# Equipment for Special Machines
# WF 725/WF 726
# Positioning Modules

Planning Instructions

Edition 10.96

## Part 1
## Description of the Hardware Interface

SIEMENS

# WF 725/WF 726
# Positioning Modules

## Planning Instructions Part 1

## Description of the Hardware Interface

Edition October 1996

**Note**

*Because of clear arrangement, this documentation does not inform about all details of all types of the product. Therefore, it cannot take into account all possible cases of installations, operation and maintenance.*

*If you require additional information or have special questions, please seek further particulars from your local SIEMENS office.*

*The content of this documentation is not part of an earlier or existing agreement, acceptance or legal matter. All obligations by SIEMENS are set in the corresponding sales contract which also contains the complete and single valid settlement. The contract guarantee will not be enlarged or limited by this documentation.*

BERO, SIMATIC, SIMODRIVE, SINEC, SINUMERIK, STEP are registered trade marks of Siemens Aktiengesellschaft.

The remaining designations contained in this configuring instructions may be trade marks whose use through third parties for their own purposes may infringe the rights of the owners of the mark.

# Contents

# 1 Structure of the Hardware

The WF positioning modules together with the drives and mechanics control single operations and sequential operations in automation systems.

Depending on type of  the operator prompting a different hardware and software configurations can be used. Basically, two configurations are available:

- Configuration with programmer and machine control panel

  This configuration consist of PG 730, PG 750 or PG 770 programmer and specific machine control panel on the hardware side and standard software I-726 and if necessary standard software overlay on the software side.

- Configuration with monitor and keyboard

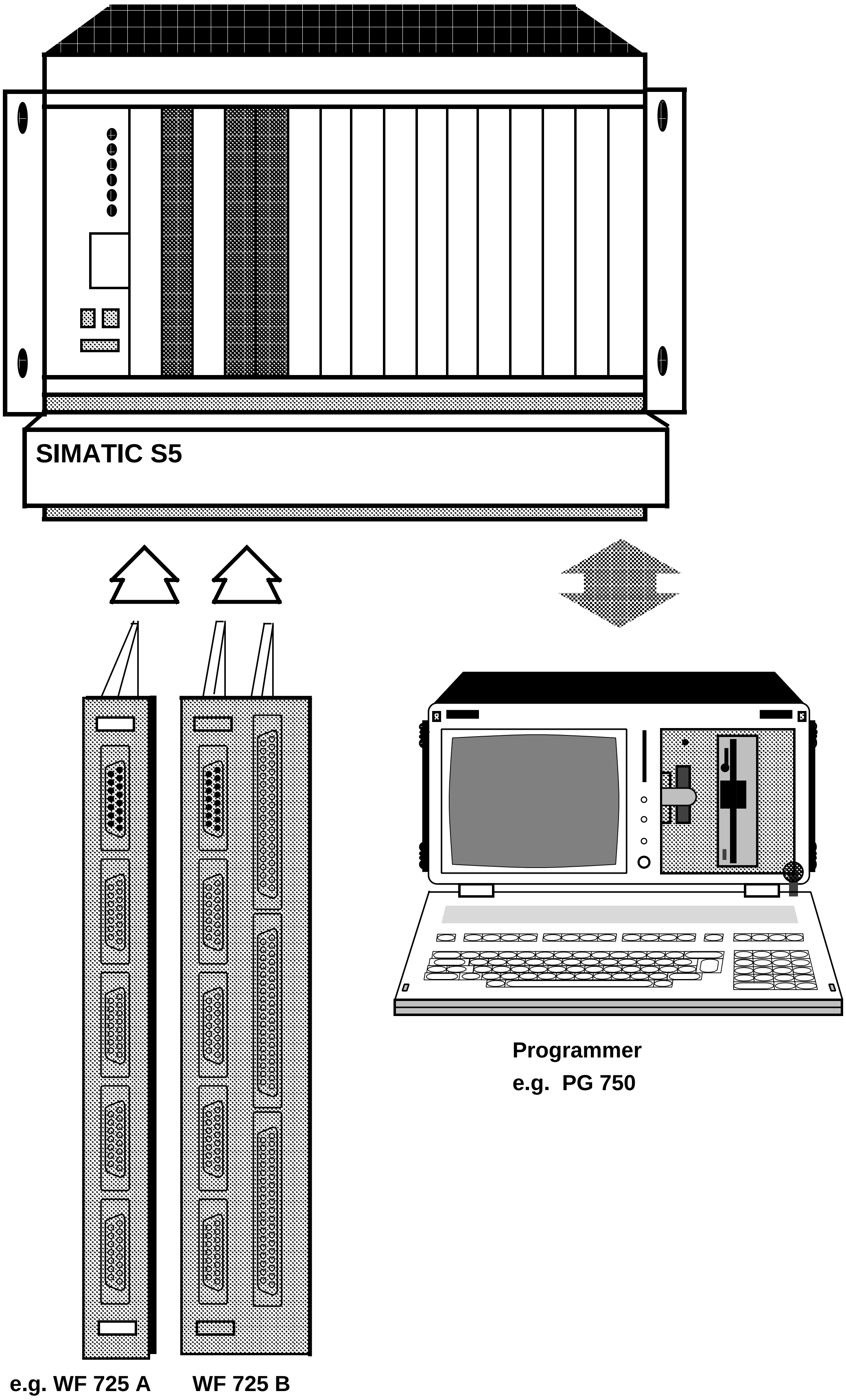
  This configuration consist of WF 470 CRT or GRACIS display system, monitor and keyboard or operator panel on the hardware side and standard software I-726 with standard software III-726 on the software side. The standard software overlay, which provides more convenience at the interface programming, can also be used.

This chapter describes the above mentioned hardware configurations.

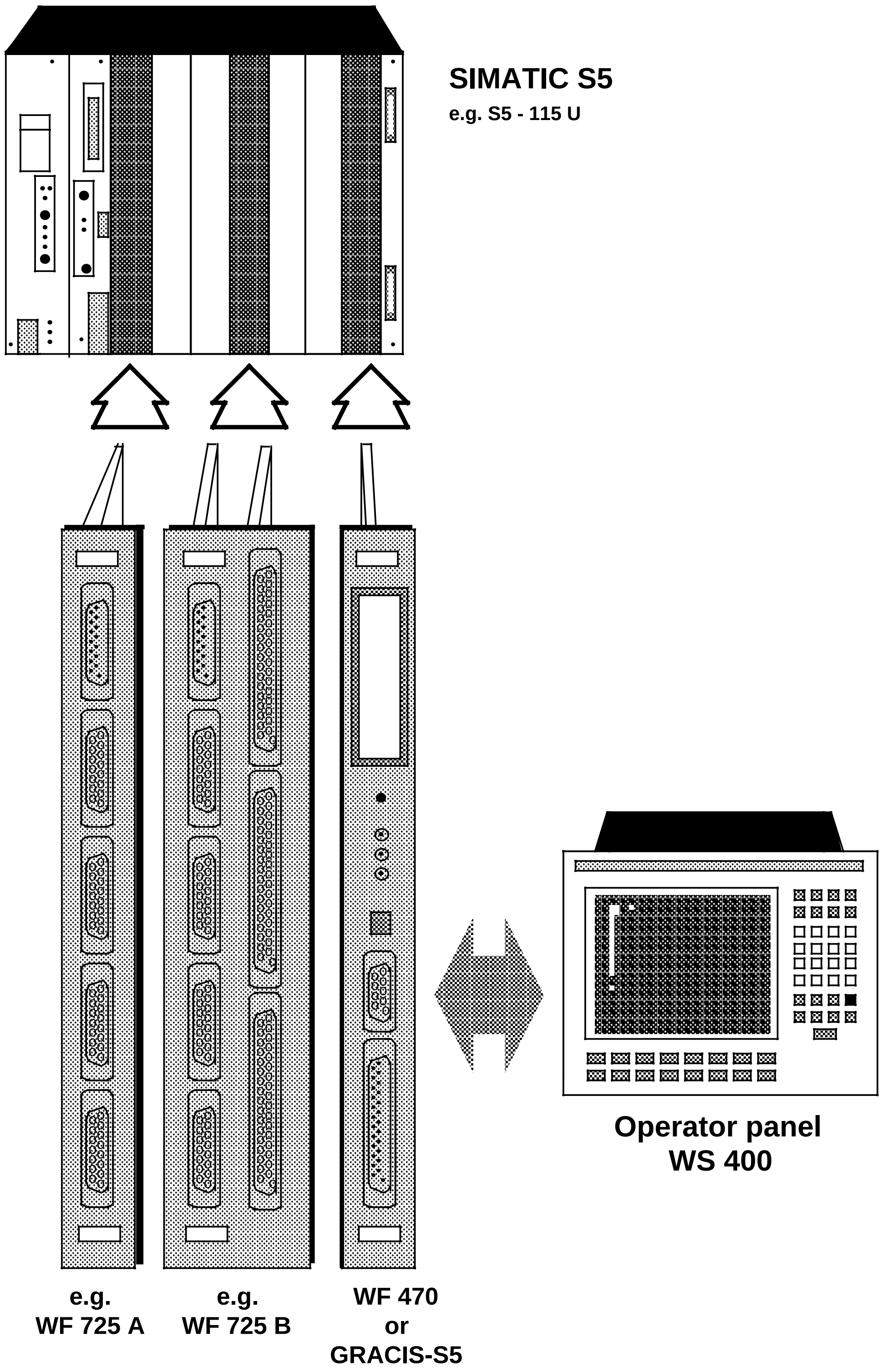
This manual is devoted solely to the hardware which consist of different configuration variants utilizing WF 725 **/** WF 726 positioning module.

The other hardware and software configurations are described in separate manuals which are listed below (see chapter 7).

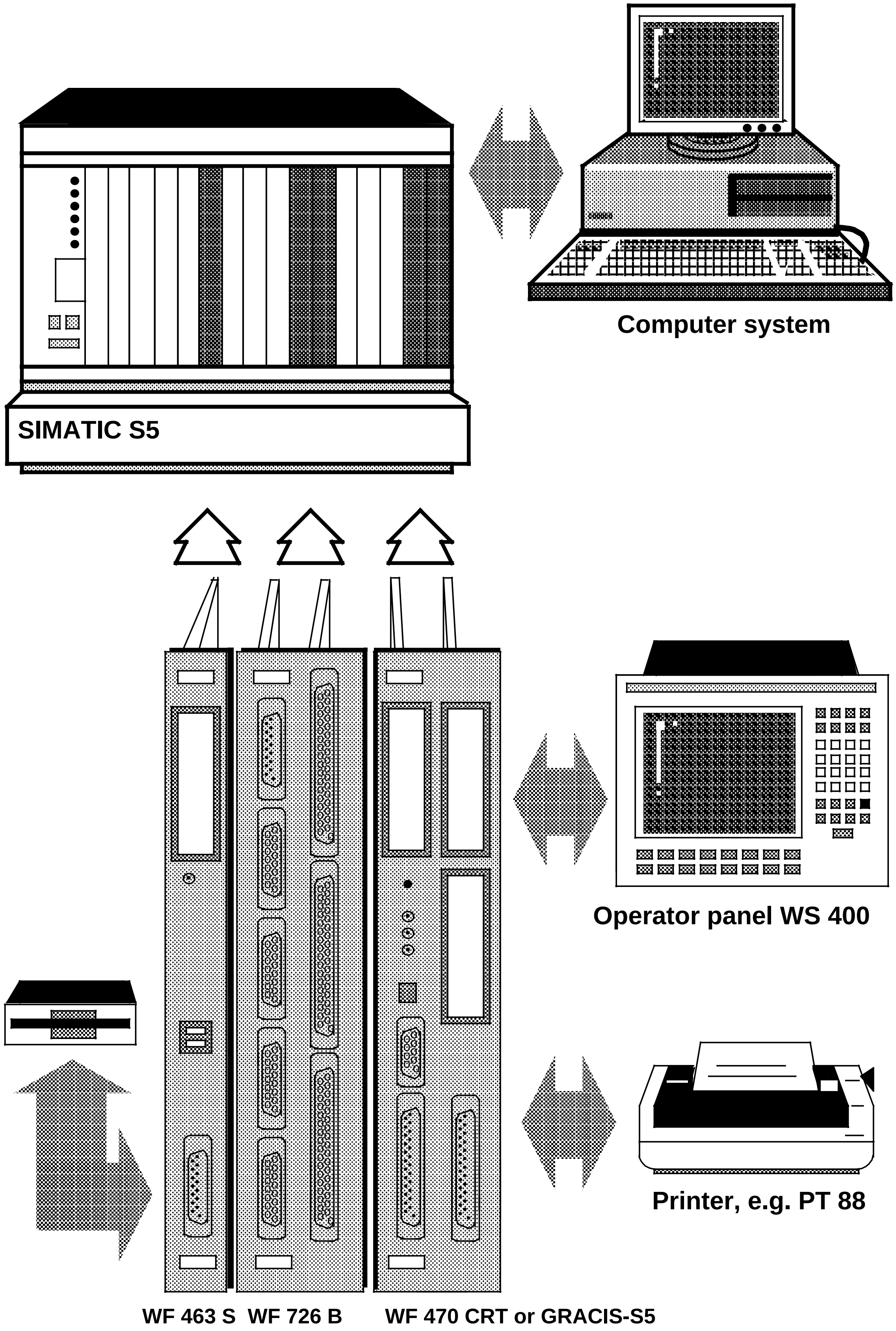
## 1.1 Hardware for Software Standard I-726



## 1.2 Hardware for Standard I-726 and III-726

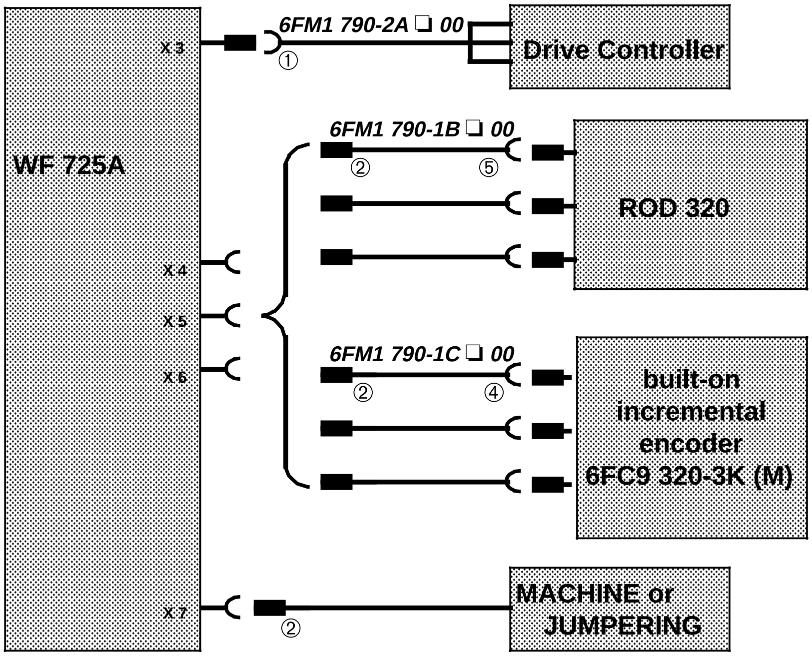


## 1.4 Hardware for Higher Application Level



# 2 Overview of Cables and Accessories

## 2.1 WF 725A

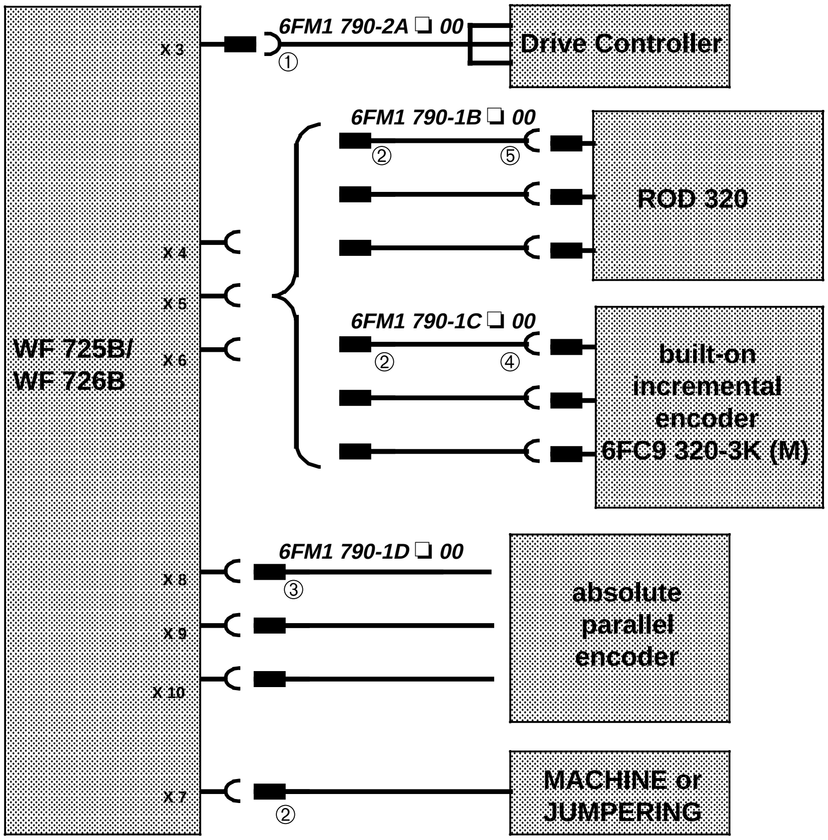


① 15pin, female
② 15pin, male
③ 37pin, male
④ 12pin, female
⑤ 17pin, female

*6FM1 790-1B❑ 00*
↑
**Space for cable length code**

see catalog AR 10 for details

## 2.2 WF 725B / 726B

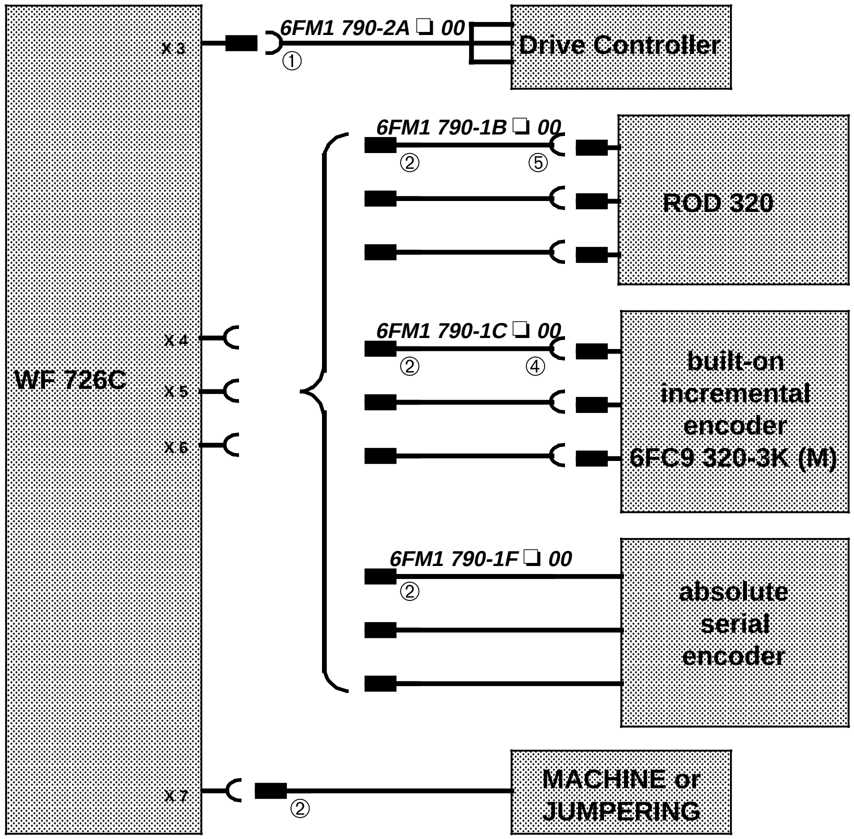


① 15pin, female
② 15pin, male
③ 37pin, male
④ 12pin, female
⑤ 17pin, female

*6FM1 790-1B❑ 00*
↑
**Space for cable**
**length code**

see catalog AR 10
for details

## 2.3 WF 726C



| | |
|---|---|
| ① | 15pin, female |
| ② | 15pin, male |
| ③ | 37pin, male |
| ④ | 12pin, female |
| ⑤ | 17pin, female |

