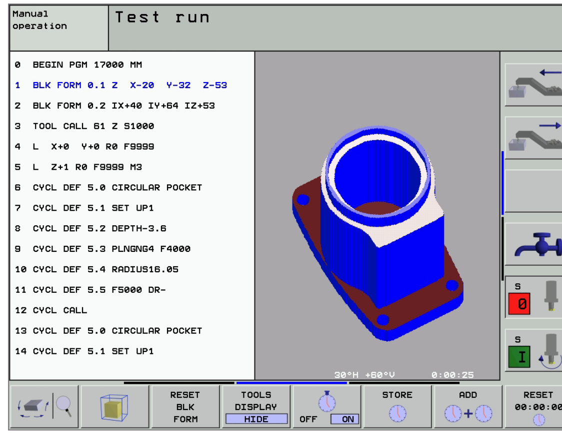
Repeating graphic simulation

A part program can be graphically simulated as often as desired, either with the complete workpiece or with a detail of it.

Function	Soft key
Restore workpiece blank to the detail magnification in which it was last shown.	RESET BLK FORM
Reset detail magnification so that the machined workpiece or workpiece blank is displayed as it was programmed with BLK FORM.	WINDOW BLK FORM

With the WINDOW BLK FORM soft key, you return the displayed workpiece blank to its originally programmed dimensions, even after isolating a detail—without TRANSFER DETAIL.

Measuring the machining time



Program Run modes of operation

The timer counts and displays the time from program start to program end. The timer stops whenever machining is interrupted.

Test Run

The timer displays the approximate time that the TNC calculates from the duration of tool movements. The time calculated by the TNC cannot be used for calculating the production time because the TNC does not account for the duration of machine-dependent interruptions, such as tool change.

Activating the stopwatch function

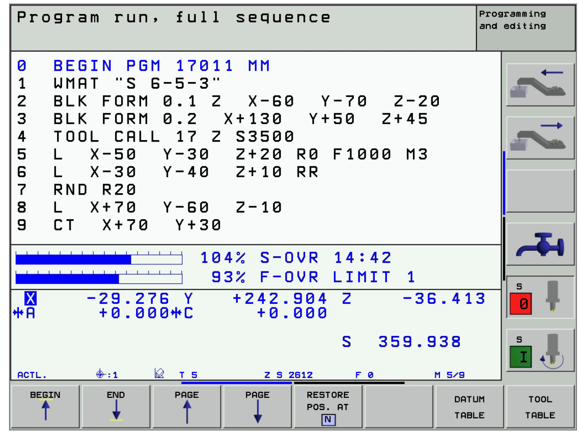
Shift the soft-key rows until the TNC displays the following soft keys with the stopwatch functions:

Stopwatch functions	Soft key
Store displayed time	STORE
Display the sum of stored time and displayed time	ADD
Clear displayed time	RESET 00:00:00

The soft keys available to the left of the stopwatch functions depend on the selected screen layout.

The time is reset when a new BLK form is entered.

11.2 Functions for Program Display



Overview

In the Program Run modes of operation as well as in the Test Run mode, the TNC provides the following soft keys for displaying a part program in pages:

Function	Soft key
Go back in the program by one screen	PAGE ↑
Go forward in the program by one screen	PAGE ↓
Go to beginning of program	BEGIN ↑
Go to end of program	END ↓

11.3 Test Run

Function

In the Test Run mode of operation you can simulate programs and program sections to prevent errors from occurring during program run. The TNC checks the programs for the following:

- Geometrical incompatibilities
- Missing data
- Impossible jumps
- Violation of the machine's working space

The following functions are also available:

- Blockwise test run
- Interrupt test at any block
- Optional block skip
- Functions for graphic simulation
- Measuring the machining time
- Additional status display

Running a program test

If the central tool file is active, a tool table must be active (status S) to run a program test. Select a tool table via the file manager (PGM MGT) in the Test Run mode of operation.

With the MOD function BLANK IN WORK SPACE, you can activate work space monitoring for the test run (see "Showing the Workpiece in the Working Space," page 459).

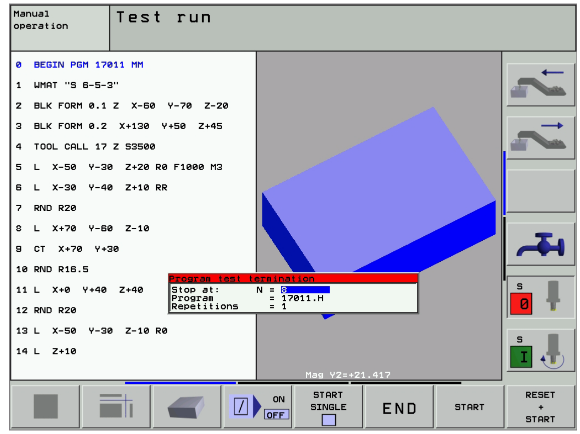
- ▶ Select the Test Run operating mode
- ▶ Call the file manager with the PGM MGT key and select the file you wish to test, or
- ▶ Go to the program beginning: Select line "0" with the GOTO key and confirm your entry with the ENT key.

The TNC then displays the following soft keys:

Function	Soft key
Test the entire program	START
Test each program block individually	START SINGLE
Show the blank form and test the entire program	RESET + START
Interrupt the test run	STOP

Run a program test up to a certain block

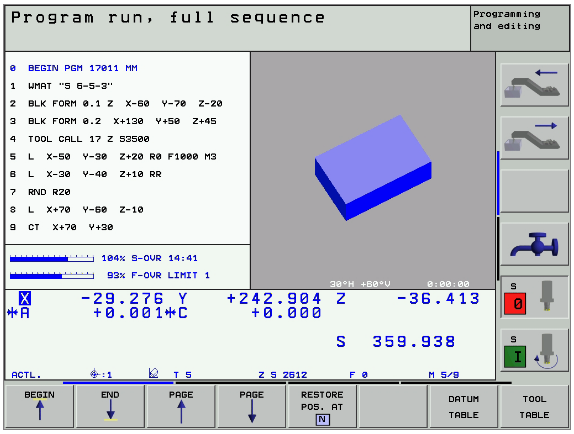
With the STOP AT N function the TNC does a test run up to the block with block number N.



- Go to the beginning of program in the Test Run mode of operation.
- To run a program test up to a specific block, press the STOP AT N soft key.

- **Stop at N:** Enter the block number at which you wish the test to stop.
- **Program:** Enter the name of the program that contains the block with the selected block number. The TNC displays the name of the selected program. If the test run is to be interrupted in a program that was called with PGM CALL, you must enter this name.
- **Repetitions:** If N is located in a program section repeat, enter the number of repeats that you want to run.
- To test a program section, press the START soft key. The TNC will test the program up to the entered block.

11.4 Program Run



Function

In the Program Run, Full Sequence mode the TNC executes a part program continuously to its end or up to a program stop.

In the Program Run, Single Block mode of operation you must start each block separately by pressing the machine START button.

The following TNC functions can be used in the program run modes of operation:

- Interrupt program run
- Start program run from a certain block
- Optional block skip
- Editing the tool table TOOL.T
- Checking and changing Q parameters
- Superimposing handwheel positioning
- Functions for graphic simulation
- Additional status display

Running a part program

Preparation

1 Clamp the workpiece to the machine table.
2 Set the datum.
3 Select the necessary tables and pallet files (status M).
4 Select the part program (status M).

> You can adjust the feed rate and spindle speed with the override knobs.
>
> It is possible to reduce the rapid traverse speed when starting the NC program using the FMAX soft key. The entered value remains in effect even after the machine has been turned off and on again. In order to re-establish the original rapid traverse speed, you need to re-enter the corresponding value.

Program Run, Full Sequence

▶ Start the part program with the machine START button.

Program Run, Single Block

▶ Start each block of the part program individually with the machine START button.

Interrupting machining

There are several ways to interrupt a program run:

- Programmed interruptions
- Pressing the machine STOP button
- Switching to Program Run, Single Block

If the TNC registers an error during program run, it automatically interrupts the machining process.

Programmed interruptions

You can program interruptions directly in the part program. The TNC interrupts the program run at a block containing one of the following entries:

- STOP (with and without a miscellaneous function)
- Miscellaneous function M0, M2 or M30
- Miscellaneous function M6 (determined by the machine tool builder)

Interrupting the machining process with the machine STOP button

- Press the machine STOP button: The block which the TNC is currently executing is not completed. The asterisk in the status display blinks.
- If you do not wish to continue the machining process, you can reset the TNC with the INTERNAL STOP soft key. The asterisk in the status display goes out. In this case, the program must be restarted from the program beginning.

Interrupting the machining process by switching to the Program Run, Single Block mode of operation

You can interrupt a program that is being run in the Program Run, Full Sequence mode of operation by switching to the Program Run, Single Block mode. The TNC interrupts the machining process at the end of the current block.

Moving the machine axes during an interruption

You can move the machine axes during an interruption in the same way as in the Manual Operation mode.

Danger of collision

If you interrupt program run while the working plane is tilted, you can change from a tilted to a non-tilted coordinate system, and vice versa, by pressing the 3-D ON/OFF soft key.

The functions of the axis direction buttons, the electronic handwheel and the positioning logic for returning to the contour are then evaluated by the TNC. When retracting the tool make sure the correct coordinate system is active and the angular values of the tilt axes are entered in the 3-D ROT menu.

Application example:
Retracting the spindle after tool breakage

- Interrupt machining.
- Enable the external direction keys: Press the MANUAL OPERATION soft key.
- Move the axes with the machine axis direction buttons.

On some machines you may have to press the machine START button after the MANUAL OPERATION soft key to enable the axis direction buttons. Refer to your machine manual.

Resuming program run after an interruption

> If a program run is interrupted during a fixed cycle, the program must be resumed from the beginning of the cycle.
> This means that some machining operations will be repeated.

If you interrupt a program run during execution of a subprogram or program section repeat, use the RESTORE POS AT N function to return to the position at which the program run was interrupted.

When a program run is interrupted, the TNC stores:

- The data of the last defined tool
- Active coordinate transformations (e.g. datum shift, rotation, mirroring)
- The coordinates of the circle center that was last defined

> Note that the stored data remain active until they are reset (e.g. if you select a new program).

The stored data are used for returning the tool to the contour after manual machine axis positioning during an interruption (RESTORE POSITION soft key).

Resuming program run with the START button

You can resume program run by pressing the machine START button if the program was interrupted in one of the following ways:

- The machine STOP button was pressed.
- An interruption was programmed.

Resuming program run after an error

If the error message is not blinking:

- ▶ Remove the cause of the error.
- ▶ To clear the error message from the screen, press the CE key.
- ▶ Restart the program, or resume program run where it was interrupted.

If the error message is blinking:

- ▶ Press and hold the END key for two seconds. This induces a TNC system restart.
- ▶ Remove the cause of the error.
- ▶ Start again.

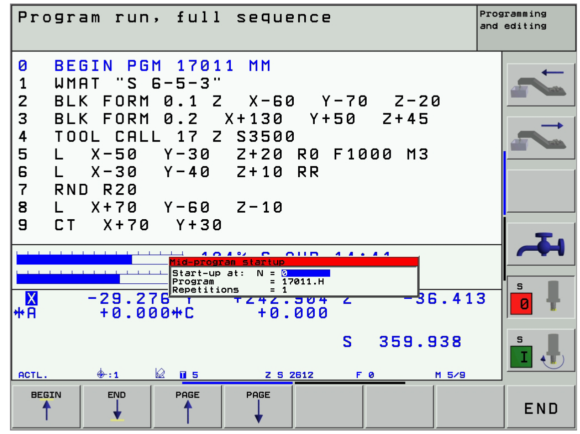
If you cannot correct the error, write down the error message and contact your repair service agency.

Mid-program startup (block scan)

The RESTORE POS AT N feature must be enabled and adapted by the machine tool builder. Refer to your machine manual.

With the RESTORE POS AT N feature (block scan) you can start a part program at any block you desire. The TNC scans the program blocks up to that point. Machining can be graphically simulated.

If you have interrupted a part program with an INTERNAL STOP, the TNC automatically offers the interrupted block N for mid-program startup.



Mid-program startup must not begin in a subprogram.

All necessary programs, tables and pallet files must be selected in a Program Run mode of operation (status M).

If the program contains a programmed interruption before the startup block, the block scan is interrupted. Press the machine START button to continue the block scan.

After a block scan, return the tool to the calculated position with RESTORE POSITION.

If you are working with nested programs, you can use MP7680 to define whether the block scan is to begin at block 0 of the main program or at block 0 of the last interrupted program.

If the working plane is tilted, you can use the 3-D ON/OFF soft key to define whether the TNC is to return to the contour in a tilted or in a non-tilted coordinate system.

The function M128 is not permitted during a mid-program startup.

If you want to use the block scan feature in a pallet table, select the program in which a mid-program startup is to be performed from the pallet table by using the arrow keys. Then press the RESTORE POS AT N soft key.

All touch probe cycles and Cycle 247 are skipped in a mid-program startup. Result parameters that are written to from these cycles might therefore remain empty.

