NUM 1060

D.I.S.C.
(DIGITAL INTEGRATED SERVO CONTROL)
INTEGRATION MANUAL

0101938907/4

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Record of Revisions

Date	Revision	Pages revised	Pages added	Pages deleted
07 - 94	1	Complete revision		
10 - 96	2	Complete revision		
06 - 97	3	All pages issued in Revision 3		
05 - 99	4	1 to 5 5-2, 5-32 Questionnaire	5-33 to 5-40 7-1 to 7-30	

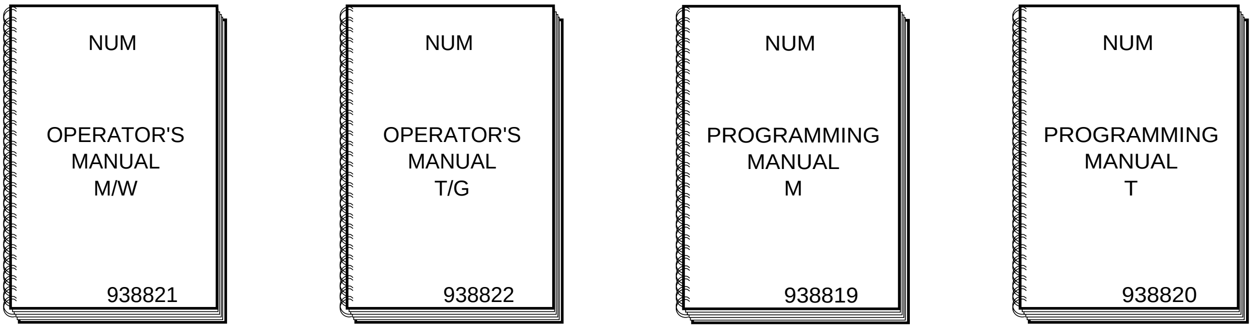
REVISIONS OF THE DOCUMENTATION

Date	Revision	Reason for revision
08 - 93	0	Conforming to NUM 1060 software at index F.
07 - 94	1	Conforming to NUM 1060 software at index F2. Miscellaneous corrections.
10 - 96	2	Conforming to NUM 1020, 1040 and 1060 software at index K. SETTool software at index E taken into account. Changes in servo-drives: transmit power and motor/servo-drive association settings on the front panel. Miscellaneous corrections.
06 - 97	3	Change in motor torques after measurements. Miscellaneous corrections.
05 - 99	4	Conforming to NUM 1000 family software at index M DISC digital servocontrol setting procedure New parameters P88, P89, P90, P91, P92, P93, P94, P116, P117, P118, P119, P120, P121, P122.

Structure of the NUM 1060 Documentation

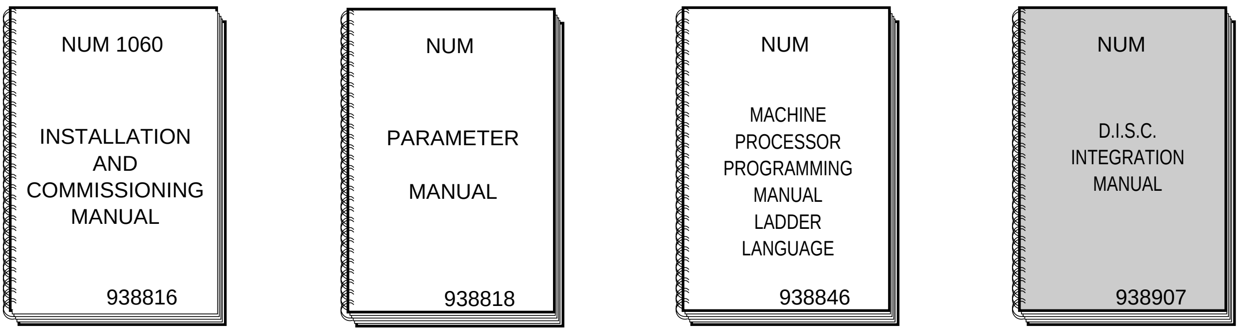
User Documents

These documents are designed for the operator of the numerical control.



OEM Documents

These documents are designed for the OEM integrating the numerical control on a machine.



List of NUM 1020 - 1040 - 1060 Utilities

A series of utilities are available for the NUM 1020 - 1040 - 1060 CNCs for integration and use of the systems.

These utilities may be included in the basic version or available as options.

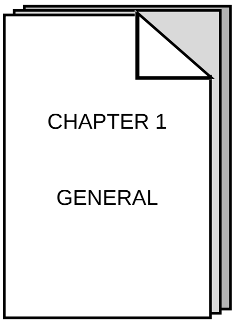
Depending on the function performed by each utility, its use is described in the integration manual or operator manual.

The table below lists the utilities and gives the references of the document describing them:

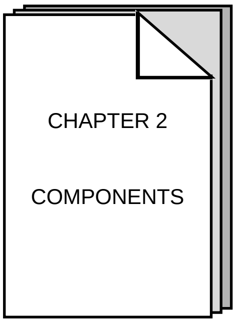
Utility	Name	Manual	Chapter
UT2	axis calibration	installation and commissioning manuals (938 816 or 938 938)	10
UT3	resident macros	operator manuals (938 821 or 938 822)	8
UT5	parameter integration	parameter manual (938 818)	12
UT7	PLC programme debugging	machine processor programming manual ladder language (938 946)	18
UT12	option locking	operator manuals (938 821 or 938 822)	8
UT20	interaxis calibration	installation and commissioning manual (938 816 or 938 938)	11
UT22	axis parameter integration	SETTool manual (938 924)	8

DISC (Digital Integrated Servo Control) Integration Manual

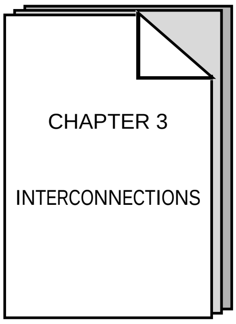
This manual is used for integrating the DISC components in the CNC.



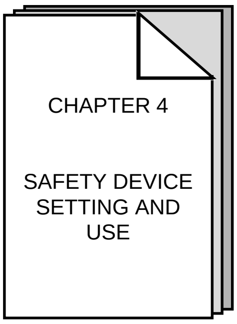
Description of the axis and spindle DISC concepts
- General description,
- Functional description,
- System architecture.



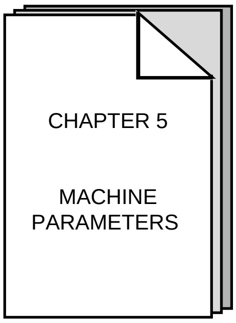
Description of the DISC components
- Physical characteristics,
- Technical characteristics,
- List of DISC-compatible drives.



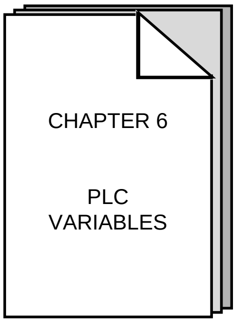
Interconnections, adjustments and settings
- Fibre-optic ring,
- Transmit power setting,
- Address settings,
- Motor/servo-drive association settings,
- Schemas.



Faults and safety device processing
- Procedure for accessing the error display pages,
- Resetting procedures.



List of machine parameters and axis and spindle configuration rules.



List of PLC variables and programming rules.

Use of the DISC Integration Manual

Agencies

The list of NUM agencies is given at the end of the manual.

Questionnaire

To help us improve the quality of our documentation, we kindly request you to return the questionnaire at the end of the manual.

1 General

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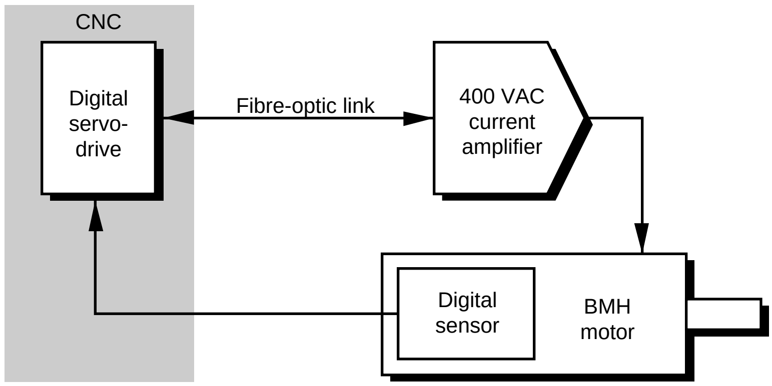
1.1 General Description

The DISC (Digital Integrated Servo-Control) concept includes:
- QVN card (heart of the DISC concept),
- Current amplifier for the axes,
- Sensor integrated in the BMH motor,
- Fibre-optic digital link.

The QVN card is built around a signal processor specially designed for servo-control (feedback) algorithms. It currently operates on conventional axis speed and position control algorithms.

This servo-control architecture is based on the following principles:



- Digital position and speed loops (in the CNC),
- Modular current amplifier directly connected to the European 400 VAC network,
- Two-way communication by optical fibre allowing transfers from the CNC to the amplifier (current reference, amplifier module control word) and from the amplifier to the CNC (module status word for processing the safety devices and diagnostic in the CNC),
- Dedicated sensor integrated in the motor,
- SETTool integration tool running on PC.

Several high-level diagnostic devices are included in the CNC for remote diagnostic from the CNC operator panel.

The SETTool integration tool with sophisticated ergonomics, running on a PC, is used to optimise the servo-control parameters. SETTool includes an oscilloscope function and automatic setting procedures (machine parameters) allowing rapid and reliable integration.

Since the speed servo-loop is fully digitised, any offset that could bias the following error has been completely eliminated, making the servo-control more accurate and the axes more stable.

Both DISC and conventional axes and spindles can be controlled by the same CNC (for the conventional axes, a +/-10 V speed reference is used by each axis card).

Two sensor configurations are possible for an axis controlled by QVN:
- A single speed and position measurement sensor (motor sensor) connected to the QVN card,
- A speed measurement sensor (motor sensor) connected to the QVN card and a position measurement sensor (on the moving assembly) connected to the same QVN card or to an axis encoder card.

A QVN sensor input can receive data from a spindle sensor, a handwheel (with complemented channels) or a position sensor for an axis that is only measured.

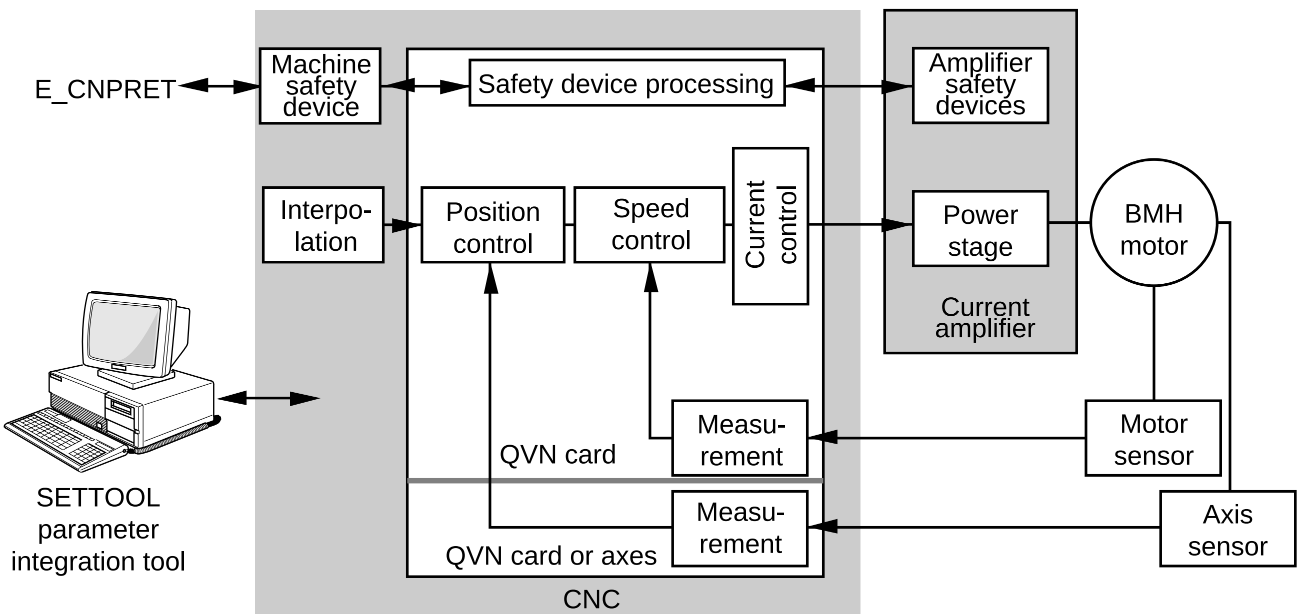
Maximum Axis Speed

Considering an internal resolution of one micron (one ten-thousandth of a degree for rotary axes), the maximum speeds are as follows:

	Axis speed (without additional sensor)		Axis speed (with additional sensor)	
Motor speed (rpm)	Linear axis (m/min)	Rotary axis (rpm)	Linear axis (m/min)	Rotary axis (x1000 °/rpm)
2000	36	100	360	100
3000	54	150	360	100
4000	72	200	360	100

1.2 Functional Description

When connected to the CNC system bus, the QVN (digital drive) card:
- Handles transfers with the current amplifier and interfaces with the motor sensors; if an additional sensor is placed on the axis, it can provide the interfacing,
- Handles feedback with position and speed control,
- Manages the safety devices specific to the axis.

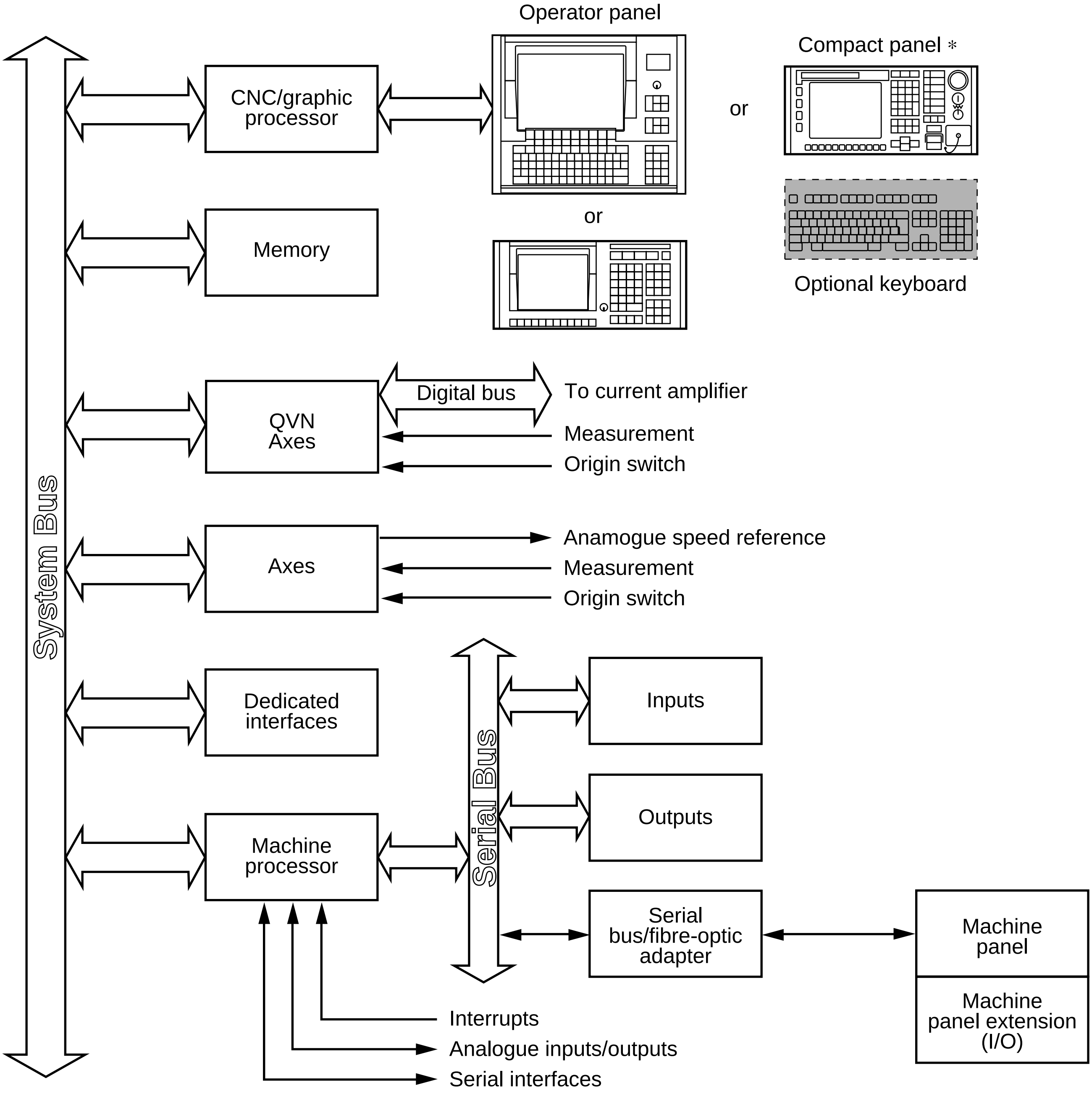


The SETTool software is used for:
- Setting the machine parameters,
- Testing of the servo-control responses to a typical signal (indicial response for the speed loop),
- Display of the response by the oscilloscope function.