*6FM1 790-1B❑ 00*
↑
**Space for cable length code**

see catalog AR 10 for details

## 2.4 SIMATIC S5-WF-Drive, Connection Diagramm

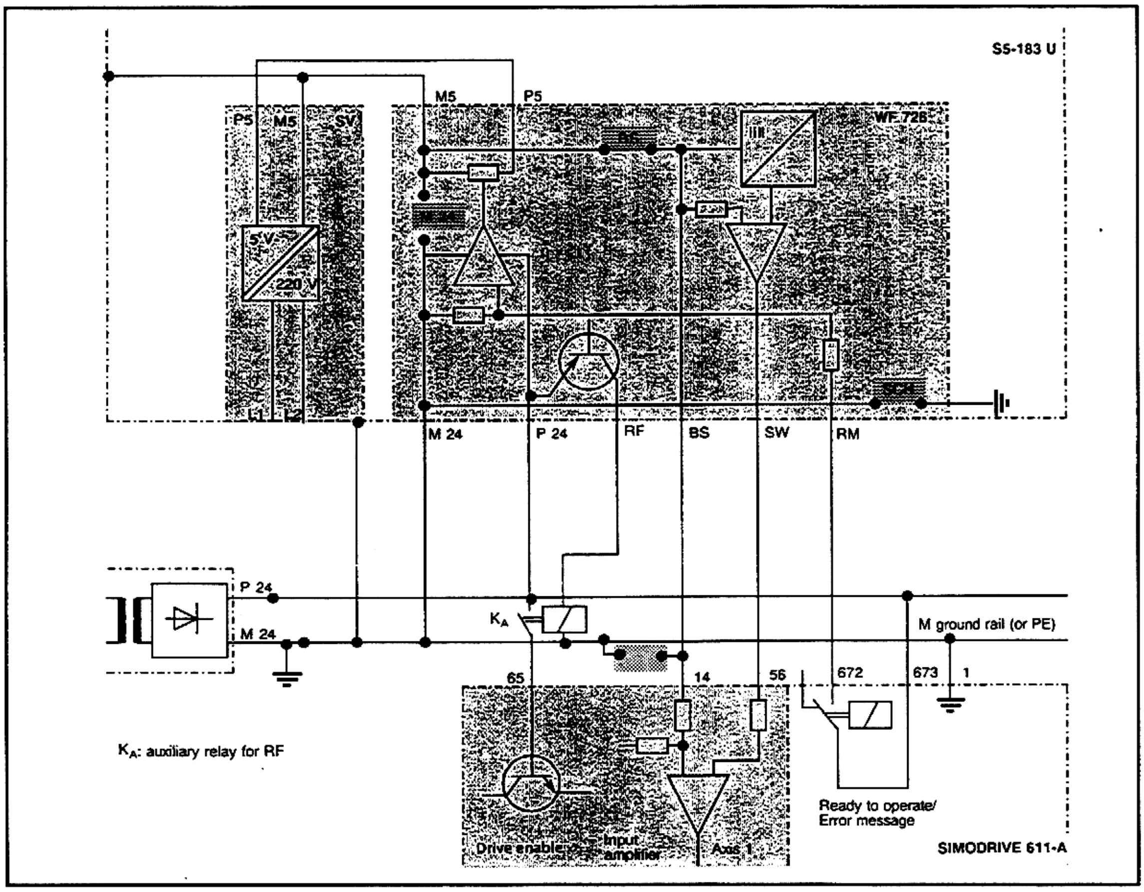


*Figure 2.1. Connection between WF 726 and Drive Controller SIMODRIVE 611-A.*

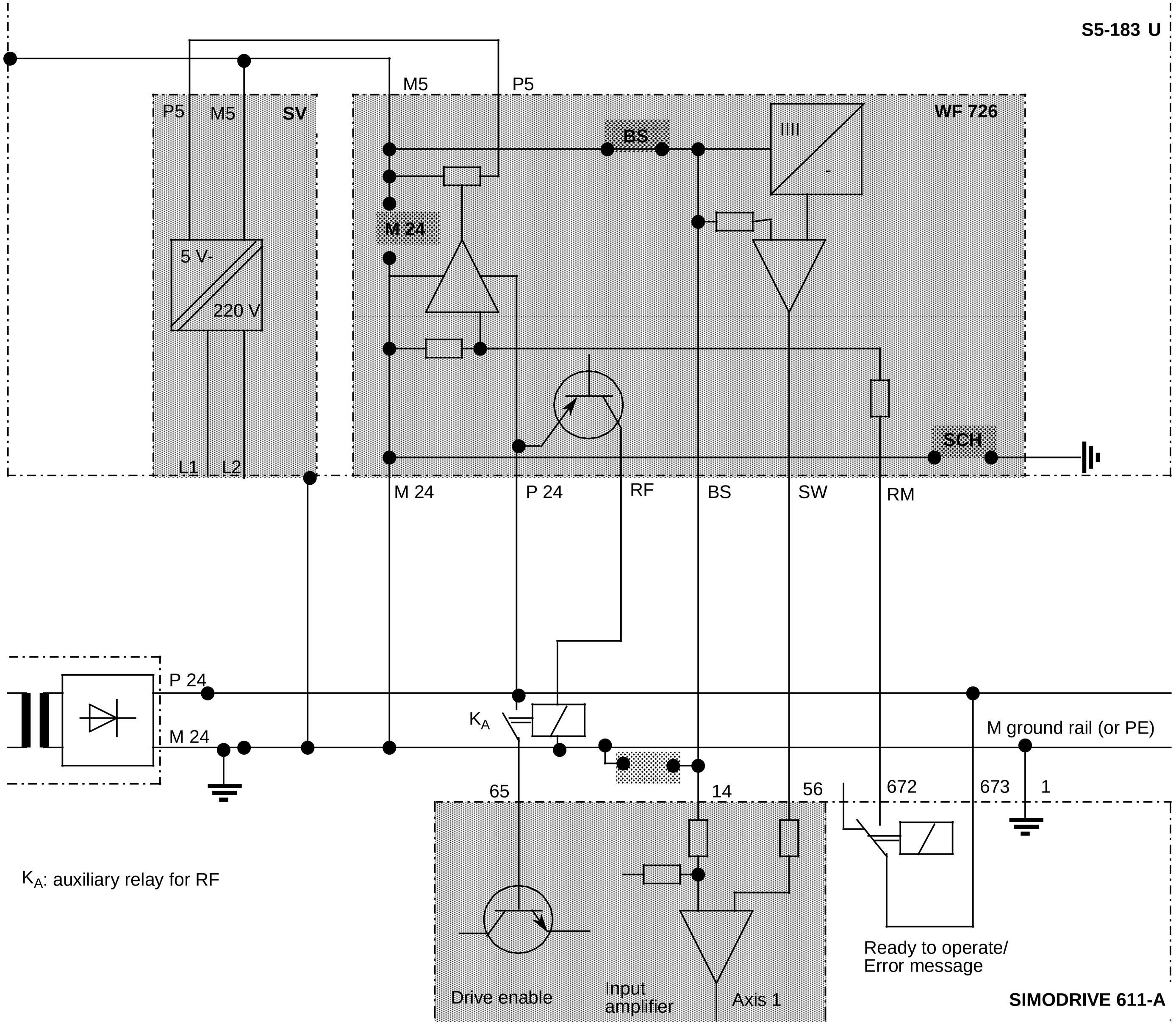
**Jumper SCH:** The jumper SCH has to be installed when WF726 module is operated in adapter casing or rack without sliding contacts for the shield connection.

**Jumper M 24:** Can only be factory-opened for tests.

**Jumper BS:** The jumper BS has to be removed, when the input of the servo controller is non-floating type of input. The voltage between M5 and BS must not exceed 0.1 V.

BS - Reference signal
SCH - M External (shield)
SV - SIMATIC power supply
SW - Command value

E - 24 V - Input } from WF 726
A - 24 V - Output }
RM - Controller response signal (ready signal)
RF - Controller enable

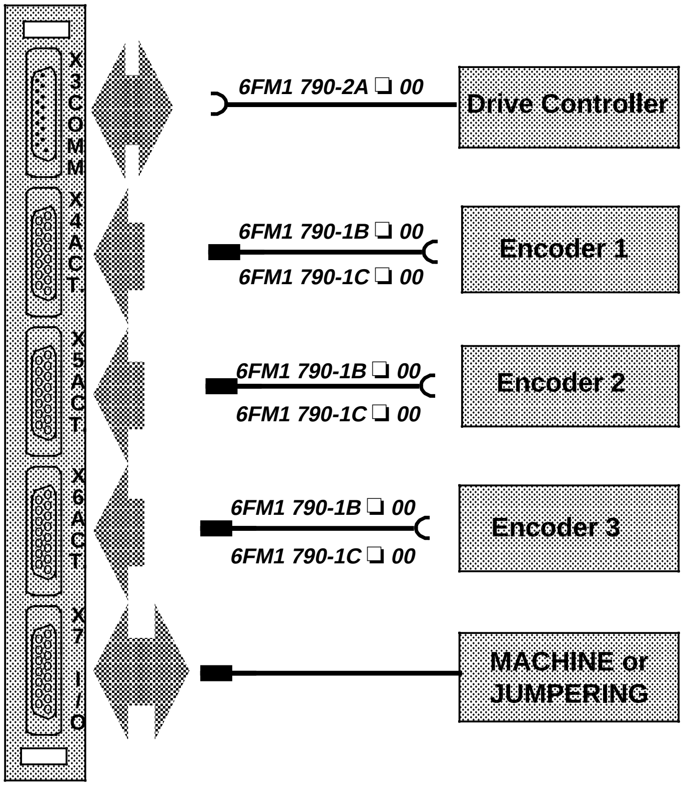


K$_A$: auxiliary relay for RF

# 3 Cable Diagrams

## 3.1 Overview of WF 725 A and WF 726 C

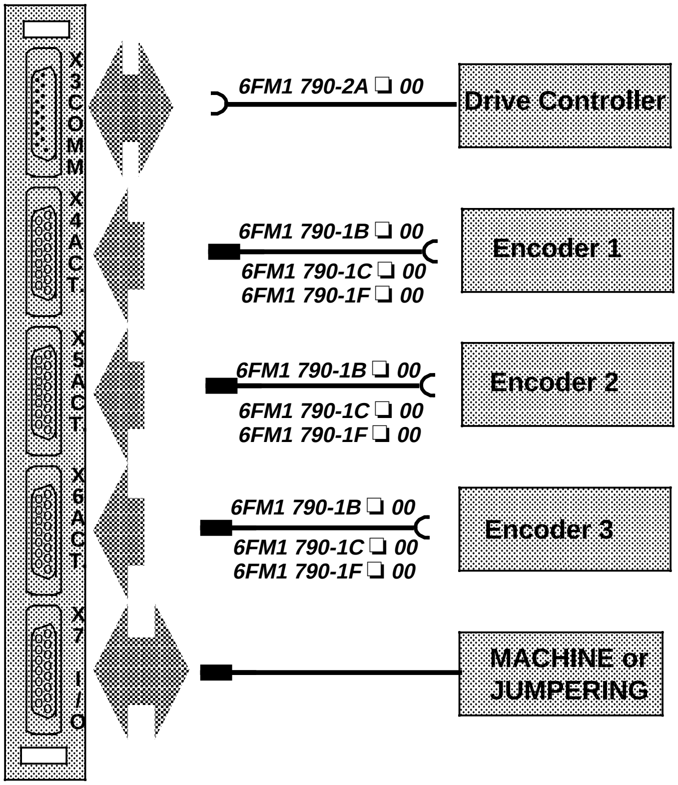
### 3.1.1 Overview of WF 725 A



*6FM1 790-1B❏ 00*
↑
**Space for cable length code**

see catalog AR 10
for details

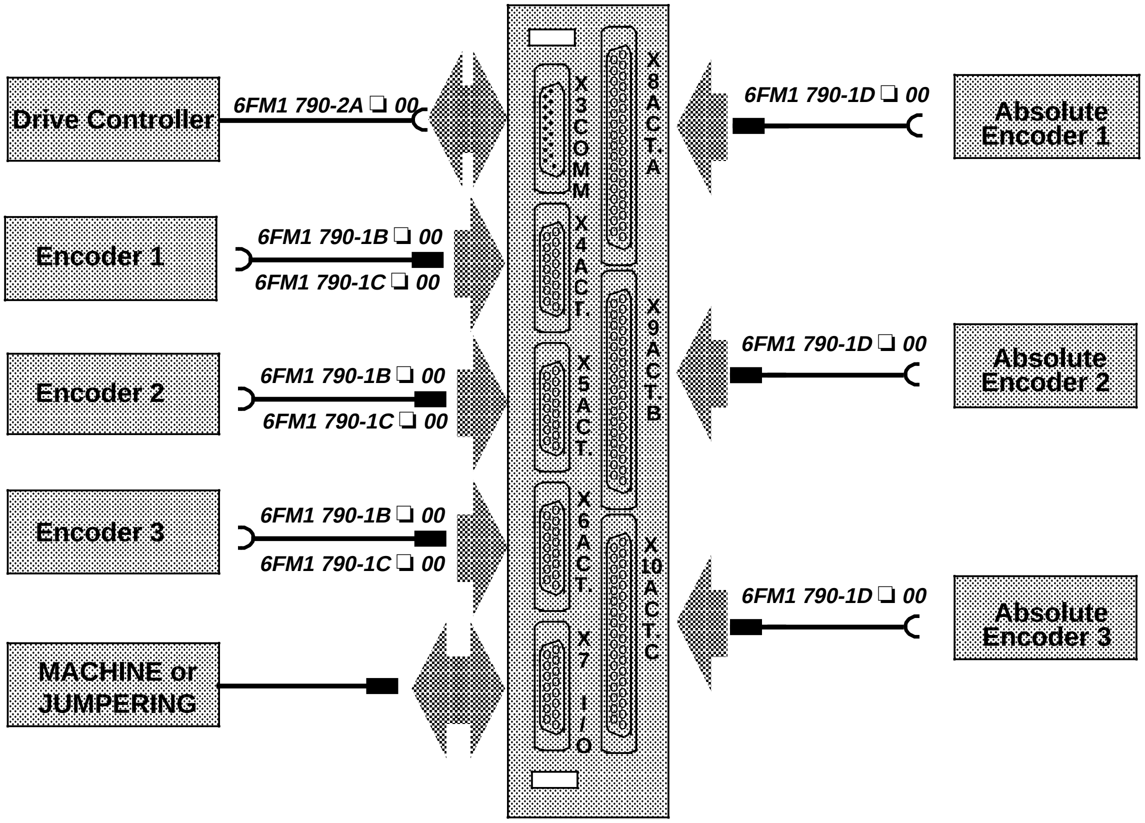
### 3.1.2 Overview of WF 726 C



*6FM1 790-1B❑ 00*
↑
**Space for cable**
**length code**

see catalog AR 10
for details

## 3.2 Overview of WF 725 B / WF 726 B



*6FM1 790-1B❑ 00*
↑

**Space for cable length code**

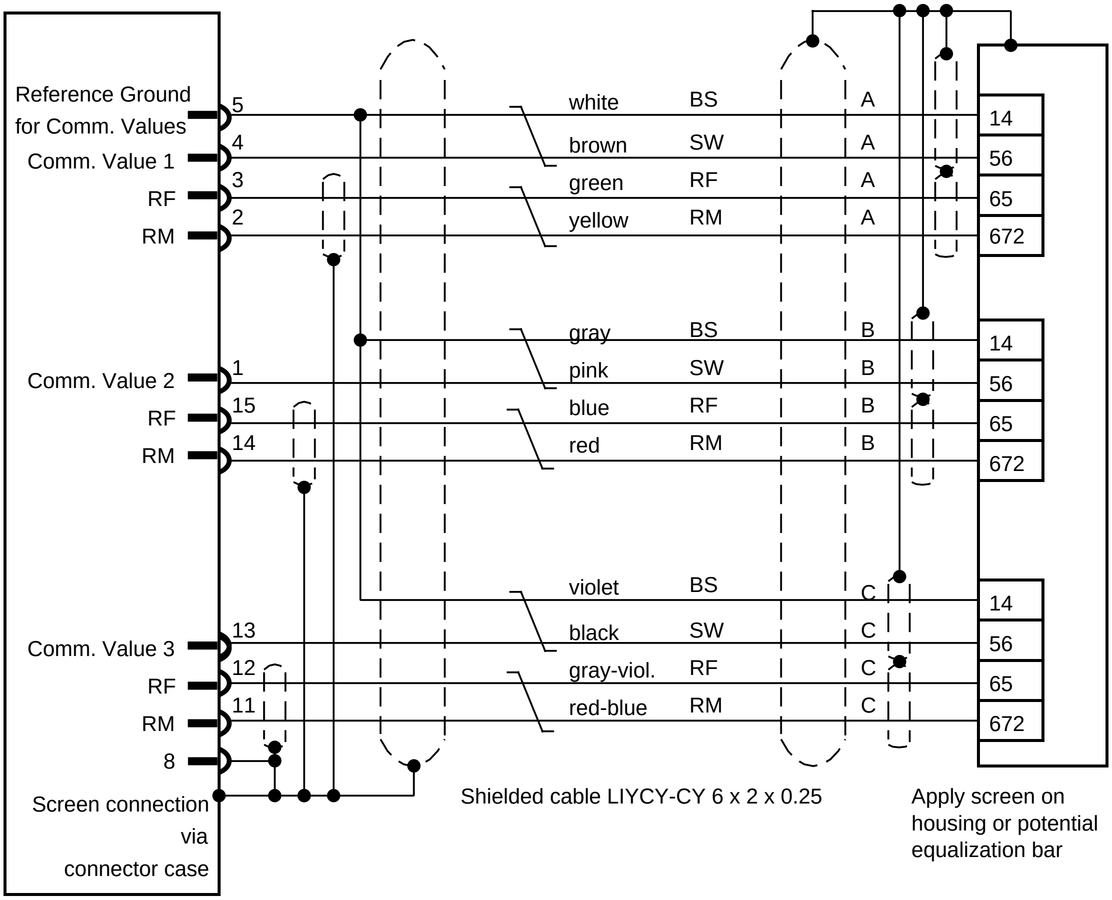
see catalog AR 10
for details

***Up to 3 encoders can be connected.***

## Cable from command value output connector to the drive controller
## Order number: 6FM1 790-2A ❑ 00

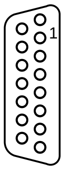
*WF 725 A,B / WF 726 B,C Module*
**Connector X3**

