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C Axis
V15

Description of Functions

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Purpose of the document This document describes the C axis functionality and the related requirements.

Configuration control

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Contents

1 General

In C axis mode, either the main spindle or a separate servo drive is moved, in addition to the main spindle drive proper, as a position-controlled rotary axis. The C axis may be included in the interpolation of other axes.

Please refer to the manual of the machine manufacturer for details about a specific CNC machine tool, a robot, or a transfer unit. The specifications of the machine manufacturer take precedence over the specifications in this user manual.

Combinations in the NC syntax and other functions that are not described in this Applications Manual may execute in the controller. In a new delivery and in servicing, however, there is no claim to those combinations and functions.

We reserve the right to modifications due to technical development.

Validity

The ‘C Axis’ Applications Manual is valid for an MTC with

- user interface software of version 04.12 / 00 or higher
- operation software of version 03.12 / B0 or higher

1.1 C Axis Mode

In lathes, the interpolating movements between the existing linear axes X, Y and, if available, Z and the main spindle C are referred to as C axis mode. It is irrelevant whether or not a separate servo drive exists in addition to the main spindle drive.

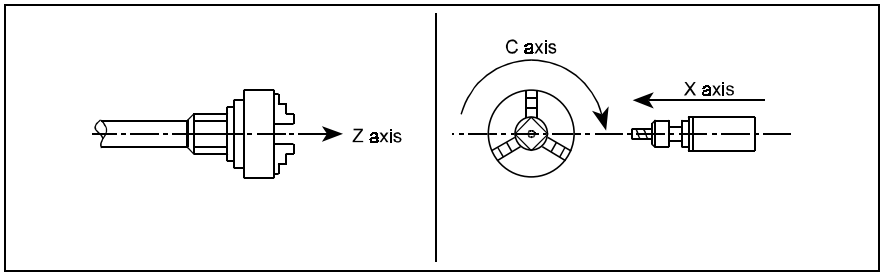


Fig. 1-1: C axis at a lathe

To a large degree, the performance of a C axis depends on the rigidity of the connection between the motor and the spindle. The highest rigidity can be achieved using a frameless motor.

The speed reached during C axis mode is usually less than 200 rpm.

Currently, it is common practice with CNC controllers to consider the C axis function as a second axis that works in position control, irrespective of the selected hardware concept.

Using the related controller units (RAC, KDA, or TDA), external controllers frequently drive the frameless motor with rotary axis capability from INDRAMAT via two analog command values. One is used as the command value for rotary axis mode, while the other one is used for main spindle mode.

Using special additional equipment (IGS and HGV box), the control units emulate an actual value for either mode during operation.

Considering the C axis as a second axis is reflected in the SPS interface and in the machine parameters. The axis interface contains the interface signals for two drives, and the machine parameters contain two axis parameter records.

1.2 NC Programming

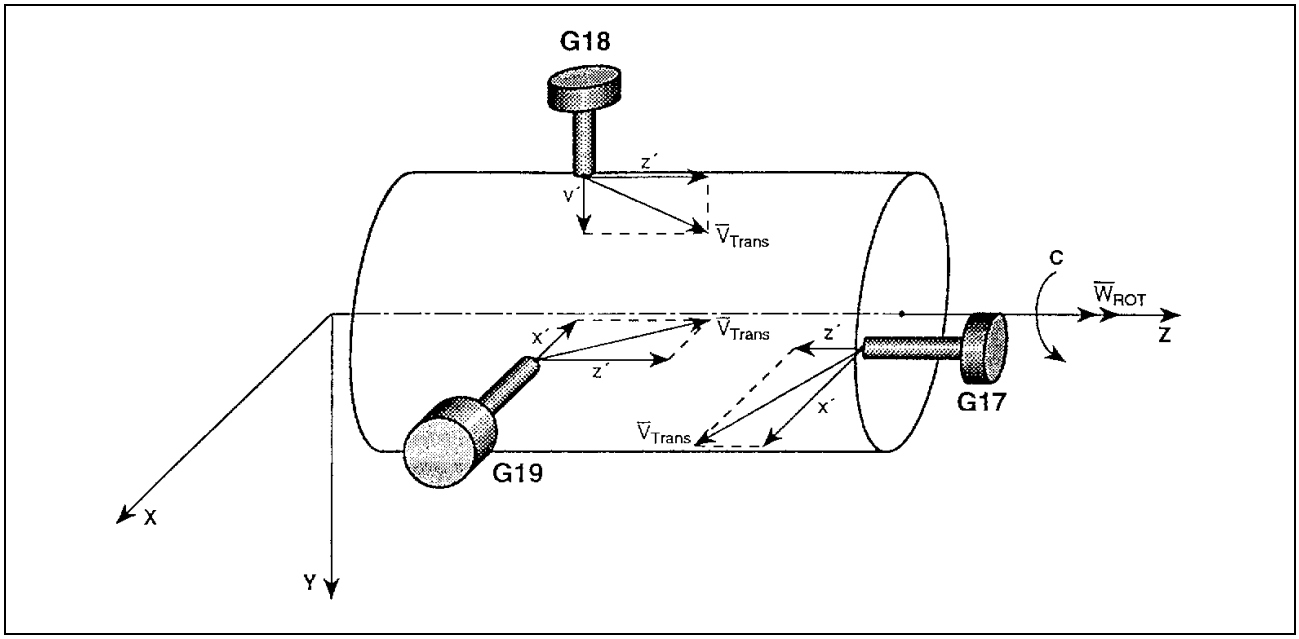


Fig. 1-2: Possibilities of machining a turned part on a lathe

Path Velocity in Linear Interpolation

In all interpolation movements using G00 or G01, the components of the position vector are considered as being constant during an NC block (average effective distance). Taking the current NC syntax into consideration, the three components of the position vector are named RX, RY, and RZ.

x(t) = RX = const. Distance between the machine zero point and the tool contact point in the direction of the 1st main axis.

y(t) = RY = const. Distance between the machine zero point and the tool contact point in the direction of the 2nd main axis.

z(t) = RZ = const. Distance between the machine zero point and the tool contact point in the direction of the 3rd main axis.

The NC only takes the velocity components that result from the rotary movements into account if the programmer wishes it by specifying the related effective distances (RX, RY, RZ). According to their definition as components of the position vector (distance between machine zero point and the tool contact point), the effective distances may also have a negative sign. The translatory and rotary movements are performed at a constant velocity.

NC Program: Machining Example

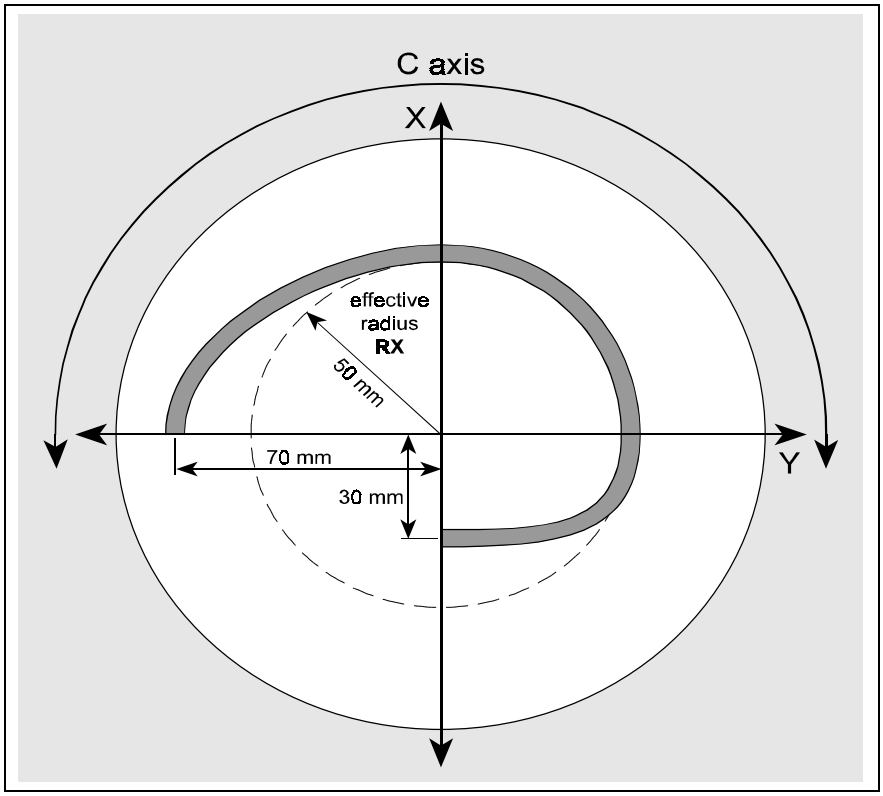


Fig. 1-3: Spiral groove machining at the end face

```
N0140 G90 G06 G17                          ; XY machining plane ,end face
  •
  •
  •
N0144 G00 X-30 Y0 Z501 C90                 ; Approaching; C axis positioning
N0145 G01 Z497 F500                        ; Lowering the cutter
[spiral groove machining]
N0146 G01 X-70 C-270 RX50 F1200            ; Spiral groove at the face end
  •
  •
N0170 RET                                  ; End of program
```

Note: In conjunction with the KDA main drive it is **compulsory** to perform C axis mode with G06, low-lag interpolation.

NC Program: Spindle/C Axis Switching

Under the aspect of the NC syntax, switching between C axis mode and main spindle mode is performed by programming the C axis (Cxxx.xxx) or the main spindle (M03 Sxxxx).

If, with active main spindle mode, the C axis is programmed in a subsequent block, the CNC performs the switching mechanism with the help of the SPS. Block preparation and block execution are stopped until the switching process is completed.

The same mechanism becomes effective in switching from C axis mode to main spindle mode.