1.3 System Architecture

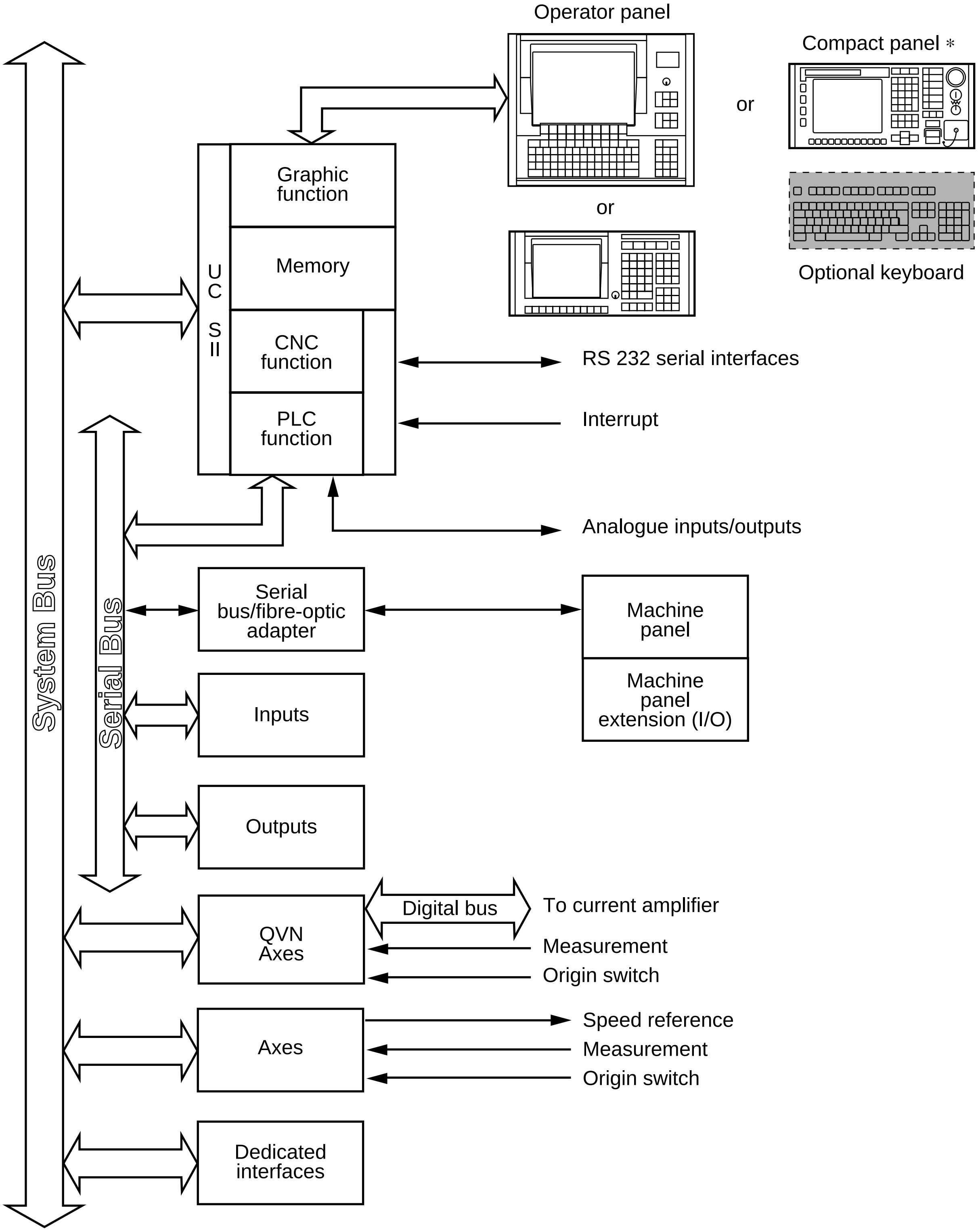
1.3.1 NUM 1060 Series 2 System

1.3.1.1 1060 Series 2 with Two Processors



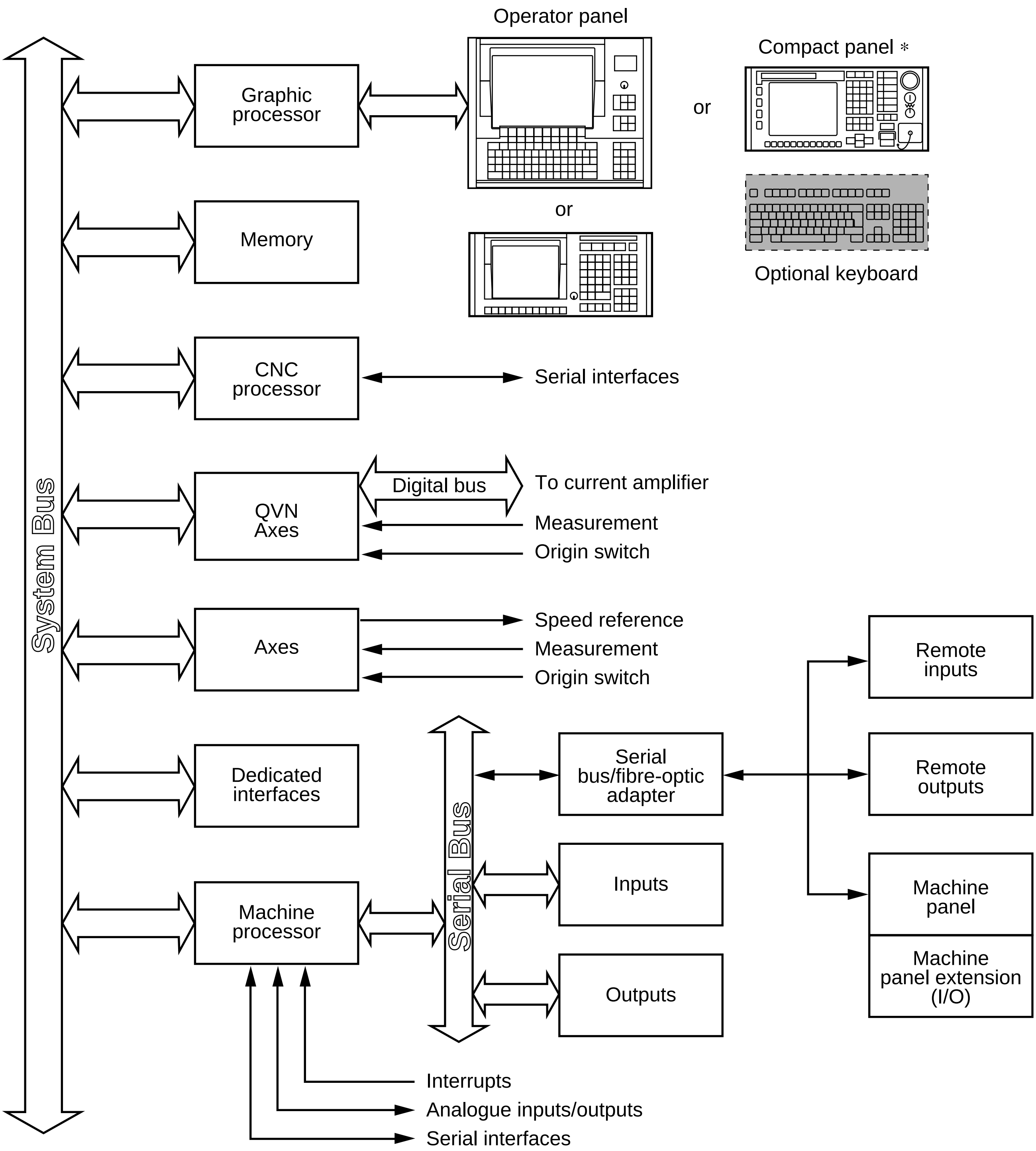
* The use of the compact panel precludes the use of a machine panel.

1.3.1.2 1060 Series 2 with UC SII Processor



* The use of the compact panel precludes the use of a machine panel.

1.3.2 NUM 1060 Series 1 System



∗ The use of the compact panel precludes the use of a machine panel.

2 Components

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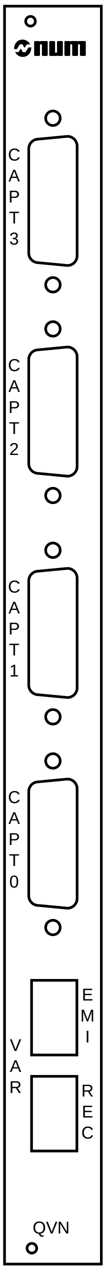
2

2.1 QVN Card

The QVN card is in double Eurocard format. It plugs into the system bus of the CNC rack. The interconnections are made on the front using four 26-contact Sub.D (high density) connectors for the sensors and one fibre-optic transmit/receive connector.

CAUTION

The QVN cards (P/N 204 202 069) must be connected to the system bus just to the left of the memory card.



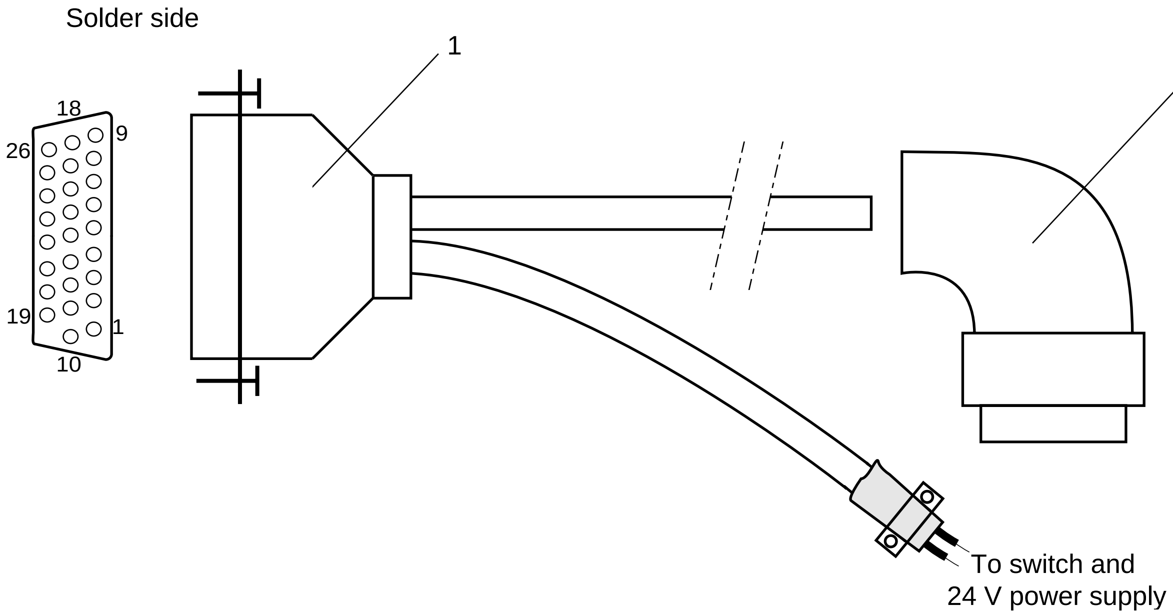
Power consumption	1.25 A (+ 0.18 A per DISC sensor)
Location	in the continuity of the CNC cards
Switch contact	one 24 V input per axis

The QVN card includes four measurement inputs and is able to drive up to four axes.

The built-in sensors on the axis motors controlled by the QVN card are connected in priority to the measurement inputs. Any additional axis, spindle and handwheel sensors can be connected to the remaining inputs, to another QVN card or to an axis encoder card.

2.2 Measurement Cable

This cable interconnects the QVN card with:
- The motor sensor,
- An encoder or a rule,
- A handwheel.



1 - Cable assembly (see P/N) including:
  - One 26-contact male Sub.D (high density) connector
  - One typical sensor and thermal probe cable (length 6, 10, 15, 20, 25, 30 or 40 m)
  - One typical FM2R switch cable (length 1.5 m)

2 - Connector supplied with the motor to be wired (see Sec. 3.4)

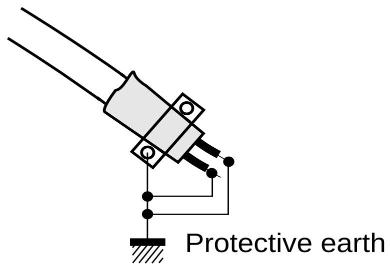
Cable Assembly Part Number

BMH Q 50 M $\boxed{\text{xx}}$

Length in m

If the switch cable is not used

When the switch cable is not used, the shielding and two conductors must mandatorily be connected to the protective earth to prevent interference.



2.3 Compatible Axis Drives

The axis drives compatible with DISC consist of BMH axis motors equipped with a dedicated sensor and 400 VAC modular current amplifiers.

REMARK *All spindle drives with UAC servo-drive are compatible with DISC.*

2

2.3.1 Motor Characteristics

BMH..D Motor	Cn 60 ∗ torque	In 60 ∗ rated current A rms	Pn 60 ∗ rated power kW dim	Nominal speed rpm	Amplifier MDL D...Q	Cmax /Cn	Cmax Nm
• 075 1 N	1.1	1.9	0.35	3000	007	2.45	2.7
					014	4.73	5.2
1 V	1.1	2.6	0.46	4000	014	3.55	3.9
• 2 N	1.8	2.3	0.63	3000	014	4.17	7.5
2 V	1.8	3	0.84	4000	014	3.28	5.9
• 4 N	3.1	3	1.07	3000	014	3.55	11
• 095 2 N	3.3	2.9	1.16	3000	014	3.33	11
2 V	3.3	5	1.55	4000	021	3.03	10
	3.3	5	1.55	4000	034	4.24	14
• 3 N	4.6	4.5	1.6	3000	021	3.48	16
3 V	4.6	8.8	2.14	4000	034	3.04	14
					050	4.13	19
• 5 N	7.1	4.9	2.45	3000	021	3.1	22
					034	4.37	31
• 115 2 N	5.7	4.7	1.98	3000	021	2.81	16
					034	3.68	21
2 V	5.7	8.9	2.64	4000	034	2.46	14
					050	3.16	18
3 K	8.1	4.5	1.86	2000	021	2.96	24
• 3 N	8.1	7.8	2.79	3000	034	2.72	22
					050	3.58	29
3 V	8.1	10.7	3.73	4000	034	2.22	18
					050	2.96	24
					075	3.7	30
• 4 K	10.2	5.3	2.37	2000	021	2.65	27
					034	3.73	38
4 N	10.2	8.6	3.55	3000	034	2.65	27
					050	3.43	35
4 V	10.2	15	4.73	4000	050	2.25	23
					075	3.14	32
					100	3.82	39
6 N	14.4	10.2	5.02	3000	034	2.29	33
					050	3.13	45

∗ : $\Delta T = 60$ K.
• : Preferred motor type.

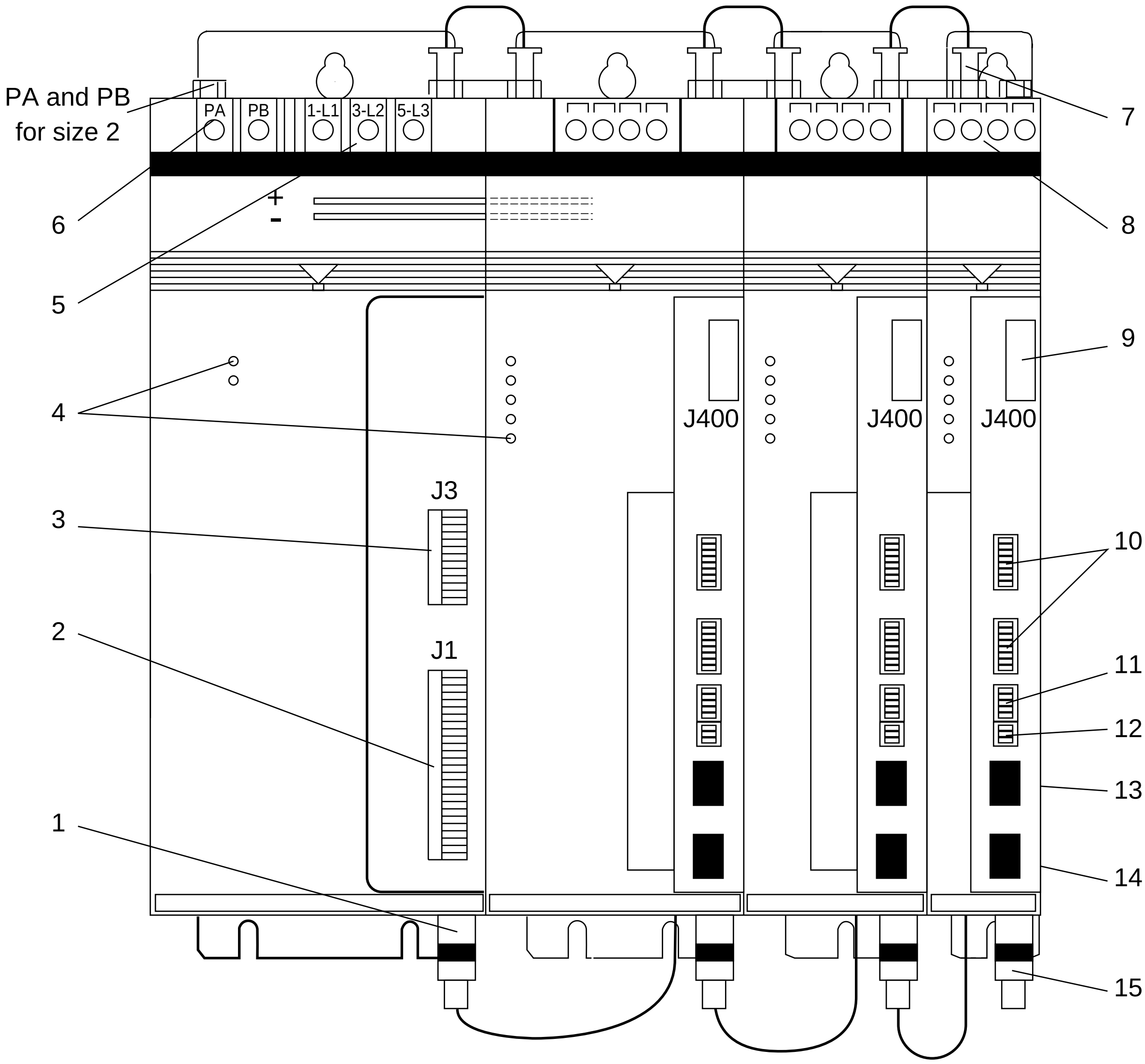
BMH..D Motor	Cn 60 ∗ torque	In 60 ∗ rated current A rms	Pn 60 ∗ rated power kW dim	Nominal speed rpm	Amplifier MDL D...Q	Cmax /Cn	Cmax Nm
142 2 K	9.2	5.1	2.09	2000	021	2.39	22
					034	3.15	29
• 2 N	9.2	8.8	3.14	3000	034	2.17	20
					050	2.93	27
2 R	9.2	9.8	4.19	4000	034	2.07	19
					050	2.72	25
3 K	13.1	8.1	2.93	2000	034	2.52	33
					050	3.28	43
• 3 N	13.1	9.9	4.4	3000	034	2.14	28
					050	2.82	37
3 R	13.1	14.4	5.86	4000	050	2.14	28
					075	2.90	38
					100	3.44	45
• 4 K	16.9	8.8	3.98	2000	034	2.43	41
					050	3.25	55
4 N	16.9	13.3	5.97	3000	034	1.72	29
					050	2.43	41
					075	3.25	55
4 R	16.9	17.7	7.95	4000	075	2.66	45
					100	3.25	55
7 N	27	20.6	9.42	3000	050	1.85	50
					075	2.63	71
					100	3.33	90

∗ : $\Delta T = 60$ K.
• : Preferred motor type.

BMH..D Motor	Cn 60 ∗ torque	In 60 ∗ rated current A rms	Pn 60 ∗ rated power kW dim	Nominal speed rpm	Amplifier MDL D...Q	Cmax /Cn	Cmax Nm
• 190 2 K	19.3	14.1	4.4	2000	034	1.55	30
					050	2.07	40
2 N	19.3	16.9	6.59	3000	050	1.81	35
					075	2.38	46
2 R	19.3	24.8	8.79	4000	075	1.87	36
					100	2.23	43
3 K	27.7	16.7	6.49	2000	050	1.88	52
					075	2.45	68
• 3 N	27.7	23.6	9.73	3000	075	1.95	54
					100	2.38	66
4 K	37	17.5	8.16	2000	050	1.84	68
					075	2.43	90
					100	2.84	105
4 N	37	25.8	12.25	3000	075	1.86	69
					100	2.3	85
5 H	43.1	17	7.54	1500	050	1.9	82
					075	2.53	109
					100	2.95	127
• 5 L	43.1	26.7	12.56	2500	075	1.83	79
					100	2.27	98
					150	2.9	125
7 K	57.8	23.7	13.4	2000	075	2.08	120
					100	2.56	148
A K	77	37.4	17.79	2000	100	1.88	145
					150	2.60	200

∗ : ΔT = 60 K.
• : Preferred motor type.