*Drive Controller SIMODRIVE 611-A*
*Cable end unfinished*



Shielded cable LIYCY-CY 6 x 2 x 0.25

Apply screen on housing or potential equalization bar



***Connector***
D-Sub, Siemens
15pin, female
6FM1 790-8CA00
**Terminal side**

***Bared cable***
Pin-type cable socket
provided with designation
for SIMODRIVE 611-A

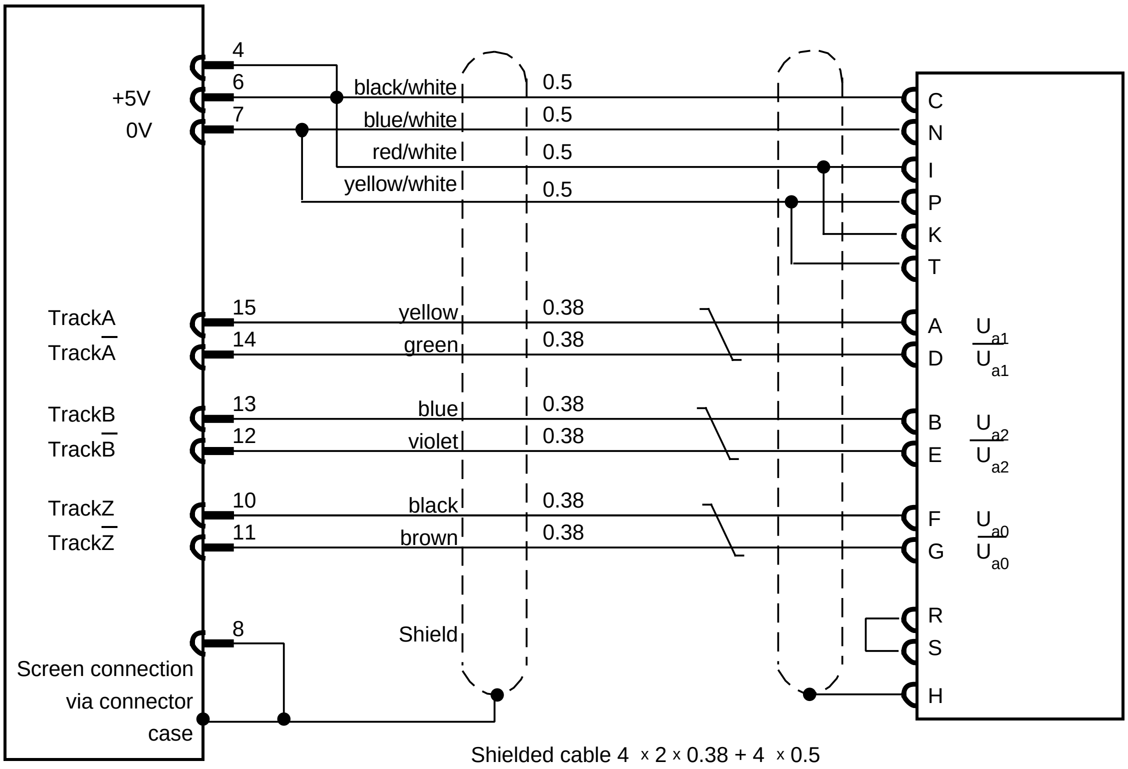
***The 24 V power supply has to be provided to the RF (controller enable signal) and to the RM (controller ready, response signal) via the connector X7.***

***If SIMODRIVE for 2 or 3 axes is used, the WF contacts of X3: 2, 14, and 11 have to be jumpered on the SIMODRIVE side.***

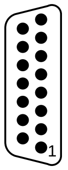
# Cable from actual value feedback connector to ROD 320 Digital Rotatory Encoder
## Order no.: 6FM1 790-1B ❑ 00

***WF 725 A,B / WF 726 B,C*** ***ROD 320 Position Encoder***

**Connectors: X4, X5, X6**



Shielded cable 4 x 2 x 0.38 + 4 x 0.5



***Connector***

D-Sub, Siemens

15pin, male

6FM1 790-8DA00

***Terminal side***

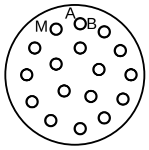
***Round Connector***

17pin, female

Amphenol-Tuchel

6FC9 341-1AC

***Terminal side***



***Connector***

***The screen of the actual-value line must be earthed over a large area on the module side when entering into the cabinet.***

## Cable from actual value feedback connector to SIEMENS Digital Rotatory Encoder

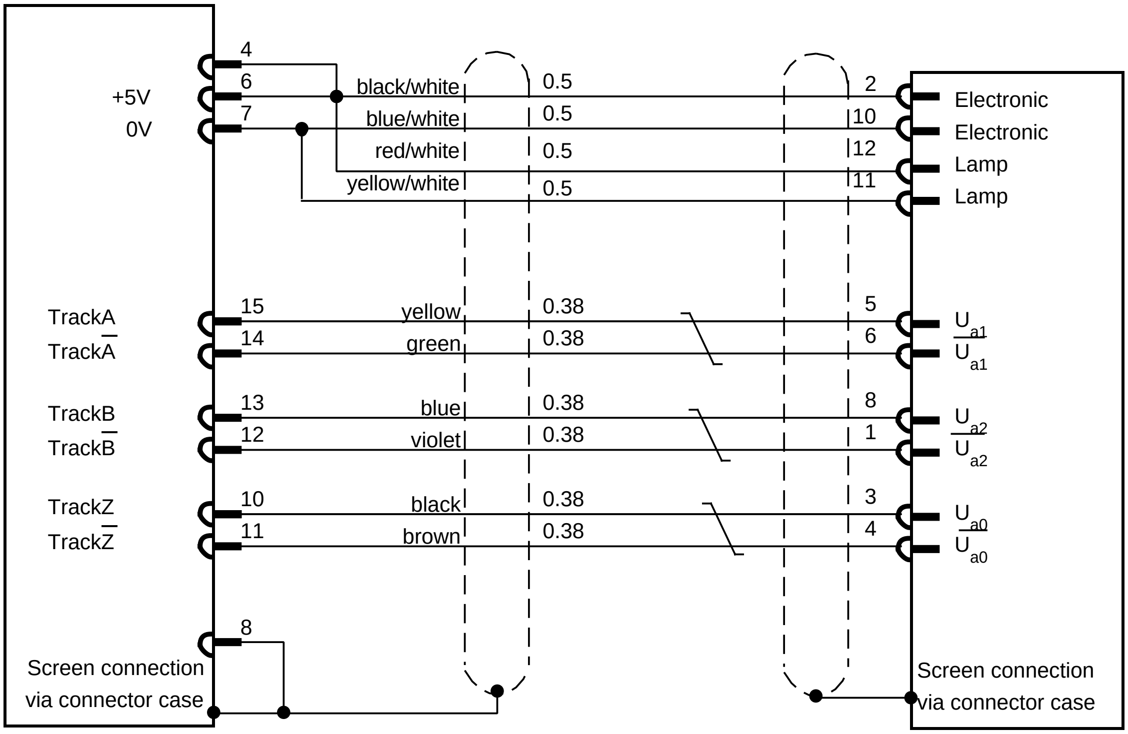
## Order no..: 6 FM1 790-1C ❑ 00

***WF 725 A,B / WF 726 B,C***

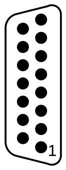
**Connectors: X4, X5, X6**

***SIEMENS Position Encoder***

**6FC9 320-3K (M)**



Shielded cable 4 x 2 x 0.38 + 4 x 0.5



***Connector***

D-Sub, Siemens

15pin, male

6FM1 790-8DA00

***Terminal side***

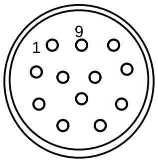
***Round Connector***

12pin, female

SIEMENS

6FC9 341-1FD

***Terminal side***

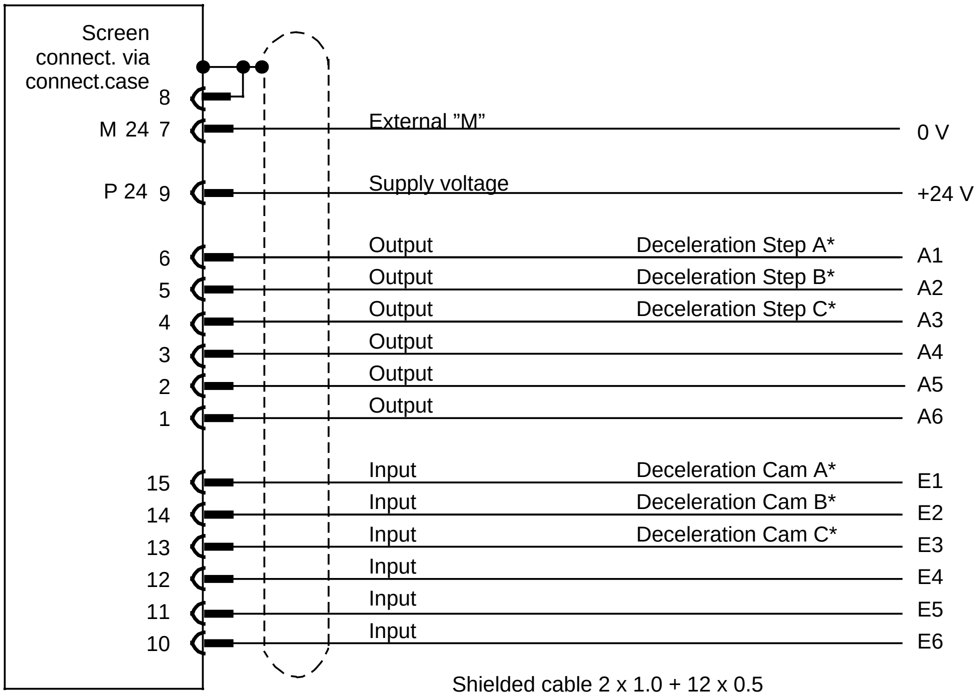


***The screen of the actual-value line must be earthed over a large area on the module side when entering into the cabinet.***

# Cable for the Connection of the Fast Inputs and Outputs

***WF 725 A, B / WF 726 B, C Module*** ***24V-Power Supply and Fast I/O***

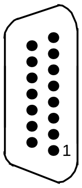
**Connector: X7**



***Connector***

D-Sub, Cannon
15pin, male
6FM1  790-8DA00

***Terminal side***



***Wire ends***

stripped and labeled

* Pin assignment as of WF 725 A/B

***In case the absolute encoder is connected to X8, X9 or X10 (X4, X5 or X6 at WF 726 C) the 24 V power supply connected to X7 must not be disconnected as long as the SIMATIC S5 is on.***

***In case of WF 726 module the pin assignment is determined by machine data 10 and 15, see Installation Instructions.***

***The inputs E1 to E6 have to be connected to the push-pull outputs or if not used, they have to remain open.***

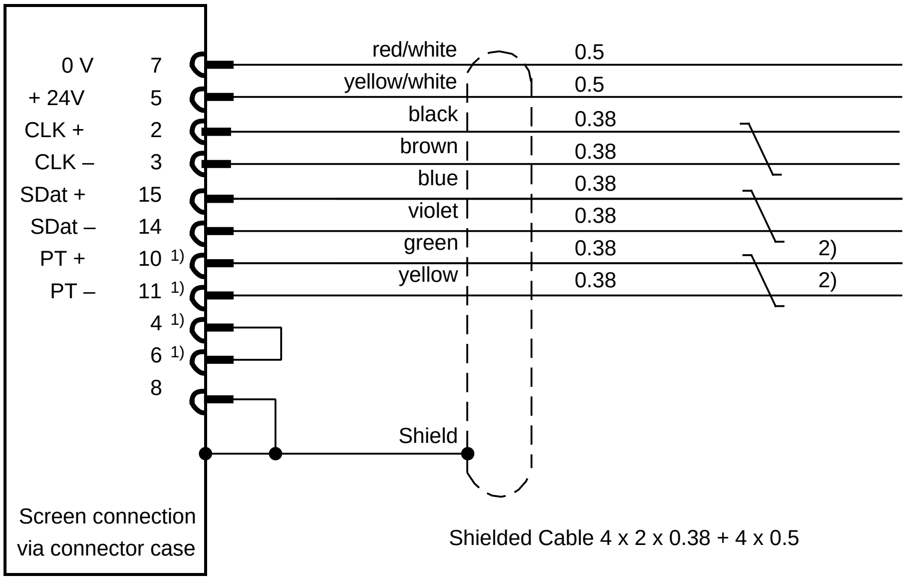
# Cable from Serial Input to Absolute Encoder
# Order no.: 6FM1 790-1F ❑ 00

***WF 726 C***

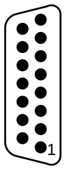
**Connectors: X4, X5, X6**

***Serial Absolute Encoder***

**Cable end unfinished**



Shielded Cable 4 x 2 x 0.38 + 4 x 0.5



***Connector***

D-Sub, Siemens
15pin, male
6FM1 790-8DA00
***Terminal side***

***Free cable end***

100 mm bared,
wires provided with pin-type
cable sockets

The above cable can be used for connection of SSI absolute encoders to various WF modules. For the WF 726 C, the line contains on pins 4, 6, 10 and 11 wired lines which are not used together with SSI absolute encoders.

***The screen of the actual-value line must be earthed over a large area on the module side when entering into the cabinet.***

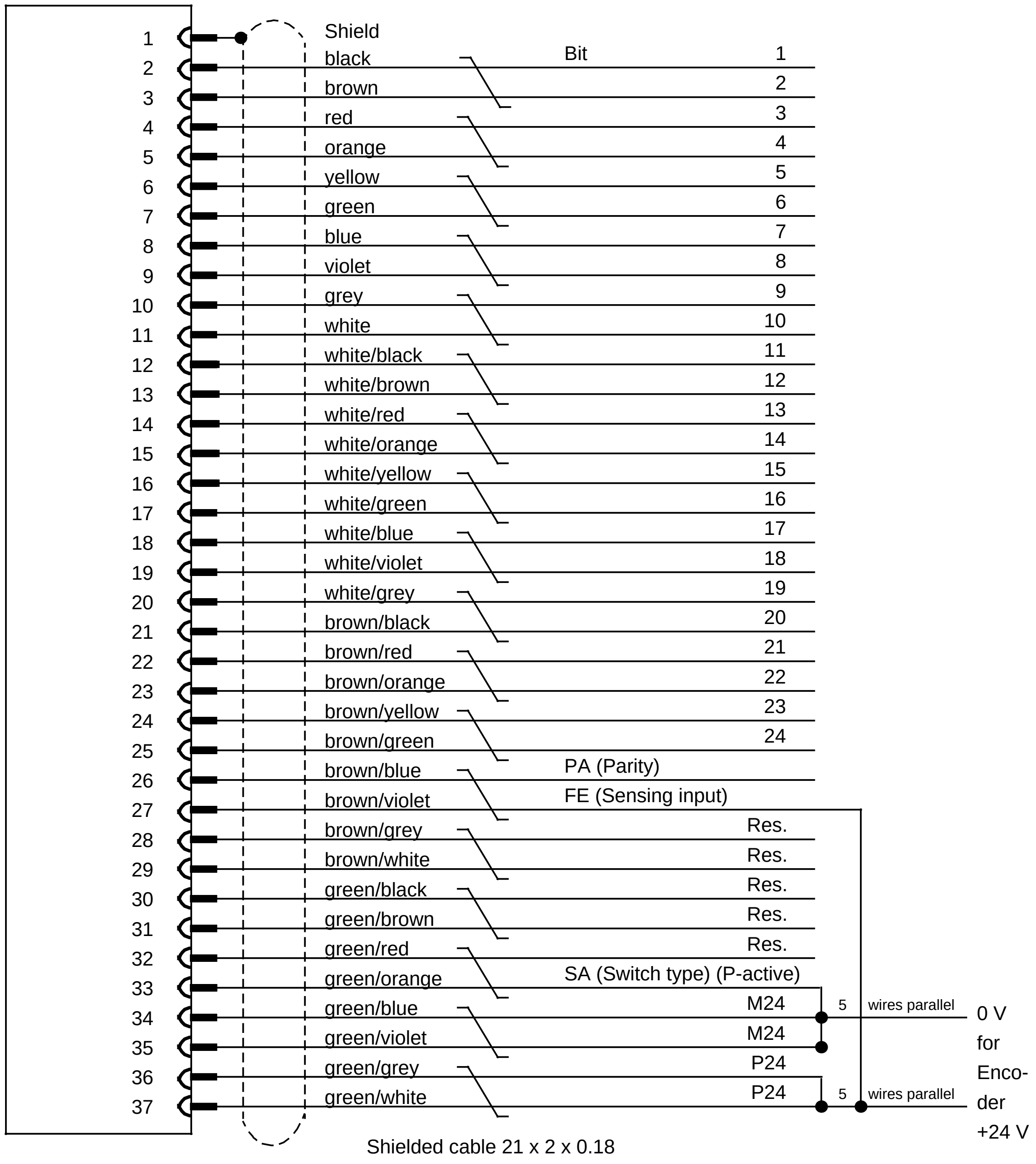
***The encoder must be connected according to manufacturer's instructions.***

1) Pins for WF 726 C are without significance in connection with SSI absolute encoders
2) Pins for WF 726 C must not be wired with the encoder, but have to be insulated on the encoder side

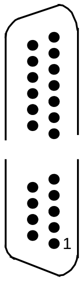
# Cable from Parallel Encoder Interface to Absolute Encoder
# Order no.: 6FM1 790-1D ❑ 00

***WF 725 B / WF 726 B Module***
**Connectors:X8, X9, X10**

***Absolute Encoder***
**Cable end unfinished**



***Connector***
D-Sub, Cannon
37pin,male
6FM1 790-8FA00
***Terminal side***



***The encoder must have the push-pull output amplifiers. Cables with unfinished ends must not be connected to the connectors X8, X9 and X10.***

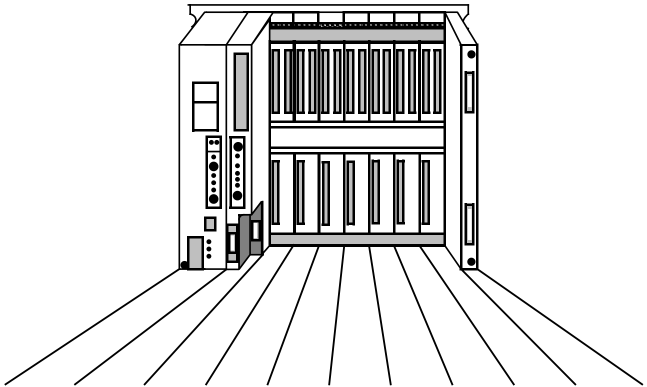
# 4 Module Locations in the SIMATIC Rack and Module Current Consumptions

The WF modules must only be plugged in the marked locations in the represented SIMATIC racks.