Switching a main spindle drive with rotary axis capability

```
N0050 M19 S0                              ; Orient main spindle
N0051 G00 G54 G90 X100 Z200 M03 S1000     ; Initial position,
                                            spindle mode
  •                                       ; machining
N0070 G00 G06 X100 Z250 C90               ; Initial position,
                                            C axis mode
  •
N0077 G01 G91 X40 C-270 RX50 F1200        ; machining
  •
N0100 G00 G54 G90 X120 Z200 M03 S1200     ; Initial position
                                            spindle mode
  •
N0150 RET                                 ; End of program
```

2 Rotary Axis Mode with a Main Spindle Drive with Rotary Axis Capability

2.1 Hardware

Main spindle drives with rotary axis capability (such as the frameless spindle motors with their related control units) are used in applications that do not require a gearbox (only a belt) between main spindle drive and spindle.

In these cases, the power train of the main spindle features a minimum rigidity which enables it to be used for interpolation mode (provided that the main spindle and the related control unit support rotary axis mode).

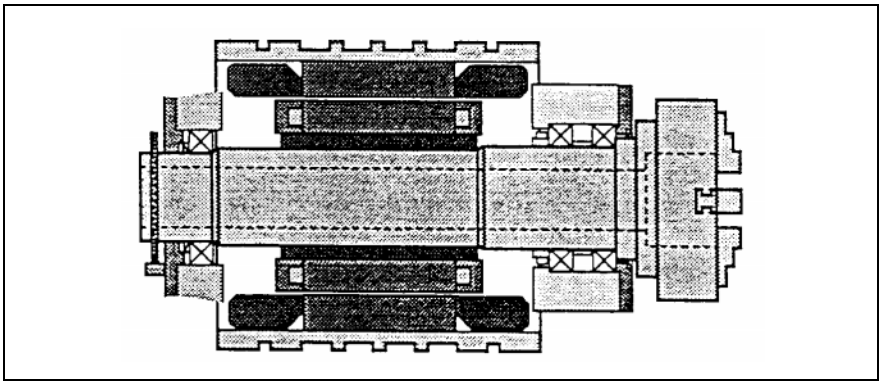


Fig. 2-1: MB frameless spindle motor

The controller drives a main spindle drive with rotary axis capability according to the specifications in the NC program either as a main spindle or as a rotary spindle. A separate drive for the interpolation with other axes is not required.

Either high-resolution incremental encoders or gear-type encoders from INDRAMAT may be used as external encoders for main spindle drives with rotary axis capability.

2.2 Parameter Setting

Select the „main spindle with rotary axis capability“ axis type for main spindles with rotary axis capability.

The associated parameter record chiefly consists of a digital main spindle and a digital rotary axis.

A parameter record for analog main spindles with rotary axis capability is not provided because frameless spindle drives with the related control units from INDRAMAT will mostly be used for rotary axis mode with a main spindle drive.

However, if using an analog main spindle drive with rotary axis capability proves necessary, the MTC may use it as a main spindle/servo drive combination (provided it processes two command values and supplies two actual values to the controller).

Axis Parameter Record of a Digital Main Spindle with Rotary Axis Capability

General parameters	Cxx.000	Associated process(es)	...	[ ]
	Cxx.001	Axis designation for main spindle mode	...	[ ]
	Cxx.0..	Axis designation for rotary spindle mode	...	[ ]
	Cxx.053	Axis defined as...	...	[ ]
Parameters for main spindle mode	Cxx.0..	Jogging speed	...	[1/min]
	Cxx.0..	Jogging speed - rapid	...	[1/min]
	Cxx.0..	Jogging spindle position	...	[°]
	Cxx.049	Max. programmable spindle speed ... [1/min]		
	Cxx.0..	Max. spindle speed gear range 1	...	[1/min]
	Cxx.0..	Min. spindle speed gear range 1	...	[1/min]
	Cxx.050	Max. spindle acceleration gear range 1	...	[1/s²]
Parameters for rotary axis mode	Cxx.016	Max. programmable spindle speed ... [°/min]		
	Cxx.017	Max. spindle speed change w/o ramp	...	[°/min]
	Cxx.018	Max. spindle acceleration rate	...	[°/s²]
	Cxx.020	Jogging speed	...	[°/min]
	Cxx.021	Jogging speed - rapid	...	[°/min]
	Cxx.022	Parametric jogging distance	...	[°]
	Cxx.023	In-position window	...	[°]
	Cxx.025	Waypoint 0	...	[°]
	.			
	Cxx.032	Waypoint 7	...	[°]
	Cxx.0..	Parameter set in drive used for rotary mode	...	[ ]

Explanation of the Axis Parameters

For a main spindle with rotary axis capability, an axis designation for rotary axis mode must be entered in addition to the axis designation for main spindle mode.

- The rotary main axis (A, B, C) or
- the secondary axis (U, V, W)

can be specified as axis meaning.

Any other axis meaning will lead to an error message being issued upon the entry.

The „main spindle with rotary axis capability“ axis type only supports single-stage gearboxes. Gearboxes with multiple selections are not supported.

The „Parameter set in drive used for rotary mode“ parameter defines the parameter record in the drive that is activated by the controller upon the selection of rotary axis mode. Entering „0“ suppresses the changeover. The drive continues work using the parameter record „0“ that has been used for main spindle mode. Valid entries are figures between 0 and 7. Currently, the digital main spindles only have four parameter records (parameter record 0 through 3).

In main spindle mode and in rotary axis mode, main spindles with rotary axis capability are used as unlimited rotary axes.

The main-spindle-specific axis parameters „Jogging speed“, „Jogging speed - rapid“, and „Jogging spindle position“ are provided with a new parameter number.

Traveling to dead stop and the axis parameters required for this:

- reduced torque at positive stop, and
- max. feed to positive stop

are currently not required with a main spindle with rotary axis capability.

Main spindles with rotary axis capability are programmed in degrees.

Note: The introduction of the „Encoder arrangement for SERCOS drives“ parameter requires this parameter to be entered additionally when the software of a controller with an external measuring system (linear encoder, spindle encoder, or second encoder) is changed.

Enhancing the Axis Meaning

Information about the axis positions are absolutely necessary for computing the

- velocity components,
- breaking velocity components, and
- acceleration components

of the individual axes using the specified axis positions and the related path velocity.

Starting from a Cartesian coordinate system, the locations of all feed axes (including the main spindles with rotary axis capability) must be specified with the „Axis defined as...“ parameter when the parameters of a machine are set.

Axis meaning	Symbol	Axis pos.	Comment
Linear main axes			Circular interpolation and tool radius path correction are performed within machining plane G17, G18, G19.
1. linear main axis	X	abscissa	
2. linear main axis	Y	ordinate	
3. linear main axis	Z	applicate	
Rotary main axes			
1. rotary main axis	A	rot. around abscissa	
2. rotary main axis	B	rot. around ordinate	
3. rotary main axis	C	rot. around applicate	
Linear and rotary main axes			
1. secondary axis	U	Each axis may have any position and any orientation in the space	
2. secondary axis	V		
3. secondary axis	W		

Within a given process, the feed axes (linear axes, rotary axes, and main spindles with rotary axis capability) may assign each axis position and, consequently, each axis meaning only once.

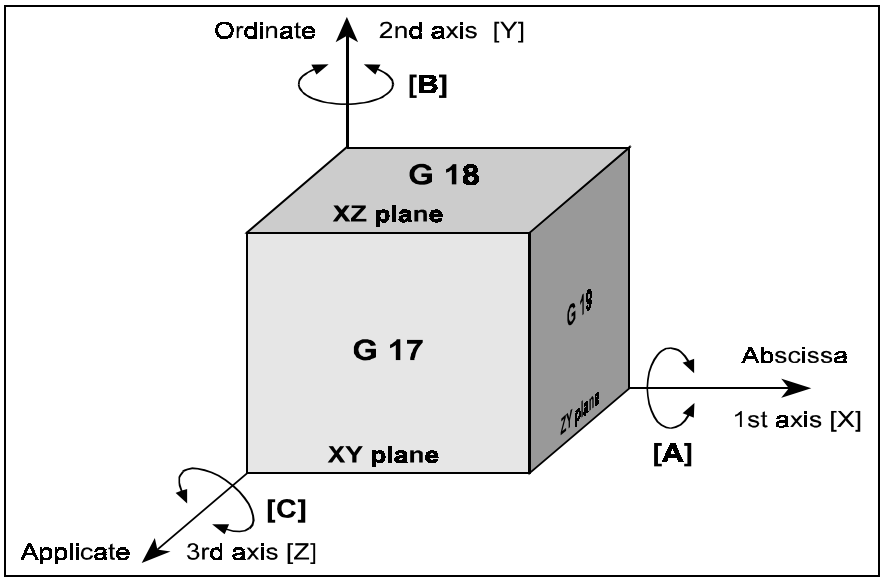


Fig. 2-2: Linear main axes (X, Y, Z) and rotary main axes (A, B, C) in a Cartesian reference coordinate system

Linear main axis

The linear main axes span a Cartesian coordinate system. They must be identified using the following axis meanings:

1. linear main axis (symbol X)
2. linear main axis (symbol Y)
3. linear main axis (symbol Z)

Circular interpolations and tool radius path correction can only be performed within the machining planes (G17, G18, G19) that are spanned by the linear main axes.

Rotary main axes

Rotary main axes rotate around the linear main axes. The axis meanings

1. rotary main axis (symbol A)
2. rotary main axis (symbol B)
3. rotary main axis (symbol C)

identify the coordinate axis around which the rotary main axis rotates (see Fig. 1-3).

Linear and rotary secondary axes

Linear and rotary secondary axes may assume any position within the space.

1. secondary axis (symbol U)
2. secondary axis (symbol V)
3. secondary axis (symbol W)

identify this axis type. The axis meanings „U“, „V“, and „W“ are fully equivalent. They may be used for linear axes, for rotary axes, or for main spindles with rotary axis capability.

Secondary axes participate in positioning and interpolation movements in the same way as the other axes, and reach their programmed end value at the same time as the other ones. The path feed rate (F value) specified in the NC program refers to the linear and rotary main axes (provided such axes have been programmed within a block) rather than to the secondary axes.

SERCOS Parameters in the Axis Processor

In the axis processor of the MTC there is a defined and reserved SERCOS parameter area that is used for handling the spindle ↔ C axis selection and for manipulating the spindle and rotary axis data from the NC program or via the SPS required data channel. This data may be influenced from the NC program via the AXD command or from the SPS via the required data channel.