2.3.2 Current Amplifier Module



1 - Ribbon cable connector
2 - Plug-in terminal board for source I / O
3 - Plug-in terminal board for serial interface (not used)
4 - LEDs
5 - Power cable connector (power lines L1, L2, L3)
6 - Terminals for dissipation resistor (PA - PB)
7 - Connectors for monitor power supplies
8 - Plug-in connector (except on size 4) for motor power supply (U, V, W, earth)
9 - Torque enable connector
10 - Microswitches for setting the motor / servo-drive associations
11 - Address microswitch
12 - Optical output power setting microswitch
13 - Fibre-optic connector (transmit)
14 - Fibre-optic connector (receive)
15 - Connector cap

2

2.3.2.1 Characteristics

Amplifier Module

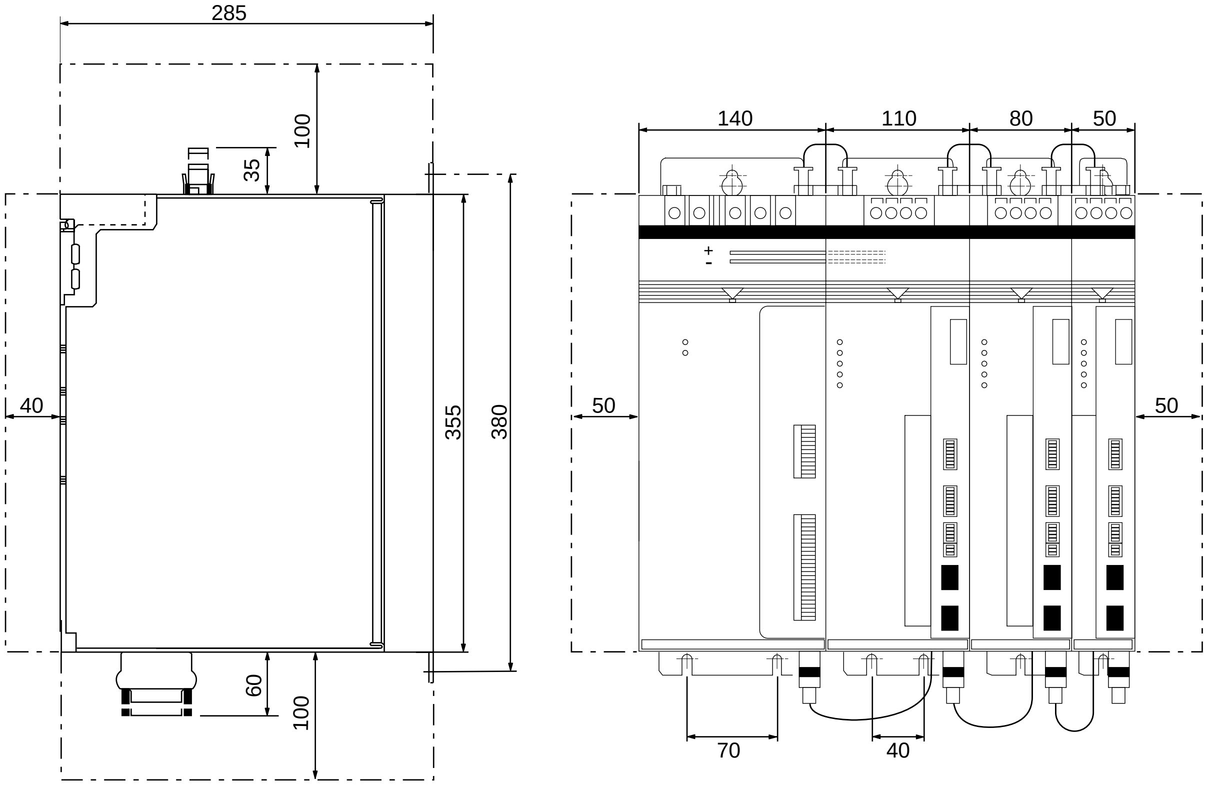
Module	Size	Pitch (mm)	Rated current (A rms)	Peak current (A)	Rated power (kW)	Nominal dissipation (W)	Weight (kg)
MDL D2 007 Q	1	50	2	7		20	4.6
MDL D2 014 Q			4	14		35	
MDL D2 021 Q			7	21		50	
MDL D2 034 Q	2	80	14	34		150	6.9
MDL D2 050 Q			20	50		170	
MDL D2 075 Q	3	110	35	75		200	9.2
MDL D2 100 Q	4	140	45	100		400	10.5
MDL D2 150 Q			60	150		460	

Power Supply Module

Module	Size	Pitch (mm)	Rated current (A rms)	Peak current (A)	Rated power (kW)	Nominal dissipation (W)	Weight (kg)
MDL L1 008 Q	2	80	14		8	50	8.1
MDL L1 015 Q			21		12	80	8.5
MDL L1 030 Q	4	140	53		30	170	10.5

Operating temperature range: 0 to +40 °C
Relative humidity: Maximum 75 percent noncondensing, nondripping
Protection class: IP20

2.3.2.2 Overall Dimensions and Mounting Dimensions



Install the components vertically, placing the amplifier modules to the right of the power supply modules.

Keep the assembly away from heat-generating components.

Provide a clearance of 100 mm at the top and bottom and 50 mm on the left and right of the assembly for ventilation.

Provide a clearance of 40 mm in front for the cables.

Use M6 attaching screws.

2.3.3 BMH Axis Motor

The overall dimensions are the same as those of standard BMH motors. The internal sensor is specific to DISC.

Example of a DISC-Compatible Motor Reference

BMH 142 2 N 1 $\boxed{\text{D}}$ F 1 L

DISC sensor

3 Interconnections

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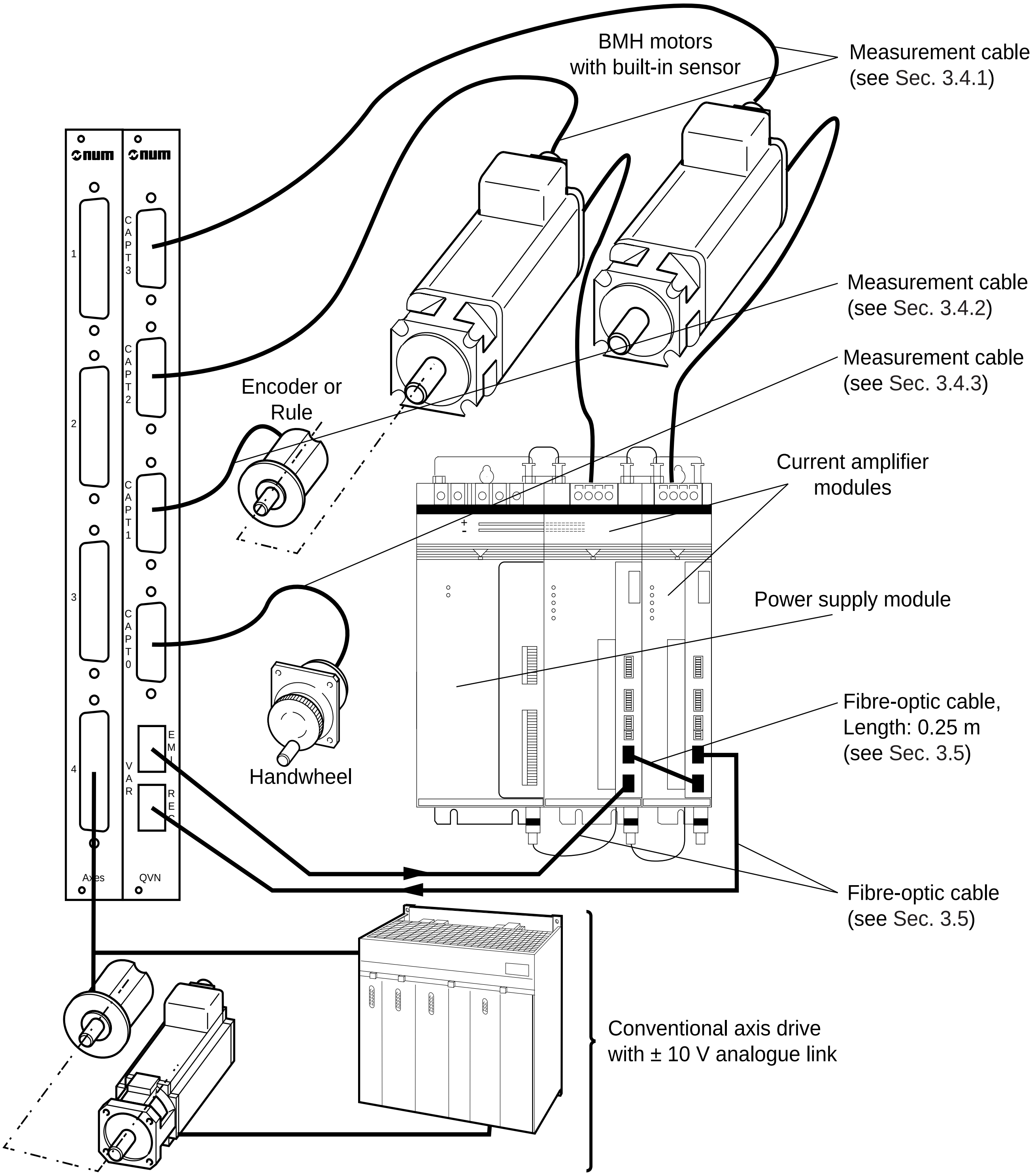
3.1 Schematic Diagram

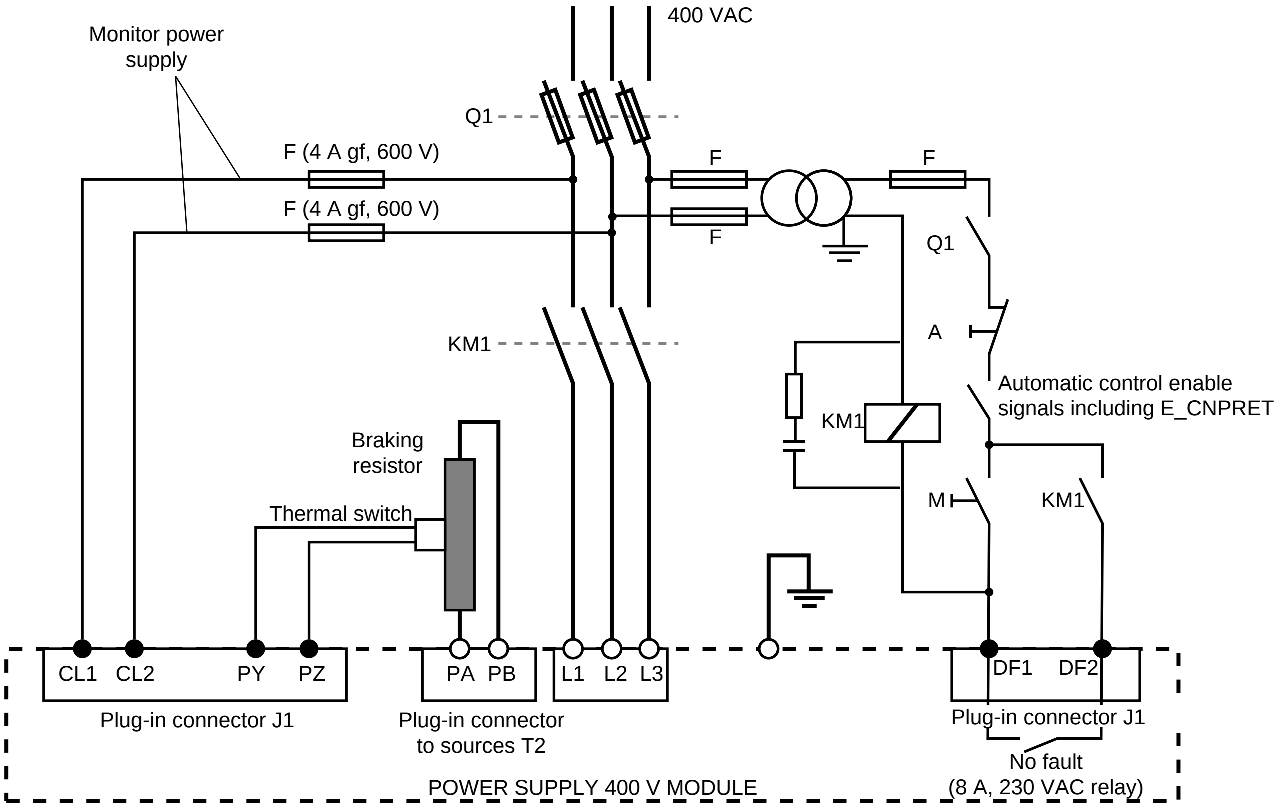


Sensor/Card Compatibility

	QVN Card	Axis card
Sensors	Motor sensor Handwheel Axis sensor	Remaining axis sensor Remaining handwheel Spindle
Measurement cable	BMH Q 50 M xx	To be assembled (see Installation and Commissioning Manual)

3.2 Servo-Drive Interconnections

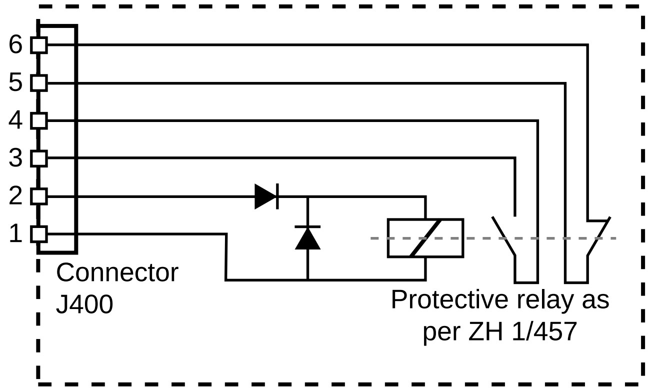
3.2.1 Connection of Axis Amplifier Power Supply



Isolating switch Q1
Size 2 power supply: 25 A fuse gf - 400 V
Size 4 power supply: 63 A fuse gf - 400 V

Contactor KM1
8 kW power supply: 25 A contactor
12 kW power supply: 40 A contactor
30 kW power supply: 80 A contactor

3.2.2 Wiring of the Torque Enable Connector



Coil
Nominal voltage 24 V
Pick-up consumption 280 mW
Operating consumption 500 mW

Contacts
Maximum current rating 6 A
Maximum switched voltage 440 V
Interrupt rating 150 W

Torque enable

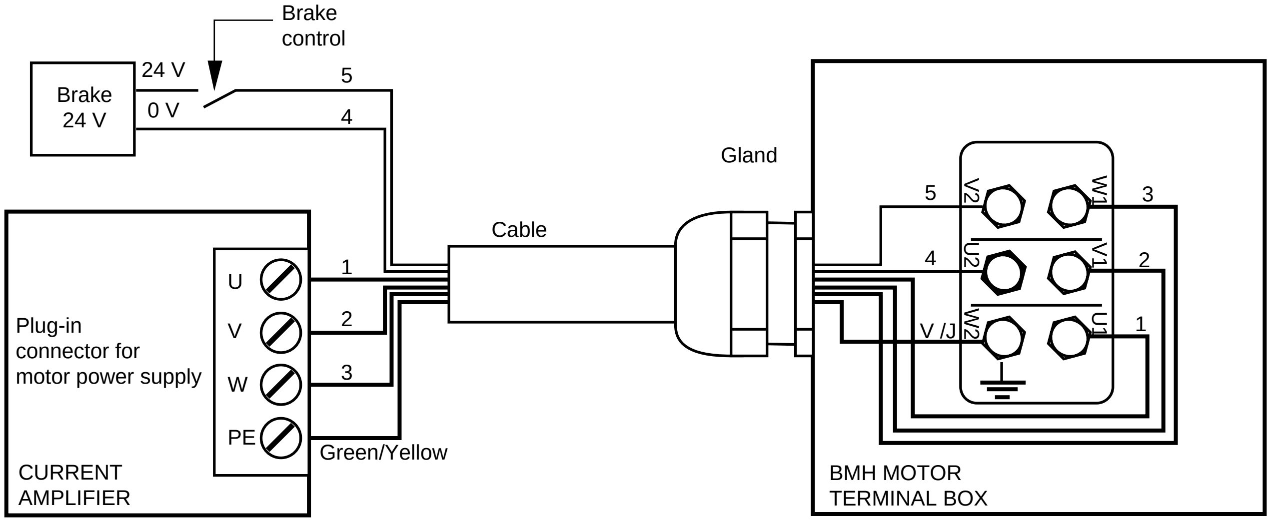
Torque is enabled when a voltage of 24 V is present across terminals 1 and 2.

Machine safety

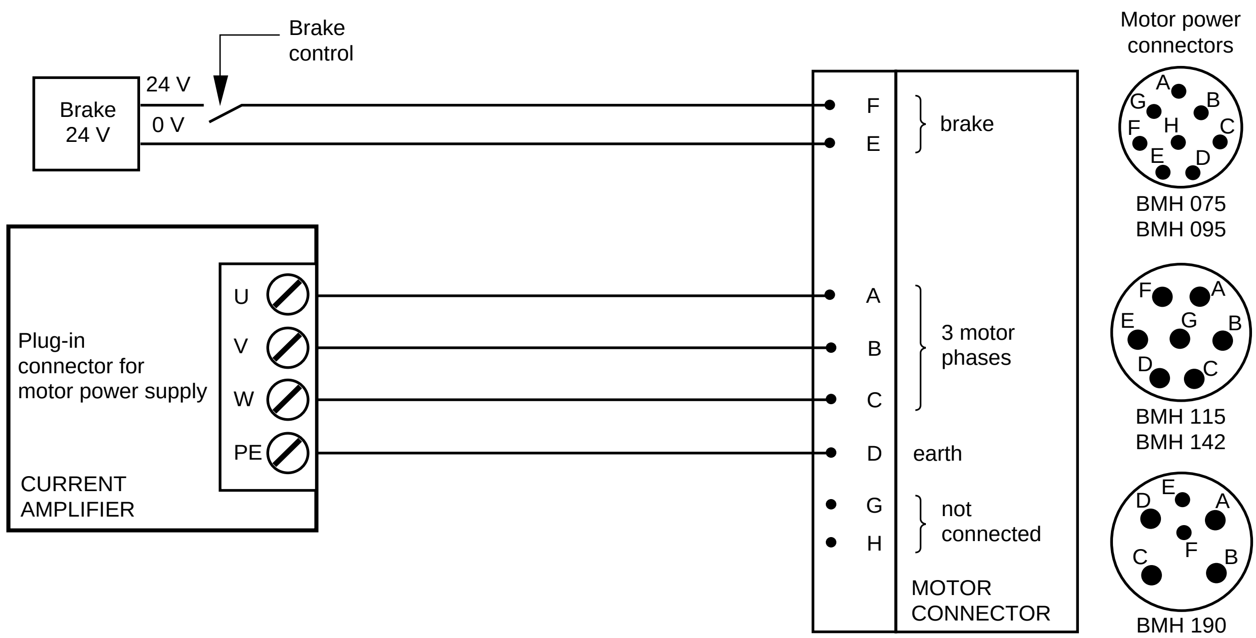
The NO contact (3-4) and/or the NC contact (5-6) are to be included in the machine safety daisy chain.