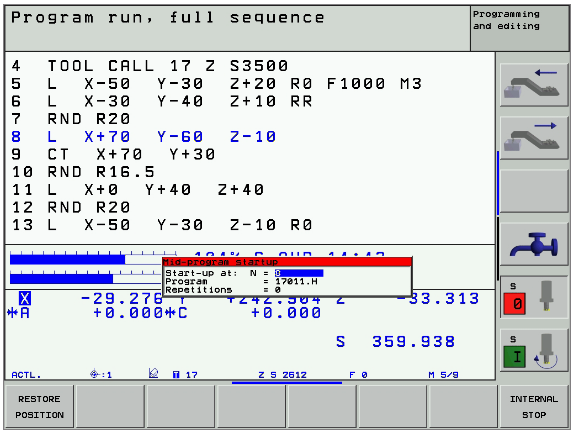
- To go to the first block of the current program to start a block scan, enter GOTO "0".

- To select mid-program startup, press the RESTORE POS AT N soft key.
- **`Start-up at N:`** Enter the block number N at which the block scan should end.
- **`Program:`** Enter the name of the program containing block N.
- **`Repetitions:`** If block N is located in a program section repeat, enter the number of repetitions to be calculated in the block scan.
- To start the block scan, press the machine START button.
- To return to the contour, see "Returning to the contour," page 437

Returning to the contour

With the RESTORE POSITION function, the TNC returns to the workpiece contour in the following situations:

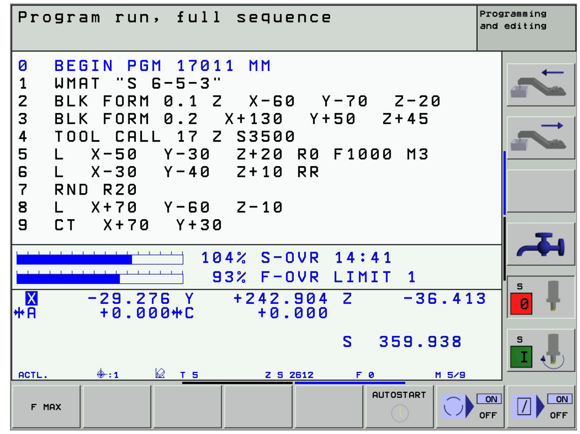
- Return to the contour after the machine axes were moved during a program interruption that was not performed with the INTERNAL STOP function.
- Return to the contour after a block scan with RESTORE POS AT N, for example after an interruption with INTERNAL STOP.
- Depending on the machine, if the position of an axis has changed after the control loop has been opened during a program interruption.



- To select a return to contour, press the RESTORE POSITION soft key.
- Restore machine status, if required.
- To move the axes in the sequence that the TNC suggests on the screen, press the machine START button.
- To move the axes in any sequence, press the soft keys RESTORE X, RESTORE Z, etc., and activate each axis with the machine START key.
- To resume machining, press the machine START key.

11.5 Automatic Program Start

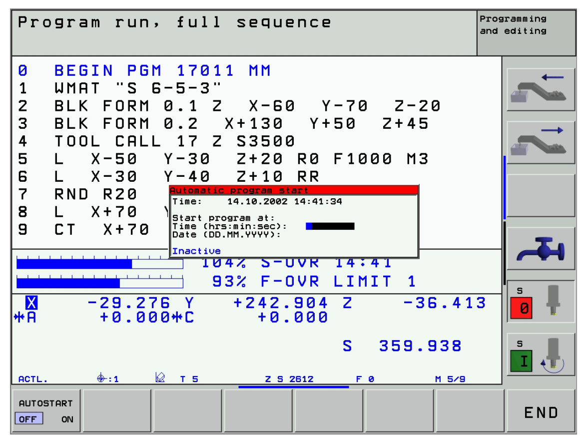
Function



> The TNC must be specially prepared by the machine tool builder for use of the automatic program start function. Refer to your machine manual.

In a Program Run operating mode, you can use the soft key AUTOSTART (see figure at upper right) to define a specific time at which the program that is currently active in this operating mode is to be started:

- Show the window for entering the starting time (see figure at center right).
- **Time (h:min:sec):** Time of day at which the program is to be started.
- **Date (DD.MM.YYYY):** Date at which the program is to be started.
- To activate the start, set the AUTOSTART soft key to ON.



11.6 Optional block skip

Function

In a test run or program run, the TNC can skip over blocks that begin with a slash "/":

- To run or test the program without the blocks preceded by a slash, set the soft key to ON.
- To run or test the program with the blocks preceded by a slash, set the soft key to OFF.

This function does not work for TOOL DEF blocks.

After a power interruption the control returns to the most recently selected setting.

11.7 Optional Program Run Interruption

Function

The TNC optionally interrupts the program run or test run at blocks containing M01. If you use M01 in the Program Run mode, the TNC does not switch off the spindle or coolant.

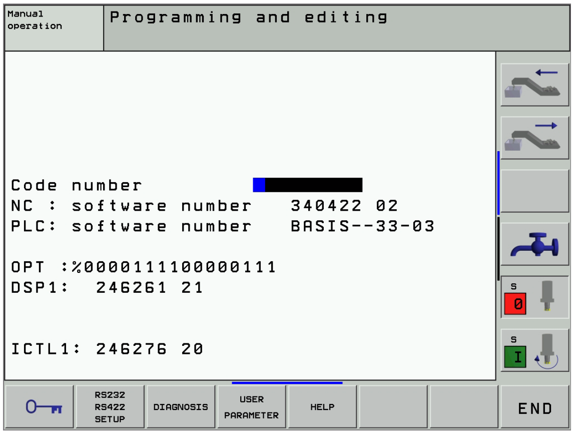
- Do not interrupt Program Run or Test Run at blocks containing M01: Set soft key to OFF.

- Interrupt Program Run or Test Run at blocks containing M01: Set soft key to ON.

12

MOD Functions

12.1 MOD functions



The MOD functions provide additional input possibilities and displays. The available MOD functions depend on the selected operating mode.

Selecting the MOD functions

Call the operating mode in which you wish to change the MOD functions.

MOD

▶ To select the MOD functions, press the MOD key. The figures at right show typical screen menus in Programming and Editing (figure at upper right), Test Run (figure at lower right) and in a machine operating mode (see figure on next page).

Changing the settings

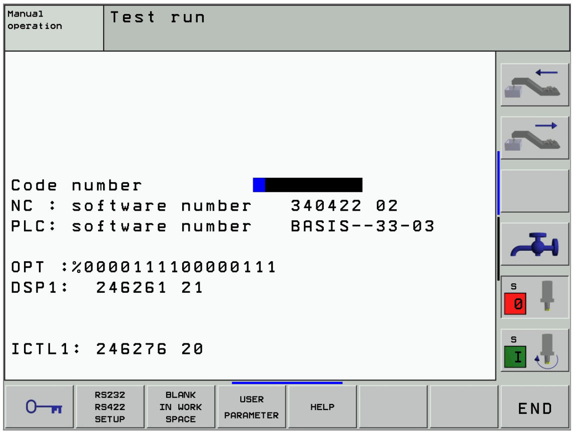
▶ Select the desired MOD function in the displayed menu with the arrow keys.

There are three possibilities for changing a setting, depending on the function selected:

- Enter a numerical value directly, e.g. when determining traverse range limit.
- Change a setting by pressing the ENT key, e.g. when setting program input.
- Change a setting via a selection window. If more than one possibility is available for a particular setting, you can superimpose a window listing all of the given possibilities by pressing the GOTO key. Select the desired setting directly by pressing the corresponding numerical key (to the left of the colon), or by using the arrow keys and then confirming with ENT. If you don't want to change the setting, close the window again with END.

Exiting the MOD functions

▶ Close the MOD functions with the END key or soft key.



Overview of MOD functions

Depending on the selected mode of operation, you can make the following changes:

Programming and Editing:

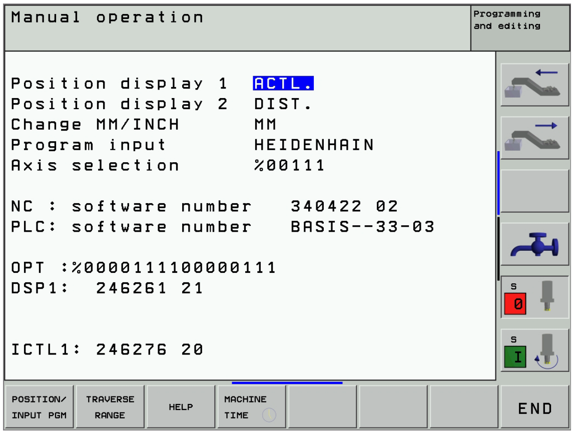
- Display software numbers
- Enter code number
- Set data interface
- Machine-specific user parameters (if provided)
- HELP files (if provided)

Test Run:

- Display software numbers
- Enter code number
- Setting the data interface
- Showing the Workpiece in the Working Space
- Machine-specific user parameters (if provided)
- Displaying HELP files (if provided)

In all other modes:

- Display software numbers
- Display code digits for installed options
- Select position display
- Unit of measurement (mm/inches)
- Programming language for MDI
- Select the axes for actual position capture
- Set the axis traverse limits
- Display the datums
- Display operating times
- HELP files (if provided)



12.2 Software Numbers and Option Numbers

Function

The following software numbers are displayed on the TNC screen after the MOD functions have been selected:

- **NC:** Number of the NC software (managed by HEIDENHAIN)
- **PLC:** Number and name of the PLC software (managed by your machine tool builder)
- **DSP1:** Number of the speed controller software (managed by HEIDENHAIN)
- **ICTL1:** Number of the current controller software (managed by HEIDENHAIN)

In addition, coded numbers for the options available on your control are displayed after the abbreviation **OPT:**

No options active	%0000000000000000
Bit 0 to bit 7: Additional control loops	%00000000**00000011**
Bit 8 to bit 15: Software options	%**00000011**00000011

12.3 Code Numbers

Function

The TNC requires a code number for the following functions:

Function	Code number
Select user parameters	123
Configuring an Ethernet card	NET123
Enable special functions for Q-parameter programming	555343

In addition, you can use the keyword **`version`** to create a file containing all current software numbers of your control:

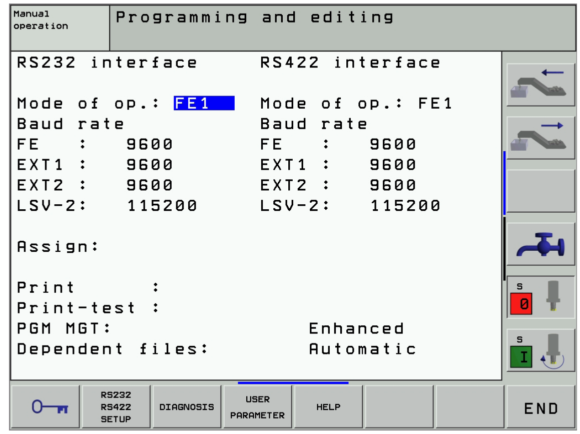
- Enter the keyword **`version`** and confirm with the ENT key.
- The TNC displays all current software numbers on the screen.
- To create the version overview, press the END key.

> If necessary, you can output the *version.a* file saved in the *TNC:* directory and send it to your machine manufacturer or HEIDENHAIN for diagnostic purposes.

12.4 Setting the Data Interfaces

Function

To set up the data interfaces, press the RS-232 / RS-422 SETUP soft key to call a menu for setting the data interfaces:



Setting the RS-232 interface

The mode of operation and baud rates for the RS-232 interface are entered in the upper left of the screen.

Setting the RS-422 interface

The mode of operation and baud rates for the RS-422 interface are entered in the upper right of the screen.

Setting the OPERATING MODE of the external device

The functions "Transfer all files," "Transfer selected file," and "Transfer directory" are not available in the operating modes FE2 and EXT.

Setting the BAUD RATE

You can set the BAUD RATE (data transfer speed) from 110 to 115 200 baud.

External device	Operating mode	Symbol
PC with HEIDENHAIN software TNCremo for remote operation of the TNC	LSV2	
PC with HEIDENHAIN data transfer software TNCremo	FE1	
HEIDENHAIN floppy disk units FE 401 B FE 401 from prog. no. 230 626 03	 FE1 FE1	
HEIDENHAIN floppy disk unit FE 401 up to prog. no. 230 626 02	FE2	
Non-HEIDENHAIN devices such as punchers, PC without TNCremo	EXT1, EXT2	

Assign

This function sets the destination for the transferred data.

Applications:

- Transferring values with Q parameter function FN15
- Transferring values with Q parameter function FN16

The TNC mode of operation determines whether the PRINT or PRINT TEST function is used:

TNC mode of operation	Transfer function
Program Run, Single Block	PRINT
Program Run, Full Sequence	PRINT
Test Run	PRINT TEST

You can set PRINT and PRINT TEST as follows:

Function	Path
Output data via RS-232	RS232:\....
Output data via RS-422	RS422:\....
Save data to the TNC’s hard disk	TNC:\....
Save the data in the same directory as the program with FN15/FN16.	- vacant -

File names

Data	Operating mode	File name
Values with FN15	Program Run	%FN15RUN.A
Values with FN15	Test Run	%FN15SIM.A
Values with FN16	Program Run	%FN16RUN.A
Values with FN16	Test Run	%FN16SIM.A

Software for data transfer

For transfer of files to and from the TNC, we recommend using the HEIDENHAIN TNCremoNT data transfer software. With TNCremoNT, data transfer is possible with all HEIDENHAIN controls via the serial interface or the Ethernet interface.