The SERCOS required data channel to the digital drives is not influenced in that process.

Description of the parameters

The ident numbers that must be used from the NC program in conjunction with the AXD command are shown in parentheses.

Ident number 65012 (P-7-3572) [Read/Write]

Spindle function during gear range selection:

Bit 0:	0:	no function
	1:	spindle hunting specification (KDA only)
Bit 1:	0:	no function
	1:	spindle positioning specification (KDA only, angle in 65015)
Bit 2:	0:	no function
	1:	spindle speed specification (speed in 65013, acceleration in 65014)
Bit 8:		spindle hunting acknowledgment
Bit 9		spindle positioning acknowledgment
Bit 10		spindle speed specification acknowledgment

Ident number 65013 (P-7-3573) [Read/Write]

Spindle speed for the „Spindle speed specification“ spindle function in 0.0001 1/min. The value may also be modified while the spindle function is activated. The maximum speed is limited to 1000 rpm.

Ident number 65014 (P-7-3574) [Read/Write]

Spindle acceleration for the „Spindle speed specification“ spindle function in rad/s^2.

Ident number 65015 (P-7-3575) [Read/Write]

Spindle angle for the „Spindle positioning“ function in 0.0001° (0°-360°).

2.3 Operating States

Power-On State

When the system is switched on, the NC assumes the mode (position or speed control) that is specified by the SPS via the standard functions „ROTMOD“ or „SPMOD“. It also ensures that the related drive parameter record is active in the digital drive.

If neither main spindle mode nor rotary axis mode exist when the system is switched on, the NC specifies a new mode selection at the next possible occasion when such a mode is needed.

The NC always selects this procedure when the SPS signals neither main spindle operation nor rotary axis operation.

Homing

Homing is only necessary if the signals from the existing encoder exceed the frequency limit of the control unit during speed mode.

While the main spindle interface for incremental encoders is able to process encoder signals up to 100 kHz, the high-resolution gear-type encoder from INDRAMAT can be used up to 24000 rpm.

In standard application that employ the high-resolution gear-type encoder from INDRAMAT, homing the drive is consequently only necessary after the power has been switched on.

Homing is possible via the G74 command or via the M19 positioning command. If a reference position did not exist at the beginning of the positioning command, M19 automatically establishes reference by crossing the related zero impulse at homing velocity. With M19, the main spindle moves to the command position that is specified in the NC block, not to the reference point, and sets command and actual value to the value of the position it has traveled to.

Immediate Stop

Upon an immediate stop during a changeover process, the MTC stops the internal sequence and brings the axes to a standstill. The NC causes the internal commands to be pending (analogous to the auxiliary functions).

It also stops the motion functions that have been activated by the APR-SERCOS parameters and commands.

Note: During the changeover phase, the “Program stopped“ (PxxSSTOP) status signal must taken into account in any movement that is caused by the SPS so that movements can be stopped without delay whenever the signal assumes the state „1“.

Control-Reset

A changeover process that has been stopped by an immediate stop can be aborted by Control-Reset. The NC resets all internal commands and all auxiliary functions that have not yet been acknowledged.

Like in the power-on phase, the NC then assumes the current mode that has been specified by the SPS via the ROTMOD or SPMOD standard functions. Furthermore, it activates the related drive parameter record in the drive.

Reverse

The „Reverse program active“ signal shows the SPS that a reverse is triggered during the main spindle mode/rotary axis mode changeover process.

In this case, the NC interrupts the internal sequence of the changeover process and restores the original state. It clears all internal commands and all auxiliary functions that have not yet been acknowledged

If the interrupted changeover process shall also be performed in reverse, a corresponding reverse vector must be programmed at the NC side.

Changing Modes

Changing the mode (automatic mode, semi-automatic mode, MDI, manual mode) does not lead to any changes in main spindle or rotary spindle operation.

If the mode is changed during a main spindle mode/rotary axis mode changeover, this leads to an immediate stop (like in the remaining program execution).

Jogging Movements

Jogging movements in manual mode do not have an effect on an interrupted changeover process. Merely the following control signals of the main spindle with rotary axis capability cause an interrupted changeover process to be aborted before the NC commands a new changeover process

- AxxCJGPOS (positive jogging),

- AxxCJGNEG (negative jogging),
- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop), and
- AxxCM19 (spindle positioning)

If neither main spindle mode nor rotary axis mode is active after a jogging movement, the NC commands a new changeover at the next possible opportunity when the main spindle is required as a spindle or a rotary axis.

Process Enabling Signal

If the process enabling signal is removed during a changeover process, the NC initiates

- initiates an immediate stop,
- stops program execution and, consequently, the internal sequence, and
- brings the axes to a standstill.

Axis Enabling Signal

Removing the axis enabling signal during a changeover process, does not have any immediate effect on the changeover process.

Errors

Drive and controller handle drive faults or other malfunctions that occur during rotary axis or main spindle operation in the same way as for a main spindle or a rotary axis.

The NC proceeds in the same way as during the power-on phase if the digital drive loop fails or the control voltage is interrupted during a main spindle mode/rotary axis mode changeover.

Feed and Spindle Override

Feed override always acts upon the axes that participate in path interpolation.

If the main spindle with rotary axis capability performs a movement that has been initiated by a G00, G01, G02, or G03 command, the feed override acts upon the axis velocity of the feed axes and on the axis velocity of the rotary axis.

As long as the M3, M4 and M19 auxiliary functions are active, merely the spindle-specific spindle override acts upon the spindle. The feed override does not have any effect.

In thread cutting (G33) and tapping (G63, G64), the previous effect of feed and spindle overrides remains unchanged.

Position Indication

The user interface displays the spindle-specific data as before as long as a main spindle with rotary axis capability is handled like a classical main spindle by

- M3 (spindle clockwise),
- M4 (spindle counter-clockwise),
- M5 (spindle stop),
- M19 (spindle positioning),
- G33 (thread cutting),
- G63 (tapping), and

- G64 (tapping)

or, in manual mode, via the control signals of the main spindle with rotary axis capability

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop) or
- AxxCM19 (spindle positioning)

The position indicator only selects the representation that is usually employed for rotary axes when the main spindle with rotary axis capability is used as a rotary axis by one of the following commands

- G00 (linear interpolation at maximum velocity),
- G01 (linear interpolation),
- G02 (circular interpolation clockwise) or
- G03 (circular interpolation counter-clockwise)

in conjunction with the related axis designation for rotary axis mode or, in manual mode, via the control signals of the main spindle with rotary axis capability

- AxxCJGPOS (positive jogging) or
- AxxCJGNEG (negative jogging)

The axis designation of the rotary axis with the related data then replaces the spindle designation.

Axis designations for main spindle mode

Designations:

Axis designation = axis letter (+ axis index)

Axis letter	∈	{S}
Axis index	∈	{1, 2, 3} (optional)

Axis designations for rotary axis mode

Addresses:

Axis designation = axis letter (+ axis index)

Axis letter	∈	{X, Y, Z, U, V, W, A, B, C}
Axis index	∈	{1, 2, 3} (optional)

Upon main spindle mode/rotary axis mode changeover, the user interface only displays the axis designation and the related axis data of the new mode after changeover has been completed and when the NC updates the related „Rotary axis/main spindle operation“ signal for the user interface.

Status Indication

In main spindle operation, the user interface displays the values for a main spindle with rotary axis capability in the status indication as before. If the main spindle with rotary axis capability is in main spindle mode, the user interface display lines instead of the programmed, current, and maximum speed. The user interface always displays the override values.

Zero Point Shifts

For main spindle with rotary axis capability, zero point shifts can be entered in the zero point shift tables. The zero point shifts cannot be activated during main spindle operation (M3, M4, M5, M19, G33, G63 or G64). Activating the zero point shifts that are entered in the zero point shift table from the NC program or programming additional zero point shifts like for a rotary axis is only possible during rotary axis operation (G00, G01, G02 or G03 in conjunction with the axis designation of rotary axis operation).

Changing over to main spindle operation cancels the zero point shifts. Changing back to rotary axis mode automatically re-activates the zero point shifts (provided they have not been cleared in the meantime by G53).

Axis Transfer

Main spindles with rotary axis capability can be transferred between the processes in the same fashion as this is done with main spindles.

Main spindle mode/rotary axis mode changeover can be done in the master process and in the slave processes.

3 Rotary Axis Mode Using a Separate Servo Drive

3.1 Hardware

If, due to the required speed and torque ranges; a multi-stage gear drive becomes necessary, rotary axis operation via the same power train is not possible. The rigidity proves insufficient for rotary axis operation.

In these cases, the machine manufacturers usually select a separate servo drive that is engaged by a machine-specific changeover mechanism at the beginning of the rotary axis operation.

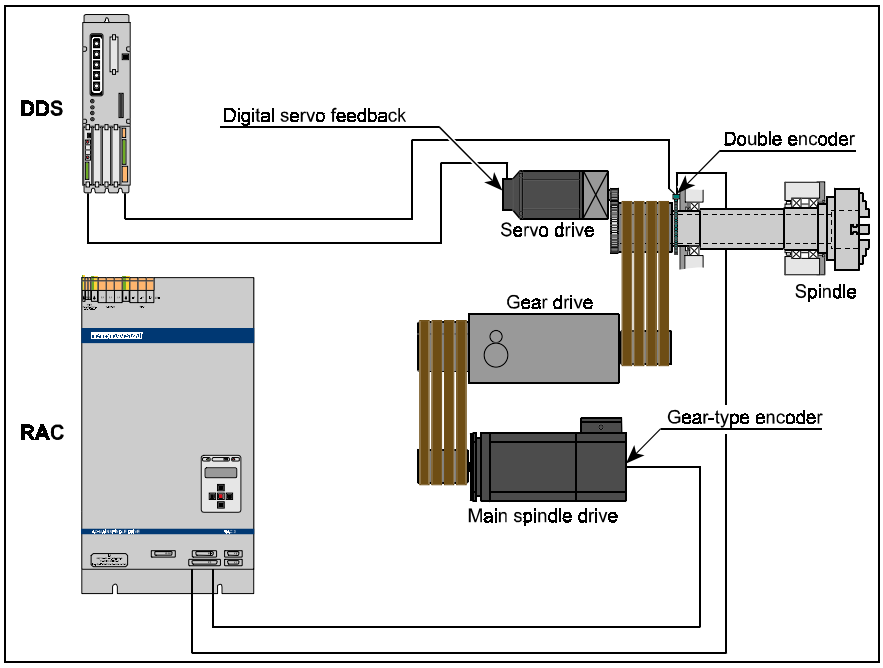


Fig. 3-1: Main spindle/servo drive combination

Since the high torque requirement s during interpolation mode needs a very high reduction ratio and, consequently, the power train of the servo drive usually tolerates only very low speed values (less than 200 rpm), the main spindle usually supports speed control mode (M3, M4, M5) and position control mode (M19, G33, G63, G64).