3.3 Motor and Brake Power Supply

3.3.1 Motor and Brake Power Supply with Terminal Box



3.3.2 Motor and Brake Power Supply with Power Connector on Motor

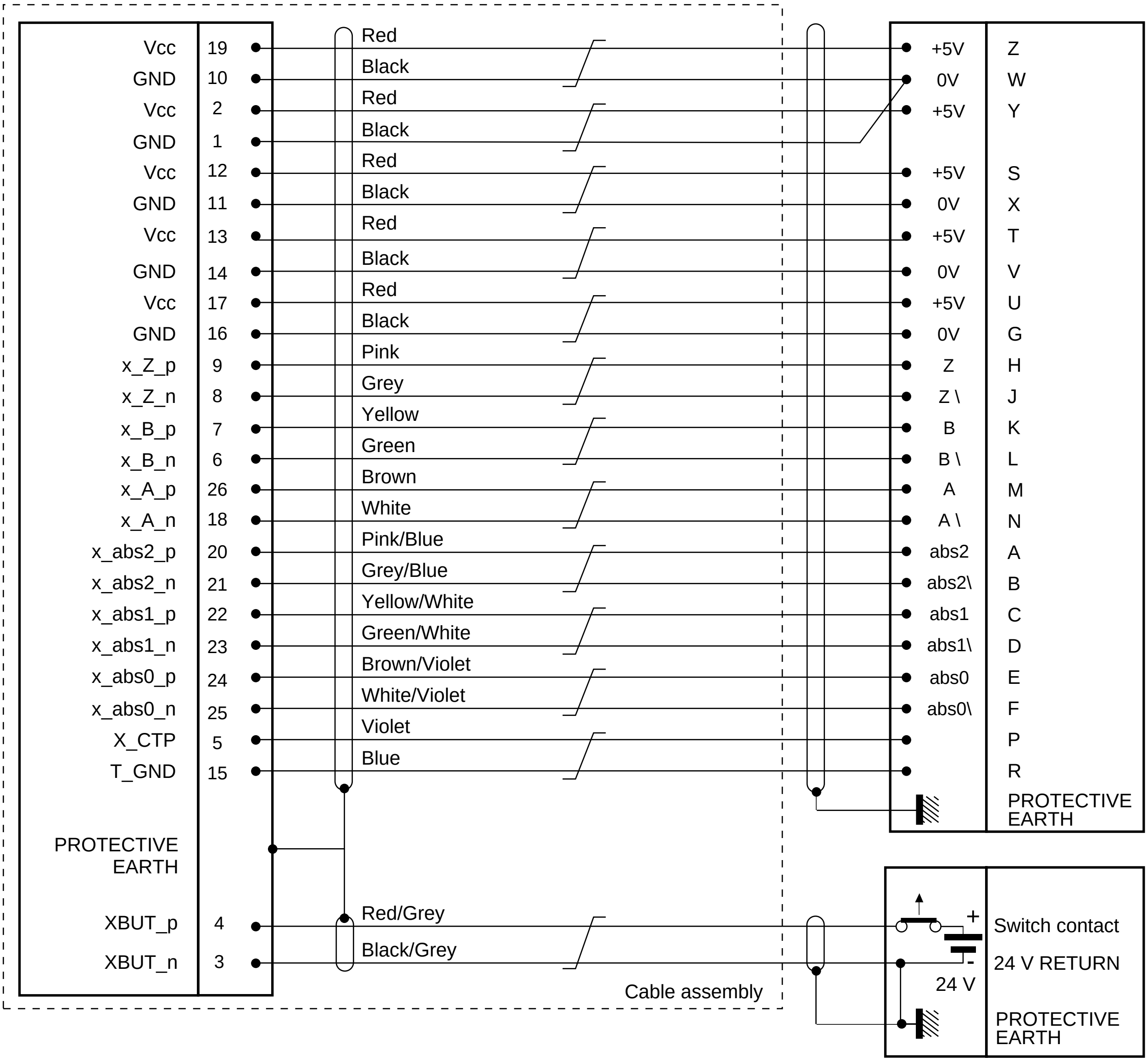


3.4 Measurement Cable Wiring Diagrams

CAUTION

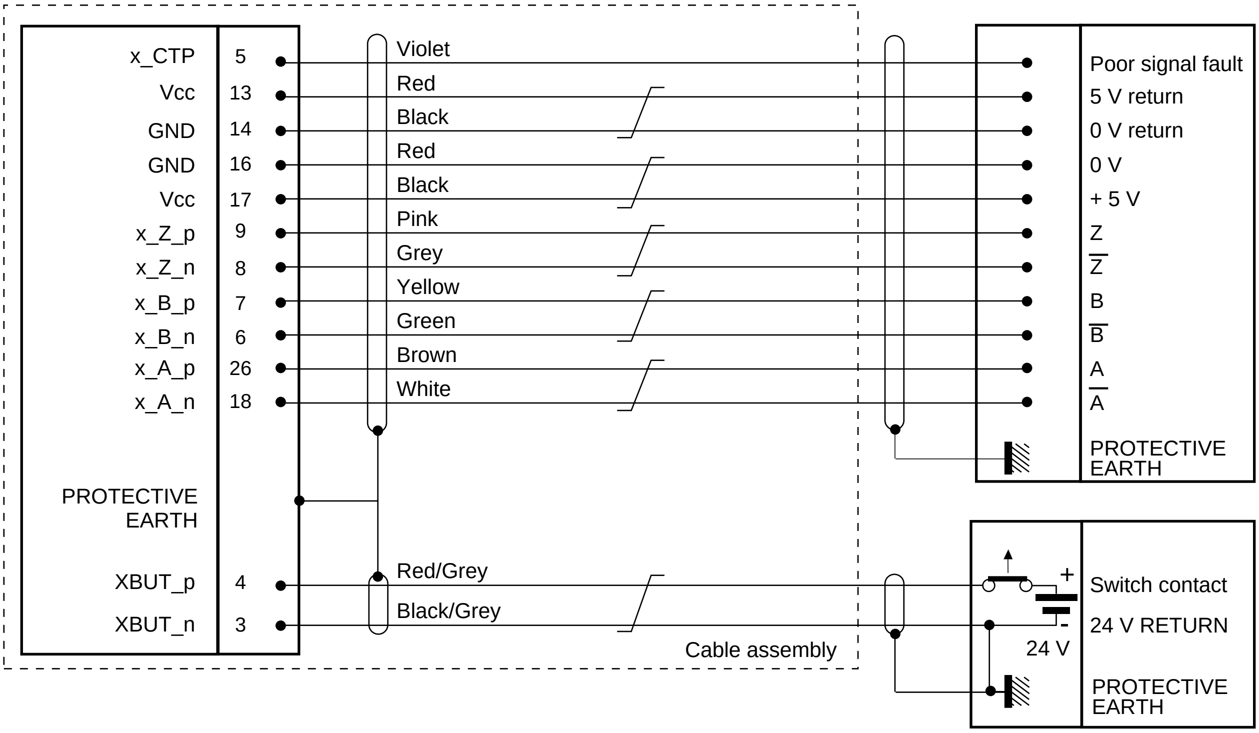
For the wiring instructions, refer to the Installation and Commissioning Manual.
When the switch cable is not used, connect the shielding and two connectors to the protective earth (see Sec. 2.2).

3.4.1 Motor Sensor - QVN Connecting Cable

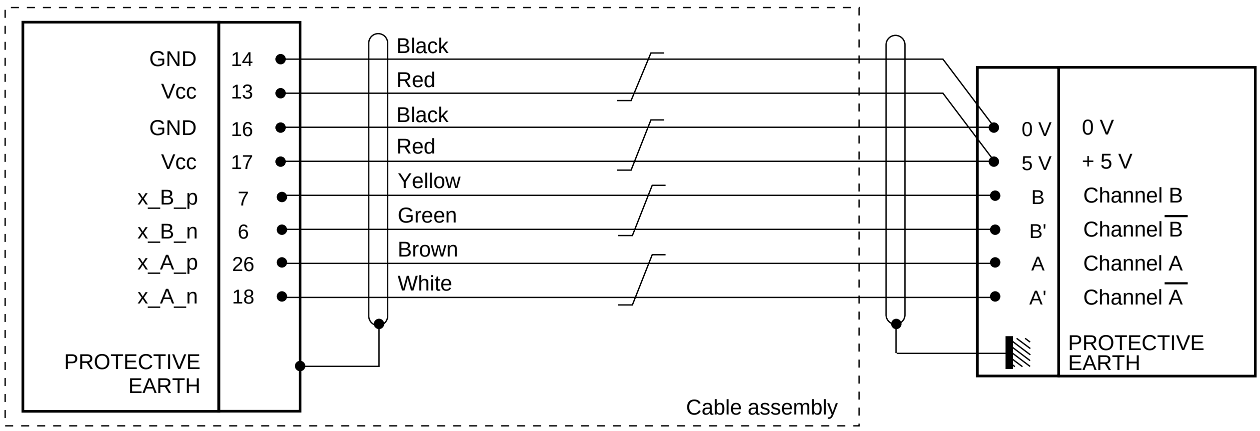


REMARK *If there is an additional sensor on the axis, the switch cable is not connected (pins 3 and 4).*

3.4.2 Encoder or Rule - QVN Connecting Cable



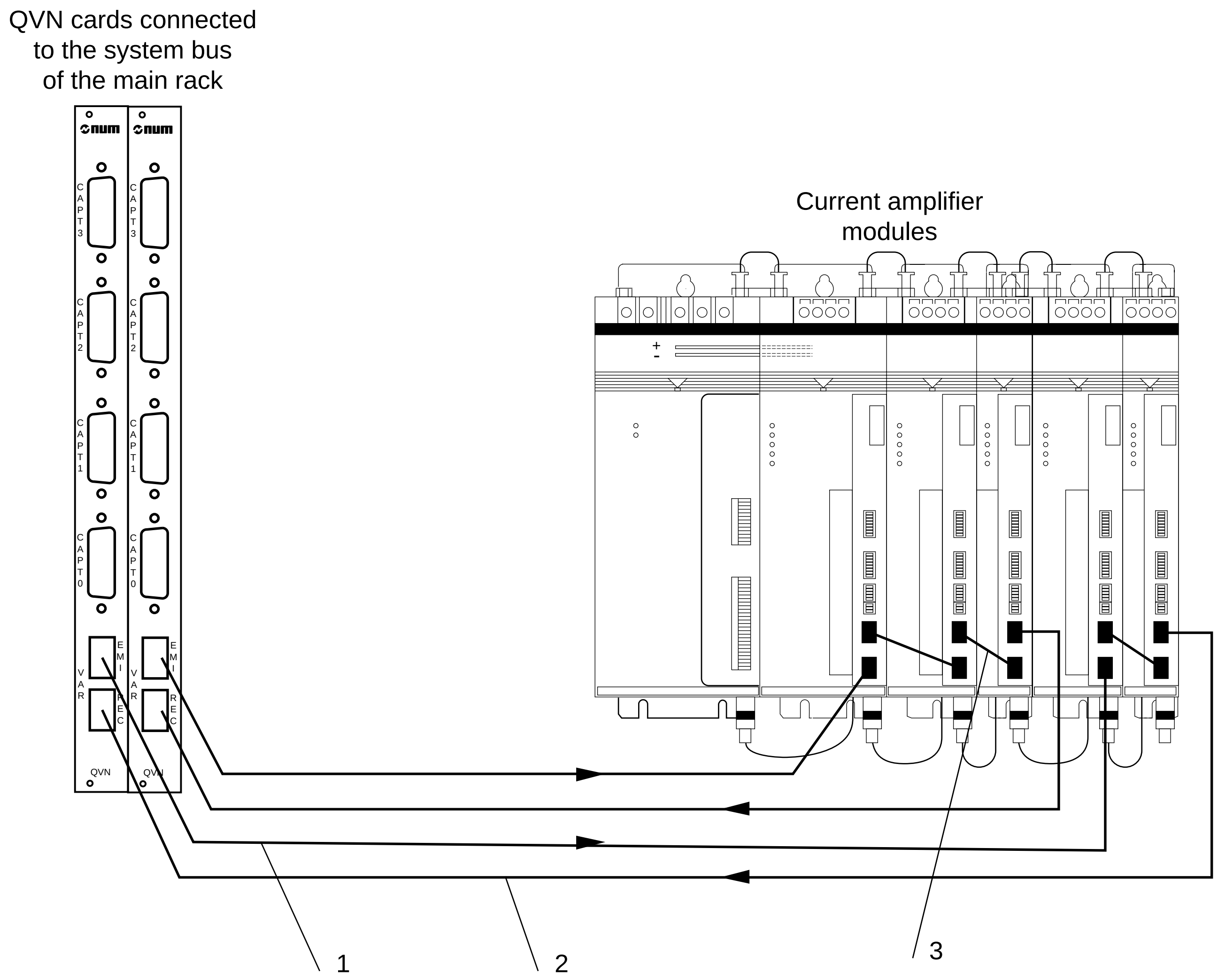
3.4.3 Handwheel - QVN Connecting Cable



REMARK *The switch cable is never connected (pins 3 and 4).*

3.5 Connection in Fibre-Optic Ring

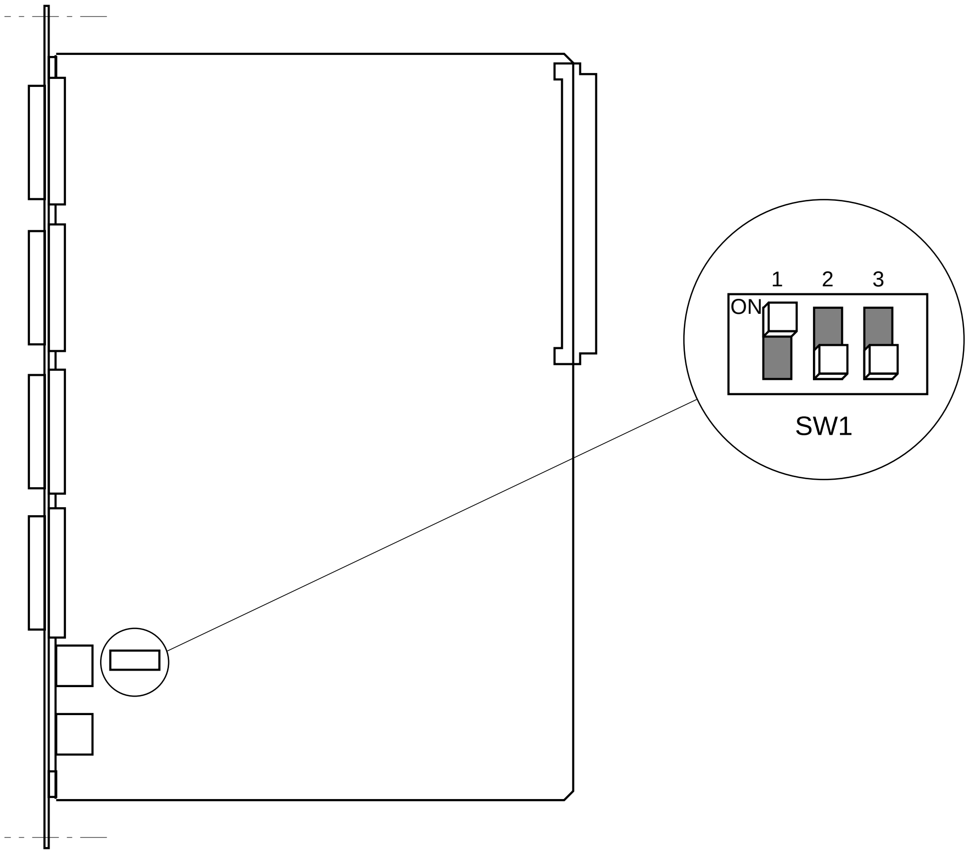
The fibre-optic bus of the QVN card forms a ring with a number of strands.

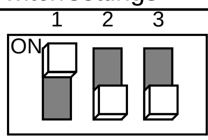
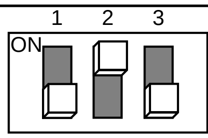
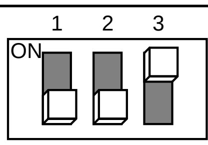


1 - Connection of the transmitter of a QVN card to the receiver of an amplifier (see Sec. 3.6.1: Power control)
2 - Connection of the transmitter of an amplifier to the receiver of a QVN card (see Sec. 3.6.2: Power control)
3 - Connections between amplifiers - length 0.25 m (see Sec. 3.6.2: Power control)

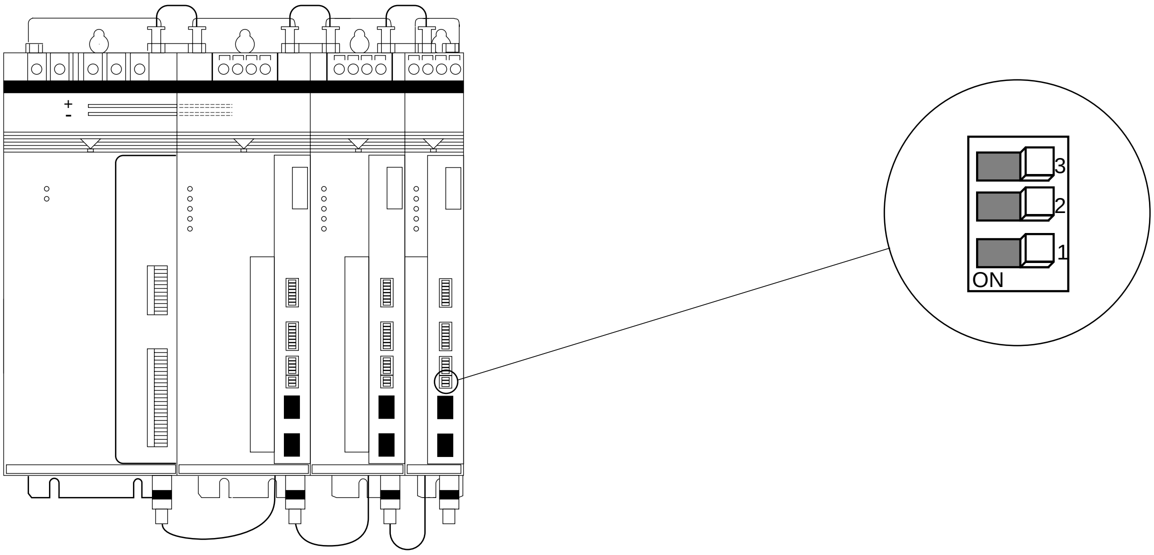
3.6 Transmit Power Control

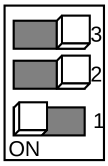
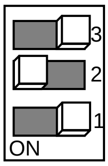
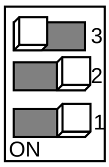
3.6.1 Control on QVN Card



Transmit fibre-optic cable length	Switch settings
0.20 m - 1 m	
5 m - 10 m - 15 m	
20 m - 30 m	

3.6.2 Setting on the Current Amplifier

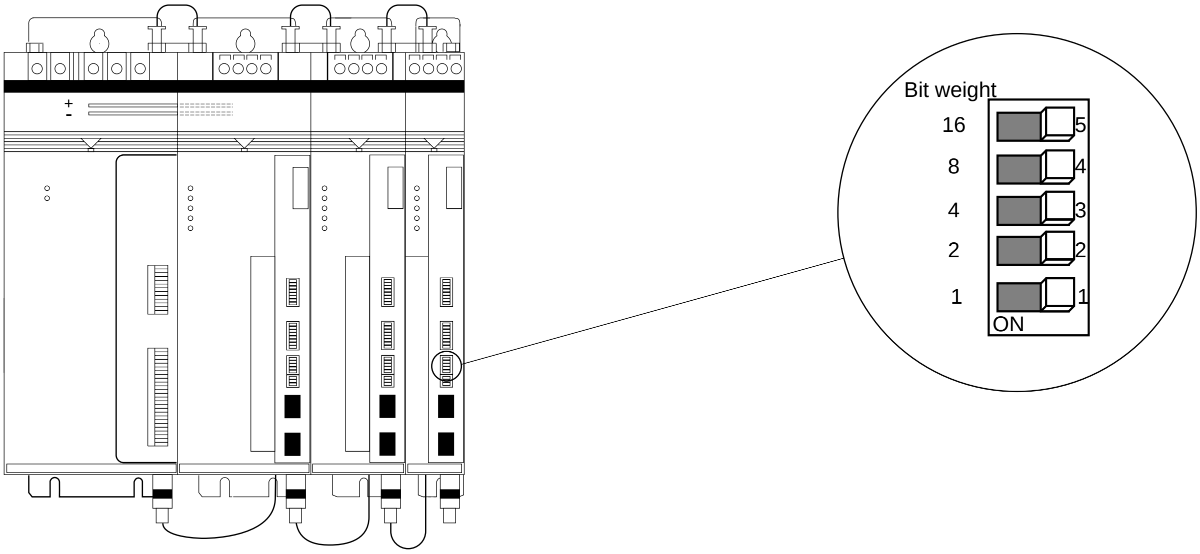


Transmit fibre-optic cable length	Switch settings
0.25 m - 1 m	
5 m - 10 m - 15 m	
20 m - 30 m	

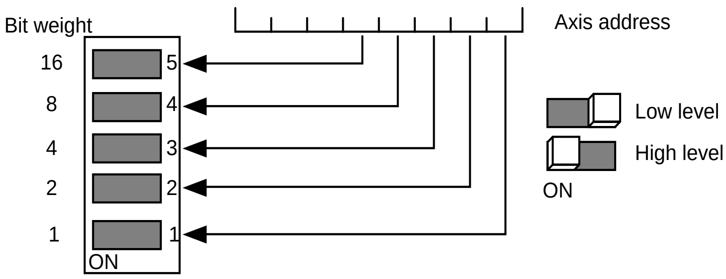
REMARK *The connections between amplifiers use 0.25 m long optical fibres.*

3.7 Setting of the Address Switch on the Serial Bus

The address of each axis must be encoded on the current amplifier:



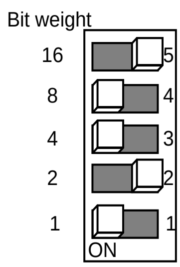
The binary code of the address set in parameter P71 for each axis is reproduced (see Sec. 5.4). The switch is set to ON for a high level and to OFF for a low level.