> You can download the current version of TNCremoNT free of charge from the HEIDENHAIN Filebase (www.heidenhain.de, <service>, <download area>, <TNCremo NT>).

System requirements for TNCremoNT:

- PC with 486 processor or higher
- Operating system Windows 95, Windows 98, Windows NT 4.0, Windows 2000, Windows ME, Windows XP
- 16 MB RAM
- 5 MB free memory space on your hard disk
- An available serial interface or connection to the TCP/IP network

Installation under Windows

- Start the SETUP.EXE installation program with the file manager (Explorer).
- Follow the setup program instructions.

Starting TNCremoNT under Windows

- Click <Start>, <Programs>, <HEIDENHAIN Applications>, <TNCremoNT>

When you start TNCremoNT for the first time, TNCremoNT automatically tries to set up a connection with the TNC.

Data transfer between the TNC and TNCremoNT

Ensure that:

- The TNC is connected to the correct serial port on your PC or to the network, respectively.

Once you have started TNCremoNT, you will see a list of all files that are stored in the active directory in the upper section of the main window **1**. Using the menu items <File> and <Change directory>, you can change the active directory or select another directory on your PC.

If you want to control data transfer from the PC, establish the connection with your PC in the following manner:

- Select <File>, <Setup connection>. TNCremoNT now receives the file and directory structure from the TNC and displays this at the bottom left of the main window **2**.
- To transfer a file from the TNC to the PC, select the file in the TNC window with a mouse click and drag and drop the highlighted file into the PC window **1**.
- To transfer a file from the PC to the TNC, select the file in the PC window with a mouse click and drag and drop the highlighted file into the TNC window **2**.

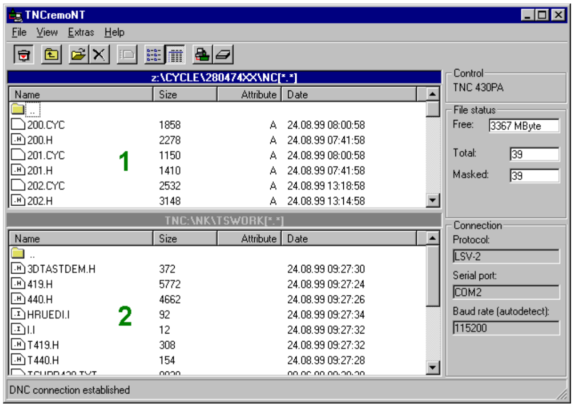
If you want to control data transfer from the TNC, establish the connection with your PC in the following manner:

- Select <Extras>, <TNCserver>. TNCremoNT is now in server mode. It can receive data from the TNC and send data to the TNC.
- You can now call the file management functions on the TNC by pressing the key PGM MGT (see "Data transfer to or from an external data medium" on page 58) and transfer the desired files.

End TNCremoNT

Select the menu items <File>, <Exit>.

> Refer also to the TNCremoNT help texts where all of the functions are explained in more detail.



12.5 Ethernet Interface

Introduction

The TNC is shipped with a standard Ethernet card to connect the control as a client in your network. The TNC transmits data via the Ethernet card with

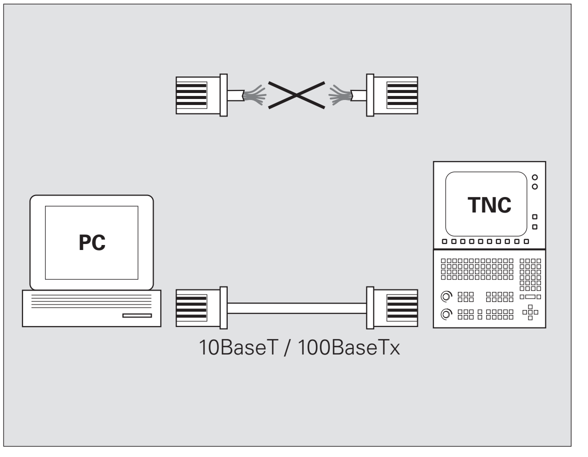
- the **smb** protocol (**s**erver **m**essage **b**lock) for Windows operating systems, or
- the **TCP/IP** protocol family (Transmission Control Protocol/Internet Protocol) and with support from the NFS (Network File System).

Connection possibilities

You can connect the Ethernet card in your TNC to your network through the RJ45 connection (X26, 100BaseTX or 10BaseT). The connection is metallically isolated from the control electronics.

For a 100BaseTX or 10BaseT connection you need a Twisted Pair cable to connect the TNC to your network.

> The maximum cable length between TNC and a node depends on the quality grade of the cable, the sheathing and the type of network (100BaseTX or 10BaseT).
>
> If you connect the TNC directly with a PC you must use a transposed cable.



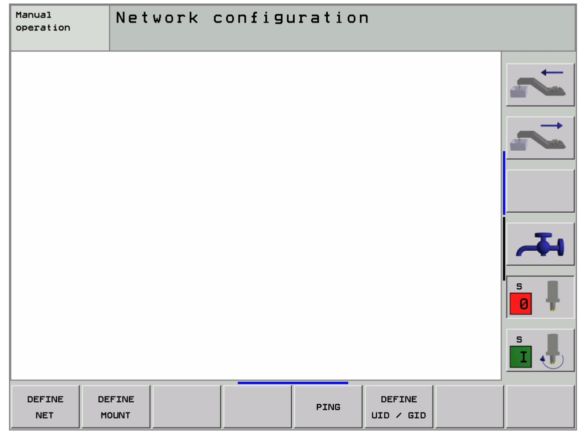
Connecting the iTNC directly with a Windows PC

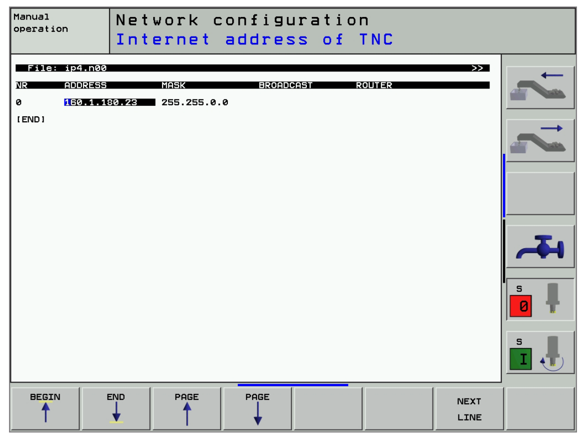
You don't need any large effort or special networking knowledge to attach the iTNC 530 directly to a PC that has an Ethernet card. You simply have to make some settings on the TNC and the corresponding settings on the PC.

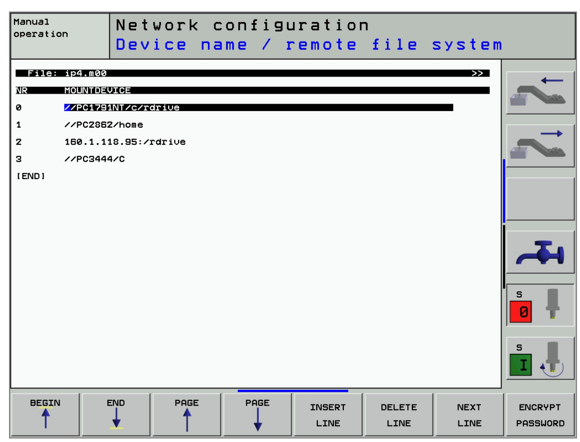
Settings on the iTNC

- Connect the iTNC (connection X26) and the PC with a crossed Ethernet cable (trade names: crossed patch cable or STP cable).
- In the Programming and Editing mode of operation, press the MOD key. Enter the keyword NET123. The iTNC will then display the main screen for network configuration (see figure at top right).
- Press the DEFINE NET soft key to enter the network setting for a specific device (see figure at center right).
- Enter any network address. Network addresses consist of four numbers separated by periods, e.g. **160.1.180.23**
- Press the right arrow key to select the next column, and enter the subnet mask. The subnet mask also consists of four numbers separated by periods, e.g. **255.255.0.0**
- Press the END key to leave the network configuration screen.
- Press the DEFINE MOUNT soft key to enter the network settings for a specific PC (see figure at bottom right).
- Define the PC name and drive that you want to access, beginning with two slashes, e.g. **//PC3444/C**
- Press the right arrow key to select the next column, and enter the name that the iTNC's file manager uses to display the PC, e.g. **PC3444:**
- Press the right arrow key to select the next column, and enter the file system type **smb**
- Press the right arrow key to select the next column and enter the following information (depending on the PC operating system): **ip=160.1.180.1,username=abcd,workgroup=SALES,password=uvwx**
- To exit the network configuration, press the END key twice. The iTNC restarts automatically.

The parameters **username, workgroup** and **password** do not need to be entered in all Windows operating systems.



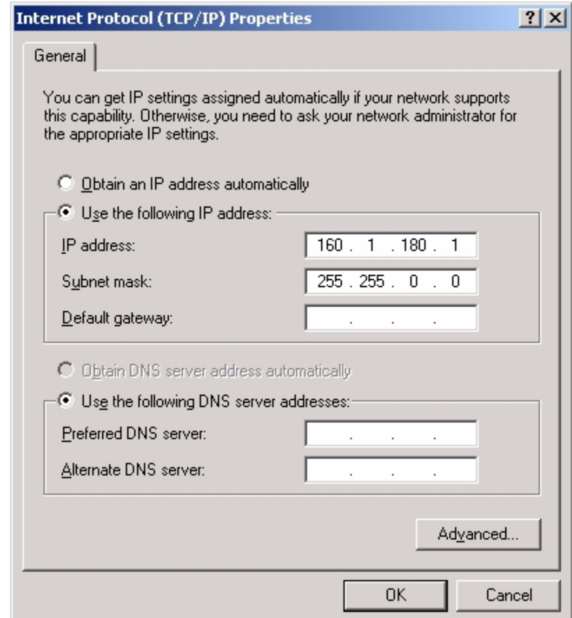




Settings on a PC with Windows 2000

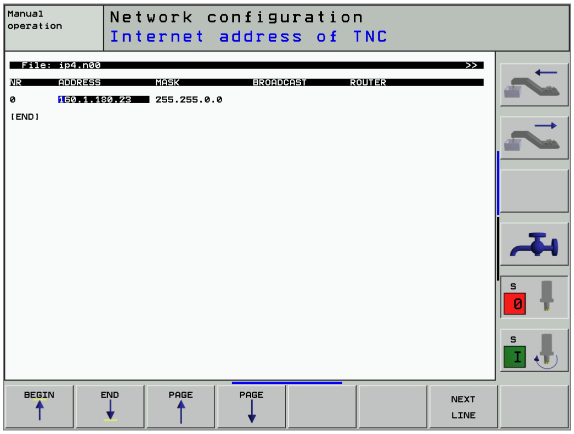
> **Prerequisite:**
>
> The network card must already be installed on the PC and ready for operation.
>
> If the PC that you want to connect the iTNC to is already integrated in your company network, then keep the PC's network address and adapt the iTNC's network address accordingly.

- To open Network Connections, click <Start>, <Control Panel>, <Network and Dial-up Connections>, and then Network Connections.
- Right-click the <LAN connection> symbol, and then <Properties> in the menu that appears.
- Double-click <Internet Protocol (TCP/IP)> to change the IP settings (see figure at top right).
- If it is not yet active, select the <Use the following IP address> option.
- In the <IP address> input field, enter the same IP address that you entered for the PC network settings on the iTNC, e.g. 160.1.180.1
- Enter 255.255.0.0 in the <Subnet mask> input field.
- Confirm the settings with <OK>.
- Save the network configuration with <OK>. You may have to restart Windows now.



Configuring the TNC

> Make sure that the person configuring your TNC is a network specialist.



- In the Programming and Editing mode of operation, press the MOD key. Enter the keyword NET123. The TNC will then display the main screen for network configuration.