## 4.1 Central Controller SIMATIC S5-115U

### 4.1.1 Module Rack CR 700-2

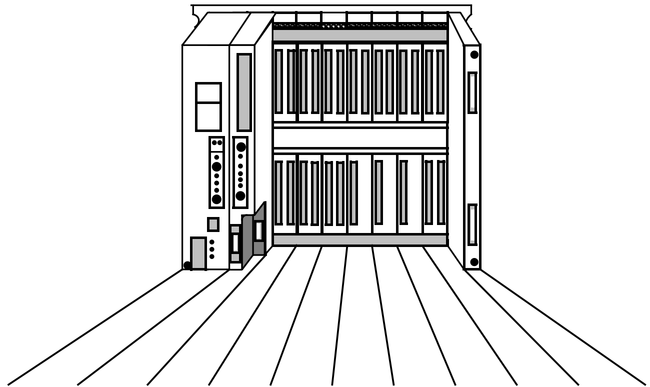
The following components are prerequisite to use of WF 725 and WF 726:
- 15 A power supply
- Fan component



| Width and max. current consumption per module without encoder | | PS | CPU | Slot designation | | | | | | | IM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | |
| | Current supply | ▨ | | | | | | | | | |
| | CPU 943 / CPU 944 | | ▨ | | | | | | | | |
| 2.5 A | WF 725A | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |
| 3.0 A | WF 725B/WF 726B | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |
| 1.3 A | WF 726C *) | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |

*) Operation without fan is possible

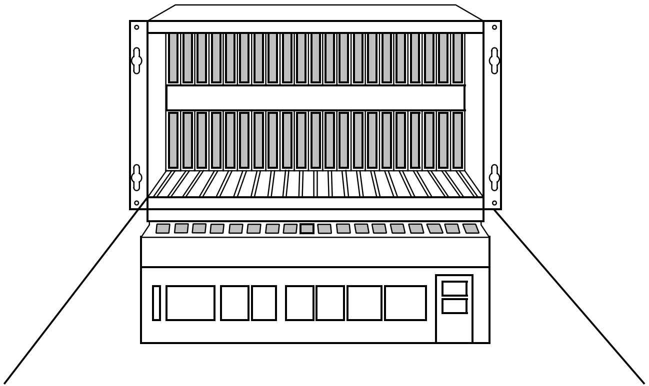
### 4.1.2 Module Rack CR 700-3



| Width and max. current consumption per module without encoder | | PS | CPU | Slot designation | | | | | | | IM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | |
| | Current supply | ▨ | | | | | | | | | |
| | CPU 943 **/** CPU 944 | | ▨ | | | | | | | | |
| 2.5 A | WF 725A | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |
| 3.0 A | WF 725B**/**WF 726B | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |
| 1.3 A | WF 726C *) | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |

*) Operation without fan is possible

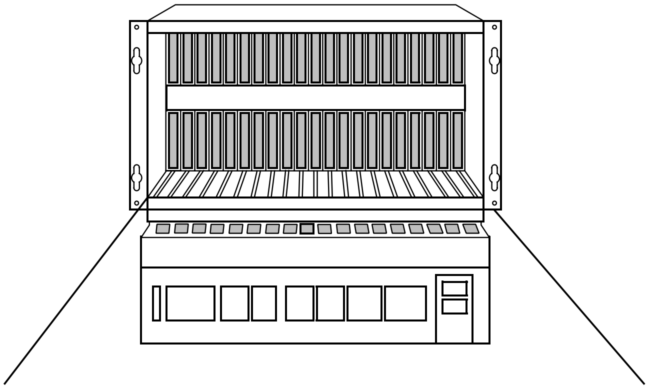
### 4.2 Central Controller SIMATIC S5-135U



| Width and max. current consumption per module without encoder | | Slot designation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 11 | 19 | 27 | 35 | 43 | 51 | 59 | 67 | 75 | 83 | 91 | 99 | 107 | 115 | 123 | 131 | 139 | 147 | 155 | 163 |
| | CPU 928 | | ▨ | | ▨ | | ▨ | | ▨ | | | | | | | | | | | | | |
| | IM 304 | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ |
| 2.5 A | WF 725A | ▨ | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | |
| 3.0 A | WF 725B**/**WF 726B | ▨ | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | |
| 1.3 A | WF 726C *) | ▨ | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | |

*) Operation without fan is possible

## 4.3 Central Controller SIMATIC S5-155U

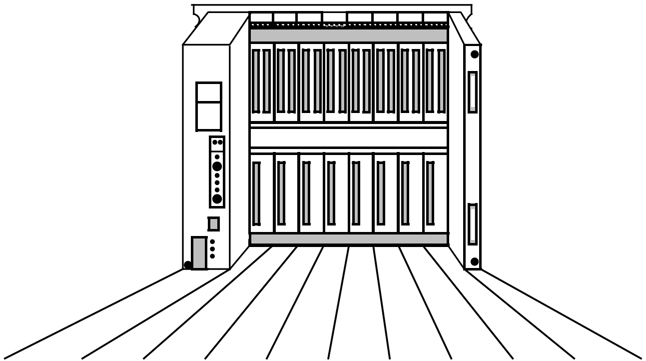


Width and max.
current consumption
per module
without encoder

| | | Slot designation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 11 | 19 | 27 | 35 | 43 | 51 | 59 | 67 | 75 | 83 | 91 | 99 | 107 | 115 | 123 | 131 | 139 | 147 | 155 | 163 |
| | CPU 928 | | ▨ | | | | | ▨ | | | | | | | | | | | | | | |
| | CPU 946 | | ▨ | | | | | ▨ | | occupies two slots | | | | | | | | | | | | |
| | CPU 947 | | | | ▨ | | | | | ▨ | | | | | | | | | | | | |
| | IM 304 | | | | | | | | | | | | | | | | | | ▨ | ▨ | ▨ | ▨ |
| ▯ 2.5 A | WF 725A | ▨ | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | |
| ▯ 3.0 A | WF 725B/WF 726B | ▨ | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | |
| ▯ 1.3 A | WF 726C *) | ▨ | | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | |

*) Operation without fan is possible

## 4.4 Expansion Unit ER 701-3

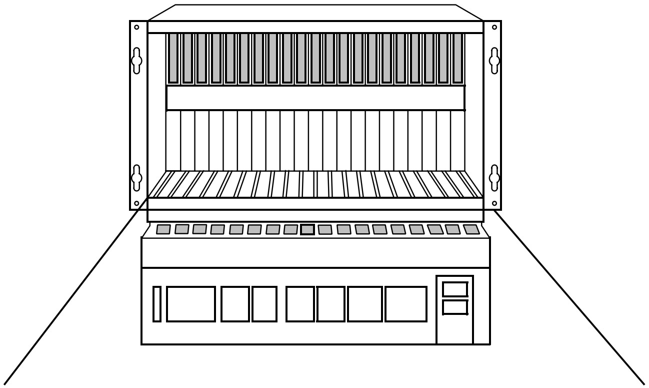


Width and max.
current consumption
per module
without encoder

| | | PS | Slot designation 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | IM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Current supply | ▨ | | | | | | | | | |
| | IM 306 | | | | | | | | | | ▨ |
| | IM 314 | | | | | | | | | ▨ | |
| ▯ 2.5 A | WF 725A | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |
| ▯ 3.0 A | WF 725B/WF 726B | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |
| ▯ 1.3 A | WF 726C *) | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | |

*) Operation without fan is possible

## 4.5 Expansion Unit SIMATIC S5-183U



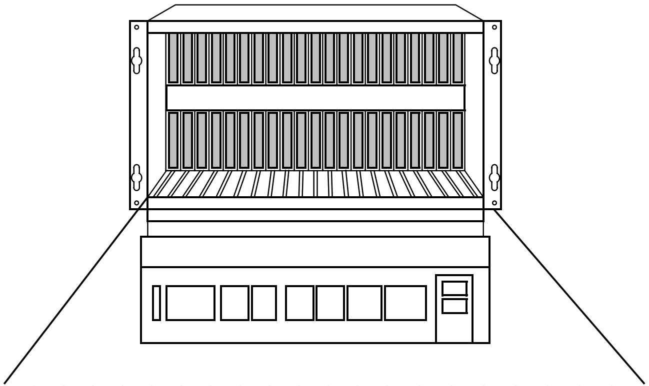
Width and max.
current consumption
per module
without encoder

▯ 2.5 A
▯▯ 3.0 A
▯ 1.3 A

| | Slot designation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 11 | 19 | 27 | 35 | 43 | 51 | 59 | 67 | 75 | 83 | 91 | 99 | 107 | 115 | 123 | 131 | 139 | 147 | 155 | 163 |
| IM 314 | ▨ | | | | | | | | | | | | | | | | | | | | |
| IM 312-3 | | | | | | | | | | | | | | | | | | | | | ▨ |
| WF 725A | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |
| WF 725B/WF 726B | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |
| WF 726C *) | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | |

*) Operation without fan is possible

## 4.6 Expansion Unit SIMATIC S5-185U



Width and max.
current consumption
per module
without encoder

▯ 2.5 A
▯▯ 3.0 A
▯ 1.3 A

| | Slot designation | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 11 | 19 | 27 | 35 | 43 | 51 | 59 | 67 | 75 | 83 | 91 | 99 | 107 | 115 | 123 | 131 | 139 | 147 | 155 | 163 |
| IM 314 | ▨ | | | | | | | | | | | | | | | | | | | | |
| WF 725A | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | |
| WF 725B/WF 726B | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | |
| WF 726C *) | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | |

*) Operation without fan is possible

# 5 Technical Data

| **Electrical and mechanical characteristics (5 V)** | **WF 725 A** | **WF 725 B**<br>**WF 726 B** | **WF 726 C**<br>****** |
|---|---|---|---|
| **Voltage level 5 V (±5%)** | Voltage is provided by SIMATIC | Voltage is provided by SIMATIC | Voltage is provided by SIMATIC |
| **Internal current consumption at 5V** (without encoder) ***** | 2.5 A | 3.0 A | 1.3A |
| **Permissible load per encoder for the internal power supply** | max. 0.3 A | max. 0.3 A | max. 0.3 A |
| **Required encoder input current** | 5 mA | 5 mA | 10 mA |

| **Electrical and mechanical characteristics (10 V)** | **WF 725 A** | **WF 725 B**<br>**WF 726 B** | **WF 726 C** |
|---|---|---|---|
| **Voltage Level ±10 V** (command value output) | Voltage is generated internally | Voltage is generated internally | Voltage is generated internally |
| **Maximum output current** | 2 mA | 2 mA | 2 mA |

| **Electrical and mechanical characteristics (24 V)** | **WF 725 A** | **WF 725 B**<br>**WF 726 B** | **WF 726 C** |
|---|---|---|---|
| **Voltage level 24 V (±5%)** | 24 V | 24 V | 24 V |
| **Inputs** | 5 mA | 5 mA | 5 mA |
| **Outputs** | 0.4 A | 0.4 A | 0.4 A |
| **Permissible load per encoder** | max. 0.3 A | max. 0.3 A | max. 0.3 A |
| **Required encoder input current** | 5 mA | 5 mA | 10 mA |
| **Space requirements in SIMATIC rack** | 1 SEP | 2 SEP | 1 SEP |
| **Frequency limit for encoder input** (before quadrupling) | 200 kHz | 200 kHz | 200 kHz |
| **Data transfer speed** | - | - | 1 MHz |

***) In the current balance, 0.3 A per incremental encoder must be provided on the 5 V side**

****) There is no need for fan component when WF 726 C is used.**

| **Environmental Conditions**<br>(Standards: VDE 0160 and DIN 40040) | |
|---|---|
| **Ambient temperature** | - Operation 0 °C to +55 °C<br>- Storage and transport -40 °C to +70 °C<br>Maximum permissible temperature change: 1.1 K/min |
| **Relative humidity** | 20 to 75%, short-term peaks up to 95% |
| **Concentration of aggressive gases and suspended matter** | Threshold limit values (maximum concentration at the place of work; list of the threshold limit values is issued by the West German Federal Department of Labor and Social Security) |
| **Mechanical stressing** | Short-term vibrations with accelerations up to 2.5 g are permitted |

# 6 How to Select Components

## 6.1 WF 725 / WF 726 and Final Control Element

### 6.1.1 Close-Loop Axis Control (Continuous Command Value Output)

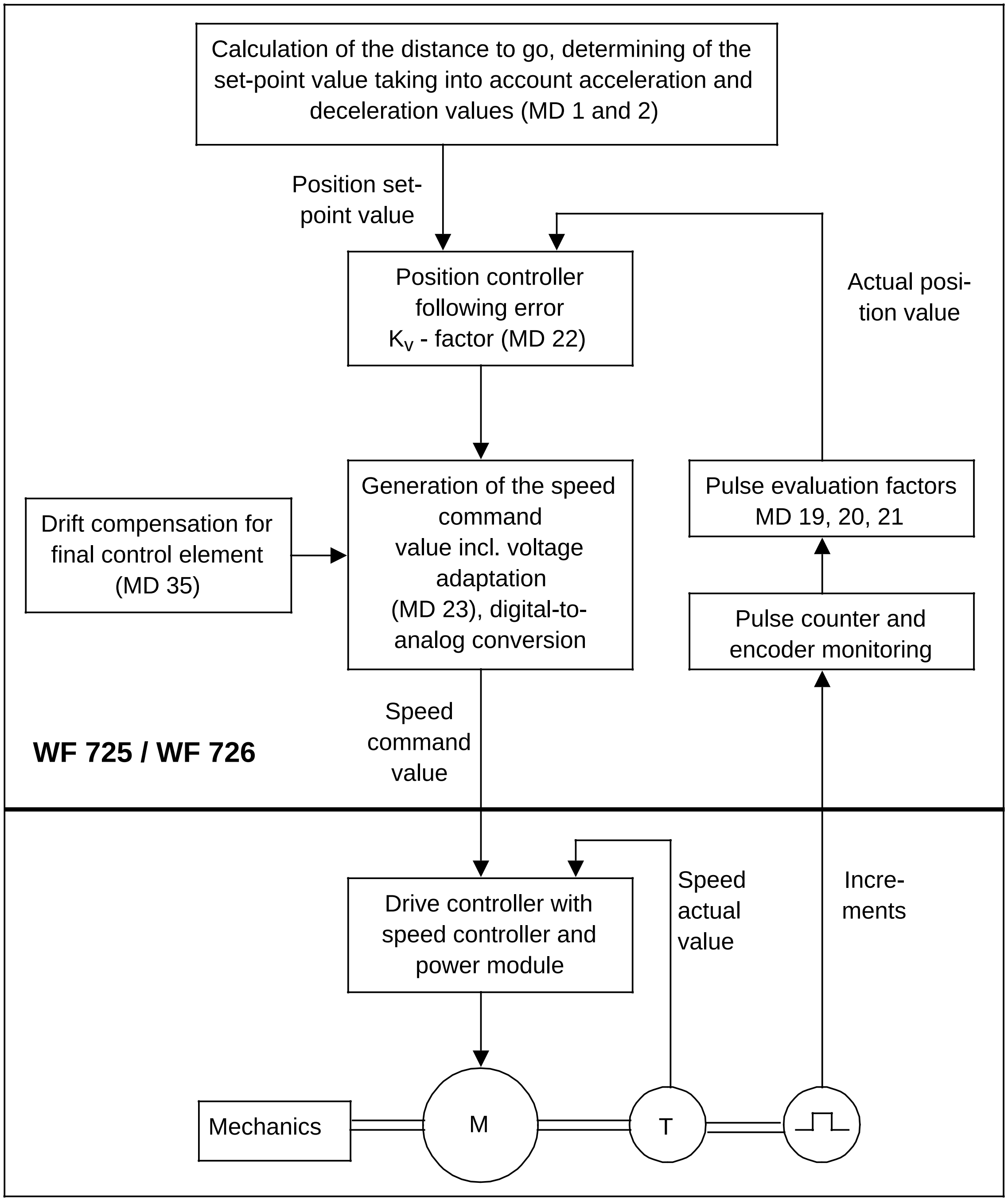


*Figure 6.1 Close-loop system with incremental encoder (one axis).*

The WF 725 or WF 726 module calculates the distance which has to be traversed in a given time unit considering acceleration and deceleration values as entered in the commissioning data 1 and 2. The calculated value is output to the position controller as the position set-point value (see fig. 6.1). This method of command value output is ideal as far as the time is concerned , because the positioning is done in shortest time possible. All characteristic values such as acceleration, programmed speed and deceleration are taken into account.

If traversing short distances, especially when the drive has to accelerate only, the deceleration follows acceleration immediately, so that under circumstances the programmed speed may not be reached at all.

With this acceleration controlled method of command value generation the position over time curve is parabolic during acceleration and deceleration phases (fig. 6.2) and the overall curve is s-shaped.

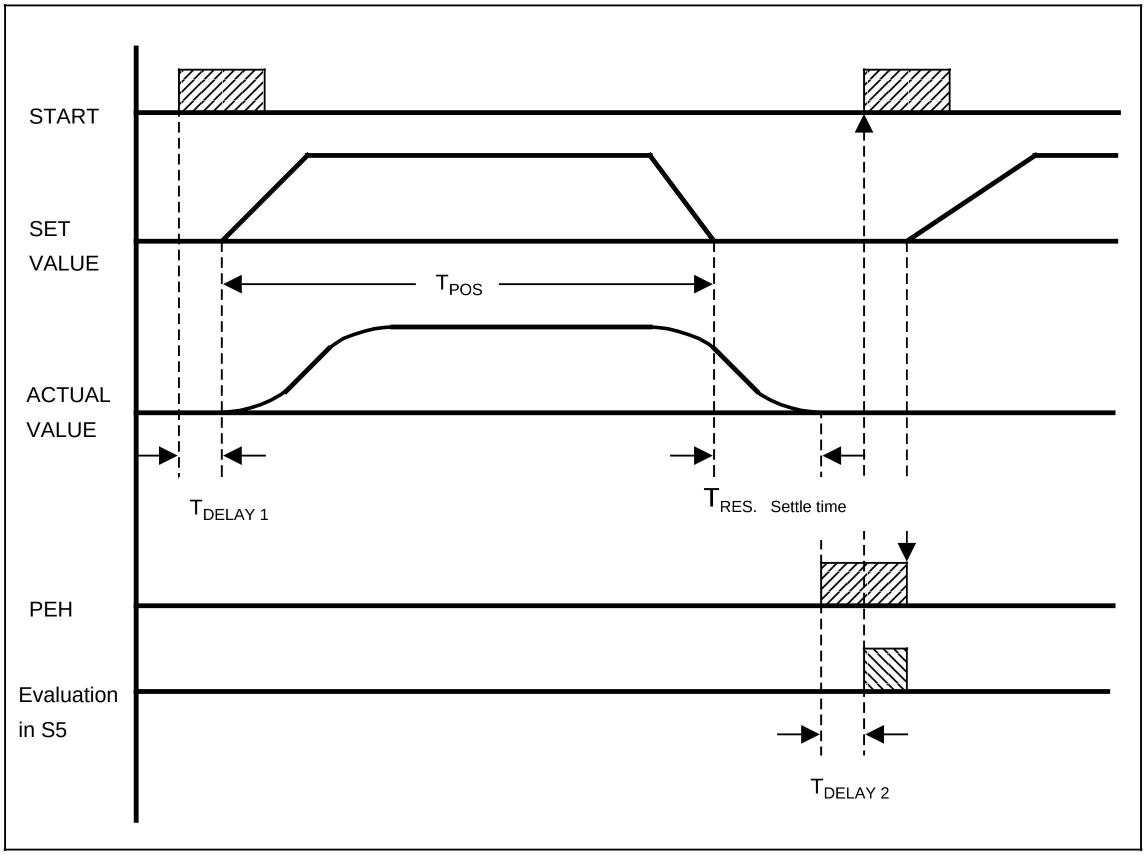


*Figure 6.2 Signal timing chart for positioning.*

Further advantages of this command value generation are:

- Possibility of the influencing of the load on the drive systems and the mechanical transmissions elements.
- The characteristic curve is not necessary and the gain factor, kv, is constant over the whole operating range.

## 6.1.2 Open-Loop Axis Control (Programmable Reduction Steps)

### 6.1.2.1 Speed Control and Positioning

The WF 725 / WF 726 module outputs BCD coded speed values and signals for the direction of traverse to the S5 controller via the software interface . The final control element receives the control signals via digital output modules (see figure 6.3).

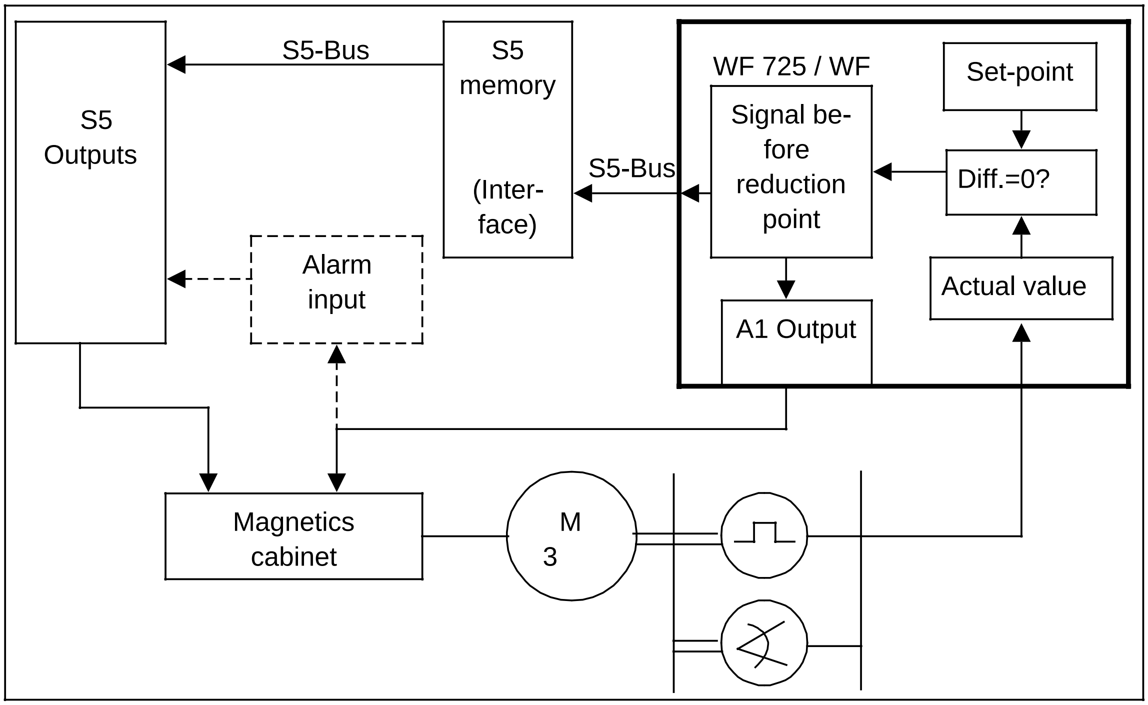


*Figure 6.3 Open-loop controller with reduction steps.*

The traversed distance is fed back to the WF module in form of the encoder pulses and compared there with the number of pulses corresponding with the programmed distance. As soon as the (pre) reduction point is reached the WF 725 / WF 726 starts to output next lower speed value to the S5 controller.