At the moment, the INDRAMAT main spindle drives are able to support the following external encoders:

- Incremental encoder or
- high-resolution INDRAMAT gear-type encoders.

In the standard motor encoder configuration, digital main spindle drives are equipped with high-resolution INDRAMAT gear-type encoders.

The servo drive exclusively works in position control. It accepts the interpolation that is initiated for the rotary axis from the NC program via the G codes G00, G01, G02 or G03 in conjunction with the related axis designation.

In their standard configuration, digital servo drives (MDD ≥ 065) are equipped with servo feedbacks as motor encoders. Due to the existing gearbox and the resulting play, multi-turn absolute encoders are not usually employed in those applications.

The following external encoders may be connected:

- High-resolution encoders, or
- incremental encoders

Currently the DDS cannot process rotary absolute value encoders and INDRAMAT gear-type encoders.

Note: Each drive must be equipped with a separate encoder. If the motor encoders prove insufficient or if, due to design or other reasons, only an external encoder can be installed, the attachment of a splitting box permits the encoder signals for the main spindle and for the feed drive to be split.

If analog drives shall be utilized, the actual values must be transferred to the controller. With analog rotary axes, the MTC only processes incremental encoders.

3.2 Parameter Setting

The controller must handle the servo drive, that performs rotary axis operation, like a separate drive. Two axes must be entered in the machine parameters, one as a main spindle and the other one as a rotary axis. The main spindle parameters are expanded by the „Axis number of the associated rotary axis“ axis parameter. That parameter permits a main spindle to be assigned to a rotary axis. The controller automatically switches over to that rotary axis if this is initiated by the corresponding commands in the NC program.

In the default configuration, the main spindle does not have a rotary axis assigned. This is shown by axis number 0 being the default setting of the said axis parameter. In addition, the axis parameters „Jogging speed“, „Jogging speed - rapid“, and „Jogging spindle position“ of a main spindle have a new parameter number assigned.

The axis parameters of a rotary axis remain unchanged.

In C axis applications, digital servo drives usually employ one drive parameter record. Digital main spindle drives usually use as many drive parameter records as there are gear stages. Thus, changing over the parameter records in the drives is only necessary for a main spindle drive in connection with a switchable gear drive.

SERCOS Parameters in the Axis Processor

A defined SERCOS parameter range in the MTC axis processor is reserved for handing spindle ↔ C axis changeover and for manipulating the spindle and rotary axis data from the NC program or via the SPS required data channel. This data may be manipulated through the AXD command from the NC channel or via the required data channel from the SPS.

The SERCOS required data channel to the digital drives is not affected by this.

Parameter description

The ident numbers that must be used from the NC program in conjunction with the AXD command are shown in parentheses.

Ident number 65012 (P-7-3572) [Read/Write]

Spindle function during gear range selection:

Bit 0:	0:	no function
	1:	spindle hunting specification (KDA only)
Bit 1:	0:	no function
	1:	spindle positioning specification (KDA only, angle in 65015)
Bit 2:	0:	no function
	1:	spindle speed specification (speed in 65013, acceleration in 65014)
Bit 8:		spindle hunting acknowledgment
Bit 9		spindle positioning acknowledgment
Bit 10		spindle speed specification acknowledgment

Ident number 65013 (P-7-3573) [Read/Write]

Spindle speed for the „Spindle speed specification“ spindle function in 0.0001 1/min. The value may also be modified while the spindle function is activated. The maximum speed is limited to 1000 rpm.

Ident number 65014 (P-7-3574) [Read/Write]

Spindle acceleration for the „Spindle speed specification“ spindle function in rad/s^2.

Ident number 65015 (P-7-3575) [Read/Write]

Spindle angle for the „Spindle positioning“ function in 0.0001° (0°-360°).

3.3 Operating States

Power-On State

When the system is switched on, the NC assumes the mode that is specified by the SPS via the standard functions „ROTMOD“ or „SPMOD“.

For the main spindle drive it ensures, on the basis of the reported actual gear stage, that the related drive parameter block is active in the digital main spindle drive.

Homing

The reference will not be lost as long as the control unit of the rotary axis drive (DDS) is able to interpret the signals from the related encoder at the maximum speed. In this case, the axis need not be homed after each changeover process.

The maximum speed in main spindle operation is usually reached when the rotary axis is switched inactive by removing the controller enabling signal. The encoder signal frequency that is achieved in this process must not exceed the limit frequency of the associated interface module.

$$n_{max}[1/s] * \text{impulses or oscillations per revolution } [1/s] \leq \text{limit frequency } [1/s]$$

Depending on the signal type, the DDS may interpret external encoders up to the following limit frequency:

Signal type	Limit frequency
Sine-wave signals	150 kHz
Square-wave signals	1 MHz

Note: The rotary axis encoder must be designed such that the maximum frequency of the encoder does not exceed the limit frequency of the DDS interface. Homing the rotary axis will then only be possible after power-up.

With main spindle control units (RAC, KDA, TDA), the processable limit frequency of external encoders is:

Signal type	Limit frequency	max. speed	Comment
Sine-wave signals Square-wave signals	150 kHz 1 MHz	24000 [1/min]	no third-party products

If the main spindle loses reference, this does not have an effect on the machining duration because homing will automatically be performed during positioning with M19.

Immediate stop

Upon an immediate stop during a changeover process, the MTC stops the internal sequence and brings the axes to a standstill. The NC causes the internal commands to be pending (analogous to the auxiliary functions).

It also stops the motion functions that have been activated by the APR-SERCOS parameters and commands.

Note: During the changeover phase, the “Program stopped“ (PxxSSTOP) status signal must taken into account in any movement that is caused by the SPS so that movements can be stopped without delay whenever the signal assumes the state „1“.

Control-Reset

A changeover process that has been stopped by an immediate stop can be aborted by Control-Reset. The NC resets all internal commands and all auxiliary functions that have not yet been acknowledged.

Like in the power-on phase, the NC then assumes the current mode that has been specified by the SPS via the ROTMOD or SPMOD standard functions. Furthermore, it activates the related drive parameter record in the drive.

Reverse

The „Reverse program active“ signal shows the SPS that a reverse is triggered during the main spindle mode/rotary axis mode changeover process.

In this case, the NC interrupts the internal sequence of the changeover process and restores the original state. It clears all internal commands and all auxiliary functions that have not yet been acknowledged

If the interrupted changeover process shall also be performed in reverse, a corresponding reverse vector must be programmed at the NC side.

Changing modes

Changing the mode (automatic mode, semi-automatic mode, MDI, manual mode) does not lead to any changes in main spindle or rotary spindle operation.

If the mode is changed during a main spindle mode/rotary axis mode changeover, this leads to an immediate stop (like in the remaining program execution).

Jogging Movements

Jogging movements in manual mode do not have an effect on an interrupted changeover process. Merely the following control signals of the main spindle

- AxxCJGPOS (positive jogging),
- AxxCJGNEG (negative jogging),
- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop) and
- AxxCM19 (spindle positioning)

and the following control signals of the rotary axis

- AxxCJGPOS (positive jogging),
- AxxCJGNEG (negative jogging),

cause an interrupted changeover process to be aborted before the NC commands a new changeover process.

If neither main spindle mode nor rotary axis mode is active after a jogging movement, the NC commands a new changeover at the next possible opportunity when the main spindle is required as a spindle or a rotary axis.

Process Enabling Signal

If the process enabling signal is removed during a changeover process, the NC initiates

- initiates an immediate stop,
- stops program execution and, consequently, the internal sequence, and
- brings the axes to a standstill.

Axis Enabling Signal

Removing the axis enabling signal during a changeover process, does not have any immediate effect on the changeover process.

Errors

Drive and controller handle drive faults or other malfunctions that occur during rotary axis or main spindle operation in the same way as for a main spindle or a rotary axis.

The NC proceeds in the same way as during the power-on phase if the digital drive loop fails or the control voltage is interrupted during a main spindle mode/rotary axis mode changeover.

Feed and Spindle Override

While the spindle-specific spindle override always acts upon the related main spindle drive, the feed override always acts upon the feed axes, including the rotary axis (C axis).

Position Indication

The user interface displays the spindle-specific data as before as long as a main spindle is handled by

- M3 (spindle clockwise),
- M4 (spindle counter-clockwise),
- M5 (spindle stop),
- M19 (spindle positioning),
- G33 (thread cutting),
- G63 (tapping) and
- G64 (tapping)

or, in manual mode, via the control signals of the main spindle

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop),
- AxxCM19 (spindle positioning),
- AxxCJGPOS (positive jogging),
- AxxCJGNEG (negative jogging),

The position indicator only selects the representation that is usually employed for rotary axes when the main spindle is used as a rotary axis by one of the following commands

- G00 (linear interpolation at maximum velocity),
- G01 (linear interpolation),
- G02 (circular interpolation clockwise) or
- G03 (circular interpolation counter-clockwise)

in conjunction with the related axis designation for rotary axis mode or, in manual mode, via the control signals of the rotary axis

- AxxCJGPOS (positive jogging) or
- AxxCJGNEG (negative jogging)

The axis designation of the rotary axis with the related data then replaces the spindle designation.

The axis control signals

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop) or
- AxxCM19 (spindle positioning)

are irrelevant for a rotary axis.