General network settings

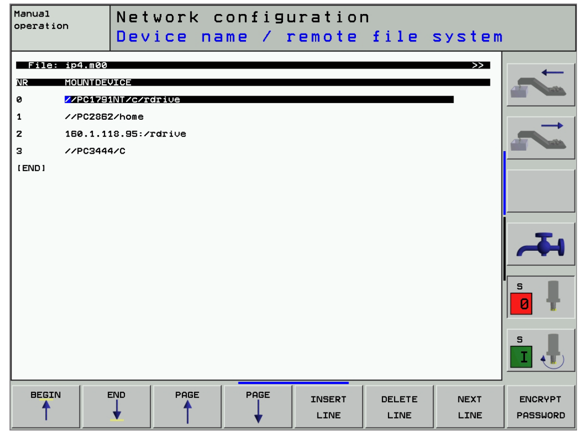
- Press the DEFINE NET soft key to enter the general network settings and enter the following information:

Setting	Meaning
ADDRESS	Address that your network specialist must assign to the TNC. Input: four numerical values separated by points, e.g. 160.1.180.20
MASK	The SUBNET MASK serves to differentiate between the network ID and the host ID in the network. Input: four numerical values separated by points. Ask your network specialist for the values, e.g. 255.255.0.0
BROADCAST	The broadcast address of the control is required only if it differs from the standard setting. The standard setting is formed from the network ID and the host ID, for which all bits are set to 1, e.g. 160.1.255.255
ROUTER	Internet address of your default router. Enter the Internet address only if your network consists of several parts. Input: four numerical values separated by points. Ask your network specialist for the values, e.g. 160.1.0.2
HOST	Name under which the TNC identifies itself in the network
DOMAIN	Domain name of the control (is not evaluated until later)
NAMESERVER	Network address of the domain server (is not evaluated until later)

> You do not need to indicate the protocol with the iTNC 530. It uses the transmission protocol according to RFC 894.

Network settings specific to the device

- Press the soft key DEFINE MOUNT to enter the network settings for a specific device. You can define any number of network settings, but you can manage only seven at one time.



Setting	Meaning
MOUNTDEVICE	■ Connection via NFS: Name of the directory that is to be logged on. This is formed by the network address of the server, a colon and the name of the directory to be mounted. Input: four numerical values separated by points. Ask your network specialist for the values, e.g. 160.1.13.4. Directory of the NFS server that you wish to connect to the TNC. Be sure to differentiate between small and capital letters when entering the path. ■ Connection to individual Windows computer: Enter the network name and the share name of the computer, e.g. //PC1791NT/C
MOUNTPOINT	Name that the TNC shows in the file manager for a connected device. Remember that the name must end with a colon.
FILESYSTEM-TYPE	File system type. **nfs**: Network File System **smb**: Windows network
OPTIONS for FILESYSTEM-TYPE=nfs	Data without spaces, separated by commas, and written in sequence. Switch between upper and lower case letters. **rsize=:** Packet size in bytes for data reception. Input range: 512 to 8192 **wsize=:** Packet size in bytes for data transmission. Input range: 512 to 8192 **time0=:** Time, in tenths of a second, after which the TNC repeats a Remote Procedure Call. Input range: 0 to 100 000. If there is no entry, the standard value 7 is used. Use higher values only if the TNC must communicate with the server through several routers. Ask your network specialist for the proper value. **soft=:** Definition of whether the TNC should repeat the Remote Procedure Call until the NFS server answers. "soft" entered: Do not repeat the Remote Procedure Call. "soft" not entered: Always repeat the Remote Procedure Call.

Setting	Meaning
OPTIONS for FILESYSTEM-TYPE=smb for direct connection to Windows networks	Data without spaces, separated by commas, and written in sequence. Switch between upper and lower case letters. **`ip=:`** ip address of PC to which the TNC is to be connected **`username=:`** User name under which the TNC is to log on **`workgroup=:`** Work group under which the TNC is to log on **`password=:`** Password that the TNC is to use for logon (up to 80 characters)
AM	Definition of whether the TNC upon switch-on should automatically connect with the network drive. 0: Do not automatically connect 1: Connect automatically

The entries **`username`**, **`workgroup`** and **`password`** in the OPTIONS column may not be necessary in Windows 95 and Windows 98 networks.

With the ENCODE PASSWORD soft key, you can encode the password defined under OPTIONS.

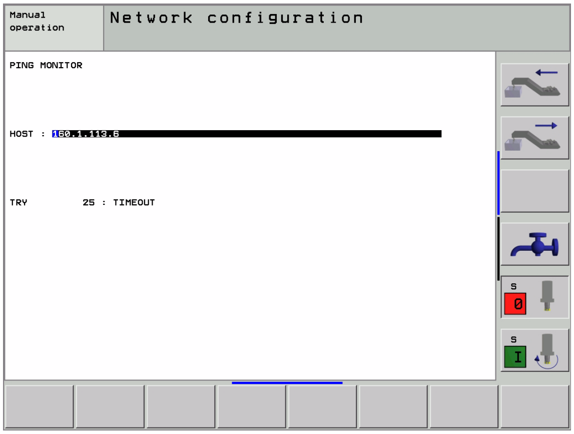
Defining a network identification

- Press the soft key DEFINE UID / GID to enter the network identification.

Setting	Meaning
TNC USER ID	Definition of the User Identification under which the end user accesses files in the network. Ask your network specialist for the proper value.
OEM USER ID	Definition of the User Identification under which the machine manufacturer accesses files in the network. Ask your network specialist for the proper value.
TNC GROUP ID	Definition of the group identification with which you access files in the network. Ask your network specialist for the proper value. The group identification is the same for end users and machine manufacturers.
UID for mount	Defines the user identification (UID) for the log-on procedure. **`USER:`** The user logs on with the USER identification. **`ROOT:`** The user logs on with the ID of the ROOT user, value = 0.

Test network connection

- Press the PING soft key.
- In the **HOST** line, enter then internet address of the computer for which you want to check the network connection.
- Confirm your entry with the ENT key. The TNC transmits data packets until you exit the test monitor by pressing the END key.



In the **TRY** line the TNC shows the number of data packets that were transmitted to the previously defined addressee. Behind the number of transmitted data packets the TNC shows the status:

Status display	Meaning
HOST RESPOND	Data packet was received again, connection is OK.
TIMEOUT	Data packet was not received, check the connection.
CAN NOT ROUTE	Data packet could not be transmitted. Check the Internet address of the server and of the router to the TNC.

12.6 Configuring PGM MGT

Function

With this function you can determine the features of the file manager:

- Standard: Simple file management without directory display
- Expanded range: File management with additional functions and directory display

Note: see "Standard File Management," page 41, and see "Advanced File Management," page 48.

Changing the setting

- Select the file manager in the Programming and Editing mode of operation: press the PGM MGT key
- Press the MOD key to select the MOD function.
- Select the PGM MGT setting: using the arrow keys, move the highlight onto the PGM MGT setting and use the ENT key to switch between STANDARD and ENHANCED.

12.7 Machine-Specific User Parameters

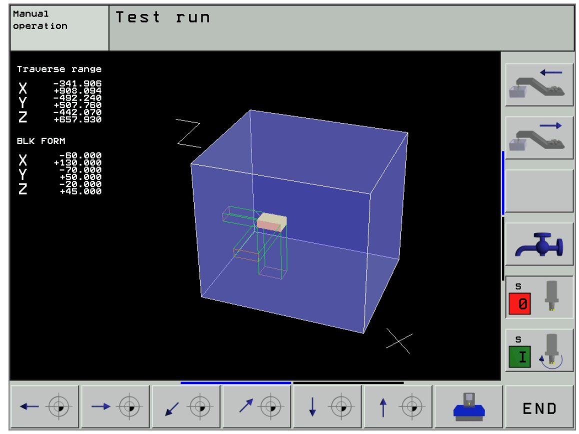
Function

To enable you to set machine-specific functions, your machine tool builder can define up to 16 machine parameters as user parameters.

This function is not available on all TNCs. Refer to your machine manual.

12.8 Showing the Workpiece in the Working Space

Function



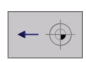
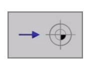
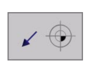
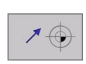
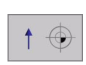
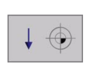
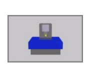
This MOD function enables you to graphically check the position of the workpiece blank in the machine's working space and to activate work space monitoring in the Test Run mode of operation. This function is activated with the BLANK IN WORK SPACE soft key.

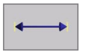
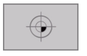
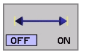
The TNC displays a cuboid for the working space. Its dimensions are shown in the "Traverse range" window. The TNC takes the dimensions for the working space from the machine parameters for the active traverse range. Since the traverse range is defined in the reference system of the machine, the datum of the cuboid is also the machine datum. You can see the position of the machine datum in the cuboid by pressing the soft key M91 in the 2nd soft-key row.

Another cuboid represents the blank form. The TNC takes its dimensions from the workpiece blank definition in the selected program. The workpiece cuboid defines the coordinate system for input. Its datum lies within the cuboid. You can see in the cuboid the position of the datum for input by pressing the corresponding soft key in the 2nd soft-key row.

For a test run it normally does not matter where the workpiece blank is located within the working space. However, if you test programs that contain movements with M91 or M92, you must graphically shift the workpiece blank to prevent contour damage. Use the soft keys shown in the table at right.

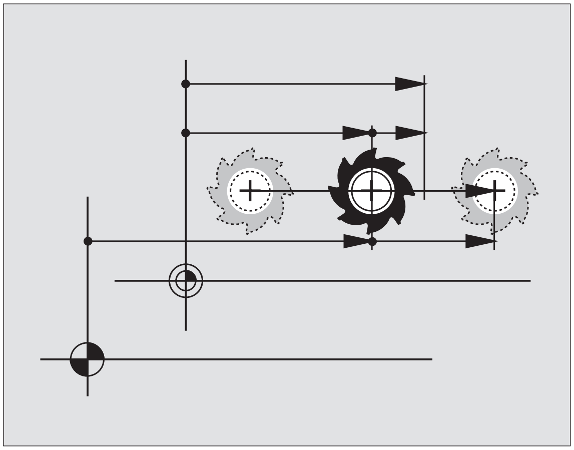
You can also activate the working-space monitor for the Test Run mode in order to test the program with the current datum and the active traverse ranges (see table below, last line).

Function	Soft key
Move workpiece blank to the left	
Move workpiece blank to the right	
Move workpiece blank forward	
Move workpiece blank backward	
Move workpiece blank upward	
Move workpiece blank downward	
Show workpiece blank referenced to the set datum	

Function	Soft key
Show the entire traversing range referenced to the displayed workpiece blank	
Show the machine datum in the working space	
Show a position determined by the machine tool builder (e.g. tool change position) in the working space	
Show the workpiece datum in the working space	
Enable (ON) or disable (OFF) working-space monitoring	

12.9 Position Display Types

Function



In the Manual Operation mode and in the Program Run modes of operation, you can select the type of coordinates to be displayed.

The figure at right shows the different tool positions:

- Starting position
- Target position of the tool
- Workpiece datum
- Machine datum

The TNC position displays can show the following coordinates:

Function	Display
Nominal position: the value presently commanded by the TNC	NOML.
Actual position; current tool position	ACTL.
Reference position; the actual position relative to the machine datum	REF
Distance remaining to the programmed position; difference between actual and target positions	DIST.
Servo lag: difference between nominal and actual positions (following error)	LAG
Deflection of the measuring touch probe	DEFL.
Traverses that were carried out with handwheel superpositioning (M118) (only Position display 2)	M118

With the MOD function Position display 1, you can select the position display in the status display.

With Position display 2, you can select the position display in the additional status display.

12.10 Unit of Measurement

Function

This MOD function determines whether the coordinates are displayed in millimeters (metric system) or inches.

- To select the metric system (e.g. X = 15.789 mm) set the Change mm/inches function to mm. The value is displayed to 3 decimal places.
- To select the inch system (e.g. X = 0.6216 inches) set the Change mm/inches function to inches. The value is displayed to 4 decimal places.

If you activate inch display, the TNC shows the feed rate in inch/min. In an inch program you must enter the feed rate larger by a factor of 10.

12.11 Select the Programming Language for $MDI

Function

The Program input MOD function lets you decide whether to program the $MDI file in HEIDENHAIN conversational dialog or in ISO format.

- To program the $MDI.H file in conversational dialog, set the Program input function to HEIDENHAIN
- To program the $MDI.I file according to ISO, set the Program input function to ISO

12.12 Selecting the Axes for Generating L Blocks

Function

The axis selection input field enables you to define the current tool position coordinates that are transferred to an L block. To generate a separate L block, press the ACTUAL-POSITION-CAPTURE soft key. The axes are selected by bit-oriented definition similar to programming the machine parameters:

Axis selection %11111 Transfer the X, Y, Z, IV and V axes

Axis selection %01111 Transfer the X, Y, Z and IV axes

Axis selection %00111 Transfer the X, Y and Z axes

Axis selection %00011 Transfer the X and Y axes

Axis selection %00001 Transfer the X axis

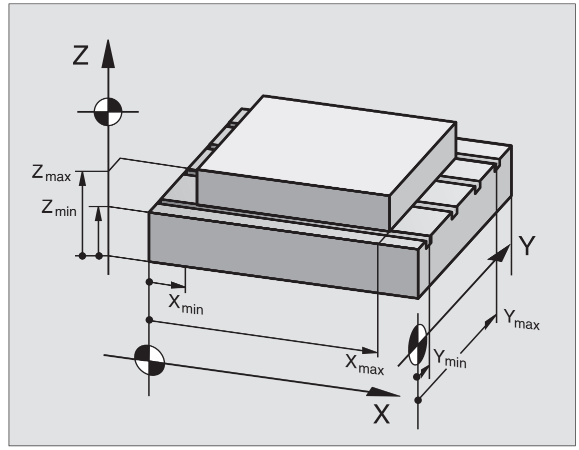
12.13 Enter the Axis Traverse Limits, Datum Display

Function

The AXIS LIMIT MOD function allows you to set limits to axis traverse within the machine's actual working envelope.