The final reduction signal to the magnetics cabinet is output via the high speed output of the WF 725 or WF 726 module. This ensures consistent positioning performance. The reduction points are referred to the target positions.

The setting of the encoder type, incremental or absolute, is done by means of commissioning data (MD) 4. The axis control with reduction steps is available as a version with **three** reduction steps and corresponding **four** deceleration distances. The speed command values which will be output during positioning are shown in figure 6.4.

This type of the command value output is possible in the following modes:
- Manual data input (MDI)
- Single block
- Automatic single block and
- Automatic continuous.

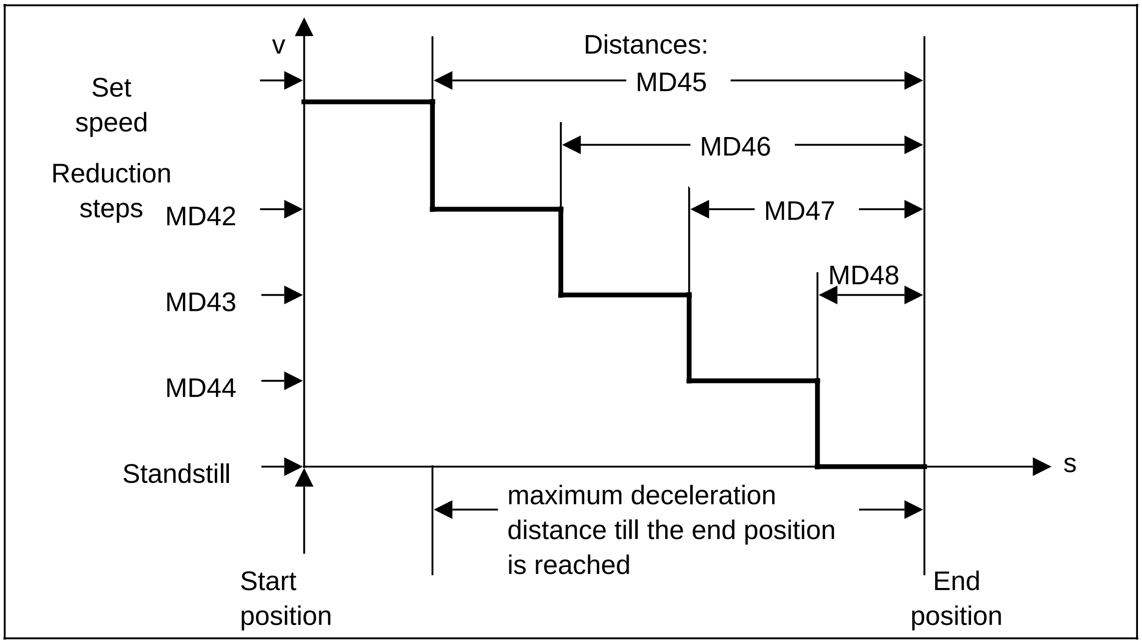


*Figure 6.4 Command value output for the positioning.*

## 6.1.2.2 Traversing in Positioning Modes

The programmed speed and position values become active after start command. The speed command value is determined by the continuously updated actual position and the difference between the set and actual position, so-called following error.

If the following error is sufficiently large, the desired speed command value is output instantaneously. If the following error, at the time when the start command is issued, is less than value entered in MD45-48, and the set speed is greater than the corresponding reduction step entered in MD42-44, the controller begins with the output of the reduction step.

If the following error is less or equal to the value entered in MD45, the speed reduction procedure (deceleration) will begin. The reduction speed, as set in MD42, will be output (see also figure 6.4, command value output for the positioning). The difference between actual position and set position will begin to decrease slower as a result of the slower speed due to the reduction step active. As soon as the difference becomes less than the values of MD46 or MD47 the corresponding reduction step of MD43 or MD44 becomes effective.

The set position approach speed, which is controlled by the following error, is thus continuously reduced. Finally, the speed command value output will be switched off before reaching the end position. The distance to the target position is determined by MD48. The command value output and the output assigned to the controlled axis are switched off.

After the command value output has been switched off the bits for forwards (F) and backwards (B) no longer indicate traversing direction, but rather the sign of the following error.

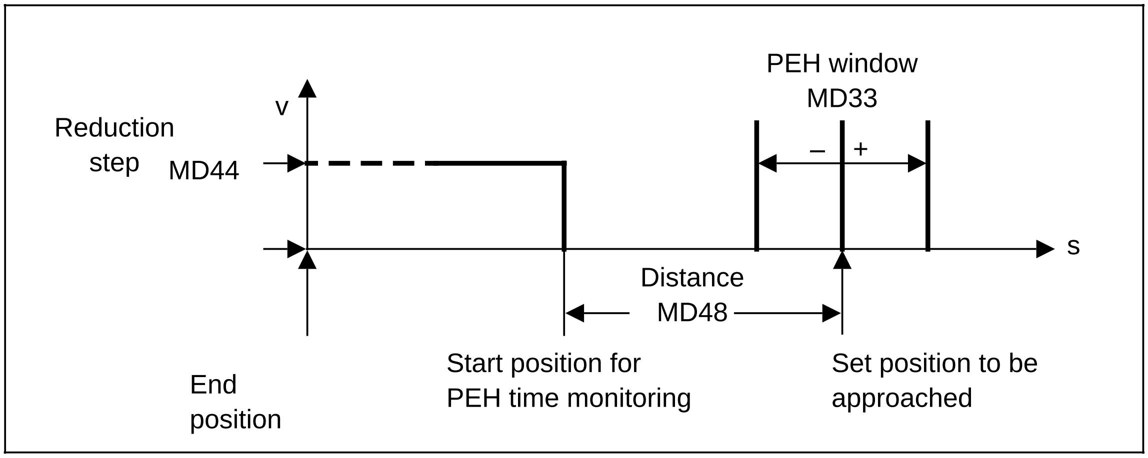


*Figure 6.5 PEH window*

The PEH time and PEH tolerance monitoring become simultaneously active with activation of the output Q1, 2, or 3.

- Time monitoring
  If the axis does not reach a position inside of the PEH window within the time defined by MD30, the alarm message 22 is output.

- Tolerance monitoring
  If the axis reaches a position inside of the PEH window before time MD30 elapsed, the PEH signal is output. If the axis then leaves this position without new speed command being issued, the alarm message 22 is output.

### 6.1.2.3 What is Different than at the Close-loop Controller

In the ”setup mode” and the ”reference point return mode” the set position is preset with the actual position and thus the following error is equal to zero.

In the setup mode the activation of the JOG plus or JOG minus signal causes output of the speed command value which corresponds with the value determined by the fixed speed bit. By deactivation of the signal the command value is cut off immediately. There is no deceleration via reduction steps.

In the reference point return mode the speed command value is switched off immediately after receiving encoder zero mark signal following deceleration cam signal on the cam side determined by MD7. The message "axis is calibrated" is output. The actual and set position values are preset with the reference point values as entered in MD16. The offset value (MD17) is not taken into account. There are no changes with regard to the speed command values outputted via the three reduction steps 1,2 and 3.

The functional sequences in other operating modes are the same as those for the close-loop controller.

Feedback of the actual speed value:
The outputs Q1, 2, or 3 and the controller enable signal are activated by the start signal (high level = 24 V). The actual speed value is present in DL4 as long as no M function(s) or no alarm message(s) have to be output. The speed bit, DR4 bit 0, is set (G=1) after three cycles of the WF module, approx. after 12 ms, the speed value can be read afterwards.

**Feedback of the actual speed value:**

| DW-No | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | | | | | | | | | M | | F | | | | | |
| 4 | Speed value<br>$10^1$ | | | | $10^0$ | | | | | | | | | | | G |

In the event of a speed transition while axis in motion, the new speed is entered immediately in DW4 and signaled to the programmable controller without status change in the G bit.

Both the G bit and speed value are reset in the event of speed reduction. Output Q1, 2, or 3 are switched off (low level = 0 V) and the servo enable signal is canceled.

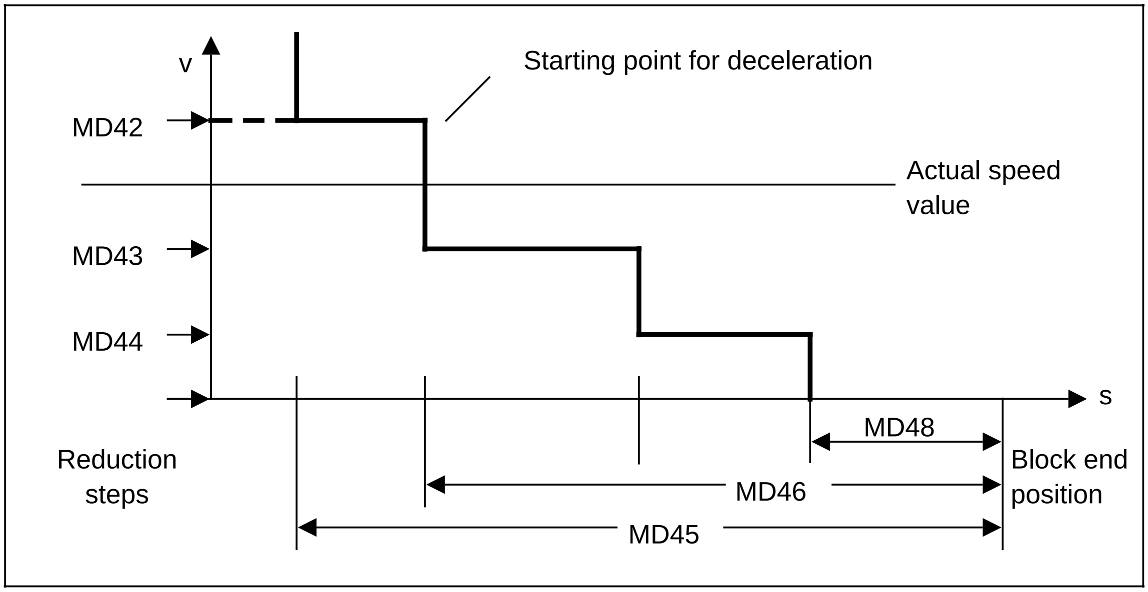
### 6.1.2.4 DAC Output

The digital-to-analog converter (DAC) outputs 0 volt as a speed command value for as long as the outputs Q1, 2, or 3 remain inactive.

Following the start signal in one of the traversing modes a voltage with an amplitude of the BCD speed value multiplied by 100 mV is present at the output of the DAC. This voltage is also output when the interface is loaded with M functions and thus cannot display the actual speed value

### 6.1.2.5 Starting Point for Deceleration

The deceleration point is reached when the following error becomes less than one of the position difference values entered in MD45 to 48, and the corresponding speed value is lower than the actual speed value. If the WF module is in the automatic mode, the block change on-the-fly will take place.



### 6.1.2.6 Block Change On-the-Fly with Speed Reduction

The deceleration starting point has been reached. If the speed in the following block is lower than the actual speed, the deceleration process from the actual block's speed will be continued. There is no adoption of the new block data until the speed of the next deceleration step, which would be triggered by the corresponding following error, becomes lower than the speed of the new block.

During this procedure the following error indicates the distance between actual position and the end position of the old block, and the distance to go shows the distance between the actual position and the end position of the new block.

Limit switch monitoring:
The limit switch monitoring becomes active after axis synchronization in the ”actual value preset” mode or ”reference point return” mode. The approaching of the limit switch will take place sooner or later and the deceleration, similarly as in the close-loop variant, will depend upon actual speed value. The criteria for the deceleration step active are the values of the commissioning data 45 to 48.

If one of the dynamic limit switches have been approached, as specified in MD 11 or 13 plus or minus the following error corresponding to the speed value active, the set position is preset with limit switch value from MD 11 or 13 and the resulting following error is used for triggering of the deceleration steps. The deceleration and approaching of the set position is done in the same manner as in the positioning mode.

### 6.1.2.7 Simulation

The user can test the automatic programs and other control sequences of the reduction step controller without machine in the simulation mode. The actual position is directly influenced by traversing with speed steps. The speed values are added or subtracted cyclically depen-ding upon direction of traverse. The outputs and the DAC are supplied independently of commissioning data MD 40 (simulation).

## 6.1.3 Selection of the Final Control Element

### 6.1.3.1 Close-Loop Control and Final Control Element

The positioning systems are required to be both highly accurate and extremely dynamic. This is usually achieved by using a combination of a digital controller with position controller and a subordinate analog speed controller.

### 6.1.3.2 Close-Loop Controller

The digital position controller which operates extremely fast and with extremely high position resolution, is a proportional-action type of controller. It responses immediately to the changes of the input variable which is the actual position value. The proportional action of the controller is characterized as the proportional servo gain factor, so-called kv factor. It is defined as the ratio of the programmed traversing speed V to the position deviation $\Delta$S (figure 6.6):

$$K_v = \frac{V}{\Delta S}$$

The actual kv factor is entered in commissioning data MD 22.
The maximum permissible servo gain factor is determined by stability and the transient response of the whole system.

The typical gain factor for machine tools is between $1 \ldots 2 \frac{mm}{min}$ /µm

If the axis traverses with the constant speed the position deviation, so-called following error, is as follows:

$$\Delta S = \frac{V}{K_v}$$

The position deviation specifies the amount by which the actual position trails the set position (see fig. 6.6).
The close-loop controller is designed for actuation of a final control element with continuous input signal. A DC voltage output signal in the range from ±10 V, 2 mA is output to actuate them.´

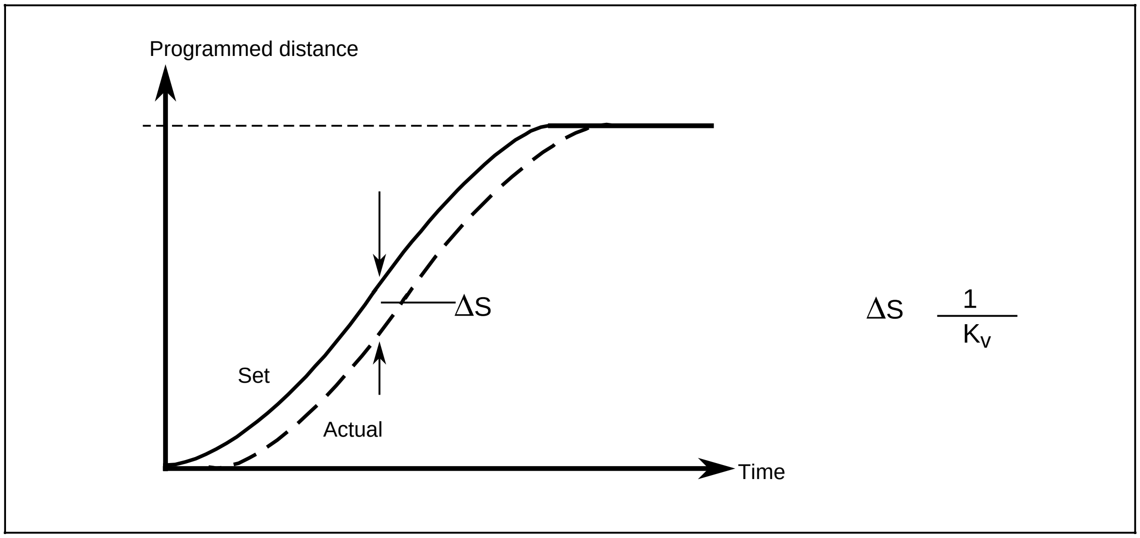


*Figure 6.6 Following error $\Delta$S and servo loop gain factor $K_v$*

### 6.1.3.3 Final Control Element

The final control element may be either a drive controller with DC servo motor connected to them or an electro-hydraulic servo actuator. Due to the non-linear characteristic of the final control element and controlled system a subordinate proportional plus integral-action controller has to be used in both cases to support the position controller. In case of a drive controller this function ist performed by the speed controller.

***If there is no subordinate speed controller available,***

***the dynamics and position accuracy of the system will be impaired.***

The sufficient torque or control reserves have to be available in order to be able to approach the programmed position without overshooting. The current controller may only be overdriven briefly so that the position controller will be able to keep the control over the whole system as far as possible. Rated torque of the motor and commissioning datum MD 2 (deceleration) must match each other.

### 6.1.3.4 Controller Enable

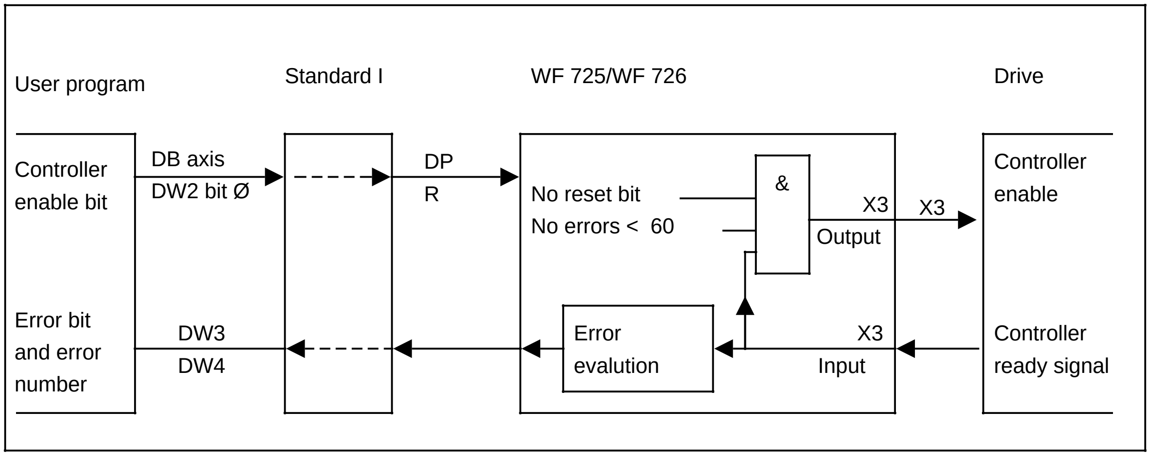


*Figure 6.7 Controller Enable and Controller Ready Signals.*

When all prerequisites for enabling the drive have been fulfilled, the user can enable controller by setting bit 0 in the DW2 of the DB axis.

The bit becomes a part of the logical operation there. The controller enable signal which is the output in connector X3 is activated (high) only if the following conditions are fulfilled:
If there is no reset bit present, if there is (are) no error(s) present with the number(s) less than 60, and the controller ready signal is active (high).

The user must ensure that the controller enable signal is present before issuing traversing commands with start signal or JOG+ or JOG- signals.

### 6.1.3.5 Open-Loop Controller and Final Control Element

The following final control elements are possible:

- Three-phase pole-changing motor
- DC motor with drive controller
- Hydraulic motor
- Hydraulic proportional valve

## 6.2 WF 725 / WF 726 with Incremental Encoders

### 6.2.1 Selection and Commissioning Data

The distance is measured by means of incremental rotatory encoders or digital linear scales. Every axis must have an encoder or scales.

Principle of operation: A graduated glass disc with radial gratings is scanned photo-electrically. The scanning elements generate two cyclic sinusoidal signals, which are converted to a square-wave signal by the electronic integrated in the encoder. The total number of signal cycles per revolution corresponds to the line number of the grating.