Example

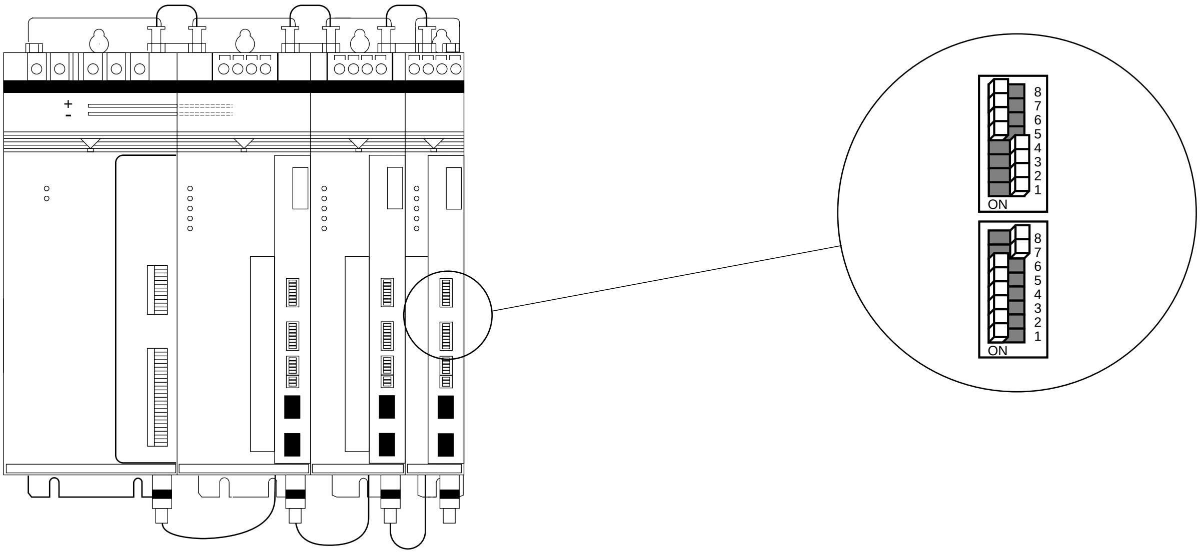
The binary code for the axis at address $0D is: | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |

The switches are coded as follows:



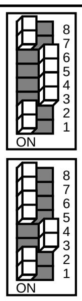
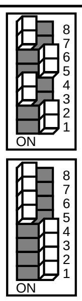
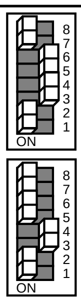
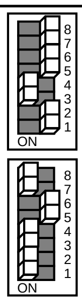
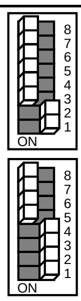
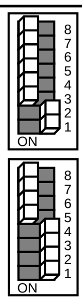
3.8 Setting a Motor/Servo-Drive Association

A motor is associated with a servo-drive by a switch array (see table below) on the current amplifier:

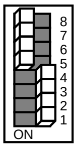
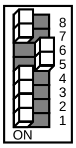
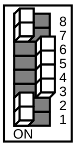
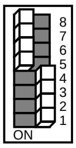
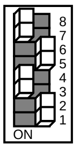
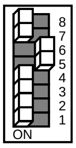
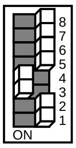
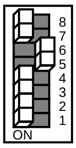
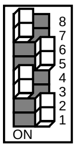
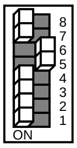
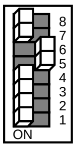
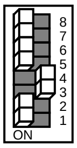
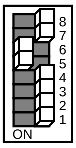
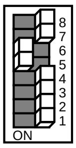
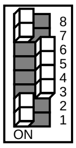
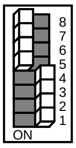


REMARK *The switches must always be set in pairs.*

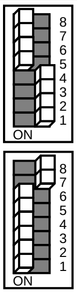
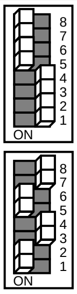
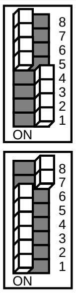
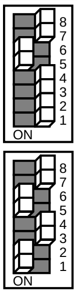
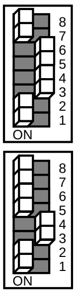
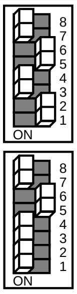
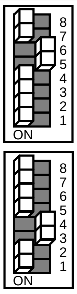
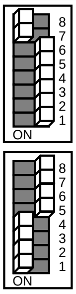
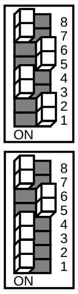
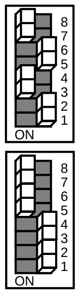
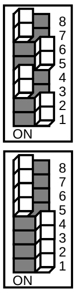
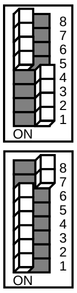
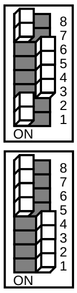
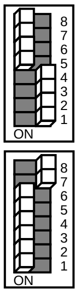
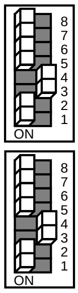
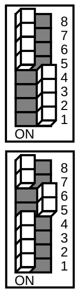
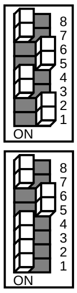
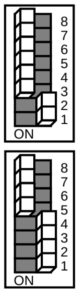
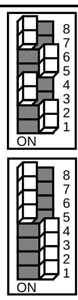
3.8.1 BMH075 Motor

Servo-drive \ Motor BMH075	1N	1V	2N	2V	4N
7A					
14A					

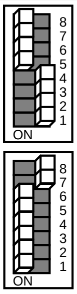
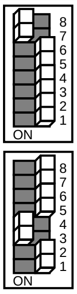
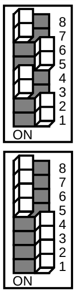
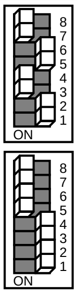
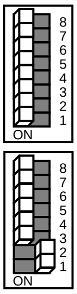
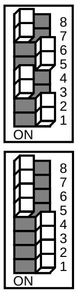
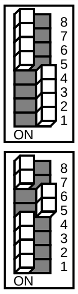
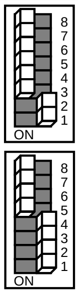
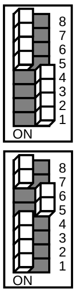
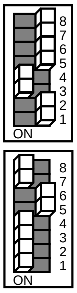
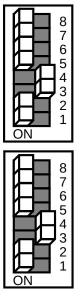
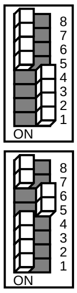
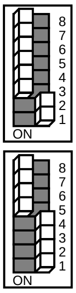
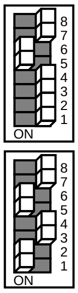
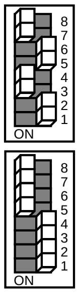
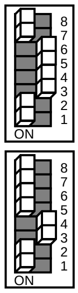
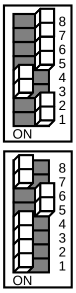
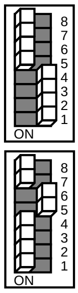
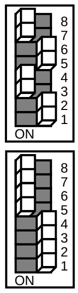
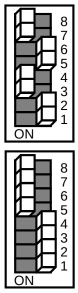
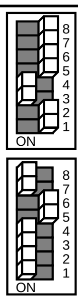
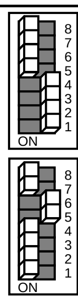
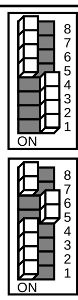
3.8.2 BMH095 Motor

Servo-drive \ Motor BMH095	2N	2V	3N	3V	5N
14A	 				
21A		 	 		 
34A		 		 	 
50A				 	

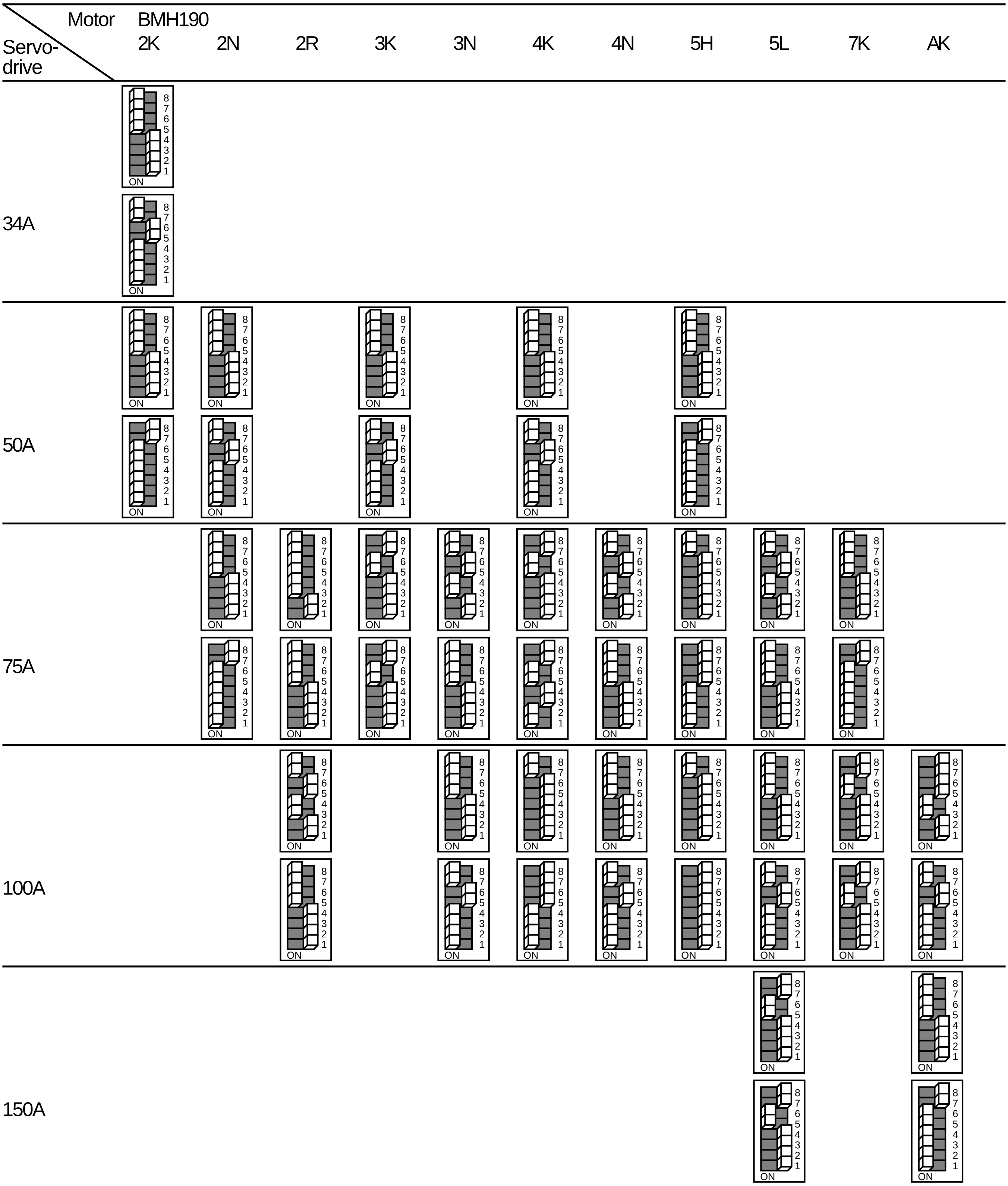
3.8.3 BMH115 Motor

Servo-drive \ Motor BMH115	2N	2V	3K	3N	3V	4K	4N	4V	6N
21A									
34A									
50A									
75A									
100A									

3.8.4 BMH142 Motor

Servo-drive \ Motor BMH142	2K	2N	2R	3K	3N	3R	4K	4N	4R	7N
21A										
34A										
50A										
75A										
100A										

3.8.5 BMH190 Motor



4 Safecty Device Setting and Use

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4

4.1 Messages Displayed at Power ON

When Loading QVN Software

The message "Loading QVN cards" is systematically displayed if a QVN card is present in the rack.

If an error occurs during loading, the message "Error in loading QVN cards" is displayed. If this message is displayed, contact NUM Customer Service.

Configuration Errors

Message	Cause
ERROR: ILLEGAL FEEDBACK NUMBER	A sensor number is outside the values authorised (00, 01, ..., 31, FF) in P70 or P71
ERROR: MULTI-DECLARED FEEDBACK EITHER CONNECTED TO QVN CARD OR DECLARED FICTITIOUS	A sensor number is declared several times in P70 (words N0 to N7 or word N8)
ERROR: MULTI-DECLARED FEEDBACK CONNECTED TO QVN CARD AND DECLARED FICTITIOUS	A sensor number is declared in P70 in the list of sensors connected to the QVN card (words N0 to N7) and in the list of fictitious sensors (word N8)
ERROR: FEEDBACK DETECTED ON ANALOGUE AXIS CARD AND ALSO DECLARED CONNECTED TO QVN CARD	A sensor number is declared connected to a QVN card in P70 (words N0 to N7) and is detected on an analogue axis card
ERROR: FEEDBACK DETECT. ON ANALOGUE AXIS CARD AND DECL. FICTIT.	A sensor number as declared fictitious in P70 (word N8) is detected on an analogue axis card
ERROR: MORE THAN ONE DRIVE HAS THE SAME ADDRESS *REMARK This error is not detected when the servo-drives are connected to the same fibre-optic serial bus, but in this case, no drive is detected, which generates another error message*	Several axis drives have the same address
ERROR: QVN SPINDLE VELOCITY FEEDBACK NOT FOUND OR ALREADY ASSIGNED	- A speed and position sensor number for a QVN spindle declared in P71 is not declared as connected to the QVN card in P70 (words N0 to N7) - A speed sensor number of a QVN spindle declared in P71 is not declared as connected to the QVN card in P70 or is assigned by priority to a handwheel or an analogue spindle
ERROR: QVN VELOCITY FEEDBACK DECLARED ON MORE THAN ONE SPINDLE	A sensor number is declared as a speed sensor on several QVN spindles in P71
ERROR: QVN SPINDLE POSITION FEEDBACK NOT FOUND OR ALREADY ASSIGNED	A position sensor number for a QVN spindle declared in P71 is not declared as connected to a QVN card in P70 and was not detected on an analogue axis card or is assigned by priority to an analogue spindle
ERROR: VELOCITY AND POSITION FEEDBACK DECLARED ON MORE THAN ONE QVN SPINDLE	A sensor number is declared as a speed sensor and a speed and position sensor on several QVN spindles in P71
ERROR: MISSING QVN DECLARED SPINDLE	The list of QVN spindles declared in P71 does not match the list of QVN spindles effectively recognised

Message	Cause
ERROR: QVN AXIS VELOCITY FEEDBACK NOT FOUND OR ALREADY ASSIGNED	- A speed and position sensor number of a QVN axis declared in P71 is not declared as connected to the QVN card in P70 (words N0 to N7 and word N8) - A speed sensor number of a QVN axis declared in P71 is not declared as connected to the QVN card in P70 (words N0 to N7) or is assigned by priority to a handwheel or an analogue spindle
ERROR: VELOCITY FEEDBACK DECLARED ON MORE THAN ONE QVN AXIS	A sensor number is declared as a speed sensor on several QVN axes in P71
ERROR: SEVERAL QVN AXES LINKED TO A QVN SPINDLE	Several QVN axes are associated with the same QVN spindle in P71
ERROR: IMPOSSIBLE TO LINK A QVN SPINDLE TO A QVN AXIS WITH FICTITIOUS FEEDBACK	A QVN axis with a fictitious sensor is associated with a QVN spindle with an additional sensor
ERROR: QVN AXIS POSITION FEEDBACK NOT FOUND OR ALREADY ASSIGNED	A position sensor number of a QVN axis declared in P71 is not declared as connected to the QVN card in P70 and was not detected on the analogue axis card
ERROR: VELOCITY AND POSITION FEEDBACK DECLARED ON MORE THAN ONE QVN AXIS	A sensor number is declared as a speed sensor and a speed and position sensor on several QVN axes in P71
ERROR: DUMMY FEEDBACK NOT USED	One or more sensors declared as fictitious in P70 (word N8) are not used
ERROR: MISMATCH BETWEEN THE DRIVES PRESENT AND THE QVN DECLARED AXES	The list of axis drives detected does not match the list of axes declared as QVN
ERROR: MISSING QVN DECLARED AXIS	The list of QVN axes declared in P71 does not match the list of recognised QVN axes
ERROR: MISSING QVN MEASURING ONLY AXIS	The list of axes declared as measured only by QVN does not match the real list of measured-only QVN axes
ERROR: ILLEGAL QVN AXIS OR SPINDLE COUPLING DECLARATION	Error in declaration in P85
ERROR: MISSING QVN SLAVED AXIS OR SPINDLE	A slave declared in P85 is not found
ERROR: UNRECOGNISED SIZE OF DRIVE	The size code read in a drive is unknown, which leads to non recognition of the corresponding QVN application

Clearing the Messages

When one these messages occurs:

Acknowledge the message.

☞ Y ⟵

The "PROSV" fixed field is displayed (blocking of modes and E_CNPRET = 0).

Check the configuration of the system axes.

Correctly set the parameters involved using SETTool or utility 5.

Reset the system.

4.2 Fault Detection and Processing of Safety Devices

4.2.1 Faults

The following components are capable detecting faults:
- Power supply module,
- Current amplifier module,
- QVN card (digital drive),
- Motor,
- Sensor.