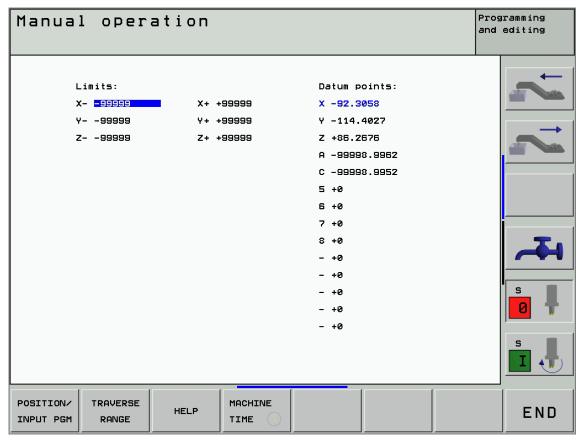
Possible application: Protecting an indexing fixture against tool collision.

The maximum range of traverse of the machine tool is defined by software limit switches. This range can be additionally limited through the TRAVERSE RANGE MOD function. With this function, you can enter the maximum and minimum traverse positions for each axis, referenced to the machine datum. If several traverse ranges are possible on your machine, you can set the limits for each range separately using the soft keys TRAVERSE RANGE (1) to TRAVERSE RANGE (3).



Working without additional traverse limits

To allow a machine axis to use its full range of traverse, enter the maximum traverse of the TNC (+/- 99 999 mm) as the TRAVERSE RANGE.



Find and enter the maximum traverse

- Set the Position display mod function to REF.
- Move the spindle to the positive and negative end positions of the X, Y and Z axes.
- Write down the values, including the algebraic sign.
- To select the MOD functions, press the MOD key.

TRAVERSE RANGE

- Enter the limits for axis traverse: Press the TRAVERSE RANGE soft key and enter the values that you wrote down as limits in the corresponding axes
- To exit the MOD function, press the END soft key.

The tool radius is not automatically compensated in the axis traverse limit value.

The traverse range limits and software limit switches become active as soon as the reference points are traversed.

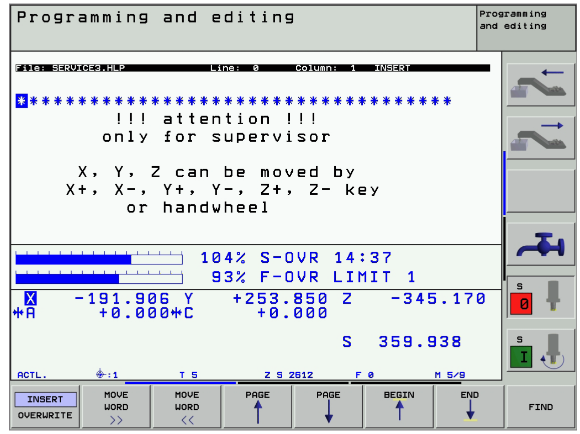
Datum display

The values shown at the lower left of the screen are the manually set datums referenced to the machine datum. They cannot be changed in the menu.

12.14 Displaying HELP Files

Function

Help files can aid you in situations in which you need clear instructions before you can continue (for example, to retract the tool after an interruption of power). The miscellaneous functions may also be explained in a help file. The figure at right shows the screen display of a help file.



> HELP files are not provided on every machine. Your machine tool builder can provide you with further information on this feature.

Selecting HELP files

- Press the MOD key to select the MOD function.

HELP

- To select the last active HELP file, press the HELP soft key.
- Call the file manager (PGM MGT key) and select a different help file, if necessary.

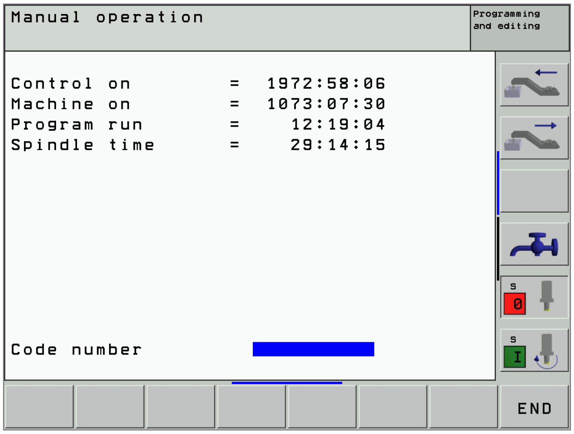
12.15 Display operating times

Function

The machine tool builder can provide further operating time displays. The machine tool manual provides further information.

The MACHINE TIME soft key enables you to show different operating time displays:

Operating time	Meaning
Control ON	Operating time of the control since commissioning
Machine ON	Operating time of the machine tool since commissioning
Program Run	Duration of controlled operation since commissioning



12.16 External Access

Function

The machine tool builder can configure teleservice settings with the LSV-2 interface. The machine tool manual provides further information.

The soft key SERVICE can be used to grant or restrict access through the LSV-2 interface.

With an entry in the configuration file TNC.SYS you can protect a directory and its subdirectories with a password. The password is requested when data from this directory is accessed from the LSV-2 interface. Enter the path and password for external access in the configuration file TNC.SYS.

The TNC.SYS file must be stored in the root directory TNC:\.

If you only supply one entry for the password, then the entire drive TNC:\ is protected.

You should use the updated versions of the HEIDENHAIN software TNCremo or TNCremoNT to transfer the data.

Entries in TNC.SYS	Meaning
REMOTE.TNCPASSWORD=	Password for LSV-2 access
REMOTE.TNCPRIVATEPATH=	Path to be protected

Example of TNC.SYS

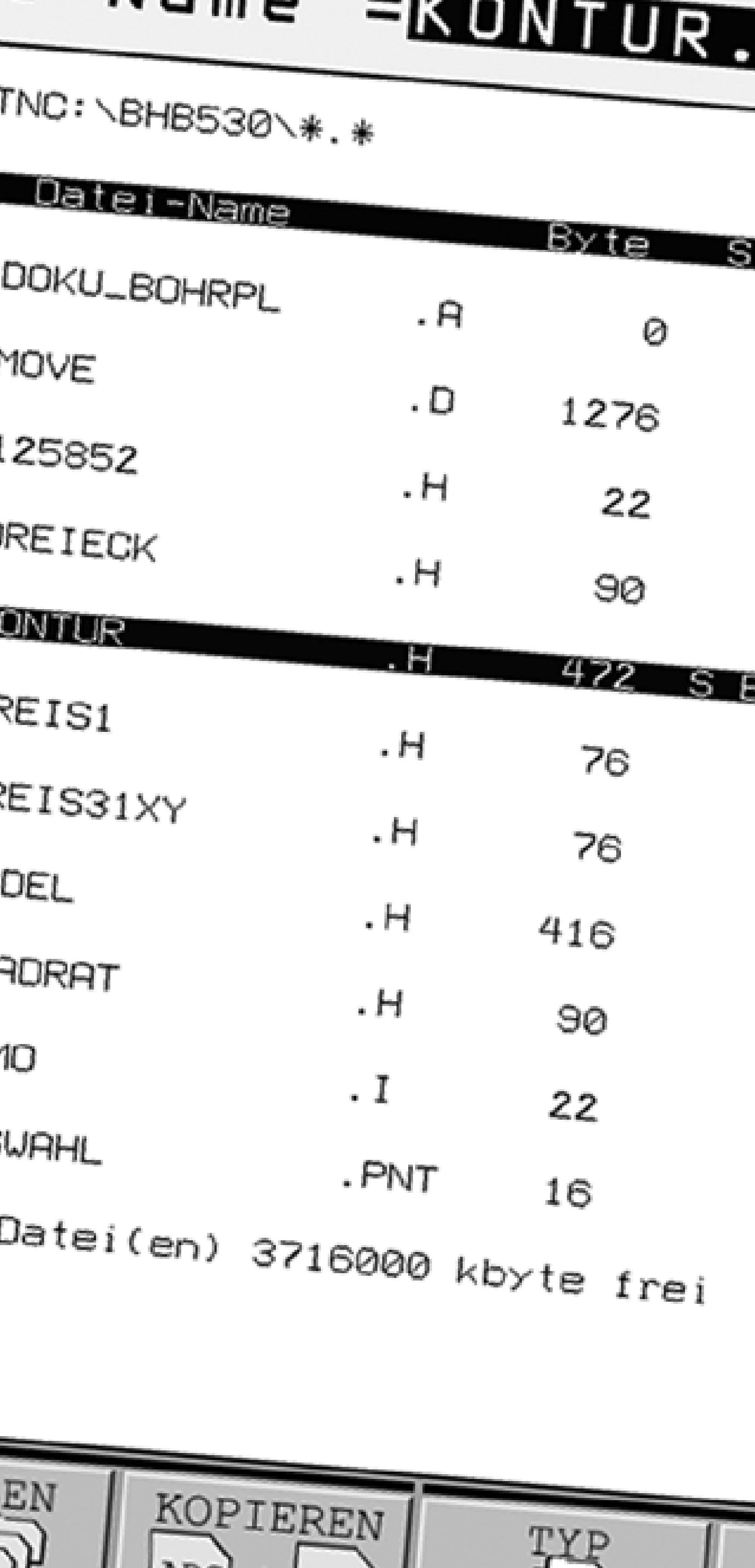
```
REMOTE.TNCPASSWORD=KR1402
REMOTE.TNCPRIVATEPATH=TNC:\RK
```

Permitting/Restricting external access

- Select any machine mode of operation.
- To select the MOD function, press the MOD key.

EXTERNAL ACCESS OFF ON

- Permit a connection to the TNC: Set the EXTERNAL ACCESS soft key to ON. The TNC will then permit data access through the LSV-2 interface. The password is requested when a directory that was entered in the configuration file TNC.SYS is accessed.
- Block connections to the TNC: Set the EXTERNAL ACCESS soft key to OFF. The TNC will then block access through the LSV-2 interface.



13

Tables and Overviews

13.1 General User Parameters

General user parameters are machine parameters affecting TNC settings that the user may want to change in accordance with his requirements.

Some examples of user parameters are:

- Dialog language
- Interface behavior
- Traversing speeds
- Sequence of machining
- Effect of overrides

Input possibilities for machine parameters

Machine parameters can be programmed as

- **Decimal numbers**
  Enter only the number
- **Pure binary numbers**
  Enter a percent sign (%) before the number
- **Hexadecimal numbers**
  Enter a dollar sign ($) before the number

Example:

Instead of the decimal number 27 you can also enter the binary number %11011 or the hexadecimal number $1B.

The individual machine parameters can be entered in the different number systems.

Some machine parameters have more than one function. The input value for these machine parameters is the sum of the individual values. For these machine parameters the individual values are preceded by a plus sign.

Selecting general user parameters

General user parameters are selected with code number 123 in the MOD functions.

The MOD functions also include machine-specific user parameters.

External data transfer	
Integrating TNC interfaces EXT1 (5020.0) and EXT2 (5020.1) to an external device	**MP5020.x** 7 data bits (ASCII code, 8th bit = parity): **+0** 8 data bits (ASCII code, 9th bit = parity): **+1** Block Check Character (BCC) any: **+0** Block Check Character (BCC) control character not permitted: **+2** Transmission stop through RTS active: **+4** Transmission stop through RTS inactive: **+0** Transmission stop through DC3 active: **+8** Transmission stop through DC3 inactive: **+0** Character parity even: **+0** Character parity odd: **+16** Character parity not desired: **+0** Character parity desired: **+32** 11/2 stop bits: **+0** 2 stop bit: **+64** 1 stop bit: **+128** 1 stop bit: **+192** Example: Use the following setting to adjust the TNC interface EXT2 (MP 5020.1) to an external non-HEIDENHAIN device: 8 data bits, any BCC, transmission stop through DC3, even character parity, character parity desired, 2 stop bits Input for **MP 5020.1:** 1+0+8+0+32+64 = **105**
Interface type for EXT1 (5030.0) and EXT2 (5030.1)	**MP5030.x** Standard transmission: **0** Interface for blockwise transfer: **1**

3-D Touch Probes	
Select signal transmission	**MP6010** Touch probe with cable transmission: **0** Touch probe with infrared transmission: **1**
Probing feed rate for triggering touch probes	**MP6120** **1** to **3000** [mm/min]
Maximum traverse to first probe point	**MP6130** **0.001** to **99 999.9999** [mm]
Safety clearance to probing point during automatic measurement	**MP6140** **0.001** to **99 999.9999** [mm]
Rapid traverse for triggering touch probes	**MP6150** **1** to **300 000** [mm/min]