Axis designations for main spindle mode

Designations:

Axis designation = axis letter (+ axis index)

Axis letter	∈	{S}
Axis index	∈	{1, 2, 3} (optional)

Axis designations for rotary axis mode

Addresses:

Axis designation = axis letter (+ axis index)

Axis letter	∈	{X, Y, Z, U, V, W, A, B, C}
Axis index	∈	{1, 2, 3} (optional)

Upon main spindle mode/rotary axis mode changeover, the user interface only displays the axis designation and the related axis data of the new mode after changeover has been completed and when the NC updates the related „Rotary axis/main spindle operation“ signal for the user interface.

Status Indication

In main spindle operation, the user interface displays the values for a main spindle with rotary axis capability in the status indication as before. In main spindle mode, the user interface display lines instead of the

programmed, current, and maximum speed. The user interface always displays the override values.

Zero Point Shifts

In contrast to the main spindles, rotary spindles permit zero point shifts to be entered in the zero point shift table. These zero point shifts can be activated from the NC program. In addition, zero point shifts can be programmed within the NC program (as for any other rotary axis).

It is recommended to bring the machine zero point of the main spindle and the machine zero point of the rotary axis into line. If this is not the case, positioning via M19, for example, moves the spindle to a different position than position via G00, G01, G02, or G03.

Axis Transfer

Main spindle/servo drive combinations can be transferred between the processes in the same fashion as this is done with main spindles or rotary axes. Both axes must be transferred separately. Axis transfer of both drives does not have an effect on main spindle operation or rotary axis operation.

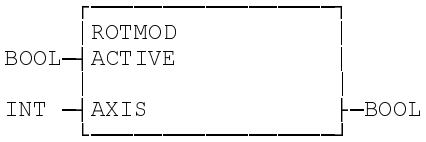
Main spindle mode/rotary axis mode changeover can be done in the master process and in the slave processes.

4 SPS Handling

4.1 SPS Functions for Changeover

Interrogating and acknowledging rotary axis mode pre-selection

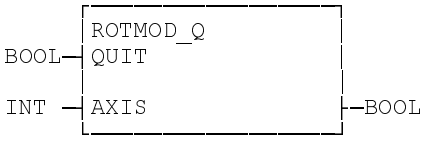
Interrogating rotary axis mode pre-selection



ACTIVE:	BOOL;	Function enabled '0' Function not active '1' Interrogation rotary axis mode pre-selection active
AXIS:	INT;	Axis number
ROTMOD:	BOOL;	Function result '0' Function is not active or rotary axis mode pre-selection is not active '1' Rotary axis mode pre-selection is active

Acknowledging rotary axis mode pre-selection

The ROTMOD_Q standard function is used for acknowledging the pre-selection of rotary axis mode. After rotary axis mode has been acknowledged for the first time, the acknowledgment signal must be applied as long as rotary axis mode is pre-selected (even after a Control-Reset or after the controller has been switched on). Canceling the acknowledgment during rotary axis operation will cause a process error to be issued.



QUIT:	BOOL;	Function enabled '0' Function not active '1' Rotary axis mode pre-selection acknowledgment (must be applied during the entire time)
AXIS:	INT;	Axis number
ROTMOD_Q:	BOOL;	Function result QUIT input is passed through

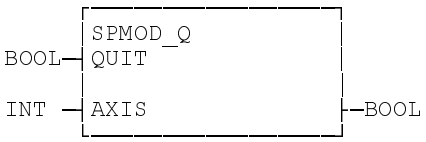
Interrogating and acknowledging Spindle Mode Pre-Selection

Interrogating spindle axis mode pre-selection

ACTIVE:	BOOL;	Function enabled 0' Function not active 1' Interrogation spindle mode pre-selection active
AXIS:	INT;	Axis number
SPMOD:	BOOL;	Function result '0' Function is not active or spindle mode pre-selection is not active '1' Spindle mode pre-selection is active

Acknowledging spindle mode pre-selection

The SPMOD_Q standard function is used for acknowledging the pre-selection of spindle mode. After spindle mode has been acknowledged for the first time, the acknowledgment signal must be applied as long as spindle mode is pre-selected (even after a Control-Reset or after the controller has been switched on). Canceling the acknowledgment during spindle operation will cause a process error to be issued.



QUIT:	BOOL;	Function enabled '0' Function not active '1' Spindle mode pre-selection acknowledgment (must be applied during the entire time)
AXIS:	INT;	Axis number
SPMOD_Q:	BOOL;	Function result QUIT input is passed through

4.2 SPS Interface, Main Spindle Drive With Rotary Axis Capability

Axis Signals

Axis control signals		Axis status signals	
HOMLS	Home switch	RF	Controller enabling signal
READY	Ready	HOMED	Reference
JGPOS	Positive jogging	MVPOS	Positive axis movement
JGNEG	Negative jogging	MVNEG	Negative axis movement
HOME	Homing	BBDIG	Ready
ENABL	Axis enabling	IDDS	Real-time status bit
STRBP	Position strobe	WP0	Waypoint 0
QDDS	Real-time command bit	WP1	Waypoint 1
OTRVL	Safety limit switch	WP2	Waypoint 2
MTAS	Thermal protection switch	WP3	Waypoint 3
M3*	Spindle clockwise	WP4	Waypoint 4
M4*	Spindle counter-clockwise	WP5	Waypoint 5
M5*	Spindle stop	WP6	Waypoint 6
M19*	Spindle positioning	WP7	Waypoint 7
GEAR1*	Actual gear stage bit 1	N_NCMD*	$N_{act}=N_{comm}$
GEAR2*	Actual gear stage bit 2	N_NMIN*	$N_{act}=0$
GEAR3*	Actual gear stage bit 3	MD_MDX*	$\|M_d\| \geq \|M_{dx}\|$
		NC_NMAX*	$\|N_{comm}\| \geq \|N_{Grenz}\|$
		INPOS*	in-position
		P_PX*	$\|P\| \geq \|\ \|$
		LOAD90*	90%LOAD
		SYNCHRON*	Synchronous run

Note: The MTC only supports the newly introduced spindle-related signals (marked by an asterisk '*' in the table) if the axes involved are of the „main spindle“ or „main spindle with rotary axis capability“ type.

Explanation of the control signals

With digital drives, the homing switch is directly connected to the control unit. Most applications (such as the C axis applications) do not contain a homing switch.

The NC employs the „axis ready“ control signal to monitor the ready state of a main spindle with rotary axis capability in rotary axis mode and in main spindle mode.

The jog commands „positive jogging“ and „negative jogging“ can be used for moving a main spindle with rotary axis capability like a feed axis. If main spindle mode is active when jogging is started, the NC automatically selects rotary axis mode. The PxxCJOGM0 - PxxCJOGM2 process control signals define the type of the jogging movements for the feed axes and, consequently, for rotary axis mode.

The „homing“ signal initiates homing like it does for the remaining axes.

Irrespective of the mode selection (rotary axis mode or spindle mode), the axis cannot be moved in manual mode without the axis enabling signal.

The „position strobe“ signal causes the NC to save the current position.

With a digital main spindle with rotary axis capability, the „safety limit switch“ and „thermal protection switch“ signals must be set to „1“.

Irrespective of the selected jog mode, a main spindle with rotary axis capability may be moved as a main spindle if the SPS applies a positive edge to the command signals:

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop) or
- AxxCM19 (spindle positioning)

The NC automatically switches over to main spindle mode if rotary axis mode is active when one of these commands is started.

If the AxxCM3 or AxxCM4 control signal is activated, the NC takes the value that is stored under the main-spindle-related „jogging parameter“ axis parameter as the command speed and performs the commanded rotation. With the AxxCM19 control signal, the NC accesses the value that has been stored under the main-spindle-related „jogging spindle position“ axis parameter and moves to the position that is specified in this parameter.

With a main spindle with rotary axis capability, the actual gear stage bits 1 through 3 need not be updated because such a spindle cannot possess a changeable gear drive.

Explanation of the status signals

With digital drives, the „controller enabling“ signal must be considered as a pure status signal. Transferring the signal to the drive is not necessary because the NC transfers the controller enabling signal via the SERCOS interface directly to the drive.

The „reference“ status signal shows, as for all axes, whether or not the axis has been homed.

The „positive/negative axis movement“ status signals signal that the axis moves in the positive/negative direction. The two status signals are valid in main spindle mode and in rotary axis mode. In a powerless state, the NC corrects the actual values and assigns them to the command values.

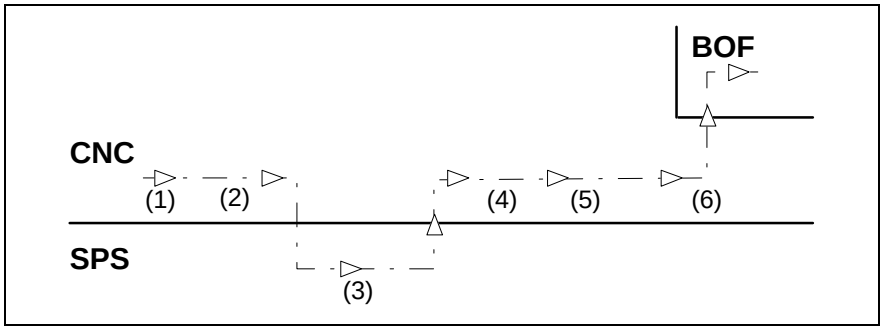
For indication purposes (such as triggering LEDs on a machine control panel), the information „and not power“ should, in addition to the „positive/negative axis movement“ signals, be inserted in the SPS in the path in order to suppress the existing encoder noise.

A digital drive employs the „digital drive ready“ signal to report its ready state.

The waypoint signals only become valid after homing has been completed. The NC updates these signals in main spindle mode and in rotary axis mode.

The remaining control signals are newly introduced spindle-related (SERCOS) signals.