4.2.1.1 Faults Detected by the Power Supply Module

Fault	Description	Probable causes
Undervoltage	The voltage level on the DC bus is below the minimum threshold	Line voltage out of tolerance. Line power isolating switch open.
Overvoltage	The voltage level on the DC bus is above the maximum threshold	Braking module faulty. Line voltage out of tolerance.
Earth fault	The current is not balanced between the two branches of the DC bus	Earth leakage (motor phase, etc.).
Resistor temperature	The thermal switch of the braking resistor or power supply module heat sink is open	Braking module faulty. Resistor rating.

REMARK *These faults are transmitted simultaneously to all the modules in the load circuit of the power supply, which all indicate the same fault to the QVN card.*

4.2.1.2 Faults Detected by the Current Amplifier Module

Fault	Description	Probable causes
Heat sink temperature	The thermal switch on the heat sink is open	rms current > amplifier Ip
Power control (monitor power supply)	Detection of an axis drive auxiliary power supply failure	
Short-circuit	Short-circuit between phases or on the DC bus	The fault may be internal or external to the module.
Serial bus	Transmission error on the serial bus between the QVN card and an axis drive	Bus not connected or open-circuited. SBC component faulty.
Overcurrent	Overcurrent detected in the axis drive	Short-circuit on a phase causing a measurement current above 1.5 x peak current.

4.2.1.3 Faults Detected by the QVN Card

Fault	Description	Probable causes
Complementarity	Faulty complementarity on one of the channels	Sensor built into the motor. Connecting cable.
Overspeed	Overspeed detected (The detection threshold is set at 1.18 x max. speed specified in parameter P73)	
Overcurrent (overtorque)	Current draw greater than $2^{1/2}/3$ x peak current detected for too long (Detection threshold = Peak current x 2 s)	Rotor stuck.
Feedback loss	With sinusoidal feedback, the electrical angle supplied by the incremental channels from the rotor position is no longer consistent with the electrical angle supplied by the absolute channels (the fault detection threshold is between 5 and 35 degrees electrical)	Sensor built into the motor. Connecting cable.
Drive runaway	The axis drive power transistor control is locked	

4.2.1.4 Faults Detected by a Sensor

Fault	Description	Probable causes
Noisy signal	Faulty read of Faulty read of the internal optical signals of the sensor	Sensor faulty. Connecting cables.
Code sur voies absolues (Code on absolute channels)	A code never used was read on one of the absolute channels of the speed sensor	

4.2.1.5 Faults Detected by the Motor

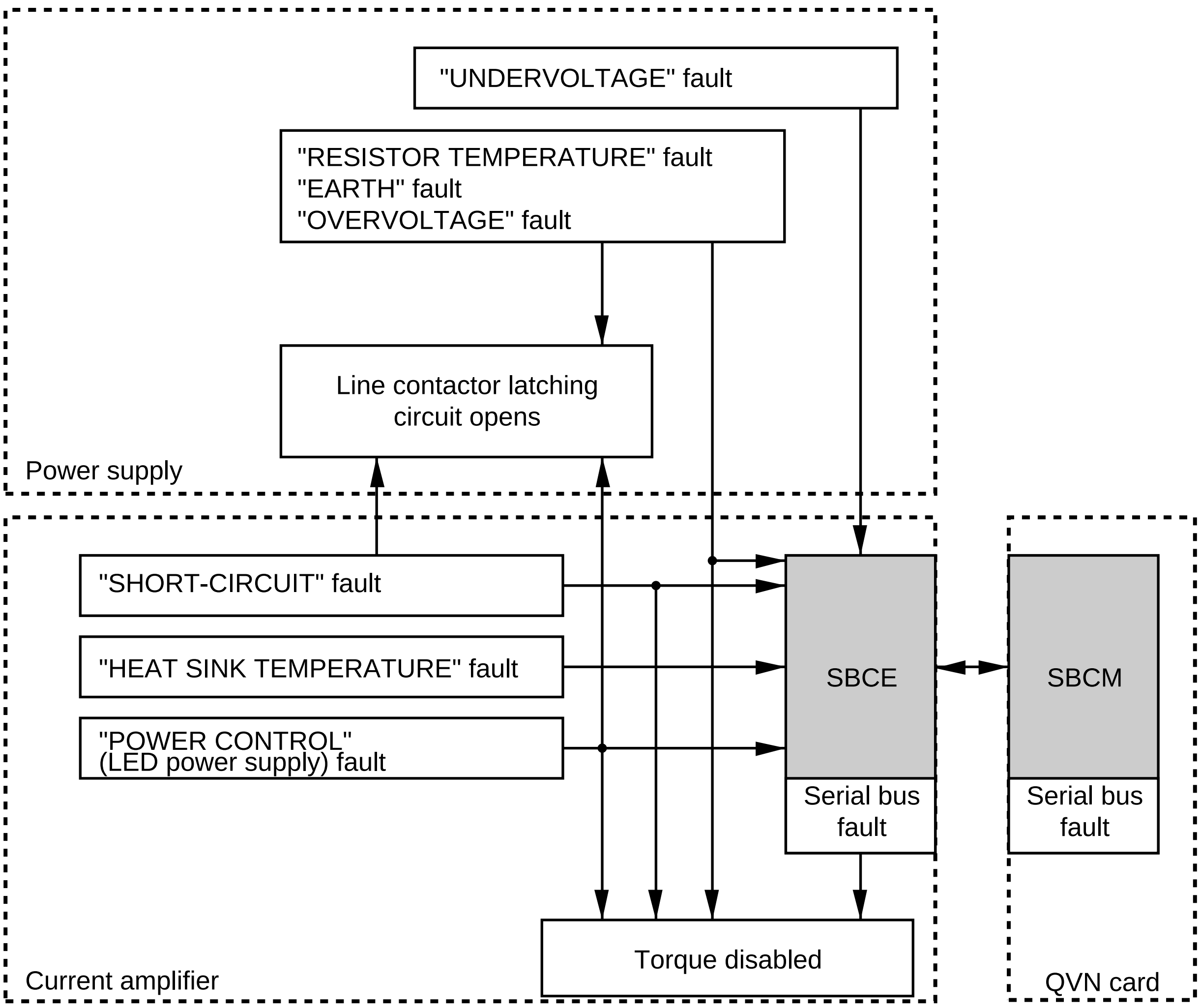
Fault	Description	Probable causes
Motor temperautre	The internal thermal switch of the motor is open	rms current in the motor > motor rated current.

4.2.2 Axis Safety Device Processing

Three component process the safety devices:
- Power supply module,
- Current amplifier module,
- QVN card (digital drive).

4.2.2.1 Hardware Processing in the Amplifier and Power Supply Modules

The processing performed in the power supply module and current amplifier module is illustrated in the diagram below. All the module faults are transmitted to the QVN card via the SBC interface of the fibre-optic bus.



4.2.2.2 Software Processing by QVN

After detection, the software processing performed by the QVN card activates one of the three following operating modes on the drive:
- Free-wheeling,
- Braking at maximum torque,
- Gradual braking.

Free-Wheeling

The motor brake is released. The axis is stopped by mechanical friction. Braking current is inhibited in the current amplifier and the internal current reference in the QVN card is forced low.

Braking at Maximum Torque

The axis is electrically braked by applying the maximum motor torque until the axis stops completely. This braking (the fastest possible) is obtained by forcing the speed reference low. The CNC resets the CNC-ready (E_CNPRE+) bit. The PLC then opens the line contactor on the amplifier power supply modules (the contactor may already have been opened by the power supply module itself: see the internal module processing diagram).

Gradual Braking

The CNC controls deceleration on all the axes according to a ramp. Deceleration is carried out immediately.

4.2.2.3 Internal Fault Processing

Fault	Internal processing
Undervoltage	Braking at maximum torque on all CNC axes. Fault LED lit for all the axes that reported the fault.
Overvoltage	Same as "Undervoltage".
Earth fault	Same as "Undervoltage".
Resistor temperature	Same as "Undervoltage".
Heat sink temperature	Gradual braking. Fault LED lit on the amplifier considered. PLC variable E_CNPRET = 0.
Power control (Monitor power supply)	Free-wheeling on the axis considered. Braking at maximum torque on all the other CNC axes. Fault LED lit on the amplifier considered.
Short-circuit	Same as "Power control" (Monitor power supply).
Serial link from QVN card to axes	Free-wheeling on the axis of the QVN card considered. Braking at maximum torque on all the other CNC axes.
Complementarity	Free-wheeling on the axis considered. Braking at maximum torque on all the other CNC axes.
Overspeed	Same as "Sensor channel complementarity".
Following error	Braking at maximum torque on all CNC axes.
Overcurrent	Free-wheeling on the axis considered. Braking at maximum torque on all the other CNC axes.
Feedback loss	Same as "Overtorque".
Communication	Free-wheeling on the axis considered.

Fault	Internal processing
Amplifier serial bus	Amplifier serial bus fault LED lit.
Noisy signal	Free-wheeling on the axis considered. Braking at maximum torque on all the other CNC axes.
Motor temperature	Gradual braking. PLC variable E_CNPRET = 0.
QVN card general failure	Free-wheeling on the axes of the QVN card considered. Braking at maximum torque on all the other CNC axes.
QVN processor	Free-wheeling on the axes of the QVN card considered. Braking at maximum torque on all the other CNC axes.

4.3 Fault Diagnostic

Fault diagnosis is provided on two levels:
- Drive status and failure origin displayed on the CNC,
- Module status displayed on the LEDs on the front of the modules.

Error Message

If an error is detected on a QVN card or on an axis controlled by a QVN card, error 245, "Défaut sur asservissement numérique" (error on digital servo-control) is displayed on the "AXIS" or "INFO" page. The field "NC ??" flashes in the CNC status window to indicate the presence of a fault that caused a power cutoff.

The origin of the fault can then be found by accessing the "QVN controlled axis" information pages via the "PLC I/O" page (see Sec. 4.4).

Power Supply Module LEDs

Green Power-on
Green Monitoring voltage on

Current Amplifier Module LEDs

Green Monitoring voltage on
Red Module fault
Green Torque enabled
Green Speed enabled (not used)
Red Serial bus fault

4.4 QVN Information Pages

In the event of a problem at power on or during operation (error 245), the field "NC ??" flashes in the CNC status window. It indicates the presence of a fault that caused a power cutoff.

For each axis processed by a QVN card, the operator can display the information pages describing the faults in natural language.

Browsing Through the Information Pages

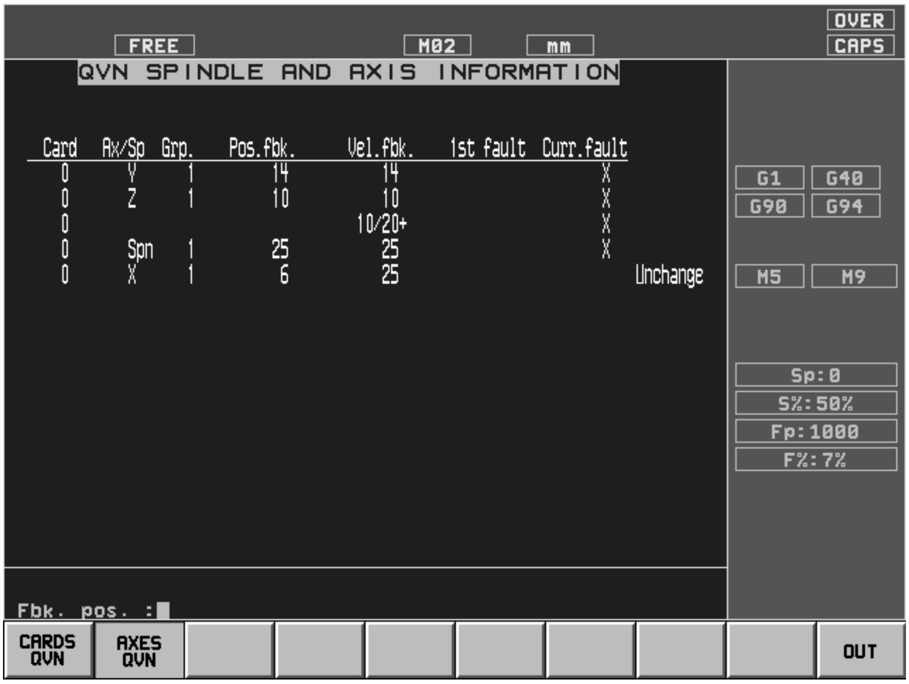
Operation	Command
Go to next page	"PgDown" key
Go to previous page	"PgUp" key
Go to last page	"End" key
Go to first page	"Home" key

Procedure

Select the "CNC COMMUNICATION DISPLAY" page. I/O

Select “QVN INFORMATION”. $ 4

The "QVN SPINDLE AND AXIS INFORMATION" page is displayed:



The "1st fault" field indicates detection of a first fault on a given axis or spindle.

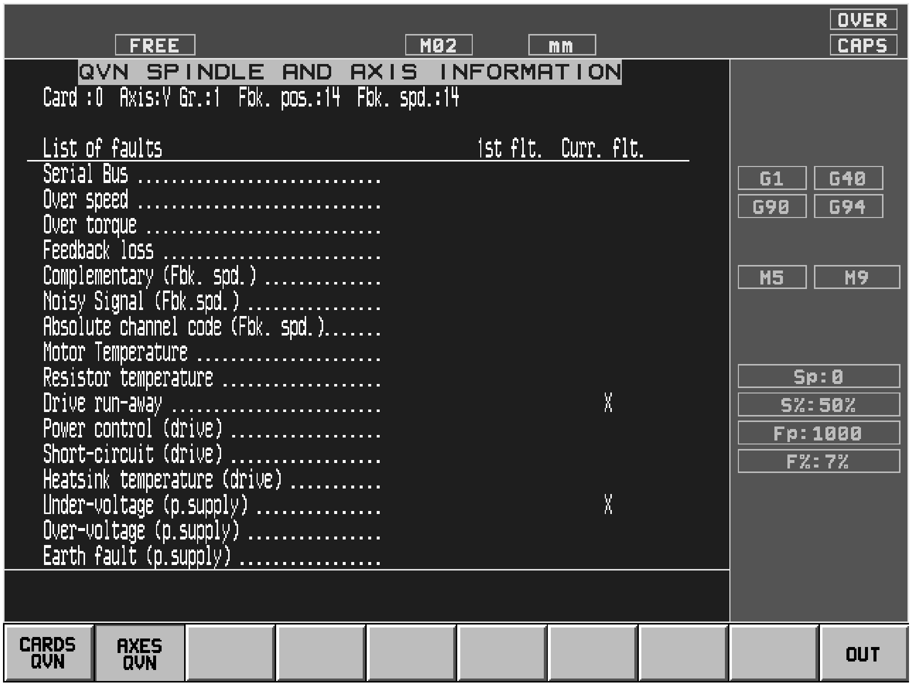
The "Curr. fault" field indicates the presence of faults on a given axis or spindle.

In the example above:
- "10/20+" indicates that "20" is a positive slave of the QVN "10" application ("10/20-" indicates a negative slave),
- The word "Unchange" for a switchful axis/spindle association indicates which of the two (axis or spindle) is not switched.

Data displayed on a position sensor

Enter the axis or spindle position sensor number in the dialogue line.

The page giving detailed information on the axis or spindle is displayed:



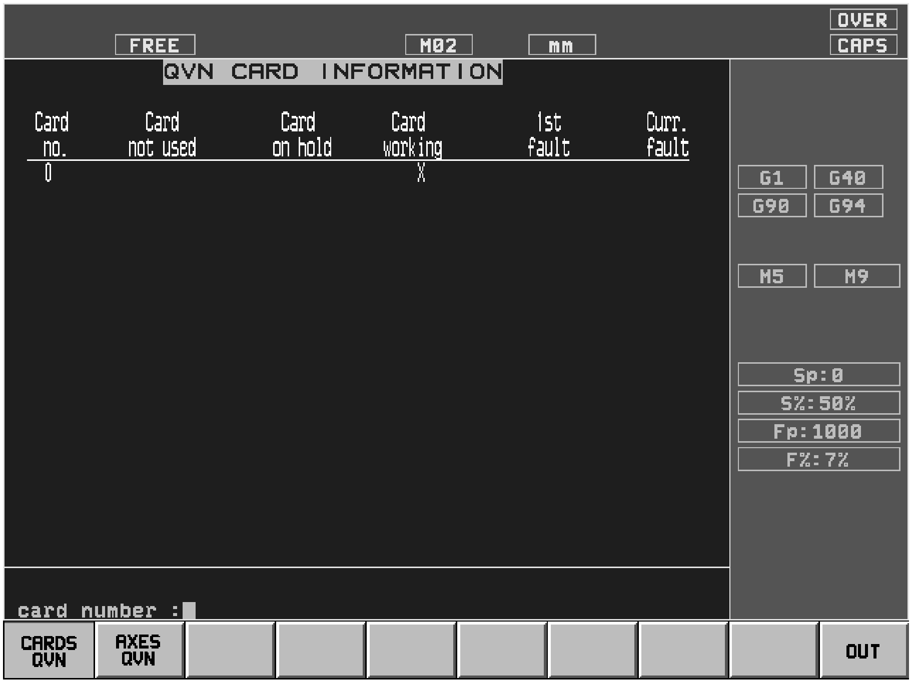
When the axis or spindle is part of a switchable axis/spindle association and is not switched, the word "Unchange" is displayed at the end of the second line.

For details on the fault, see Sec. 4.2.1.

Information on the Cards

Select the general card information page. CARDS QVN

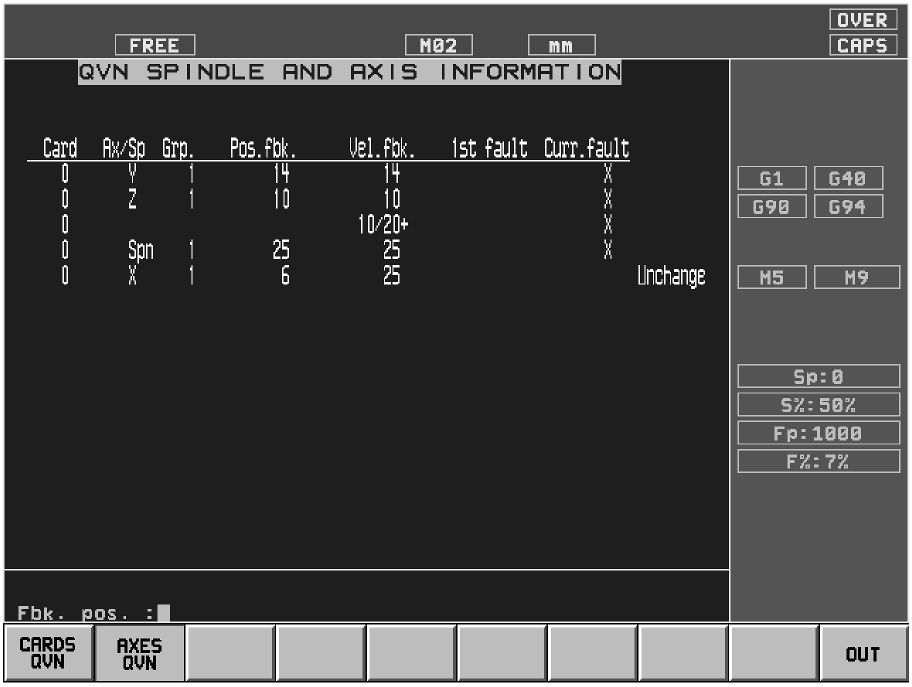
The "QVN CARD INFORMATION" page is displayed:



Information on a QVN card is displayed

Enter the card number in the dialogue line.