Direction discrimination: The encoder outputs two square-wave signals Ua1 and Ua2 which are 90 degree phase shifted. The discriminator in the WF module determines the direction of rotation from these signals.

Reference Point: It is determined roughly by the position of the limit switch (deceleration cam). The exact determination is done by means of the encoder reference pulse Ua0 (zero mark). There is only one such pulse available per encoder revolution.

***Noise signal suppression: In addition to the square-wave output signals, the inverted signals are also output and used for suppression of the noise signals.***

The figure 6.8 shows assignment of the encoders types to the lead screw pitch given.

### 6.2.2 Commissioning Data Referring to the Encoders

1. Pulse evaluation factor (MD 19 und 20)
2. Pulse multiplication factor(MD 21)
3. Number of pulses per encoder revolution (MD 34)
4. Encoder monitoring (MD 41)
5. Basic resolution (parameter of FB 211)

Application example:

| | | |
|---|---|---|
| Travel | 4500 mm | |
| Number of increments (steps) | 17,000 | after quadrupling! |
| Resolution | 4,500 : 17,000 = 0.26470588 mm | |
| Basic resolution setting | 100 µm | |

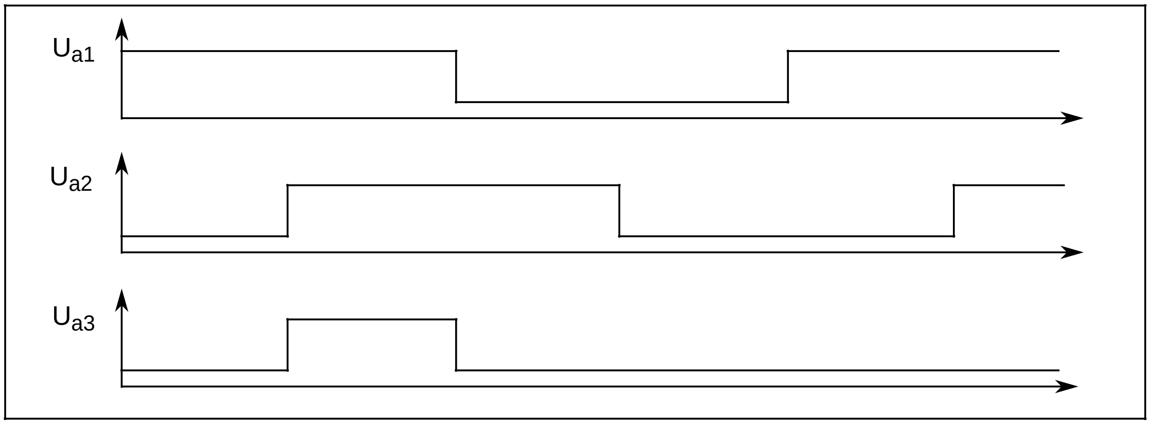


*Figure 6.8 Output signals of the incremental encoder.*

| | |
|---|---|
| | MD 49 : 3 |
| Number right from decimal point | 2 |
| Decimal point | MD 19 |
| Number left from decimal point | 64705880 |
| | MD 20 |
| Pulse multiplication | 4 (MD 21) |
| (with incremental encoder only) | |
| (pulse quadrupling should generally be set!) | |

Multiplication:
Actual increments x factor
(Number/Steps)

| | | | | | |
|---|---|---|---|---|---|
| **Example:** | 8500 | x | 2.64705880 | = | 22500 (x100 µm) |
| | increments | x | factor | = | distance |

## 6.2.3 Location for the Encoder

### 6.2.3.1 Lead Screw and Slide System

Depending upon the location of the measuring device we distinguish between the direct and indirect position measuring systems (fig. 6.9).

If the indirect measuring system is used, the actual position of the table is fed back indirectly as the rotation angle of the encoder which is coupled with the ball screw or motor shaft. The measuring is distorted by the backlash of the mechanics. These position errors can partly be eliminated by the system. The compensation factor is entered in the commissioning data.

If the direct measuring system is used, the measuring system is mounted directly between stationary and movable part of the machine, so that distance traversed is measured directly. The mechanical backlash is captured within the position control loop. There are no permanent position deviations. In order to be able to optimize the position loop properly, the backlash has to be as small as possible. To achieve that the appropriate technical and designing measures have to be taken. The backlash causes that the axis oscillates around the set position, or when damping effective, the set position is not exactly reached. Joint points of the scale segments influence the position accuracy too.

### 6.2.3.2 Transport Systems

In case of transport systems equipped with rail and wheel rather than rack and pinion, the indirect measuring system can only be used. In such systems the slip error is expected to be present. It leads to the positioning errors.

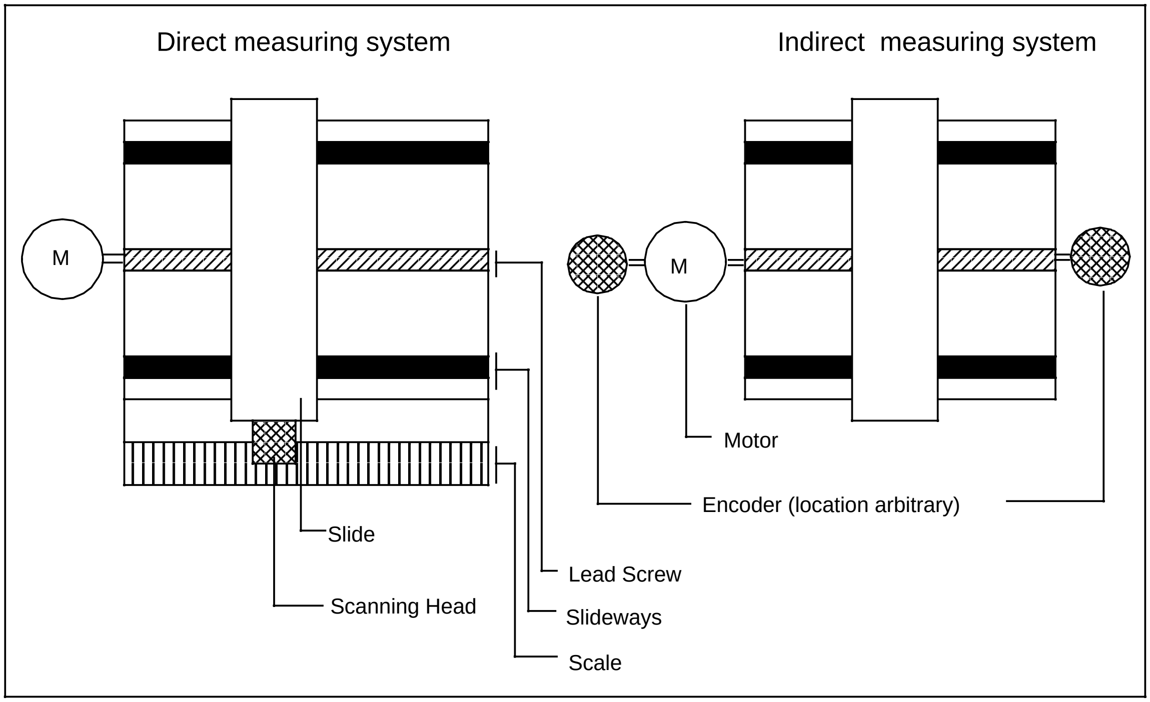


*Figure 6.9 Lead screw - slide system with the direct and indirect measuring systems.*

## 6.2.4 Monitoring

The fault monitoring has become a very important function in todays microprocessor controlled electronic systems. The encoder monitoring is among the most important at the positioning systems. The WF 725 and WF 726 modules are equipped with hardware and software monitors which are able to detect the most of the faults possible.

The following are the general conditions for the encoder connection:

- Actual value feedback
  Difference of the output signal levels > 0.5 V
  Encoder frequency, maximum 200 kHz
  Phase shift between signal A and B : + or - 90 degree, depending on direction (also inverted signals)

- Encoder monitoring

- Cable breakage monitoring
  TTL level of the encoder signals (2.4 V / 0.8 V - H/L)
  Frequency limit for the input signals : 800 kHz
  Encoder with inverted signals

- Pulse / zero mark monitoring
  TTL level of the inverted zero mark signal
  One zero mark per revolution (pulse length 90 degree, see fig. 6.10)

### 6.2.4.1 Cable Breakage Monitoring

Both the encoder output signals and the zero mark signal are linked with its inverted signals in the exclusive OR gates of the WF 725/726. As soon as both the signals have the same level for longer than 1.25 µs, the cable breakage is assumed and the alarm 7 for the corresponding axis is output.

This way following faults are recognized:
- Cable not connected
- Cable is or became severed
- One track is bend aside
- One of the encoder output signal channels is open or defect

### 6.2.4.2 Pulse Monitoring

The inverted zero mark signal is used for encoder monitoring too. If the zero mark occurs during axis traverse the pulse difference to the previous mark is compared. If traversing in the same direction the difference is compared with the number of pulses per revolution. If traversing in opposite direction the comparison with 0 takes place. The result is added considering the sign. If a certain tolerance is exceeded the alarm 8 for the corresponding axis is output. The tolerance is set for the worst case. It considers the number of pulses between occurring of the zero mark, reading of the pulse counter at the maximum speed and simultaneous occurrence of an another interrupt.

Output signals: Square-wave signal 1:1, 2 channels 90 degree shifted, and zero mark (once per revolution, length 90 degrees), there is an inverted signal for every signal available,
Diagram is valid for clockwise rotation (as seen on the shaft end)

Signal sequence:

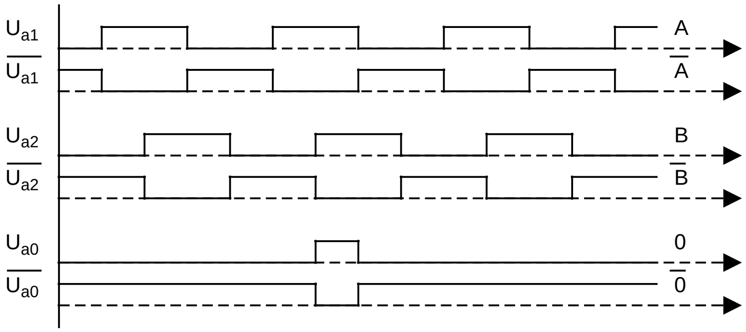


*Figure 6.10 Necessary encoder signals.*

Pulse monitoring recognizes following faults:
- Missing pulses, or
- Additional spurious pulses

### 6.2.4.3 Zero Mark Monitoring

The pulse monitoring can also be considered as a zero mark monitoring. If the zero mark is missing sporadically the alarm 8 for the corresponding axis is output. In addition to this if the zero mark does not appear after one revolution after passing the deceleration cam in the reference point return mode, the alarm 9 is output.

### 6.2.4.4 Following Error Monitoring

The difference between the set and the actual position is compared cyclically (position controller scan every 4 ms) with the maximum following error as entered in the commissioning data. If the error is exceeded alarm 10 is output, if a standstill occurs the alarm 11 is signaled.

Possible causes:
- Encoder lamp is blown
- Mechanical coupling is damaged

### Caution !!

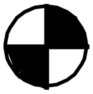
The assumption is made that the fault which led to the alarm 7, cable breakage, is fixed before the alarm is acknowledged (reset bit). The zero mark alarm and cable breakage alarm are connected to the same interrupt function block. After power on all static errors are displayed at first. After recognizing of the zero mark during referencing, the switch-over to the flank triggered pulse monitoring is made.

## 6.2.5 Interface between the WF 725 / WF 726 and Incremental Encoder

The following have to be considered at the encoder selection:

- Encoder output signals (figure 6.10)
- Voltage level
- Frequency limit
- Voltage drop in the cable
- Output circuitry of the encoder

## 6.2.6 Deceleration Cam for Referencing

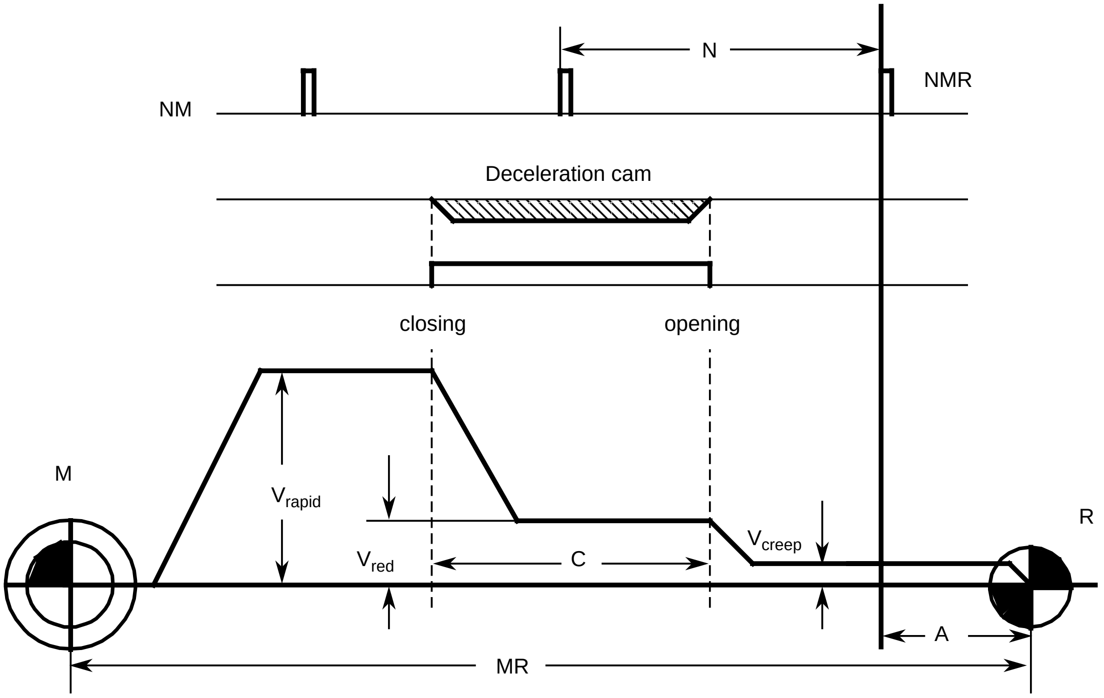


In order to synchronize the mechanics with the control a machine reference point is defined within range of travel. Using digital encoders the approximate location of this point is determined by a cam, and the exact location by the zero mark of the encoder.

The location for the reference point should be convenient to be reached fast and easy after the power has been switched on or has been restored. After pushing the plus or minus JOG push button the axis traverses with the preset rapid speed V rapid towards the deceleration cam. After making the cam the axis slows down to the reduced speed V red. After leaving the deceleration cam the axis slows down again and moves with the creep speed V creep till the zero mark has been recognized and the shift distance has been traversed. The speeds V red and V creep are setable as well (see figure 6.11).

Whether the deceleration cam is connected to S5-WF interface or high speed input of the WF module, is determined by means of the commissioning data 15.

The software limit switches become active after axis synchronization. The message "axis is synchronized" is output to the S5 (positioning enable).



| | |
|---|---|
| MR | reference point coordinate |
| NM | encoder zero mark |
| N | distance per encoder revolution |
| R | reference point of the machine |
| C | length of the deceleration cam |
| M | reference point |
| A | offset (zero mark) |
| $V_{rapid}$ | rapid traverse speed |
| $V_{red}$ | reduced speed |
| $V_{creep}$ | creep speed |

*Figure 6.11 Approaching of the machine reference point when incremental encoder is used.*

The encoder zero mark NMR is moved to the reference point (distance A) by means of the commissioning data 17 during commissioning. This saves the mechanical adjustment of the encoder to the reference point.

## 6.3 WF 725 / WF 726 with Absolute Encoders

### 6.3.1 General

Every point of travel is determined by a distinct bit pattern univocally. Rotary encoders with coded discs are usually used. Up to three such encoders can be connected to the WF 725 B or WF 726 B.
The encoder information is given as a parallel signal. This information is decoded by the WF module. The counting operation, as necessary with incremental encoder, doesn't take place here. The smallest measuring unit is one step "T" as shown in the figure 6.12. It corre-sponds to the one increment which is generated by the incremental encoder.

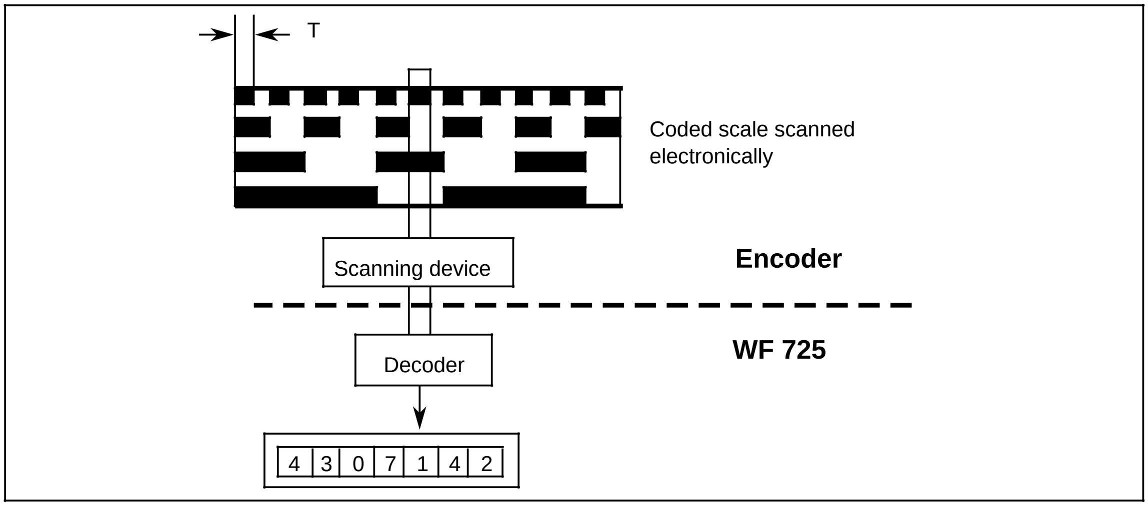
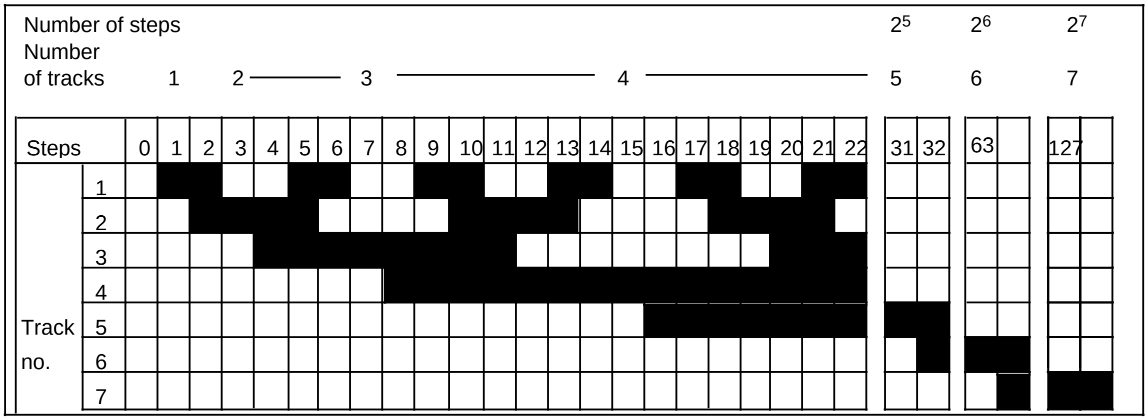


*Figure 6.12 Absolute position measurement, principle of operation.*

There are only such codes allowed, where only one bit changes in the time. The Gray Code is most suitable for this. This principle makes the operation more save and improves the encoder monitoring. The reflection and mirror image effects are used to ensure the single bit change principle, see figure 6.13. At the transition from step 15 to 16 only the bit in track 5 changes. The tracks 1 to 4 are mirrored at this place.



| Steps | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 31 | 32 | 63 | | 127 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | | | | | |
| | 2 | | | ■ | ■ | ■ | ■ | | | | | ■ | ■ | ■ | ■ | | | | | ■ | ■ | ■ | ■ | | | | | | | |
| | 3 | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | ■ | ■ | ■ | | | | | | |
| | 4 | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | |
| Track | 5 | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| no. | 6 | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | |
| | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ |

*Figure 6.13 Reflection method shown as used at the Gray code.*

If the number of steps does not exceed 8000, a single coded disk can be used. The encoder shaft turns only once to cover the whole range of traverse (single-turn). Depending on encoder location and the accuracy required, the encoder shaft has to make several revolutions (multi-turn). There are coarse, medium, and fine scales inside of the encoder. The absolute measurement is done utilizing cascade principle.