Main Spindle Mode/Rotary Axis Mode Changeover



(1) Activate changeover process
(2) Internal changeover
(3) External changeover
(4) De-activate changeover process
(5) Position control/speed control changeover
(6) Information to the user interface

Fig. 4-1: Sequence of a main spindle mode/rotary axis mode changeover process

Activating the changeover process

The NC automatically activates the main spindle mode/rotary axis mode changeover on the basis of the NC commands. While the G codes

- G00 (linear interpolation at maximum velocity),
- G01 (linear interpolation),
- G02 (circular interpolation clockwise) and
- G03 (circular interpolation counter-clockwise),

in conjunction with the axis designation for rotary axis mode, initiate a changeover to rotary axis mode, the commands

- G33 (thread cutting),
- G63 (tapping),
- G64 (tapping),
- M3 (spindle clockwise),
- M4 (spindle counter-clockwise) and
- M5 (spindle stop)
- M19 (spindle positioning),

trigger the changeover to main spindle mode (provided that the respective mode has not yet been selected).

In manual mode, the NC switches the main spindle with rotary axis capability to rotary axis mode if the SPS employs the control signals

- AxxCJGPOS (positive jogging) or
- AxxCJGNEG (negative jogging)

for moving the axis (if rotary axis mode has not been selected).

The control signals

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop), and
- AxxCM19 (spindle positioning),

in contrast, trigger the changeover to main spindle mode (provided that main spindle mode has not yet been selected).

Note: The main spindle mode/rotary axis mode changeover processes correspond to a program sequence that can only be activated via NC commands.

Internal changeover

The axis processor:

- decelerates the drive,
- switches over to speed control,
- activates the associated parameter record in the digital drive (provided this is required due to the „Drive parameter record for rotary axis mode“ parameter being not equal to zero), and
- acknowledges the internal changeover process.

Note: Internal changeover is only available to digital main spindles, digital main spindle with rotary axis capability, and digital rotary axes.

External changeover

The SPS employs the ROTMOD and SPMOD function blocks for recognizing the request for external changeover to rotary axis mode or main spindle mode.

Using APR-SERCOS parameters and commands, the SPS may use the following motion functions during that phase:

- hunting
- any movement, and
- positioning.

If mechanical switchover processes or sequences are not required, the SPS immediately acknowledges the required mode, using the associated ROTMOD_Q or SPMOD_Q function block.

Irrespective of the fact whether or not external changeover for main spindle mode and rotary axis mode is required, the SPS must, using the ROTMOD_Q and SPMOD_Q function blocks, continually report the current state to the NC.

De-activating the changeover process

The NC de-activates the changeover process as soon as it recognizes the end of the external changeover.

Note: The SPS may only employ the APR-SERCOS parameters and commands for the „hunting“, „any movement“, and „positioning“ functions as long as a changeover process is active. The NC ignores those commands in any other situation.

Position control/speed control changeover

Upon switching over from spindle mode to rotary axis mode,

- the axis processor decelerates the drive,
- updates the position command value, and
- switches the main spindle with rotary axis capability over to position control.

In rotary axis mode/main spindle mode changeover, the axis processor switches the main spindle with rotary axis capability over to speed control.

Note: The position control/speed control changeover process is only available to digital main spindles, digital main spindles with rotary axis capability, and digital rotary axes.

4.3 SPS Interface, Rotary Axis with Separate Servo Drive

A separate axis interface is available to main spindle and servo axis.

Axis signals

The axis signals listed in Chapter „Axis Signals“ (page 4-3) are available to main spindles and to rotary spindles. The NC does not take the spindle-related signals into account for a rotary axis.

Explanation of the interface signals

Using the „positive jogging“ and „negative jogging“ jog commands, a main spindle can be moved as before. The PxxCJOGM0 - PxxCJOGM2 process control signals define the type of the jogging movements for the feed axes, including the main spindles. In contrast to rotary axes, main spindles may additionally be moved independently of the selected jog mode if the SPS employs the following command signals:

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop) and
- AxxCM19 (spindle positioning)

When an edge of the AxxCM3 or AxxCM4 control signals is encountered, the NC takes the value that is stored under the main-spindle-related „jogging speed“ axis parameter as the command speed and performs the commanded rotation.

When an edge of the AxxCM19 control signal is encountered, the NC accesses the value that has been stored under the main-spindle-related „jogging spindle position“ axis parameter and moves to the position that is specified in this parameter.

If a changeable gear drive exists, the current gear stage must be reported to the NC on the basis of the actual gear stage bits 1 through 3.

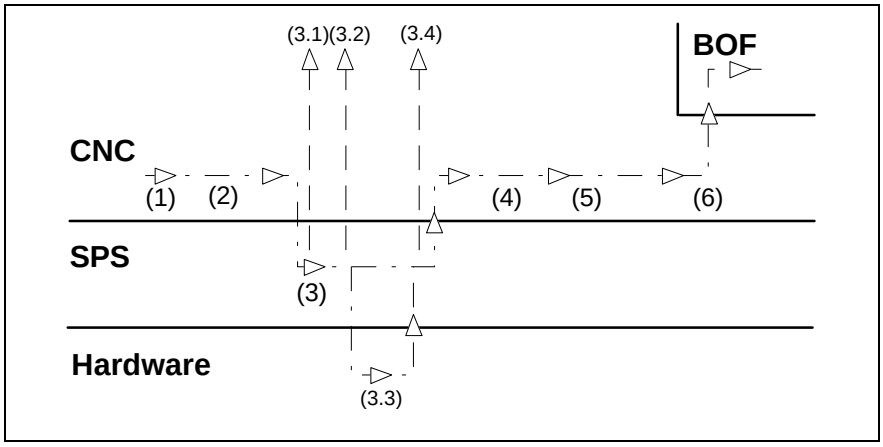
Main spindle mode/rotary axis mode changeover

Like with a main spindle with rotary axis capability, the standard functions

- ROTMOD,
- ROTMOD_Q,
- SPMOD and
- SPMOD_Q

are available to the main spindle for performing the main spindle mode/rotary axis mode changeover processes.

In contrast to a main spindle with rotary axis capability, a main spindle/servo combination requires the SPS to perform a mechanical changeover and to activate/de-activate the axis enabling signals of the drives.



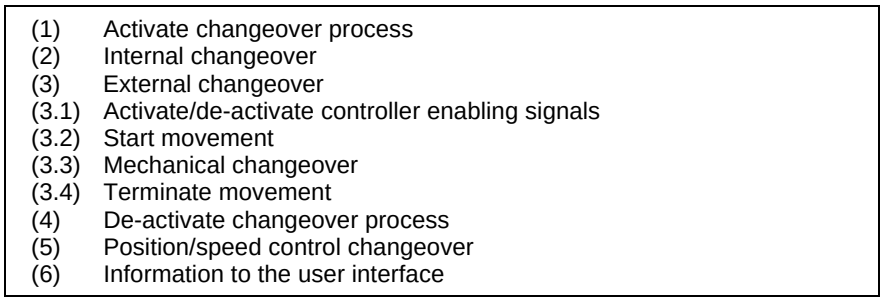


Fig. 4-2: Sequence of a main spindle mode/rotary axis mode changeover process

Activating the changeover process

The NC automatically activates the main spindle mode/rotary axis mode changeover on the basis of the NC commands.

While the G codes

- G00 (linear interpolation at maximum velocity),
- G01 (linear interpolation),
- G02 (circular interpolation clockwise) and
- G03 (circular interpolation counter-clockwise),

in conjunction with the axis designation for rotary axis mode, initiate a changeover to rotary axis mode, the commands

- G33 (thread cutting),
- G63 (tapping),
- G64 (tapping),
- M3 (spindle clockwise),
- M4 (spindle counter-clockwise) and
- M5 (spindle stop)
- M19 (spindle positioning),

trigger the changeover to main spindle mode (provided that the respective mode has not yet been selected).

In manual mode, the NC switches the main spindle with rotary axis capability to rotary axis mode if the SPS employs the control signals

- AxxCJGPOS (positive jogging) or
- AxxCJGNEG (negative jogging)

for moving the axis (if rotary axis mode has not been selected).

The control signals

- AxxCM3 (spindle clockwise),
- AxxCM4 (spindle counter-clockwise),
- AxxCM5 (spindle stop), and
- AxxCM19 (spindle positioning),

in contrast, trigger the changeover to main spindle mode (provided that main spindle mode has not yet been selected).

Note: The main spindle mode/rotary axis mode changeover processes correspond to a program sequence that can only be activated via NC commands.

Internal changeover

Irrespective of the changeover direction (main spindle mode/rotary axis mode or rotary axis mode/main spindle mode), the axis processor always performs the following steps:

- decelerating the drive
- switching over to speed control, and
- acknowledging internal changeover process.

Note: Internal changeover is only available to digital main spindles, digital main spindle with rotary axis capability, and digital rotary axes.

External changeover

The SPS employs the ROTMOD and SPMOD function blocks for recognizing the request for external changeover to rotary axis mode or main spindle mode.
Using APR-SERCOS parameters and commands, the SPS may use the following motion functions during that phase for both drives:

- hunting
- any movement, and
- positioning (with motor encoder)

Whether or not the SPS uses motion functions, which motion functions are employed, at what time it activates/de-activates the controller enabling signals of the drives, and performs the mechanical changeover process depends on the SPS user program.
Before the SPS reports the completion of the changeover process, using the ROTMOD_Q and SPMOD_Q standard functions, the SPS must activate the controller enabling signal of the associated drive and de-activate the controller enabling signal of the other drive. The AxxCREADY interface signal must be used for activating/de-activating the controller enabling signal from the SPS. De-activating the controller enabling signal switches the axis over to follow-up mode, thus avoiding an error message to be issued due to the progressing actual values of the encoder.
During operation, only one drive is responsible for spindle operation. The other drive is tracked in a disengaged or engaged state.
After a changeover process, the SPS must, using the ROTMOD_Q and SPMOD_Q standard functions, continually report the current state to the NC.

De-activating the changeover process

The NC de-activates the changeover process when it recognizes the end of the external changeover.

Note: The SPS may only employ the APR-SERCOS parameters and commands for the „hunting“, „any movement“, and „positioning“ functions as long as a changeover process is active. The NC ignores those commands in any other situation.

Position control/speed control changeover

Upon switching over from spindle mode to rotary axis mode,

- the axis processor decelerates the rotary axis drive,
- updates the position command value, and
- switches the rotary axis over to position control.

Upon switching over from rotary axis mode to main spindle mode, the axis processor switches the main spindle drive over to speed control.