The page containing detailed information on a QVN card is displayed:



CAUTION

If the fields "Card on hold" or "Curr. fault" are checked,
contact NUM Customer Service.

Exit from the Procedure

Return to the "CNC COMMUNICATION DISPLAY" page. Out

4.5 Reset After a Fault

After occurrence of a fault:

Analyse the reason for the fault (see Sec. 4.2.1) then proceed to clear it.

After clearing the fault, the reset procedure can be carried out.

Case of "serial bus" and "power control" (monitor power supply) faults

Reset the CNC (by the reset button on the front of the power supply card).

Turn on the drives.

Other faults

Reset the CNC.

Turn on the drives.

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5.26	Complementary Loop Application Frequency	P94	5-36
5.27	Speed Observer - Ratio Kc/j	P116	5-37
5.28	Speed Observer - Gain for Position Estimate	P117	5-37
5.29	Speed Observer - Gain for Speed Estimate	P118	5-37
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5.31	Speed Observer - Supervision Device	P120	5-38
5.32	Vibration Elimination When Stopped by Processing of the Speed Measurement	P121	5-39
5.33	Vibration Elimination When Stopped by Clipping of the Proportional Gain	P122	5-39

5.1 General

5.1.1 Control of an Axis or Spindle by QVN Card

A QVN card can be used to control one or more QVN axes and spindles.

The possible sensor configurations include:
- Axis or spindle measured with the motor sensor,
- Axis or spindle measured with an additional position sensor.

The configuration with unmeasured QVN axis or spindle is excluded, since there is always a sensor (motor sensor).

The additional position sensor can be connected to:
- The QVN card to which the speed sensor is connected,
- A different QVN card from the one to which the speed sensor is connected,
- An analogue axis card.

5.1.2 Declaring a QVN Axis

A QVN axis is declared in parameters:
- P2 for the general axis declaration,
- P3 for the slaved axis declaration,
- P70 for the speed (or speed and position) sensors and any additional position sensors included in the configuration,
- P71 to associate a speed sensor with a position sensor.

5.1.3 Declaring a QVN Spindle

A QVN spindle is declared in parameters:
- P6 for the general spindle declaration,
- P70 for the speed (or speed and position) sensors and any additional position sensors included in the configuration,
- P71 (words N24 to N27) to associate a speed sensor with a position sensor.

REMARK *A spindle sensor can also be declared in P2 in order to continuously monitor its presence.*

5.1.4 Speed Loop Parameters

The parameters for setting the speed loop apply to the QVN axes (and also to the QVN spindles for software at index K or above):
- P72 defines the direction of rotation of the motor,
- P73 defines the maximum motor rpm,
- P74 sets the proportional action coefficient of the speed loop corrector,
- P75 sets the integral action cut-off pulse of the speed loop corrector,
- P76 averages the speed measurement,
- P77 filters the speed measurement,
- P78 filters the torque reference.

Contrary to a QVN axis, for a QVN spindle, the word number identifying the location of a parameter for the speed loop is determined by the spindle position sensor address instead of the speed sensor address:
- For parameter P72, spindle addresses 24 to 27 correspond to bits 0 to 3 of word N01,
- For parameters P73, P74, P75, P76, P77, P78, spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

5.1.5 Associating a Switchable QVN Spindle and Axis

QVN spindle/QVN axis switching is possible with CNC software index K and above.

5.1.5.1 General

The purpose is to use the same assembly including {current servo-drive - motor - motor sensor} alternately as QVN spindle and as QVN axis.

The principle consists of associating a QVN axis with a QVN spindle.

The QVN spindle/QVN axis association is specified by a parameter. It is recognised and determined at initialisation and cannot be modified during operation.

There are at most 4 possible associations (as many as there are QVN spindles). Only one QVN axis can be associated with a QVN spindle.

The configuration after initialisation is the QVN spindle configuration.

The switch from the QVN spindle configuration to QVN axis configuration and vice versa is made during operation by an external parameter.

5.1.5.2 Associating a QVN Axis with a QVN Spindle

There are 4 possible configurations for a QVN spindle/QVN axis association:

- QVN spindle and QVN axis whose speed and position are measured by the same motor sensor. In this case, the axis sensor is physically the same as the spindle sensor, but must be declared at a separate address (fictitious sensor) in word N8 of parameter P70,
- QVN spindle whose speed and position are measured by the motor sensor and QVN axis whose position is measured by an additional sensor,
- QVN spindle whose speed is measured by the motor sensor and whose position is measured by an additional sensor and QVN axis whose speed and position are measured by the motor sensor,
- QVN spindle and QVN axis whose speed is measured by the motor sensor and whose position is measured by additional sensors.

5.1.5.3 Speed Loop Operational Parameters

Two parameter tables are available in the QVN card, one for operation as QVN spindle and the other for operation as QVN axis.

For a QVN spindle/QVN axis association, a switch in the operating configuration causes a switch of the parameter table used.

5.1.5.4 QVN Spindle/QVN Axis Switching

The switch is made by programming external parameter E942xx = yy: position sensor @yy is switched to servo-drive @xx.

REMARK *In the case of a QVN spindle and QVN axis whose speed and position are measured by the same motor sensor, for the switch to the QVN axis, @xx is the address of the fictitious axis sensor (in this case only, the speed sensor address is different from the servo-drive address).*

Examples

QVN spindle and QVN axis whose speed and position are measured by the same motor sensor

Spindle speed sensor @24, spindle position sensor @24

Current servo-drive @24

Axis speed sensor @00, axis position sensor @00 (fictitious sensor)

Switch from QVN spindle to QVN axis: E94200 = 00

Switch from QVN axis to QVN spindle: E94224 = 24

QVN spindle and QVN axis whose speed is measured by the motor sensor and whose position is measured by additional sensors

Speed sensor @01

Current servo-drive @01

Spindle position sensor @24

Axis position sensor @00

Switch from QVN spindle to QVN axis: E94201 = 00

Switch from QVN axis to QVN spindle: E94201 = 24

Homing

The switch to a configuration without additional position sensor causes a loss of homing:
- For a QVN spindle, the homing request is activated automatically,
- For a QVN axis, homing must be requested.

The switch to a configuration with additional position sensor causes a feedback reset request to ensure operation in trapezoid mode. For a configuration with additional sensor, it is mandatory to leave the origin switch open to allow detection of the sensor zero pulse and thereby always enable reset, when required, of the rotor position measurement.

5.1.6 Torque Master/Slave Function

5.1.6.1 General

This function is available for a QVN axis or for a non-switchable QVN spindle with the CNC software at index K or above.

The principle consists of associating one or more torque slaves with a master QVN application. Torque control of the slaves is provided by the torque reference of the master QVN application.

The characteristics are as follows:
- The master is a QVN axis or a non-switchable QVN spindle,
- The master and the associated slaves are all processed by the same QVN card (speed sensors and servo-drives connected to the same QVN card),
- A maximum number of three slaves can be associated with a master QVN application.

5.1.6.2 Declaring a Torque Slave QVN Application

Where i is the slave QVN application to be declared (i: speed sensor number):
- Sensor i is not declared in P2 nor in P71,
- Sensor i is declared in P70,
- The current servo-drive address is i,
- The application is associated with a master QVN application j (j: speed sensor number) in P85.

5.1.6.3 Parameters

The parameters associated with torque slave QVN application i (i: speed sensor number) are:
- Direction of rotation of the slave with respect to that of the master (parameter P86),
- Maximum motor speed (P73, word Ni),
- Static current limiting (P79, word Ni).

The maximum motor speed and static current limiting can be set independently for each of the master and slave QVN applications.

5.1.6.4 Precaution

The speed sensor of a torque slave is managed as an independent speed sensor. For feedback, the switch from trapezoidal operation to sinusoidal operation is made on detection of the first zero pulse after one motor revolution at most, if the origin switch is open.

This means that the origin switch must always be left open for a slave QVN application.

5.1.7 Anti-Pitching

This function is a special case of the torque master/slave function.

It is not available unless the following conditions are satisfied:
- The master QVN application is a QVN axis,
- Only one QVN slave application is associated with the master QVN application,
- The slave QVN application is slaved in the positive direction.

The principle consists of adding a preload current of the same magnitude for the master and slave but of opposite signs for the master and slave to the master and slave current reference.

The preloading current is defined in parameter P87.

5.1.8 Static Current Limiting

The maximum current of each QVN application (axis, spindle, torque slave) can be set by P79.

5.1.9 Sensor Fault Monitoring

For the position and spindle sensors, the poor signal and channel complementarity fault monitoring is determined by parameters P25 and P26 (see "Parameter Manual").

For the speed measurement or speed and position measurement sensors, poor signal and channel complementarity fault monitoring is always forced at initialisation of the CNC independently of parameters P25 and P26.

5.1.9.1 Monitoring a QVN Motor Sensor

With the software in version K or above, word 1 of parameter P25 (see Sec. 5.4) enables or inhibits monitoring of a QVN motor sensor.

5.1.9.2 Consequences of Inhibiting Monitoring of a QVN Motor Sensor

Operation of a QVN application is not enabled unless monitoring of the motor sensor is enabled. That means that when monitoring of the QVN motor sensor is inhibited, the torque on the corresponding QVN application is also inhibited.

In the case of a switchable QVN spindle/QVN axis configuration, inhibiting monitoring of the motor sensor inhibits the torque in both the axis configuration and the spindle configuration. In the particular case where the motor sensor is used as speed and position sensor (in both the axis configuration and spindle configuration), it is the bit defined by the spindle sensor number in P25 N1 that determines whether motor sensor monitoring is enabled or inhibited.

In the case of a torque master/slave configuration:
- Inhibiting motor sensor monitoring on the master QVN application inhibits the torque only on the master QVN application,
- Inhibiting motor sensor monitoring on a slave QVN application inhibits the torque only on the slave QVN application.

5.1.9.3 Modifying Sensor Monitoring During Operation

Monitoring of a sensor can be inhibited or enabled during operation by modifying parameter P25 by a DNC1000 request.

The sensors concerned include:
- Incremental type and rule type position sensors with coded references (mixed and SSI position sensors are excluded),
- Motor sensors for QVN,
- Handwheels.

Modification has the following effects on a motor sensor for QVN:
- Inhibiting sensor monitoring inhibits torque on the QVN application (as defined above),
- Enabling sensor monitoring cancels forced torque inhibiting,
- Inhibiting or enabling sensor monitoring during operation forces trapezoidal mode for feedback.

5.1.9.4 Precaution for Modifying Monitoring of a Position Sensor

For an axis or spindle position sensor, homing on the axis or spindle is required after connecting the sensor.

5.1.9.5 Precaution for Modifying Monitoring of a QVN Motor Sensor

For a motor sensor used for speed measurement, the switch from trapezoidal mode to sinusoidal mode is made after one motor revolution at most after enabling sensor monitoring (in the same way as after initialisation).

For a motor sensor used for speed measurement and for position measurement, homing is required after enabling monitoring to allow the switch from trapezoidal mode to sinusoidal mode (in the same way as after initialisation).

5.2 Miscellaneous Parameters

5.2.1 QVN Sampling period

The QVN sampling period is set in word N1 of parameter P50 (see Sec. 5.4).

5.2.2 Measured, Servo-Controlled and Interpolated Axes

Parameters P2 and P3 include only the list of position measurement or speed and position measurement sensors. For axes controlled by the QDD card with two separate sensors, only the position sensor is declared in P2 and P3 (see Parameter Manual).

5.3 Servo-Control Loop Gain Coefficient

P21

Category	Servo-control
Type 5	Unsigned decimal
No. of words	32

Description

Defines the coefficient used by the CNC to calculate the reference supplied to the servo-drive according to the following error.

Principle

Each word corresponds to the physical address of an axis:
- The value in word N0 is assigned to the axis with physical address 0,
- The value in word N1 is assigned to the axis with physical address 1,
- The value in word N2 is assigned to the axis with physical address 2,
- etc.

The value of each word gives the proportional action coefficient of the servo-drive for the corresponding axis.

KVAR Calculation

For Vmax, we have:

$$\text{Max. speed reference} = \text{KVAR} \times \varepsilon p \text{ max.}$$

The speed reference for a QVN axis is expressed on 18 signed bits, giving the equation for KVAR as a function of the time constant T = 1/Gain:

$$K_{VAR} = (131071 / (V_{max} \times T)) \times k$$

where:
- T : position servo-loop time constant (s),
- V_{max} : maximum axis speed (mm/s or deg/s),
- k : internal measurement coefficient.

Internal measurement	Coefficient k
1/10 mm	100
1/100 mm	10
µm	1
1/10 µm or 1/10000°	0.1
1/100 µm	0.01

5.4 Noisy Signal and Encoder Channel Complementarity Monitoring Declaration

P25

Category	Measurements
Type 6	32-bit hexadecimal
No. of words	1 (2 for index K and above)

Description

Declaration of the axes that can be included in the noisy signal and encoder channel complementarity monitoring as well as the fault filtering value.

Declaration of the QVN motor sensors that can be included in noisy signal and channel complementarity monitoring.

Word N0 is described in the Parameter Manual.

Word N1

Word N1 is available with software index K and above.

The noisy signal and/or QVN motor sensor complementarity monitoring are enabled or inhibited in this word.

The default value of this word is $FFFFFFFF (monitoring of all the QVN motor sensors).

The bit position corresponds to the physical address of the axis.

Monitoring on the QVN motor sensor concerned is inhibited when the bit is a 0 and enabled when the bit is a 1.

Example

Monitoring enabled on the axes with addresses 2, 3 and 7.

Bit 31 … Bit 24	Bit 23 … Bit 16	Bit 15 … Bit 8	Bit 7 … Bit 0
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	1 0 0 0 1 1 0 0

Word N1 of P25 = $0000008C

Word N0	0000008C

5.5 Sampling Period

P50

Category	Miscellaneous
Type 5	Unsigned decimal
No. of words	2

Description

Defines the CNC sampling period and the QVN card sampling period.

Word N0 is described in the Parameter Manual.

Word N1

Defines the sampling period for all the QVN cards present in the CNC rack.

5

Restrictions

The range of authorised values is from 400 µs to 1000 µs in steps of 50 µs. Any value outside this range is limited to 400 µs or 1000 µs.

The ratio between the CNC sampling period (N0) and QVN sampling period (N1) must be an integer.

Failure to comply with one these requirements results in display of one of the following error messages at initialisation and inhibiting of a change of mode:

Sampling period outside the range or step

SAMPLING PERIOD QVN MUST
BE BETWEEN 0.4 ms and 1 ms
BY STEPS OF 0.05 ms

Ratio not an integer

SAMPLING PERIOD MUST BE A
MULTIPLE OF PERIOD QVN AND EQUAL
AT LEAST AT 2 ms FOR AXIS QVN

5.6 Card Mapping

P70

Category	QVN
Type 6	32-bit hexadecimal
No. of words	8 (9 for index K and above)

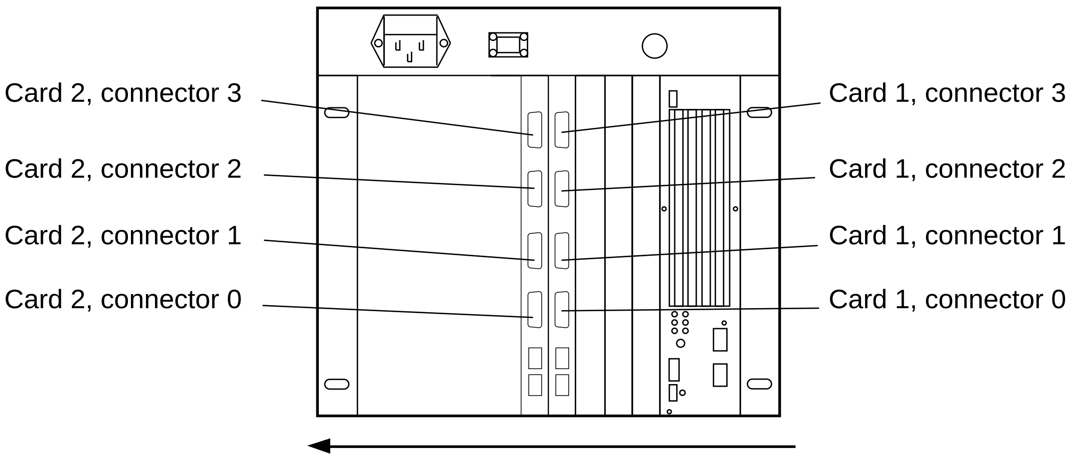
Description

Specifies the physical addresses of the sensors (speed, position, spindles or handwheel) connected to the QVN cards.

Principle

The word position corresponds to that card number in the rack.

From right to left in the rack:
- Word N0 is assigned to the first card encountered,
- Word N1 is assigned to the second card encountered,
- etc.

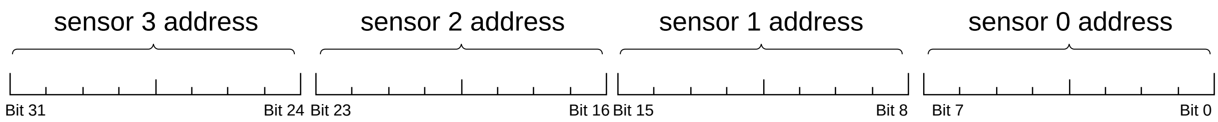


QVN card numbering direction
(0 and 1 on 1060 series 2 rack or 0 to 7 on 1060 series 1 rack)

Card No. in rack	List of words		
Card 1	Word N0		
Card 2	Word N1		
"	"	"	
Card 8	Word N7		
Declaration of fictitious sensors	Word N8		At index K and above

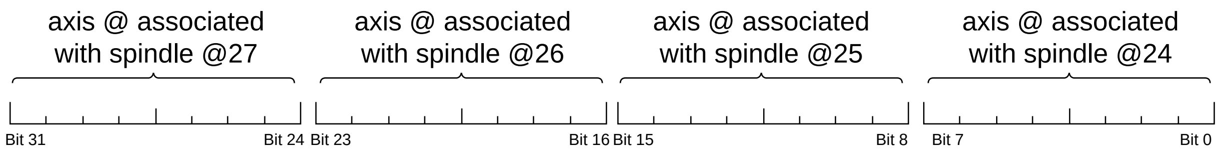
Word Format

Each byte of a word is loaded with a hexadecimal value corresponding to the physical address of the sensor wired to the card connector. The value FF indicates no sensor.



Switchable QVN Spindle/QVN Axis (CNC Software at Index K or above)

In the case where a switchable QVN spindle and QVN axis have the same speed and position sensor (motor sensor), it is necessary to declare a fictitious sensor for the axis. The address of the fictitious axis sensor is associated with the physical address of the corresponding spindle in word N8:

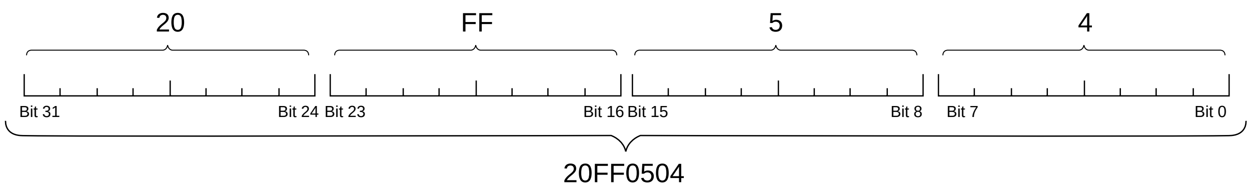


The value FF is used when no fictitious axis sensor is associated with a spindle address.