3-D Touch Probes	
Measure center misalignment of the stylus when calibrating a triggering touch probe	**MP6160** No 180° rotation of the 3-D touch probe during calibration: **0** M function for 180° rotation of the touch probe during calibration: **1** to **999**
M function for orienting the infrared sensor before each measuring cycle	**MP6161** Function inactive: **0** Orientation directly through the NC: **-1** M function for orienting the touch probe: **1 to 999**
Angle of orientation for the infrared sensor	**MP6162** **0** to **359.9999** [°]
Difference between the current angle of orientation and the angle of orientation set in MP 6162; when the entered difference is reached, an oriented spindle stop is to be carried out.	**MP6163** **0** to **3.0000** [°]
Automatically orient the infrared sensor before probing to the programmed probing direction	**MP6165** Function inactive: **0** Orient infrared sensor: **1**
Multiple measurement for programmable probe function	**MP6170** **1** to **3**
Confidence range for multiple measurement	**MP6171** **0.001** to **0.999** [mm]
Automatic calibration cycle: Center of the calibration ring in the X axis referenced to the machine datum	**MP6180.0 (traverse range 1) to MP6180.2 (traverse range3)** **0** to **99 999.9999** [mm]
Automatic calibration cycle: Center of the calibration ring in the Y-axis referenced to the machine datum for	**MP6181.x (traverse range 1) to MP6181.2 (traverse range3)** **0** to **99 999.9999** [mm]
Automatic calibration cycle: Upper edge of the calibration ring in the Z axis referenced to the machine datum for	**MP6182.x (traverse range 1) to MP6182.2 (traverse range3)** **0** to **99 999.9999** [mm]
Automatic calibration cycle: Distance below the upper edge of the ring where the calibration is carried out by the TNC	**MP6185**.x (traverse range 1) to MP6185.2 (traverse range 3) **0.1** to **99 999.9999** [mm]
Radius measurement with the TT 130 touch probe: Probing direction	**MP6505.0 (traverse range 1) to 6505.2 (traverse range 3)** Positive probing direction in the angle reference axis (0° axis): **0** Positive probing direction in the +90° axis: **1** Negative probing direction in the angle reference axis (0° axis): **2** Negative probing direction in the +90° axis: **3**
Probing feed rate for second measurement with TT 120, stylus shape, corrections in TOOL.T	**MP6507** Calculate feed rate for second measurement with TT 130, with constant tolerance: **+0** Calculate feed rate for second measurement with TT 130, with variable tolerance: **+1** Constant feed rate for second measurement with TT 130: **+2**

3-D Touch Probes	
Maximum permissible measuring error with TT 130 during measurement with rotating tool Required for calculating the probing feed rate in connection with MP6570	**MP6510.0** **0.001** to **0.999** [mm] (recommended input value: 0.005 mm) **MP6510.1** **0.001** to **0.999** [mm] (recommended input value: 0.01 mm)
Feed rate for probing a stationary tool with the TT 130	**MP6520** **1** to **3000** [mm/min]
Radius measurement with the TT 130: Distance from lower edge of tool to upper edge of stylus	**MP6530.0 (traverse range 1) to MP6530.2 (traverse range 3)** **0.001** to **99.9999** [mm]
Set-up clearance in the tool axis above the stylus of the TT 130 for pre-positioning	**MP6540.0** **0.001** to **30 000.000** [mm]
Clearance zone in the machining plane around the stylus of the TT 130 for pre-positioning	**MP6540.1** **0.001** to **30 000.000** [mm]
Rapid traverse for TT 130 in the probe cycle	**MP6550** **10** to **10 000** [mm/min]
M function for spindle orientation when measuring individual teeth	**MP6560** **0** to **999**
Measuring rotating tools: Permissible rotational speed at the circumference of the milling tool Required for calculating rpm and probe feed rate	**MP6570** **1.000** to **120.000** [m/min]
Measuring rotating tools: Permissible rotational rpm	**MP6572** **0.000** to **1000.000** [rpm] If you enter 0, the speed is limited to 1000 rpm

3-D Touch Probes	
Coordinates of the TT 120 stylus center relative to the machine datum	**MP6580.0 (traverse range 1)** X axis **MP6580.1 (traverse range 1)** Y axis **MP6580.2 (traverse range 1)** Z axis **MP6581.0 (traverse range 2)** X axis **MP6581.1 (traverse range 2)** Y axis **MP6581.2 (traverse range 2)** Z axis **MP6582.0 (traverse range 3)** X axis **MP6582.1 (traverse range 3)** Y axis **MP6582.2 (traverse range 3)** Z axis
Monitoring the position of rotary axes and parallel axes	**MP6585** Function inactive: **0** Function active: **1**
Defining the rotary axes and parallel axes to be monitored	**MP6586.0** Do not monitor the position of the A axis: **0** Monitor the position of the A axis: **1** **MP6586.1** Do not monitor the position of the B axis: **0** Monitor the position of the B axis: **1** **MP6586.2** Do not monitor the position of the C axis: **0** Monitor the position of the C axis: **1** **MP6586.3** Do not monitor the position of the U axis: **0** Monitor the position of the U axis: **1** **MP6586.4** Do not monitor the position of the V axis: **0** Monitor the position of the V axis: **1** **MP6586.5** Do not monitor the position of the W axis: **0** Monitor the position of the W axis: **1**

TNC displays, TNC editor	
Cycles 17, 18 and 207: Oriented spindle stop at beginning of cycle	**MP7160** Oriented spindle stop: **0** No oriented spindle stop: **1**
Programming station	**MP7210** TNC with machine: **0** TNC as programming station with active PLC: **1** TNC as programming station with inactive PLC: **2**
Acknowledgment of POWER INTERRUPTED after switch-on	**MP7212** Acknowledge with key: **0** Acknowledge automatically: **1**
ISO programming: Set the block number increment	**MP7220** **0** to **150**
Disabling the selection of file types	**MP7224.0** All file types selectable via soft key: **+0** Disable selection of HEIDENHAIN programs (soft key SHOW .H): **+1** Disable selection of ISO programs (soft key SHOW .I): **+2** Disable selection of tool tables (soft key SHOW .T): **+4** Disable selection of datum tables (soft key SHOW .D): **+8** Disable selection of pallet tables (soft key SHOW .P): **+16** Disable selection of text files (soft key SHOW .A):**+32** Disable selection of point tables (soft key SHOW .PNT): **+64**
Disabling the editor for certain file types **Note:** If a particular file type is inhibited, the TNC will erase all files of this type.	**MP7224.1** Do not disable editor: **+0** Disable editor for ■ HEIDENHAIN programs: **+1** ■ ISO programs: **+2** ■ Tool tables: **+4** ■ Datum tables: **+8** ■ Pallet tables: **+16** ■ Text files: **+32** ■ Point tables: **+64**
Configure pallet files	**MP7226.0** Pallet table inactive: **0** Number of pallets per pallet table: **1** to **255**
Configure datum files	**MP7226.1** Datum table inactive: **0** Number of datums per datum table: **1** to **255**
Program length for program check	**MP7229.0** Blocks **100** to **9999**
Program length up to which FK blocks are permitted	**MP7229.1** Blocks **100** to **9999**

TNC displays, TNC editor	
Dialog language	**MP7230** English: **0** German: **1** Czech: **2** French: **3** Italian: **4** Spanish: **5** Portuguese: **6** Swedish: **7** Danish: **8** Finnish: **9** Dutch: **10** Polish: **11** Hungarian: **12** Reserved: **13** Russian: **14**
Internal clock of the TNC	**MP7235** Universal time (Greenwich time): **0** Central European Time (CET): **1** Central European Summer Time: **2** Time difference to universal time: **-23** to **+23** [hours]
Configure tool tables	**MP7260** Inactive: **0** Number of tools generated by the TNC when a new tool table is opened: **1** to **254** If you require more than 254 tools, you can expand the tool table with the function APPEND N LINES see "Tool Data," page 102
Configure pocket tables	**MP7261.0 (magazine 1)** **MP7261.1 (magazine 2)** **MP7261.2 (magazine 3)** **MP7261.3 (magazine 4)** Inactive: **0** Number of pockets in the tool magazine: **1** to **254** If the value 0 is entered in MP7261.1 to MP7261.3, only one tool magazine will be used.
Index tool numbers in order to be able to assign different compensation data to one tool number	**MP7262** Do not index: **0** Number of permissible indices: **1** to **9**
Soft key for pocket tables	**MP7263** Show the POCKET TABLE soft key in the tool table: **0** Do not show the POCKET TABLE soft key in the tool table: **1**

TNC displays, TNC editor	
Configure tool table (To omit from the table: enter 0); Column number in the tool table for	**MP7266.0** Tool name – NAME: **0** to **32**; column width: 16 characters **MP7266.1** Tool length – L: **0** to **32**; column width: 11 characters **MP7266.2** Tool radius – R: **0** to **32**; column width: 11 characters **MP7266.3** Tool radius 2 – R2: **0** to **32**; column width: 11 characters **MP7266.4** Oversize length – DL: **0** to **32**; column width: 8 characters **MP7266.5** Oversize radius – DR: **0** to **32**; column width: 8 characters **MP7266.6** Oversize radius 2 – DR2: **0** to **32**; column width: 8 characters **MP7266.7** Tool locked – TL: **0** to **32**; column width: 2 characters **MP7266.8** Replacement tool – RT: **0** to **32**; column width: 3 characters **MP7266.9** Maximum tool life – TIME1: **0** to **32**; column width: 5 characters **MP7266.10** Maximum tool life for TOOL CALL – TIME2: **0** to **32**; column width: 5 characters **MP7266.11** Current tool life – CUR. TIME: **0** to **32**; column width: 8 characters

TNC displays, TNC editor	
Configure tool table (To omit from the table: enter 0); Column number in the tool table for	**MP7266.12** Tool comment – DOC: **0** to **32**; column width: 16 characters **MP7266.13** Number of teeth – CUT.: **0** to **32**; column width: 4 characters **MP7266.14** Tolerance for wear detection in tool length – LTOL: **0** to **32**; column width: 6 characters **MP7266.15** Tolerance for wear detection in tool radius – RTOL: **0** to **32**; column width: 6 characters **MP7266.16** Cutting direction – DIRECT.: **0** to **32**; column width: 7 characters **MP7266.17** PLC status – PLC: **0** to **32**; column width: 9 characters **MP7266.18** Offset of the tool in the tool axis in addition to MP6530 – TT:L-OFFS: **0** to **32** column width: 11 characters **MP7266.19** Offset of the tool between stylus center and tool center – TT:R-OFFS: **0** to **32** column width: 11 characters **MP7266.20** Tolerance for break detection in tool length – LBREAK: **0** to **32**; column width: 6 characters **MP7266.21** Tolerance for break detection in tool radius – RBREAK: **0** to **32**; column width: 6 characters **MP7266.22** Tooth length (Cycle 22) – LCUTS: **0** to **32**; column width: 11 characters **MP7266.23** Maximum plunge angle (Cycle 22) – ANGLE.: **0** to **32**; column width: 7 characters **MP7266.24** Tool type –TYP: **0** to **32**; column width: 5 characters **MP7266.25** Tool material – TMAT: **0** to **32**; column width: 16 characters **MP7266.26** Cutting data table – CDT: **0** to **32**; column width: 16 characters **MP7266.27** PLC value – PLC-VAL: **0** to **32**; column width: 11 characters **MP7266.28** Center misalignment in reference axis – CAL-OFF1: **0** to **32**; column width: 11 characters **MP7266.29** Center misalignment in minor axis – CAL-OFF2: **0** to **32**; column width: 11 characters **MP7266.30** Spindle angle for calibration – CALL-ANG: **0** to **32**; column width: 11 characters **MP7266.31** Tool type for the pocket table–PTYP: **0** to **32**; column width: 2 characters

TNC displays, TNC editor	
Configure tool pocket tables; Column number in the pocket table for (To omit from the table: enter 0)	**MP7267.0** Tool number – T: **0** to **7** **MP7267.1** Special tool – ST: **0** to **7** **MP7267.2** Fixed pocket – F: **0** to **7** **MP7267.3** Pocket locked – L: **0** to **7** **MP7267.4** PLC status – PLC: **0** to **7** **MP7267.5** Tool name from tool table – TNAME: **0** to **7** **MP7267.6** Comment from tool table – DOC: **0** to **7**
Manual Operation mode: Display of feed rate	**MP7270** Display feed rate F only if an axis direction button is pressed: **0** Display feed rate F even if no axis direction button is pressed (feed rate defined via soft key F or feed rate of the "slowest" axis): **1**
Decimal character	**MP7280** The decimal character is a comma: **0** The decimal character is a point: **1**
Display mode	**MP7281.0 Programming and Editing operating mode** **MP7281.1 Program Run mode** Always display multiple line blocks completely: **0** Display multiline blocks completely if the multiline block is the active block: **1** Display multiline blocks completely if the multiline block is being edited: **2**
Position display in the tool axis	**MP7285** Display is referenced to the tool datum: **0** Display in the tool axis is referenced to the tool face: **1**
Display step for the spindle position	**MP7289** 0,1 °: **0** 0,05 °: **1** 0,01 °: **2** 0,005 °: **3** 0,001 °: **4** 0,0005 °: **5** 0,0001 °: **6**
Display step	**MP7290.0 (X axis) to MP7290.8 (9th axis)** 0.1 mm: **0** 0.05 mm: **1** 0.01 mm: **2** 0.005 mm: **3** 0.001 mm: **4** 0.0005 mm: **5** 0.0001 mm: **6**