## 6.3.2 Commissioning Data Referring to the Encoders:

1. Monitoring of the absolute encoder (MD 16 A)
2. Number of steps of the encoder (MD 5)
3. Pulse evaluation factor (MD 19 and 20)
4. Basic resolution (parameters of the FB 211)

### 6.3.2.1 Criteria for the Encoder Selection (Multi-turn):

1. Minimum number of steps is calculated from travel and resolution:

$$\text{Minimum number of steps} = \frac{\text{Travel in mm}}{\text{Resolution in mm}}$$

2. Number of steps per encoder revolution is calculated from number of steps of the encoder and number of encoder revolutions. The encoder location determines how many encoder revolutions are necessary.

$$\text{Steps per revolution} = \frac{\text{Number of steps}}{\text{Number of revolution}}$$

The encoder location determines how many encoder revolutions are necessary.

3. It is necessary to verify the calculations, because the encoders are available with certain numbers of steps and certain number of revolutions only.

Example:

① Travel: 1 m, Resolution: 0.1 mm
② Number of encoder revolutions: 80

re. ① The encoder must have at least 10,000 steps
re. ② 80 revolutions are not available, the next higher number, 128, has to be chosen

③ The 80 encoder revolutions have to be distributed over the entire travel.
80 rev. for 10,000 steps results in 125 steps per rev. Available are 128 steps per revolution.

④ Encoder ordering data:
  (a) 128 steps per revolution
  (b) 128 revolutions

⑤ Calculation of the machine data:
  (a) Basic resolution: 0.1 mm ( = 100 µm, the parameter for the FB 211 is equal to 3).
  (b) Pulse evaluation factor: the scale factor (MD 20) is equal to 125/128 = 0.97656250. It is entered into MD 19.
  (c) Number of encoder steps is entered in MD 5. It is a product of the ④ a) multiplied by ④ b).

### 6.3.2.2 Selection of Single-Turn:

Calculation of the number of tracks:

In this case there is a relationship between the three parameters:

| | |
|---|---|
| • Entire travel | S |
| • Resolution | A |
| • Number of encoder tracks | n |
| or | |
| • Number of encoder steps | T |

The following applies:

$$S = T \times A$$

and

$$T = 2^n$$

and $$S = A \times 2^n \qquad (*)$$

The logarithm of the equation above (*) gives the number of tracks necessary:

$$\boxed{n \geq \frac{\lg \frac{S}{A}}{\lg 2}}$$

Example: $$\left.\begin{array}{ll} S = & 100mm \\ A = & 0.1mm \end{array}\right\} \text{results in } n = 10$$

### 6.3.3 Encoder Monitoring

The following are the encoder checks:

a) The actual position is scanned many times. It allows the recognition of the change of the pulse signal edges.
b) Parity monitoring (programmable, used when parity bit present).
c) Number of steps between 2 measurements (= WF cycle time).

When Gray coded encoder is used the a) and c) can almost be omitted, because only one bit changes in the time.

e.g. Change from...to:

| | | | |
|---|---|---|---|
| 0111 | 1111 | 1111 | $7FF_{Hex}$ |
| | ↓ | | |
| 1000 | 0000 | 0000 | $800_{Hex}$ |

During the reading of the actual position all values between 000hex and FFFhex are possible.

### 6.3.4 Interface between WF 725 / WF 726 and Absolute Encoder

The following have to be considered when selecting an encoder:

- Output signals and code type
- The total number of steps and number of steps per revolution
- Voltage level
- Cut-off frequency
- Voltage drop in the cable
- Output circuit of the encoder

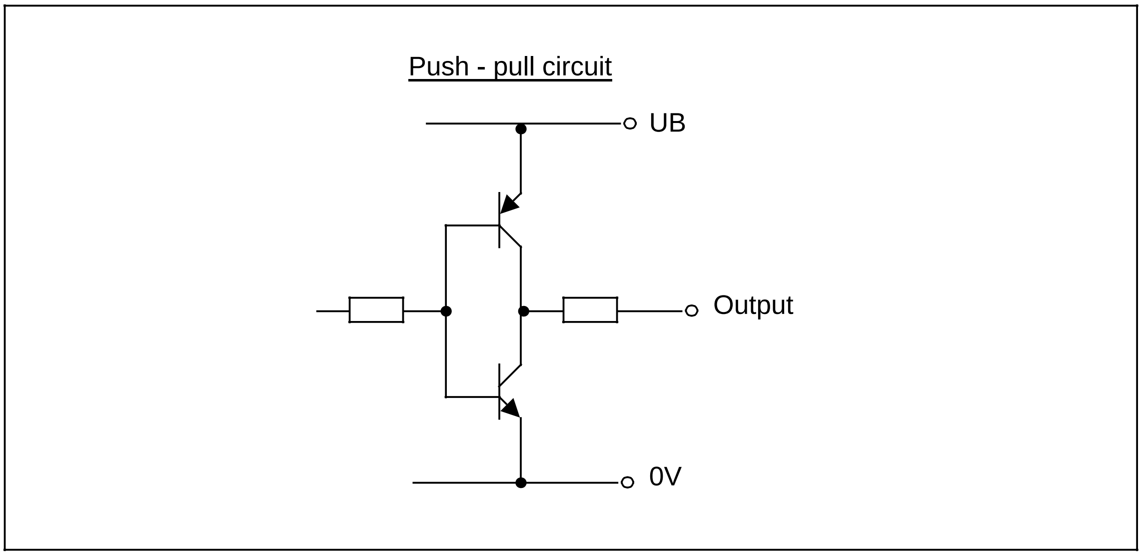


*Figure 6.14 Permissible output circuit of the absolute encoder.*

***Note:*** Encoder pins or encoder tracks which are not used may not be connected to the WF 725 B or WF 726 B.

### 6.3.5 Rotary Axis

The WF module can operate as linear or rotary axis controller. The controller type is set by means of the commissioning data MD 18. If the rotary axis is chosen, a commissioning data determines the number of encoder pulses after which the actual value counter of the WF module starts counting from zero again. In case of the incremental encoders the setting of the commissioning data MD18 does not depend upon the number of the encoder pulses per revolution and can be set at your discretion. In case of the absolute encoders, the total number of encoder steps and the MD18 setting must be equal.

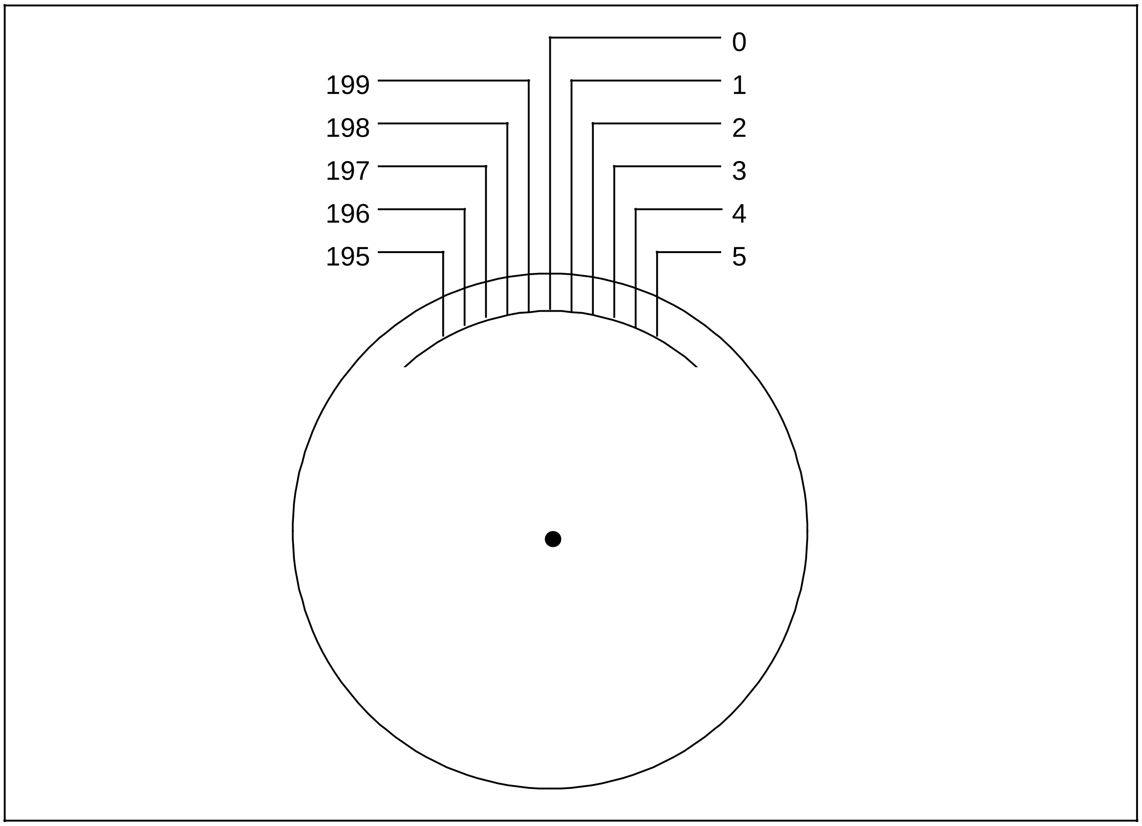


*Figure 6.15 Example of the rotary axis. 1 revolution = 200 pulses.*

In case of the linear axis the MD18 is equal to 1. In case of the rotary axis the actual position is corrected when the number of pulses counted exceeds the value of MD18 and when it falls below 0. The pulses are counted as follows ( see the example above, MD18 = 200):

| | | | | |
|---|---|---|---|---|
| Forwards | ...198 - | 199 - | 0 - | 1.. |
| Backwards | .......1 - | 0 - | 199 - | 198... |

In case of absolute programming, the approaching direction of the set point can be programmed. In this case the same input bits as for motion command in the "setup" mode are used. If there is no direction programmed or both the input bits carry 1 signal, the set position is approached via the shortest path. In case of incremental programming, the sign of the value programmed is used to determine the approach direction. Using incremental programming is also possible to program several revolutions.

If the absolute encoders are used the commissioning data MD7 (omitted area) and MD34 (distance difference monitoring) have also to be considered.

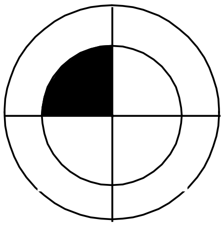
## 6.4 Calculation of the Distance to Go and Actual Value Display

### 6.4.1 Reference Points

Machining of the workpieces in case the incremental encoders are used:

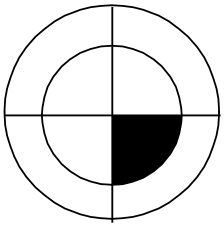
The machine reference points which are established in the working area of the machine, make the programming, operating and handling easier (see figure 6.16).

Machine zero point M



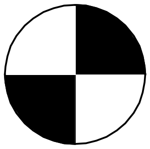
The machine zero point lays invariable in the origin of the machine coordinate system. It cannot be moved to any other place.

Workpiece zero point W



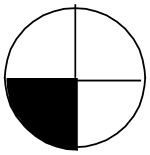
The workpiece zero point lays in the origin of the workpiece coordinate system. The workpiece programming is related to this point. The location of this point can be chosen arbitrary

Machine reference point R



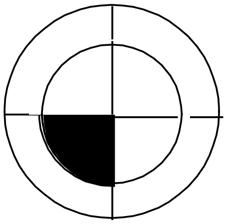
It is present when incremental encoders are used.

Program zero point P



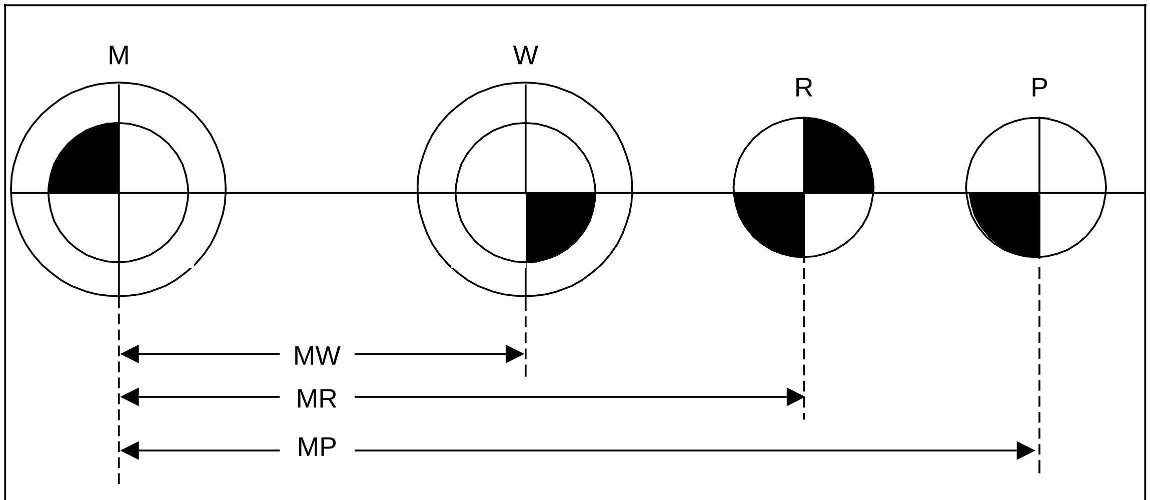
It is determined with G92 on the beginning of the program. Its values are not stored permanently.

Controller zero point C



The controller zero point lays in the origin of the control coordinate system. Usually, it lays in the machine zero point (C=M). It can be moved elsewhere as a result of the actual value setting, e.g. into workpiece zero point W. The tool length can also be compensated that way. The programmed values are set directly into actual value memory.

.



| | |
|---|---|
| MW | Zero offset |
| MR | Reference point coordinate |
| MP | Coordinate shift via G92 (actual value setting) |

*Figure 6.16 Reference points for the machining.*

### Transport Applications

In this case the travel limits are more important as at other systems, especially if the absolute encoders are used:

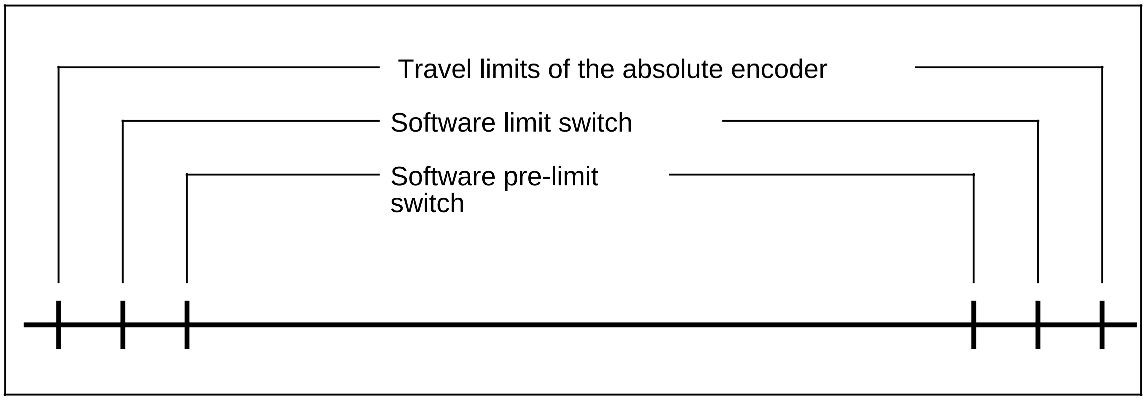


*Figure 6.17 Reference points for transport applications.*

In case of the incremental position measurement, a one reference point is established between the pre-limit switches.

## 6.4.2 Calculation of the Distance to Go

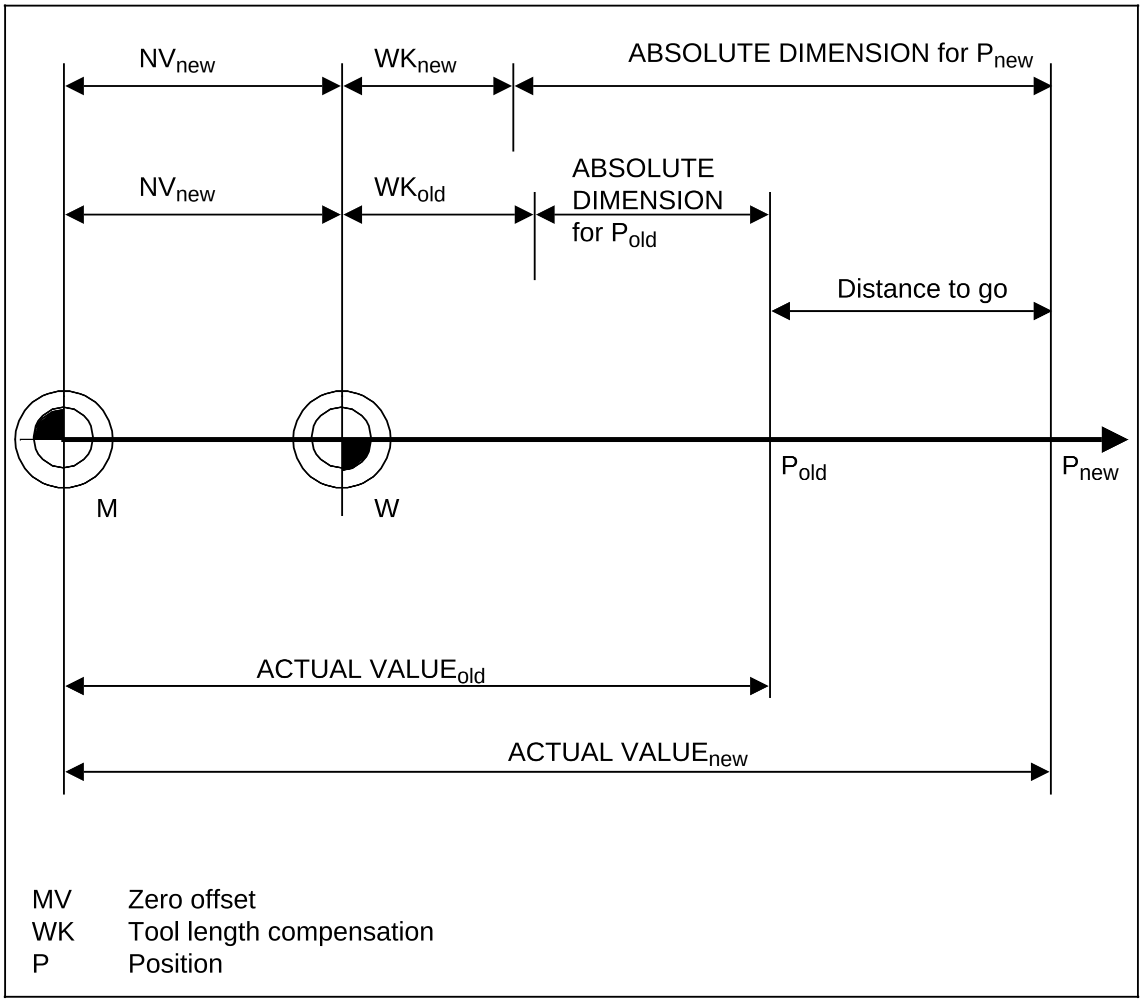


*Figure 6.18 Calculation of the distance to go.*

$$\text{Distance to go:} \quad = \underbrace{(\pm \text{ Absolute dimension for } P_{new})}_{x} - \underbrace{(\pm \text{ Absolute dimension for } P_{old})}_{y}$$

$$- \underbrace{(\pm NV_{old}) + (\pm NV_{new})}_{\text{Change NV}} - \underbrace{(\pm WK_{old}) + (\pm WK_{new})}_{\text{Change WK}}$$

If incremental programming is used, the x = incremental distance for $P_{new}$.........and
y = 0

The tool length compensation is always considered at calculation of the distance to go. The axis does not move the amount of the compensation only, regardless of the programming method, absolute or incremental. The tool offset remains without any effect as long no positioning distance is programmed.