Note: The position control/speed control changeover process is only available to digital main spindles, digital main spindles with rotary axis capability, and digital rotary axes.

4.4 Typical SPS Program: C Axis Mode

Mechanical Structure

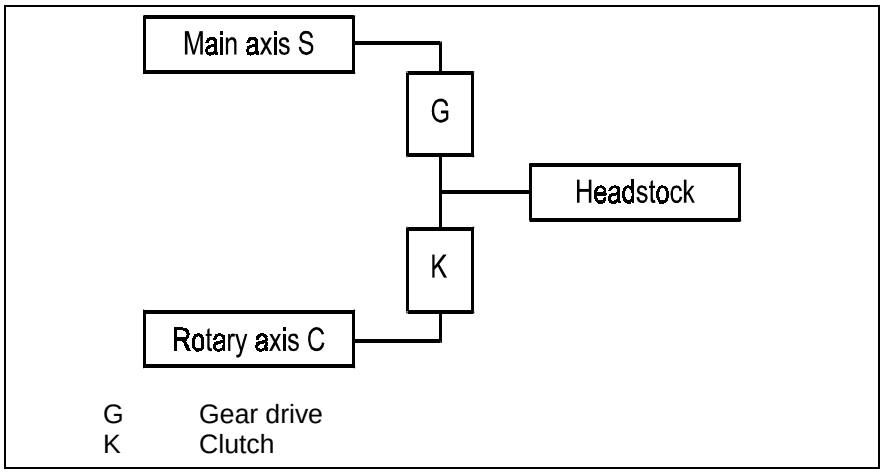


Fig. 4-3: C axis operation - mechanical structure

In main axis mode, the main axis S drives the headstock via a gear drive G. The clutch K is disengaged. This means that the rotary axis C is not involved in this movement.

In rotary axis mode, the rotary axis C is activated via a clutch K. Once the clutch has successfully been switched, the spindle's controller enabling signal is switched off so that the spindle idles. The controller enabling signal is activated upon the changeover to main axis mode.

SPS program sequence

When the controller is switched on, the spindle is initialized in the SPS program. The „spindle velocity", „spindle acceleration" and „spindle position" parameters are set via the SERCOS required data channel.

The CNC initiates main axis mode/rotary axis mode changeover. Changeover to rotary axis mode is performed by:

- jogging the C axis
- NC command with C axis

In the SPS, changeover to rotary axis mode is interpreted by the ROTMOD standard function. The SPS activates the clutch. The ROTMOD_Q standard function acknowledges the execution of the action. The ROTMOD_Q standard function must be controlled until main axis mode is selected.

Changeover to spindle mode is initiated by

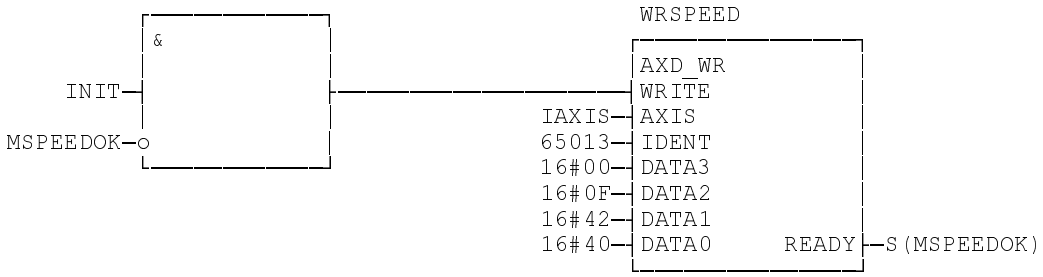
- jogging the main axis
- NC command with spindle

In the SPS, changeover to main axis mode is interpreted by the SPMOD standard function. The SPS releases the clutch. The SPMOD_Q standard function acknowledges the execution of the action. The SPMOD_Q standard function must be controlled until main rotary axis mode is selected.

Initializing the Main Spindle

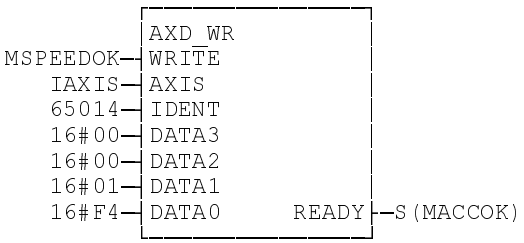
Simple solution Writing to parameters without safety request

```
1  (*Initializing spindle speed 100 1/min = $F4240*)
2
```



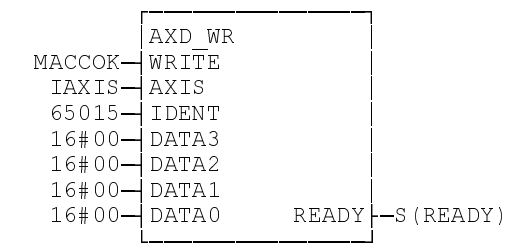
WRSPEED	Spindle speed specification		AXD_WR
INIT	Initiate spindle initialization	VAR_INPUT	BOOL
MSPEEDOK	Spindle speed initialized		BOOL
IAXIS	Axis number	VAR_INPUT	INT
65013	Spindle speed ID no. 65013		UINT
16#00	Spindle speed data byte 3		BYTE
16#0F	Spindle speed data byte 2		BYTE
16#42	Spindle speed data byte 1		BYTE
16#40	Spindle speed data byte 0		BYTE
MSPEEDOK	Spindle speed initialized		BOOL

```
3  (*Spindle acceleration initialization 500 1/s^2=$1F4*)
4         WRACC
```



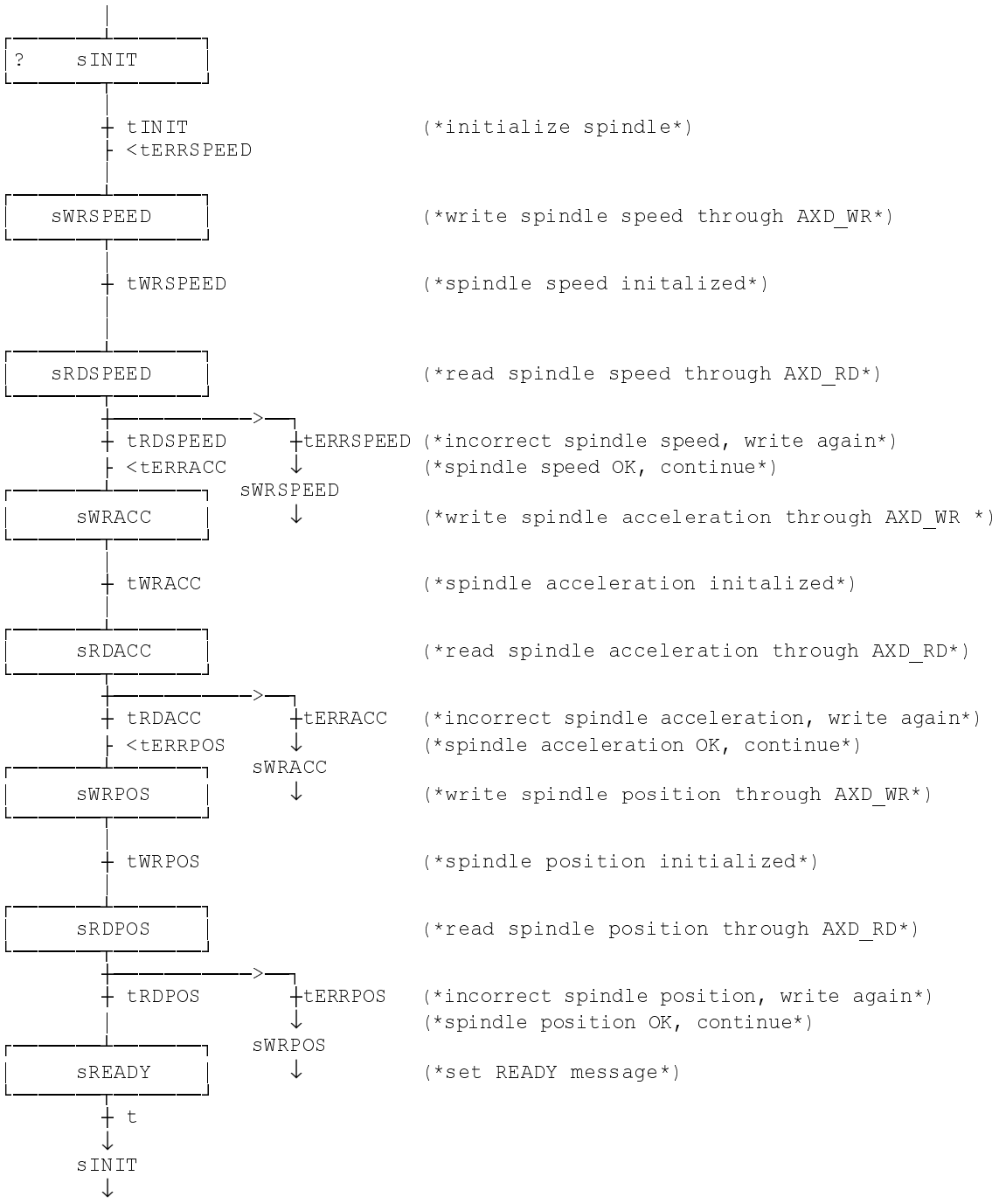
WRACC	Spindle speed specification		AXD_WR
MSPEEDOK	Spindle speed initialized	BOOL	
IAXIS	Axis number	VAR_INPUT	INT
65014	Spindle speed ID no. 65014	UINT	
16#00	Spindle acceleration data byte 3		BYTE
16#00	Spindle acceleration data byte 2		BYTE
16#01	Spindle acceleration data byte 1		BYTE
16#F4	Spindle acceleration data byte 0		BYTE
MACCOK	Spindle speed initialized	BOOL	

```
5  (*Initialization spindle position 0 degrees = $=0*)
6         WRPOS
```



WRPOS	Spindle position specification		AXD_WR
MACCOK	Spindle acceleration initialized		BOOL
IAXIS	Axis number	VAR_INPUT	INT
65015	Spindle position ID no. 65015		UINT
16#00	Spindle position data byte 3		BYTE
16#00	Spindle position data byte 2		BYTE
16#00	Spindle position data byte 1		BYTE
16#00	Spindle position data byte 0		BYTE
READY	Spindle initialized ready message		BOOL