TNC displays, TNC editor	
Disable datum setting	**MP7295** Do not disable datum setting: **+0** Disable datum setting in the X axis: **+1** Disable datum setting in the Y axis: **+2** Disable datum setting in the Z axis: **+4** Disable datum setting in the IVth axis: **+8** Disable datum setting in the Vth axis: **+16** Disable datum setting in the 6th axis: **+32** Disable datum setting in the 7th axis: **+64** Disable datum setting in the 8th axis: **+128** Disable datum setting in the 9th axis: **+256**
Disable datum setting with the orange axis keys	**MP7296** Do not disable datum setting: **0** Disable datum setting with the orange axis keys: **1**
Reset status display, Q parameters, machining time and tool data	MP7300 Reset all when a program is selected: **0** Reset all when a program is selected and with M02, M30, END PGM: **1** Reset only status display and tool data when a program is selected: **2** Reset only status display, machining time and tool data when a program is selected and with M02, M30, END PGM: **3** Reset status display, machining time and Q parameters when a program is selected: **4** Reset status display, machining time, and Q parameters when a program is selected and with M02, M30, END PGM: **5** Reset status display and machining time when a program is selected: **6** Reset status display and machining time when a program is selected and with M02, M30, END PGM: **7**

TNC displays, TNC editor	
Graphic display mode	**MP7310** Projection in three planes according to ISO 6433, projection method 1: **+1** Projection in three planes according to ISO 6433, projection method 2: **+1** Do not rotate coordinate for graphic display: **+0** Rotate coordinate system for graphic display by 90°: **+2** Display new BLK FORM in Cycle 7 DATUM SHIFT referenced to the old datum: **+0**
Graphic simulation without programmed tool axis: Tool radius	**MP7315** **0** to **99 999.9999** [mm]
Graphic simulation without programmed tool axis: Penetration depth	**MP7316** **0** to **99 999.9999** [mm]
Graphic simulation without programmed tool axis: M function for start	**MP7317.0** **0** to **88** (0: Function inactive)
Graphic simulation without programmed tool axis: M function for end	**MP7317.1** **0** to **88** (0: Function inactive)
Screen saver Enter the time after which the TNC should start the screen saver	**MP7392** **0** to **99** [min] (0: Function inactive)

Machining and program run	
Effect of Cycle 11 SCALING FACTOR	**MP7410** SCALING FACTOR effective in 3 axes: **0** SCALING FACTOR effective in the working plane only: **1**
Manage tool data/calibration data	**MP7411** Overwrite current tool data by the calibrated data from the 3-D touch probe system: **+0** Current tool data are retained: **+1** Manage calibrated data in the calibration menu: **+0** Manage calibrated data in the tool table: **+2**
SL Cycles	**MP7420** Mill channel around the contour - clockwise for islands and counterclockwise for pockets: **+0** Mill channel around the contour - clockwise for pockets and counterclockwise for islands: **+1** First mill the channel, then rough out the contour: **+0** First rough out the contour, then mill the channel: **+2** Combine compensated contours: **+0** Combine uncompensated contours: **+4** Complete one process for all infeeds before switching to the other process: **+0** Mill channel and rough-out for each infeed depth before continuing to the next depth: **+8** The following note applies to the Cycles 6, 15, 16, 21, 22, 23, and 24: At the end of the cycle, move the tool to the position that was last programmed before the cycle call: **+0** At the end of the cycle, retract the tool in the tool axis only: **+16**
Cycle 4 POCKET MILLING, Cycle 5 CIRCULAR POCKET MILLING, and Cycle 6 ROUGH OUT: Overlap factor	**MP7430** **0.1** to **1.414**
Permissible deviation of circle radius between circle end point and circle starting point	**MP7431** **0.0001** to **0.016** [mm]
Operation of various miscellaneous functions M **Note:** The k_V factors for position loop gain are set by the machine tool builder. Refer to your machine manual.	**MP7440** Program stop with M06: **+0** No program stop with M06: **+1** No cycle call with M89: **+0** Cycle call with M89: **+2** Program stop with M functions: **+0** No program stop with M functions: **+4** k_V factors cannot be switched through M105 and M106: **+0** k_V factors switchable through M105 and M106: **+8** Reduce the feed rate in the tool axis with M103 F.. Function inactive: **+0** Reduce the feed rate in the tool axis with M103 F.. Function active: **+16** Exact stop for positioning with rotary axes inactive: **+0** Exact stop for positioning with rotary axes active: **+64**

Machining and program run	
Error message during cycle call	**MP7441** Error message when M3/M4 not active: **0** Suppress error message when M3/M4 not active: **+1** reserved: +2 Suppress error message when positive depth programmed: **+0** Output error message when negative depth programmed: **+4**
M function for spindle orientation in the fixed cycles	**MP7442** Function inactive: **0** Orientation directly through the NC: **-1** M function for orienting the spindle: **1** to **999**
Maximum contouring speed at feed rate override setting of 100% in the Program Run modes	**MP7470** **0** to **99 999** [mm/min]
Feed rate for rotary-axis compensation movements	**MP7471** **0** to **99 999** [mm/min]
Datums from a datum table are referenced to the	**MP7475** Workpiece datum: **0** Machine datum: **1**
Running pallet tables	**MP7683** Program Run, Single Block: Run one line of the active NC program at every NC start; Program Run, Full Sequence: Run the entire NC program at every NC start: **+0** Program Run, Single Block: Run the entire NC program at every NC start: **+1** Program Run, Full Sequence: Run all NC programs up to the next pallet at every NC start: **+2** Program Run, Full Sequence: Run the entire NC pallet file at every NC start: **+4** Program Run, Full Sequence: If running of the complete pallet file is selected (+4), then run the pallet file without interruption, i.e. until you press NC stop: **+8** Pallet tables can be edited with the EDIT PALLET soft key: **+16** Display the AUTOSTART soft key: **+32** Pallet table or NC program is displayed: **+64**

13.2 Pin Layout and Connecting Cable for the Data Interfaces

RS-232-C/V.24 interface for HEIDENHAIN devices

The interface complies with the requirements of EN 50 178 for "low voltage electrical separation."

When using the 25-pin adapter block:

TNC		Adapter block 310 085-01			Connecting cable 365 725-xx				
Male	**Assignment**	**Female**	**Color**	**Female**	**Male**	**Female**	**Male**	**Color**	**Female**
1	Do not assign	1		1	1	1	1	WH/BN	1
2	RXD	2	Yellow	3	3	3	3	Yellow	2
3	TXD	3	Green	2	2	2	2	Green	3
4	DTR	4	Brown	20	20	20	20	Brown	8
5	Signal GND	5	Red	7	7	7	7	Red	7
6	DSR	6	Blue	6	6	6	6		6
7	RTS	7	Gray	4	4	4	4	Gray	5
8	CTR	8	Pink	5	5	5	5	Pink	4
9	Do not assign	9					8	Violet	20
Hsg.	Ext. shield	Hsg.	Ext. shield	Hsg.	Hsg.	Hsg.	Hsg.	Ext. shield	Hsg.

When using the 9-pin adapter block:

TNC		Connecting cable 355 484-xx			Adapter block 363 987-02		Connecting cable 366 964-xx		
Male	**Assignment**	**Female**	**Color**	**Male**	**Female**	**Male**	**Female**	**Color**	**Female**
1	Do not assign	1	Red	1	1	1	1	Red	1
2	RXD	2	Yellow	2	2	2	2	Yellow	3
3	TXD	3	White	3	3	3	3	White	2
4	DTR	4	Brown	4	4	4	4	Brown	6
5	Signal GND	5	Black	5	5	5	5	Black	5
6	DSR	6	Violet	6	6	6	6	Violet	4
7	RTS	7	Gray	7	7	7	7	Gray	8
8	CTR	8	WH/GN	8	8	8	8	WH/GN	7
9	Do not assign	9	Green	9	9	9	9	Green	9
Hsg.	Ext. shield	Hsg.	Ext. shield	Hsg.	Hsg.	Hsg.	Hsg.	Ext. shield	Hsg.

Non-HEIDENHAIN devices

The connector pin layout of a non-HEIDENHAIN device may differ considerably from that on a HEIDENHAIN device.

This often depends on the unit and type of data transfer. The table below shows the connector pin layout on the adapter block.

Adapter block 363 987-02		Connecting cable 366 964-xx		
Female	**Male**	**Female**	**Color**	**Female**
1	1	1	Red	1
2	2	2	Yellow	3
3	3	3	White	2
4	4	4	Brown	6
5	5	5	Black	5
6	6	6	Violet	4
7	7	7	Gray	8
8	8	8	WH/GN	7
9	9	9	Green	9
Hsg.	Hsg.	Hsg.	Ext. shield	Hsg.

RS-422/V.11 interface

Only non-HEIDENHAIN devices are connected to the RS-422 interface.

> The interface complies with the requirements of EN 50 178 for "low voltage electrical separation."
>
> The pin layouts on the TNC logic unit (X28) and on the adapter block are identical.

TNC		Connecting cable 355 484-xx			Adapter block 363 987-01	
Female	**Assignment**	**Male**	**Color**	**Female**	**Male**	**Female**
1	RTS	1	Red	1	1	1
2	DTR	2	Yellow	2	2	2
3	$\overline{\text{RXD}}$	3	White	3	3	3
4	$\overline{\text{TXD}}$	4	Brown	4	4	4
5	Signal GND	5	Black	5	5	5
6	CTS	6	Violet	6	6	6
7	DSR	7	Gray	7	7	7
8	RXD	8	WH/GN	8	8	8
9	TXD	9	Green	9	9	9
Hsg.	Ext. shield	Hsg.	Ext. shield	Hsg.	Hsg.	Hsg.

Ethernet interface RJ45 socket

Maximum cable length: Unshielded: 100 m
Shielded: 400 m

Pin	Signal	Description
1	TX+	Transmit Data
2	TX–	Transmit Data
3	REC+	Receive Data
4	Vacant	
5	Vacant	
6	REC–	Receive Data
7	Vacant	
8	Vacant	

13.3 Technical Information

User functions	
Description	■ Basic version: 3 axes plus spindle ● 4th NC axis plus auxiliary axis (axis option) or ● 8 additional axes or 7 additional axes plus 2nd spindle ■ Digital current and speed control
Programming	HEIDENHAIN conversational and ISO formats
Position entry	■ Nominal positions for line segments and arcs in Cartesian or polar coordinates ■ Absolute or incremental dimensions ■ Display and entry in mm or inches ■ Display of the handwheel path during machining with handwheel superimposition
Tool compensation	■ Tool radius in the working plane and tool length ■ Calculating the radius-compensated contour up to 99 blocks in advance (M120) ■ Three-dimensional tool-radius compensation for subsequent changing of tool data without having to recalculate the program
Tool tables	Multiple tool tables with any number of tools
Cutting data tables	Cutting data tables for automatic calculation of spindle speed and feed rate from tool-specific data (cutting speed, feed per tooth)
Constant cutting speed	■ With respect to the path of the tool center ■ With respect to the cutting edge
Background programming	Create one program with graphical support while another program is running.
3-D machining (software option 2)	□ Motion control with minimum jerk □ 3-D compensation through surface normal vectors □ Using the electronic handwheel to change the angle of the swivel head during program run without affecting the position of the tool point (TCPM = **T**ool **C**enter **P**oint **M**anagement) □ Keeping the tool normal to the contour □ Tool radius compensation normal to the direction of traverse and the tool direction □ Spline interpolation
Rotary table machining (software option 1)	❍ Programming of cylindrical contours as if in two axes ❍ Feed rate in length per minute
Contour elements	■ Straight line ■ Chamfer ■ Circular path ■ Circle center ■ Circle radius ■ Tangentially connecting circle ■ Corner rounding

User functions	
Contour approach and departure	■ Via straight line: tangential or perpendicular ■ Via circular arc
FK free contour programming	■ FK free contour programming in HEIDENHAIN conversational format with graphic support for workpiece drawings not dimensioned for NC
Program jumps	■ Subprograms ■ Program section repeat ■ Program as subprogram
Fixed cycles	■ Drilling cycles for drilling, pecking, reaming, boring, tapping with a floating tap holder, rigid tapping ■ Cycles for milling internal and external threads ■ Milling and finishing rectangular and circular pockets ■ Cycles for multipass milling of flat and twisted surfaces ■ Cycles for milling linear and circular slots ■ Linear and circular hole patterns ■ Contour pockets—also with contour-parallel machining ■ Contour train ■ OEM cycles (special cycles developed by the machine tool builder) can also be integrated
Coordinate transformation	■ Datum shift, rotation, mirroring ■ Axis-specific scaling ❍ Tilting the working plane (software option 1)
Q parameters Programming with variables	■ Mathematic functions =, +, –, *, /, sin α , cos α , angle α of sin α and cos α , $\sqrt{a}$, $\sqrt{a^2 + b^2}$ ■ Logical comparisons (=, =/, <, >) ■ Calculating with parentheses ■ tan α, arc sin, arc cos, arc tan, a^n, e^n, ln, log, absolute value of a number, the constant π , negation, truncation of digits before or after the decimal point ■ Functions for calculating circles
Programming support	■ Pocket calculator ■ Context-sensitive help function for error messages ■ Graphical support during programming of cycles ■ Comment blocks in the NC program
Actual position capture	■ Actual positions can be transferred directly into the NC program
Test Run graphics Display modes	Graphic simulation before a program run, even while another program is being run ■ Plan view / projection in 3 planes / 3-D view ■ Magnification of details
Interactive Programming graphics	■ In the Programming and Editing mode, the contour of the NC blocks is drawn on screen while they are being entered (2-D pencil-trace graphics), even while another program is running