### 6.4.3 Reference for Actual Value

a) Reference point for actual value is determined by data codes 2 and 27 and the additional information 00 and 01.
The programming of the G90 or G91 has no influence on the actual value reference.

b) Actual value display:
The position of the decimal point does not depend on the basic resolution chosen. The user can notice the difference by the number of the decimal places right from decimal point (0,1,or 2).

## 6.5 How to Design Drives and Mechanics

### 6.5.1 Positioning and Positioning Time at Accelerating Drives

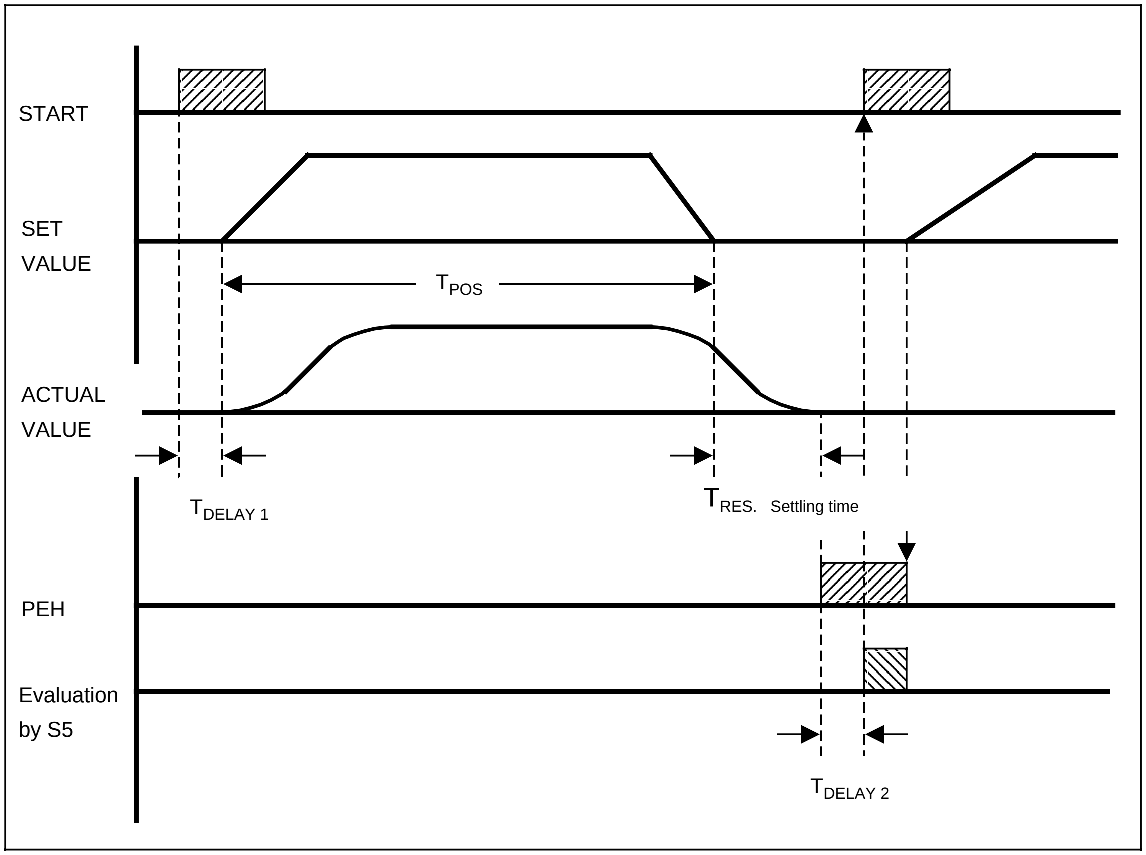


*Figure 6.19 Positioning or cycle time diagrams.*

The cycle time of the machine tool or the positioning time of the transport system depends upon various factors. Some of them are present inside of the control and other are present outside of the control. The total positioning time $T_{Pos.\ tot.}$ consist of the following components (see fig. 6.19):

$$T_{pos} = T_{D1} + T_{Pos} + T_{Res} + T_{D2} + T_{UP}$$

$T_{D1}$ : Depending upon whether the START signal is given via machine control panel or generated in the S5 controller, the delay time $T_{D1}$ is likely to be one or more S5 cycle scans.

$T_{Pos}$ : Positioning time
This time is determined by the program and commissioning data only, i.e. it reflects the set values only.

$T_{Res}$ : Residual or settling time
It counts from the moment when the set value reaches zero to the moment when the axis reaches PEH window. This time reflects complicated time constants of the drive and mechanics. It can only be estimated or measured with recording instruments such as "Oszillomink".

$T_{D2}$ : Delay time 2
Similar as delay time 1, one or more S5 cycle scans.

$T_{UP}$ : This time reflects unknown process delays such as checking of the interlock conditions. It has to be analyzed separately on case to case basis.

**Correlation between motion parameters**

The goal is to position the axes as fast as possible. However there are some conditions to be observed:

- The acceleration is limited because of:
  - Mechanical machine stress
  - Encoder capabilities
  - Economical reasons at motor and drive selection

- The traversing speed is limited because of:
  - Speed limit of the motor
  - Technological reasons, e.g. machining proprieties of the workpiece
  - Frequency limit of the encoder and the electronics

The correlation between the motion parameters derived from these factors is shown in figure 6.20. The following is shown as internal control values: Distance and speed as programmed in the program block, acceleration and deceleration values as entered in the commissioning data. The speed curve over the time, v(t), can be measured at the command value output using the commissioning data "simulation".

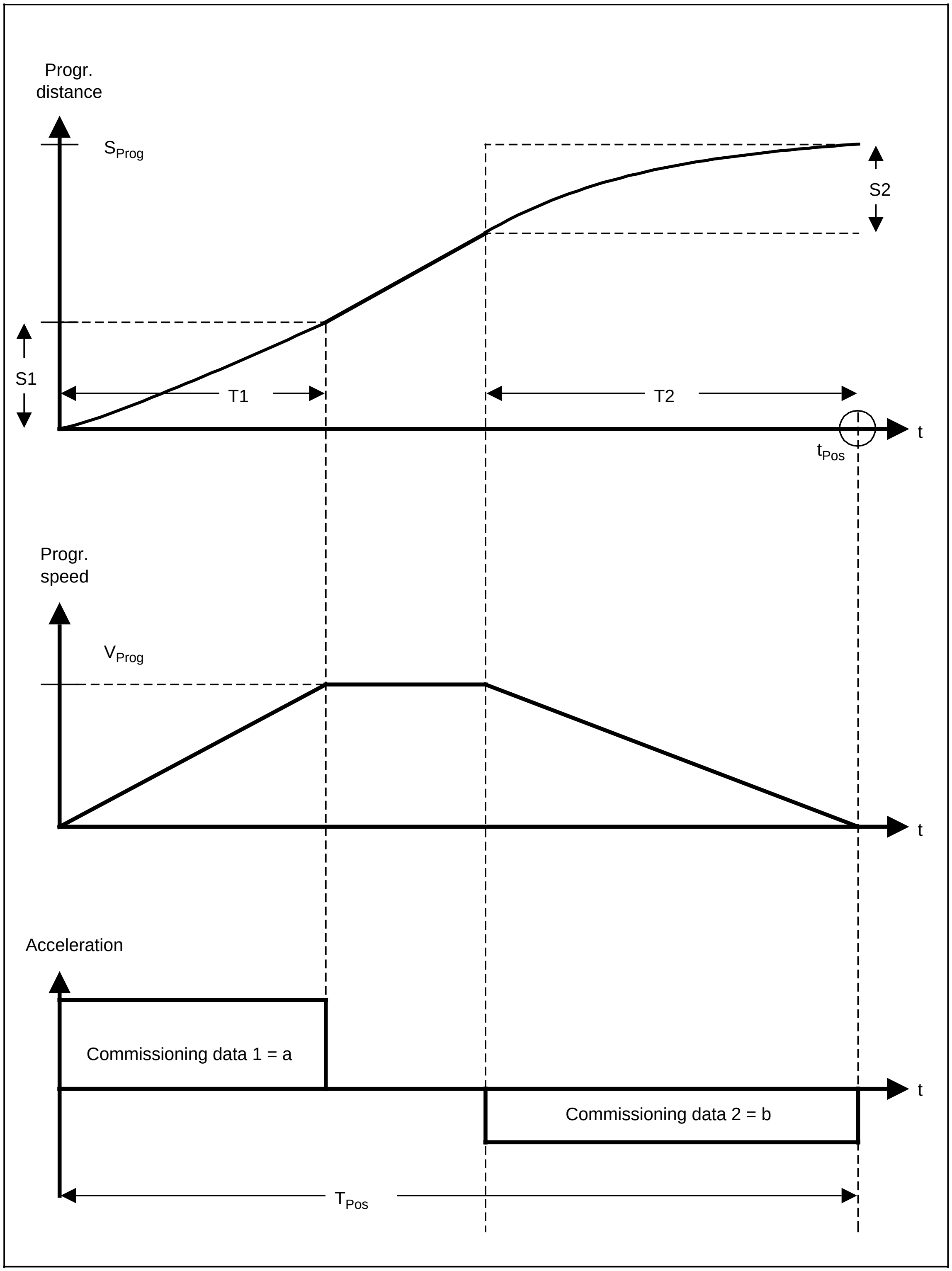


*Figure 6.20 Positioning procedure (command value) without jerk limiting.*

### 6.5.2 Calculation of the Positioning Time (Command Value) without Jerk Limiting

$$T_{Pos} = T1 \quad \frac{S_{Prog} - S_1 - S_2}{V_{Prog}} + T_2$$

1) Check: $\mathbf{S_{Prog} - S_1 - S_2 > 0}$

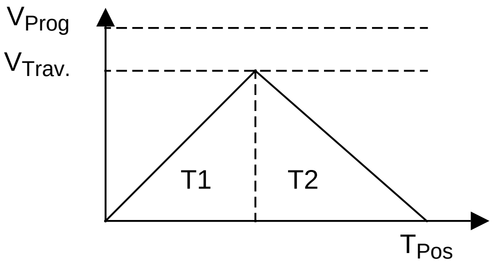
converted: $$S_{Prog} - \frac{V_{Prog}^2}{2a} \left(1 + \frac{a}{b}\right) > 0$$

2) If **yes**, then $V_{Trav.} = V_{Prog}$ and

$$\boxed{T_{Pos} = \frac{S_{Prog}}{V_{Prog}} + \frac{V_{Prog}}{2a} \left(1 + \frac{a}{b}\right)}$$

3) If **not**, then $V_{Trav.} < V_{Prog}$ and

$$\boxed{T_{Pos} = \sqrt{\frac{2\,S_{Prog}}{a} \left(1 + \frac{a}{b}\right)}}$$



$S_{Prog} = S_1 + S_2$

## 6.5.3 Calculation of the Positioning Time with Jerk Limiting

***As from firmware version 1.6, jerk limitation is no longer integrated.***

Positioning with jerk limiting:
Which formula has to be used?

Procedure:

1. Check if

$$\mathbf{s_{prog} - 2\, s_a > 0}$$

$s_a$: Acceleration/ deceleration distance

or

$$s_{prog} - \frac{v_{prog}^2}{a} - \frac{v_{prog}\, a}{r} > 0$$

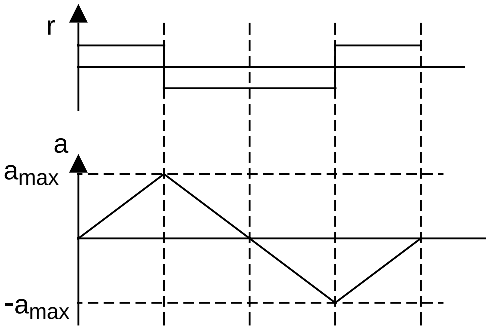
if **yes**, use formula ③,
if **not**, proceed with point 2.

2. Check if

$$\mathbf{s_{prog} - 2\, s_a = 0}$$

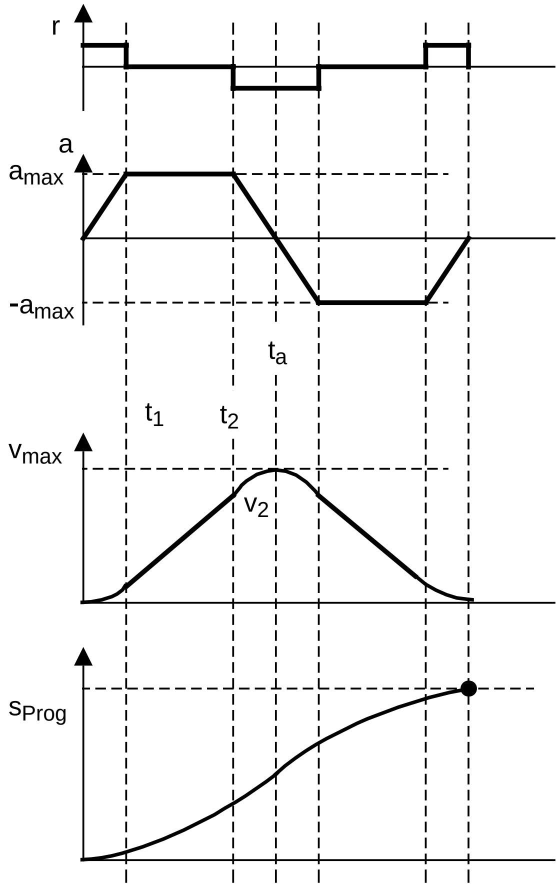
if **yes**, use formula ①,
if **not**, use formula ②

① a $_{max}$ will not be reached (or only at one point)



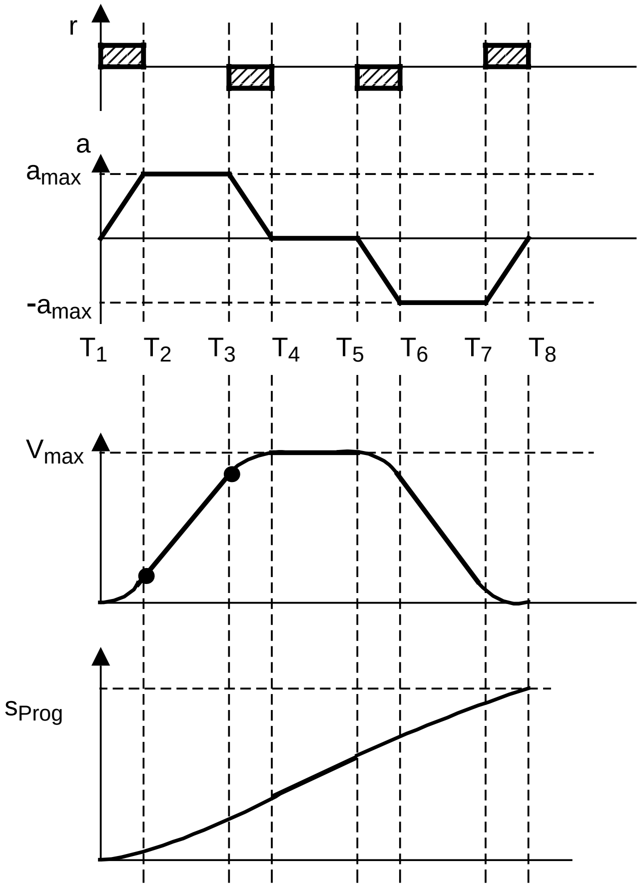
$$s = 4 * \frac{r}{6} * t^3 \rightarrow \boxed{T_{Pos} = \sqrt[3]{\frac{3\, s_{prog}}{2\, r}}}$$ ①

② $a_{max}$ has been reached, but not the $V_{max}$ (or only at one point)



$$\boxed{T_{Pos} = \frac{a}{r} + \sqrt{\frac{a^2}{r^2} + \frac{4\, s_{Prog}}{a}}}$$ ②

③ The programmed speed $V_{Prog.}$ has been reached



$$\boxed{T_{pos} = \frac{s_{prog}}{v_{prog}} + \frac{v_{prog}}{a} + \frac{a}{r}}$$ ③

# 7 Documentation and Ordering Data

## 7.1 Documentation

**Documentation:** **necessary ▓ or sensible ░ for using the software for**

| **WF modules with SIMATIC S5** | FB-Schale + | | | | | |
|---|---|---|---|---|---|---|
| | S I-726 | S I-726 + S III-726 | S I-726 + COM 726 | S I-726 | S I-726 + S III-726 | S I-726 + COM 726 |
| Planning Instructions<br>Hardware<br>6ZB5 440-0GJ02-0AA5 | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| Planning Instructions<br>Software Shell<br>6ZB5 440-0GK02-0AA2 | ▓ | ▓ | ▓ | | | |
| Planning Instructions<br>Software I, III<br>6ZB5 440-0GL02-0AA3 | ░ | ░ | ░ | ▓ | ▓ | ▓ |
| Installation Instructions<br>Description<br>6ZB5 440-0FW02-0AA3 | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| Installation Instructions<br>Lists<br>6ZB5 440-0JQ02-0AA2 | ░ | ░ | ░ | ░ | ░ | ░ |
| Operating Instructions<br>Standard II with WS 780<br>6ZB5 440-0FY02-0AA0 | | ▓ | | | ▓ | |
| Operating Instructions<br>Standard III with WF 470<br>6ZB5 440-0FX02-0AA1 | | ▓ | | | ▓ | |
| WF 470 Description<br>Video Display Module<br>6ZB5 440-0JF02-0BA5 | | ▓ | | | ▓ | |
| Programming Instruction<br>6ZB5 440-0GA02-0AA1 | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| Description<br>Software COM 726<br>6ZB5 440-0AX02-0AA5 | | | ▓ | | | ▓ |

## Further documentation

| | | |
|---|---|---|
| /1/ | WF 725/ WF 726 Positioning Modules<br>**Description** | Order No. 6ZB5 440-0JH02-0BA1 |
| /2/ | WS 495/ WS 496 Operating System<br>**Description** | Order No. 6ZB5 440-0JX02-0BA1 |
| /3/ | WS 400-10/20/22 Operator Panels<br>**Description** | Order No. 6ZB5 440-0AR02-0BA3 |
| /4/ | WF 463 S External Memory<br>**Description** | Order No. 6ZB5 440-0JG02-0BA1 |
| /4/ | WF 470 Display System<br>**Planning Guide** | Order No. 6ZB5 440-0FH02-0AA0 |
| /5/ | AR 10 WS/WF series | Order No. E86060-K6310-A101-A5-7600 |

## 7.2 Further Ordering Data

For the hardware and software ordering data, please refer to the valid catalog AR 10.

Siemens AG

AUT V 24
Postfach 31 80
D-91050 Erlangen
Fed. Rep. of Germany

**Suggestions/Corrections**

For Publication/Manual:

WF 725/WF 726
Positioning Modules

Planning Instructions, Part 1
Description of the Hardware Interface
Order No.: 6ZB5 440-0GJ02-0AA6
Edition: October 1996

**From:**

Name

Company/Dept.

Address

Telephone **/**

If you find any printing errors when reading this publication, please let us know, using this form. We also welcome any suggestions to improve the manual.

**Suggestions and/or corrections**

# Equipment
# for
# Special Machines

## WF 725/WF 726

## Planning Instructions

Siemens AG
Automation Group
Automation Systems
for Machine Tools, Robots
and Special-Purpose Machines
P.O. Box 31 80, D-91050 Erlangen
Federal Republic of Germany

This edition was printed on paper bleeched
using an evironmentally friendly chlorine-free
method

---

Siemens Aktiengesellschaft

Order No.: 6ZB5 440-0GJ02-0AA6
Printed in the Fed. Rep. of Germany
232/720012 PJ 10960.1