Better solution SFC structure for initialization with safety request



Rotary Axis Mote/Spindle Mode Changeover

```
1  (*changeover to rotary axis mode*)
2
          ┌──────────────┐
          │ROTMOD        │
       2#1┤ACTIVE        │
  ISP_NR──┤              ├─┬─M_ROTAC
          └──────────────┘ ├─R(MPENDOS)
                           └─R(MPENDIS)
```

ROTMOD			ROTMOD
2#1			Dual
ISP_NR	Main spindle axis number	VAR_INPUT	INT
MROTAC	Rotary axis mode changeover flag		BOOL
MPENDOS	Hunting OFF, spindle		BOOL
MPENDIS	Hunting ON, spindle		BOOL

```
3
          ┌──────────────┐
          │:=            │
 M_ROTAC─o              │
          │              ├─>>norot
          └──────────────┘
```

M_ROTAC	Rotary axis mode changeover flag		BOOL
norot			LABEL

```
4  (*Initiate drifting, rotary axis*)
5
          ┌──────────────┐                    AXD1R
          │:=            │                  ┌──────────────────┐
IROTMODE─o              │                  │AXD_WR            │
 MPEND1R─o              ├──────────────────┤WRITE             │
          └──────────────┘            IROT_NR─┤AXIS              │
                                   IDSPDLFCT─┤IDENT             │
                                          ──┤DATA3             │
                                          ──┤DATA2             │
                                          ──┤DATA1             │
                                2#00000100──┤DATA0      READY├─S(MPEND1R)
                                            └──────────────────┘
```

AXD1R	FB drifting ON, rotary axis			AXD_WR
IROTMODE	Rotary axis mode active	VAR_INPUT	BOOL	
MPEND1R	Hunting ON, rotary axis		BOOL	
IROT_NR	Axis number of rotary axis	VAR_INPUT	INT	
IDSPDLFCT	Spindle ID no. 65012		UINT	
2#00000100			DUAL	
MPEND1R	Hunting ON, rotary axis		BOOL	

```
6  (*trigger valves for changeover to rotary axis mode*)
7
          ┌──────────────┐
          │:=            │
       2#1┤              │
          │              ├─┬─R(QSPMODE)
          └──────────────┘ └─S(QROTMODE)
```

2#1			Dual
QSPMODE	Activate spindle mode	VAR_OUTPUT	BOOL
QROTMODE	Activate rotary axis mode	VAR_OUTPUT	BOOL

```
8  (*Switch off hunting, rotary axis*)
9                                          AXD0R
          ┌─────────────┐                ┌─────────────────┐
 MPEND0R─o &            │                │AXD_WR           │
IROTMODE─┤              │                │WRITE            │
 ISPMODE─o              ├────────────────┤AXIS             │
          └─────────────┘          IROT_NR─┤IDENT            │
                                 IDSPDLFCT─┤DATA3            │
                                           ─┤DATA2            │
                                           ─┤DATA1            │
                                 2#00000000─┤DATA0      READY├─S(MPEND0R)
                                            └─────────────────┘
```

AXD0R	FB drifting OFF, rotary axis		AXD_WR
IROTMODE	Rotary axis mode active	VAR_INPUT	BOOL
ISPMODE	Main spindle mode active	VAR_INPUT	BOOL
MPEND0R	Hunting OFF, rotary axis		BOOL
IROT_NR	Axis number of rotary axis	VAR_INPUT	INT
IDSPDLFCT	Spindle ID no. 65012		UINT
2#00000000			DUAL
MPEND0R	Hunting OFF rotary axis		BOOL

```
10 (*Acknowledge changeover to rotary mode*)
11  norot:
          ┌─────────────┐
 MPEND0R─o &            │
IROTMODE─┤              │                ┌─────────────────┐
 ISPMODE─o              ├────────────────┤ROTMOD_Q         │
          └─────────────┘                │QUIT             │
                                  ISP_NR─┤AXIS             ├─X
                                         └─────────────────┘
```

IROTMODE	Rotary axis mode active	VAR_INPUT	BOOL
ISPMODE	Main spindle mode active	VAR_INPUT	BOOL
ROTMODE_Q			ROTMODE_Q
MPEND0R	Hunting OFF, rotary axis		BOOL
ISP_NR	Axis number of main spindle	VAR_INPUT	INT
X	Auxiliary flag		BOOL

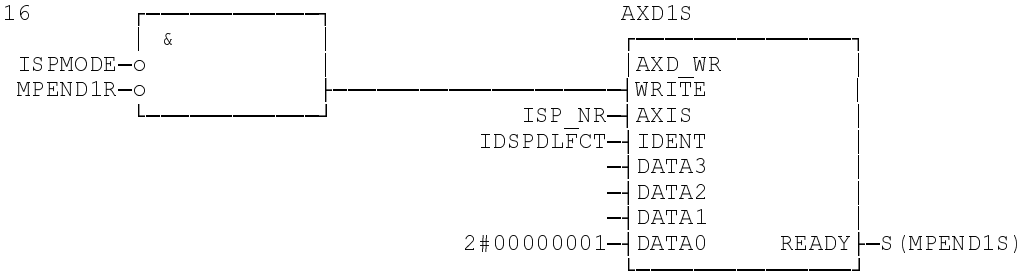
```
12 (*Changeover spindle mode*)
13
          ┌─────────────┐
          │SPMOD        │
      2#1─┤ACTIVE       │
   ISP_NR─┤AXIS         ├─┬─M_SPLAC
          └─────────────┘ ├─R(MPEND0R)
                          └─R(MPEND1R)
```

SPMOD			SPMOD
2#1			Dual
ISP_NR	Main spindle axis number	VAR_INPUT	INT
M_SPLAC	Spindle mode changeover flag		BOOL
MPEND0R	Hunting OFF, rotary axis		BOOL
MPEND1R	Hunting ON, rotary axis		BOOL

```
14
          ┌─────────────┐
          │:=           │
 M_SPLAC─o              │
          │             ├─>>nosp
          └─────────────┘
```

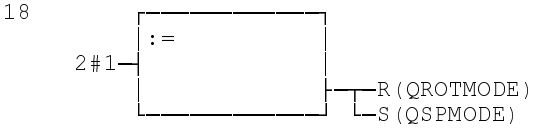
M_SPLAC	Spindle mode changeover flag		BOOL
nosp			LABEL

```
15 (*Initiate hunting, spindle*)
16
```



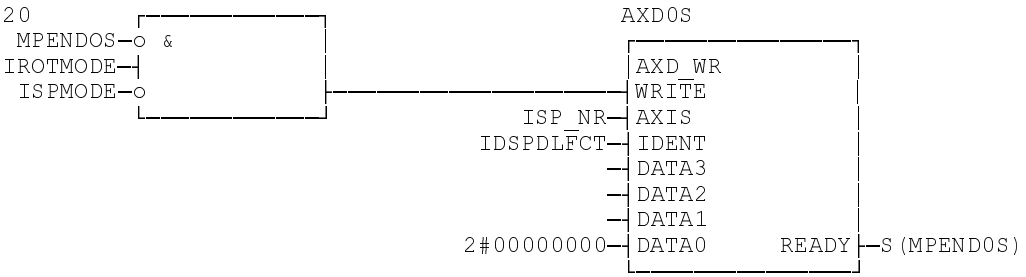
AXD1S	FB hunting ON, spindle		AXD_WR
ISPMODE	Main spindle mode active	VAR_INPUT	BOOL
MPEND1R	Hunting ON, rotary axis		BOOL
ISP_NR	Main spindle axis number	VAR_INPUT	INT
IDSPDLFCT	Spindle ID no. 65012		UINT
2#00000001			DUAL
MPEND1S	Hunting ON, spindle		BOOL

```
17 (*trigger valves for changeover to spindle mode*)
18
```



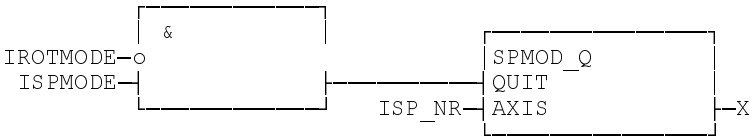
2#1			Dual
QROTMODE	Activate rotary axis mode	VAR_OUTPUT	BOOL
QSPMODE	Activate spindle mode	VAR_OUTPUT	BOOL

```
19 (*Switch off hunting, spindle*)
20
```



AXD0S	FB hunting OFF rotary axis		AXD_WR
IROTMODE	Rotary axis mode active	VAR_INPUT	BOOL
ISPMODE	Main spindle mode active	VAR_INPUT	BOOL
MPEND0S	Hunting OFF spindle		BOOL
ISP_NR	Main spindle axis number	VAR_INPUT	INT
IDSPDLFCT	Spindle ID no. 65012		UINT
2#00000000			DUAL
MPEND0S	Hunting OFF spindle		BOOL

```
21 (*Acknowledge changeover to main spindle mode*)
22  nosp:
```



IROTMODE	Rotary axis mode active	VAR_INPUT	BOOL
ISPMODE	Main spindle mode active	VAR_INPUT	BOOL
SPMODE_Q			SPMODE_Q
ISP_NR	Main spindle axis number	VAR_INPUT	INT
X	Auxiliary flag		BOOL

5 Index

P

R

S

T

6 Figures

List of Customer Service Points

Germany

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INDRAMAT GmbH D-97816 Lohr am Main Bgm.-Dr.-Nebel-Str. 2 Phone: 09352/40-0 Fax: 09352/40-4885	INDRAMAT GmbH D-09120 Chemnitz Beckerstraße 31 Phone: 0371/3555-0 Fax: 0371/3555-230	INDRAMAT GmbH D-40849 Ratingen Hansastraße 25 Phone: 02102/4318-0 Fax: 02102/41315	INDRAMAT GmbH D-22085 Hamburg Fährhausstraße 11 Phone: 040/227126-16 Fax: 040/227126-15
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European customer service points without Germany

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Notes


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