User functions	
Program Run graphics Display modes	■ Graphic simulation of real-time machining in plan view / projection in 3 planes / 3-D view
Machining time	■ Calculating the machining time in the Test Run mode of operation ■ Display of the current machining time in the Program Run modes
Returning to the contour	■ Mid-program startup in any block in the program, returning the tool to the calculated nominal position to continue machining ■ Program interruption, contour departure and reapproach
Datum tables	■ Several datum tables
Pallet tables	■ Pallet tables (with as many entries as desired for the selection of pallets, NC programs and datums) can be machined workpiece by workpiece or tool by tool
Touch probe cycles	■ Calibrating a touch probe ■ Compensation of workpiece misalignment, manual or automatic ■ Datum setting, manual or automatic ■ Automatic workpiece measurement ■ Cycles for automatic tool measurement

Specifications	
Components	■ MC 422 main computer ■ CC 422 controller unit ■ Keyboard ■ TFT 10.4-inch or 15.1-inch flat-panel display with soft keys
Program memory	■ Hard disk with at least 2 GB for NC programs
Input resolution and display step	■ To 0.1 µm for linear axes ■ To 0.0001° for angular axes
Input range	■ Maximum 99 999.999 mm (3937 in.) or 99 999.999°
Interpolation	■ Line in 4 axes □ Line in 5 axes (subject to export permit) (software option 2) ■ Arc in 2 axes ○ Arc in 3 axes with tilted working plane (software option 1) ■ Helix: Combination of circular and linear motion ■ Spline: Execution of splines (3rd degree polynomials)
Block processing time 3-D straight line without radius compensation	■ 3.6 ms □ 0.5 ms (software option 2)

Specifications	
Axis feedback control	■ Position loop resolution: Signal period of the position encoder/1024 ■ Cycle time of position controller: 1.8 ms ■ Cycle time of speed controller: 600 µs ■ Cycle time of current controller: minimum 100 µs
Traverse range	■ Maximum 100 m (3973 inches)
Spindle speed	■ Maximum 40 000 rpm (with 2 pole pairs)
Error compensation	■ Linear and nonlinear axis error, backlash, reversal spikes during circular movements, thermal expansion ■ Stick-slip friction
Data interfaces	■ One each RS-232-C /V.24 and RS-422 / V.11 max. 115 kilobaud ■ Expanded data interface with LSV-2 protocol for remote operation of the TNC through the data interface with the HEIDENHAIN software TNCremo ■ Ethernet interface 100 Base T approx. 2 to 5 megabaud (depending on file type and network load)
Ambient temperature	■ Operation: 0 °C to +45 °C (32 °F to 113 °F) ■ Storage: –30 °C to +70 °C (–22 °F to 158 °F)

Accessories	
Electronic handwheels	■ One **HR 410:** portable handwheel or ■ One **HR 130:** panel-mounted handwheel or ■ Up to three **HR 150:** panel-mounted handwheels via HRA 110 handwheel adapter
Touch probes	■ **TS 220:** 3-D touch trigger probe with cable connection, or ■ **TS 632:** 3-D touch trigger probe with infrared transmission ■ **TT 130:** 3-D touch trigger probe for workpiece measurement

Software option 1	
Rotary table machining	❍ Programming of cylindrical contours as if in two axes ❍ Feed rate in length per minute
Coordinate transformations	❍ Tilting the working plane
Interpolation	❍ Circle in 3 axes (with tilted working plane)

Software option 2	
3-D machining	☐ Motion control with minimum jerk ☐ 3-D compensation through surface normal vectors ☐ Using the electronic handwheel to change the angle of the swivel head during program run without affecting the position of the tool point (TCPM = **T**ool **C**enter **P**oint **M**anagement) ☐ Keeping the tool normal to the contour ☐ Tool radius compensation normal to the direction of traverse and the tool direction ☐ Spline interpolation
Interpolation	☐ Line in 5 axes (subject to export permit)
Block processing time	☐ 0.5 ms

Input format and unit of TNC functions	
Positions, coordinates, circle radii, chamfer lengths	–99 999.9999 to +99 999.9999 (5.4: places before decimal point, places after decimal point) [mm]
Tool numbers	0 999 99 to 32 767.9 999 99 (5.1)
Tool names	16 characters, enclosed by quotation marks with TOOL CALL. Permitted special characters: #, $, %, &, -
Delta values for tool compensation	–99.9999 to +99.9999 (2.4) [mm]
Spindle speeds	0 to 99 999.999 (5.3) [rpm]
Feed rates	0 to 99 999.999 (5.3) [mm/min] or [mm/rev]
Dwell time in Cycle 9	0 to 3600.000 (4.3) [s]
Thread pitch in various cycles	–99.9999 to +99.9999 (2.4) [mm]
Angle of spindle orientation	0 to 360.0000 (3.4) [°]
Angle for polar coordinates, rotation, tilting the working plane	-360.0000 to 360.0000 (3.4) [°]
Polar coordinate angle for helical interpolation (CP)	–5400.0000 to +5400.0000 (4.4) [°]
Datum numbers in Cycle 7	0 999 99 to 2 999 999 99 (4.0)
Scaling factor in Cycles 11 and 26	0.000 001 to 99.999 999 (2.6)
Miscellaneous functions M	0 999 99 to 999 999 99 (1.0)
Q parameter numbers	0 999 99 to 399 999 99 (1.0)
Q parameter values	-99 999.9999 999 99 to +99 999.9999 999 99 (5.4)
Labels (LBL) for program jumps	0 999 99 to 254 999 99 (3.0)
Number of program section repeats REP	1 999 99 to 65 534 999 99 (5.0)
Error number with Q parameter function FN14	0 999 99 to 1 099 999 99 (4.0)
Spline parameter K	–9.999 999 99 to +9.999 999 99 (1.8)
Exponent for spline parameter	-255 999 99 to 255 999 99 (3.0)
Surface-normal vectors N and T with 3-D compensation	–9.999 999 99 to +9.999 999 99 (1.8)

13.4 Exchanging the Buffer Battery

A buffer battery supplies the TNC with current to prevent the data in RAM memory from being lost when the TNC is switched off.

If the TNC displays the error message **Exchange buffer battery**, then you must replace the batteries:

> To exchange the buffer battery, first switch off the TNC.
>
> The buffer battery must be exchanged only by trained service personnel.

Battery type:1 Lithium battery, type CR 2450N (Renata)
ID Nr. 315 878-01

1 The backup battery is at the back of the MC 422.
2 Exchange the battery. The new battery can only be inserted correctly.

Symbole

A

B

C

C

D

E

F

Table of Cycles

Cycle number	Cycle designation	DEF-active	CALL-active	Page
1	Pecking		■	page 217
2	Tapping with a floating tap holder		■	page 232
3	Slot milling		■	page 279
4	Rectangular pockets		■	page 267
5	Circular pocket		■	page 273
6	Rough out SL I		■	
7	Datum shift	■		page 339
8	Mirror image	■		page 344
9	Dwell time	■		page 356
10	Rotation	■		page 346
11	Scaling factor	■		page 347
12	Program call	■		page 357
13	Oriented spindle stop	■		page 358
14	Contour definition	■		page 296
15	Pilot drilling SL I		■	
16	Finishing SL I		■	
17	Tapping with a floating tap holder		■	page 235
18	Thread cutting		■	page 238
19	Tilting the working plane	■		page 349
20	Contour data SL II	■		page 299
21	Pilot drilling SL II		■	page 300
22	Rough out SL II		■	page 301
23	Floor finishing SL II		■	page 302
24	Side finishing SL II		■	page 303
25	Contour train		■	page 304
26	Axis-specific scaling	■		page 348
27	Cylinder surface		■	page 306

Cycle number	Cycle designation	DEF-active	CALL-active	Page
28	Cylindrical surface slot	■	■	page 308
30	Run digitized data		■	page 330
32	Tolerance	■		page 359
200	Drilling		■	page 218
201	Reaming		■	page 220
202	Boring		■	page 222
203	Universal drilling		■	page 224
204	Back boring		■	page 226
205	Universal pecking		■	page 228
206	Tapping with a floating tap holder, new		■	page 233
207	Rigid tapping, new		■	page 236
208	Bore milling		■	page 230
210	Slot with reciprocating plunge		■	page 281
211	Circular slot		■	page 283
212	Rectangular pocket finishing		■	page 269
213	Rectangular stud finishing		■	page 271
214	Circular pocket finishing		■	page 275
215	Circular stud finishing		■	page 277
220	Point pattern on circle	■		page 288
221	Point patterns on lines	■		page 290
230	Multipass milling		■	page 331
231	Ruled surface		■	page 333
247	Datum setting	■		page 343
262	Thread milling		■	page 243
263	Thread milling/countersinking		■	page 245
264	Thread drilling/milling		■	page 249
265	Helical thread drilling/milling		■	page 252
267	Outside thread milling		■	page 255

Table of Miscellaneous Functions

M	Effect	Effective at block start	end	Page
M00	Stop program/Spindle STOP/Coolant OFF		■	page 183
M01	Optional program STOP		■	page 440
M02	Stop program/Spindle STOP/Coolant OFF/Clear status display (depending on machine parameter)/Go to block 1		■	page 183
M03	Spindle ON clockwise	■		page 183
M04	Spindle ON counterclockwise	■		
M05	Spindle STOP		■	
M06	Tool change/Stop program run (depending on machine parameter)/Spindle STOP		■	page 183
M08	Coolant ON	■		page 183
M09	Coolant OFF		■	
M13	Spindle ON clockwise/Coolant ON	■		page 183
M14	Spindle ON counterclockwise/Coolant ON	■		
M30	Same function as M02		■	page 183
M89	Vacant miscellaneous function **or**	■		page 210
	Cycle call, modally effective (depending on machine parameter)		■	
M90	Only in lag mode: Constant contouring speed at corners		■	page 187
M91	Within the positioning block: Coordinates are referenced to machine datum	■		page 184
M92	Within the positioning block: Coordinates are referenced to position defined by machine tool builder, such as tool change position	■		page 184
M94	Reduce display of rotary axis to value under 360°	■		page 199
M97	Machine small contour steps		■	page 189
M98	Machine open contours completely		■	page 190
M99	Blockwise cycle call		■	page 210
M101	Automatic tool change with replacement tool if maximum tool life has expired	■		page 112
M102	Reset M101		■	
M103	Reduce feed rate during plunging to factor F (percentage)	■		page 191
M104	Reactivate the datum as last defined	■		page 186
M105	Machining with second kv factor	■		page 482
M106	Machining with first kv factor	■		
M107	Suppress error message for replacement tools	■		page 112
M108	Reset M107		■	

M	Effect	Effective at block	start	end	Page
M109	Constant contouring speed at tool cutting edge (increase and decrease feed rate)		■		page 192
M110	Constant contouring speed at tool cutting edge (feed rate decrease only)		■		
M111	Reset M109/M110			■	
M114	Automatic compensation of machine geometry when working with tilted axes		■		page 200
M115	Reset M114			■	
M116	Feed rate for angular axes in mm/minn		■		page 198
M117	Reset M116			■	
M118	Superimpose handwheel positioning during program runn		■		page 194
M120	Pre-calculate radius-compensated contour (LOOK AHEAD)		■		page 192
M124	Do not include points when executing non-compensated line blocks		■		page 188
M126	Shortest-path traverse of rotary axes		■		page 198
M127	Reset M126			■	
M128	Maintain the position of the tool tip when positioning with tilted axes (TCPM)		■		page 201
M129	Reset M128			■	
M130	Moving to position in an untilted coordinate system with a tilted working plane		■		page 186
M134	Exact stop at nontangential contour transitions when positioning with rotary axes		■		page 203
M135	Reset M134			■	
M136	Feed rate F in millimeters per spindle revolution		■		page 192
M137	Reset M136			■	
M138	Select tilting axes		■		page 203
M140	Retraction from the contour in the tool-axis direction		■		page 195
M141	Suppress touch probe monitoring		■		page 196
M142	Delete modal program information		■		page 197
M143	Delete basic rotation		■		page 197
M144	Compensating the machine's kinematic configuration for ACTUAL/NOMINAL positions at end of block		■		page 204
M145	Reset M144			■	
M200	Laser cutting: Output programmed voltage directly		■		page 205
M201	Laser cutting: Output voltage as a function of distance		■		
M202	Laser cutting: Output voltage as a function of speed		■		
M203	Laser cutting: Output voltage as a function of time (ramp)		■		
M204	Laser cutting: Output voltage as a function of time (pulse)		■		