Example

On the third QVN card encountered in a rack:
- Connector 0 is wired to the sensor with address 4,
- Connector 1 is wired to the sensor with address 5,
- Connector 2 is not wired,
- Connector 3 is wired to the sensor with address 20.

Word N2 is loaded with the value:



Word N2	20FF0504

5.7 Axes Controlled by QVN

P71

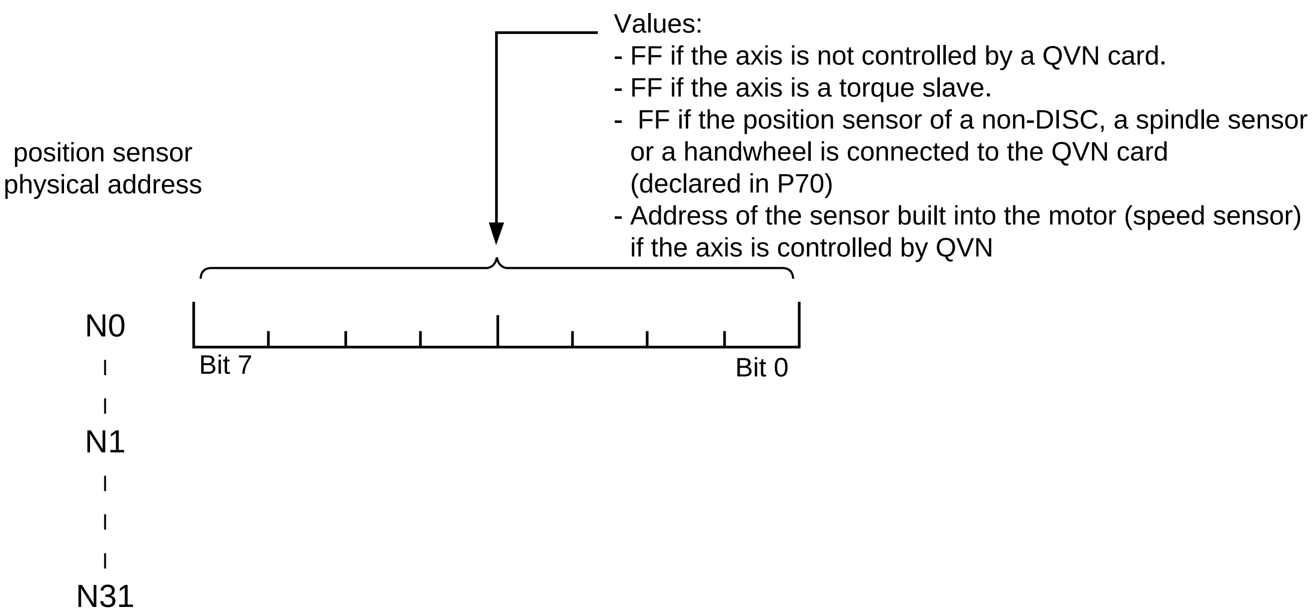
Category	QVN
Type 0	8-bit hexadecimal
No. of words	32

Description

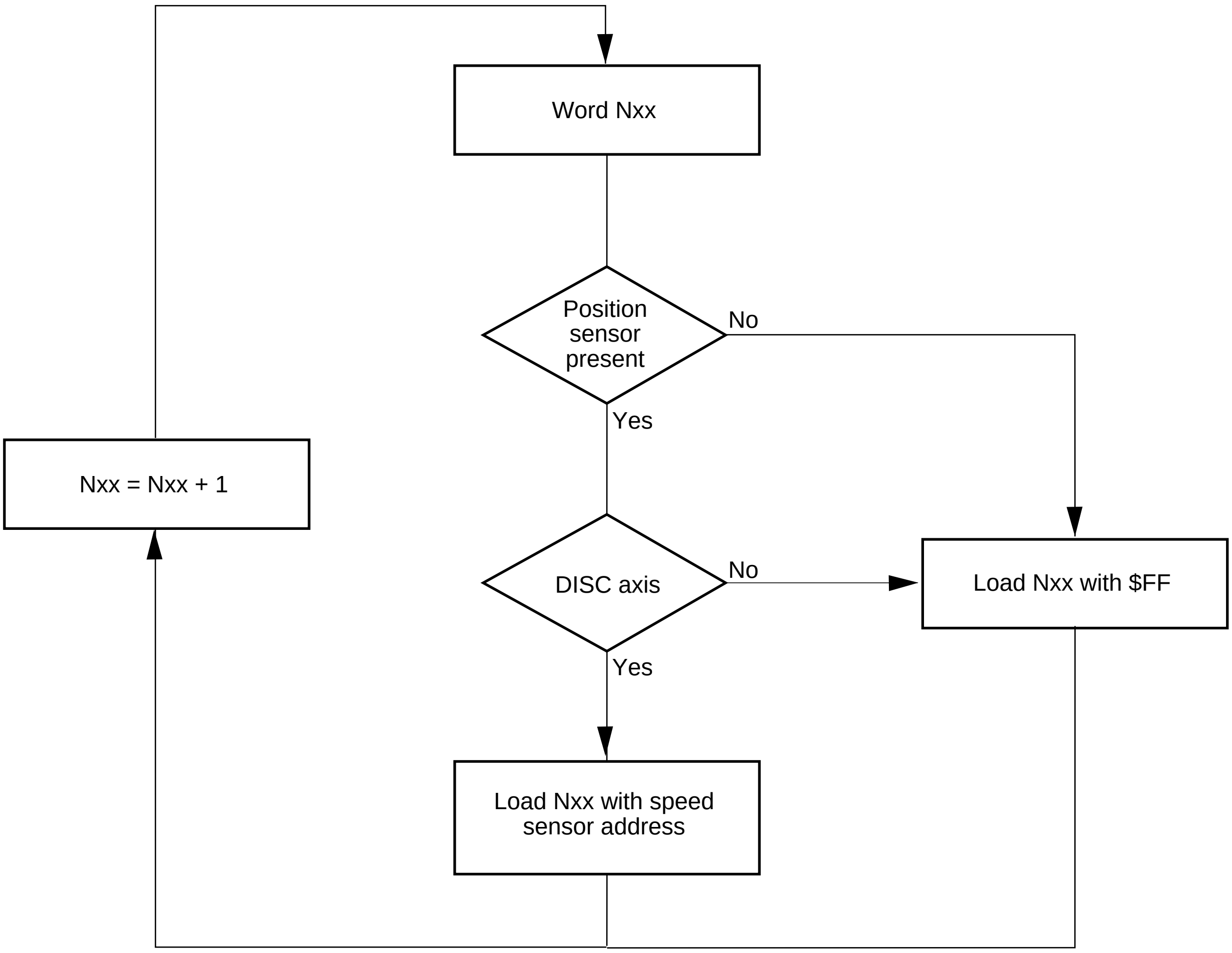
Defines the sensor configurations for the axes controlled by a QVN card. For each axis, it specifies the speed sensor (motor sensor) associated with the position sensor.

Principle

The word position corresponds to the physical address of the position sensor (axis address).

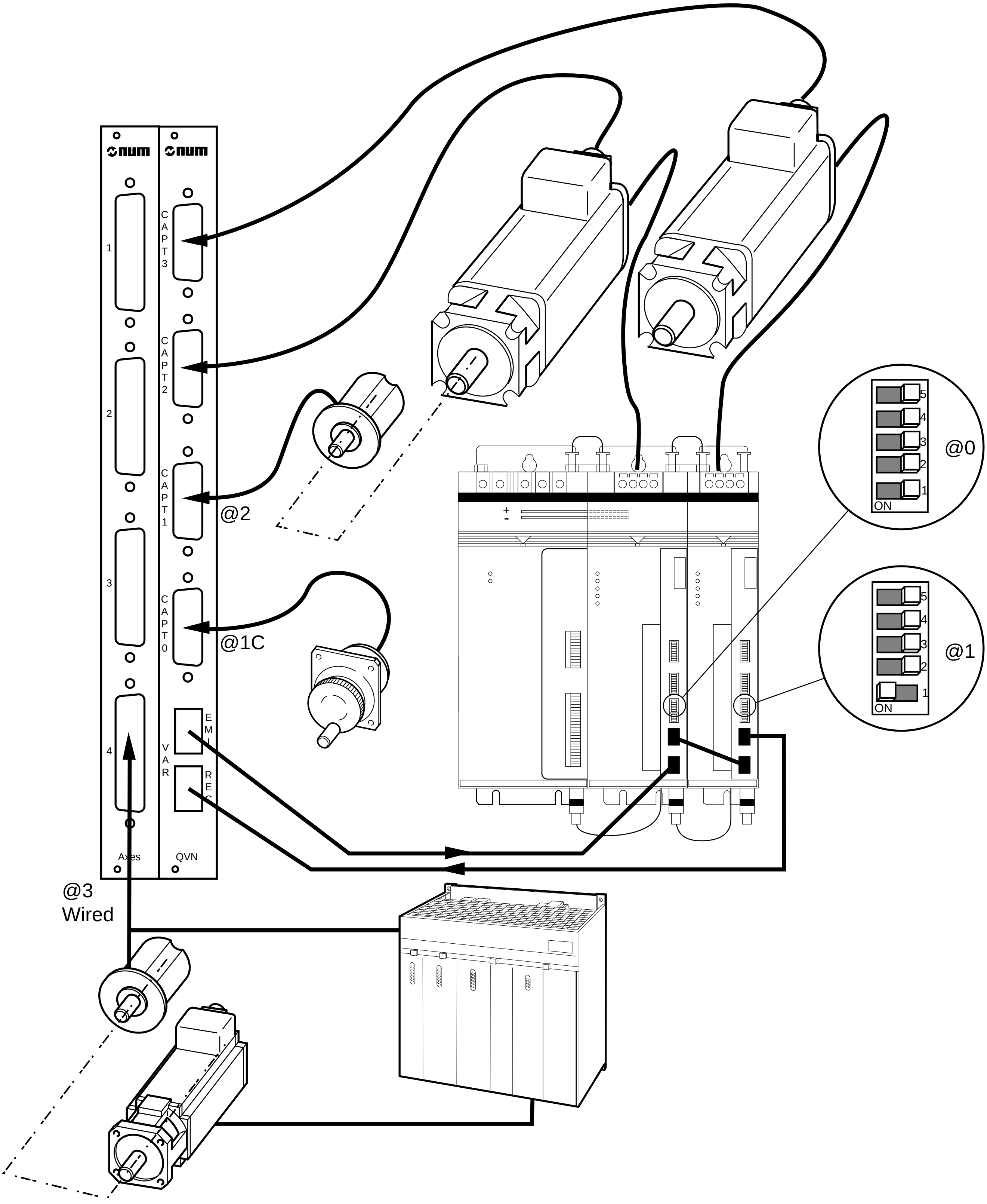


Assigning values



Example

System equipped with three axes and one handwheel



Parameter declaration

Parameters relative to position sensors

Bit 31 … Bit 24	Bit 23 … Bit 16	Bit 15 … Bit 8	Bit 7 … Bit 0
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 1 1 1 0

P2 = $0000000E

Bit 31 … Bit 24	Bit 23 … Bit 16	Bit 15 … Bit 8	Bit 7 … Bit 0
0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	0 0 0 0 1 1 1 0

P3 = $0000000E

P9

N0 = $FF

N1 = $00

N2 = $01

N3 = $02

N4 = $FF

etc...

P14

N0 = $01

P21, P30, P22, P57 ...

N0 = not significant

N1 = value

N2 = value

N3 = value

N4 = not significant

etc...

QVN configuration parameters

P70

N0 = $0100021C

N1 = $FFFFFFFF

P71

N0 = $FF

N1 = $01

N2 = $00

N3 = $FF

etc...

Parameters relative to speed sensors

P73, P74, P75

N0 = value

N1 = value

N2 = not significant

N3 = not significant

etc...

5.8 Motor Direction of Rotation

P72

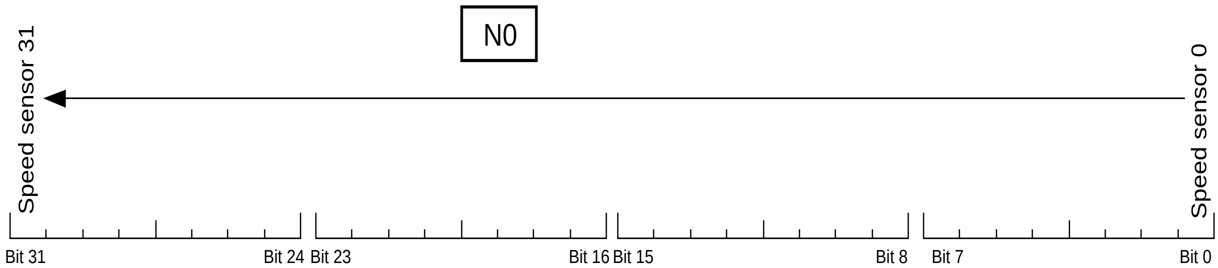
Category	QVN
Type 6	32-bit hexadecimal
No. of words	1 (2 for index K or above)

Description

Specifies the direction of rotation of the motor for a positive speed reference. The direction of rotation is seen facing the motor shaft.

Word N0

The bit position in word N0 corresponds to the physical address of the speed sensor.



If the bit is a 0, the motor shaft rotates clockwise.

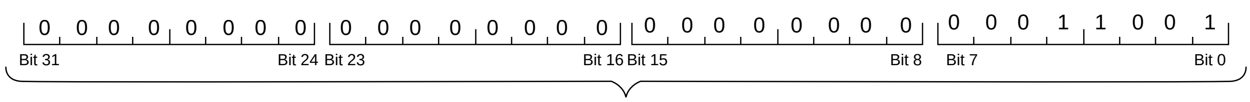
If the bit is a 1, the motor shaft rotates counterclockwise.

This parameter is irrelevant for the general case of an axis with position feedback.

Example

Out of the 7 sensors in this configuration, the sensors at addresses 0, 3 and 4 rotate counterclockwise.

Sensor address	0	1	2	3	4	5	6
Direction of rotation	CCW	CW	CW	CCW	CCW	CW	CW

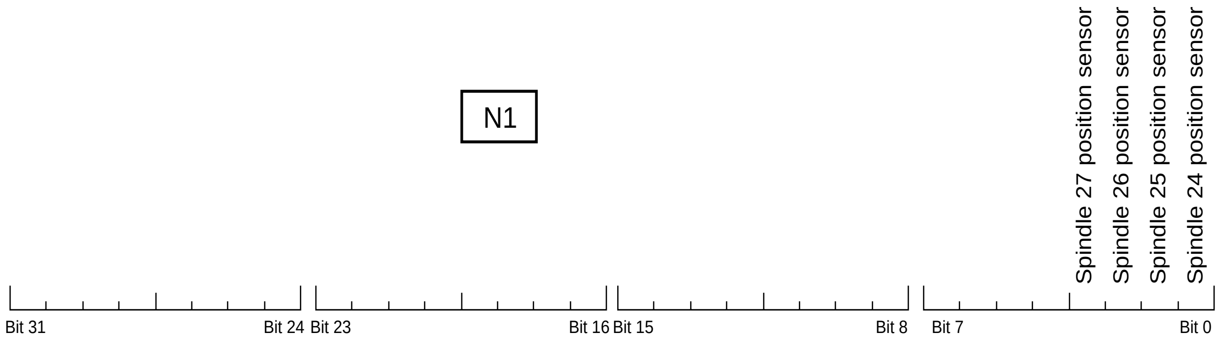


Word N0 of P72 = $00000019

Word N0	00000019

Word N1 (CNC software at index K or above)

Word N1 is used to declare the direction of rotation of the spindle motors using the address of their position sensor. Spindle addresses 24 to 27 correspond to bits 0 to 3 of word N1 respectively. The rotation direction is defined in the same way as for the axis motors.



5.9 Maximum Motor Speed

P73

Category	QVN
Type 5	Unsigned decimal
No. of words	32 (36 for index K or above)

Description

Defines the maximum motor speeds corresponding to the maximum speed on the axis declared in parameter P30.

Principle

The speeds are expressed in rpm. The values must be between 1 and 4000 rpm.

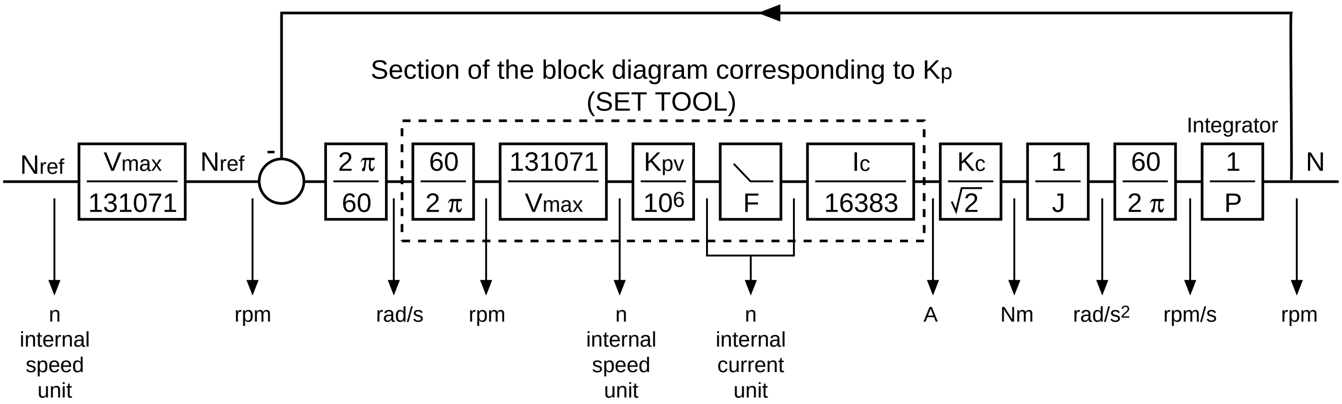
If the value specified is outside these limits, the default speed used by the system is 1000 rpm.

The bit position corresponds to the physical address of the speed sensor.

Speed sensor physical @ or spindle @	List of words		
@ 0	Word N0		
@ 1	Word N1		
"	"	"	
@ 31	Word N31		
Spindle @ 24	Word N32		At index K or above
"	"	"	At index K or above
Spindle @ 27	Word N35		At index K or above

With the CNC software at index K or above, words N32 to N35 are used to define the maximum spindle motor speeds using the address of their position sensors. Spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

5.10 Block Diagram of the Speed Loop



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Description of the variables

N_{ref}: motor reference speed

V_{max}: motor speed corresponding to the maximum numerical value of the speed measurement (P73: see Sec. 5.9)

K_{pv}: proportional action coefficient (P74: see Sec. 5.11)

F: integral action cut-off frequency (Hz, P75: see Sec. 5.12)

I_c: servo-drive peak current

K_c: torque coefficient in Nm/A rms

J: total inertia on the motor shaft

N: measured motor speed

Gain to be introduced in SETTool

$$K_p \text{ (A/rad/s)} = \frac{60}{2\pi} \times \frac{131071}{V_{max}} \times \frac{K_{pv}}{10^6} \times \frac{I_c}{16383}$$

$$K_p \text{ (A/rad/s)} = 7.64 \times 10^{-5} \times \frac{K_{pv} \times I_c}{V_{max}}$$

5.11 Speed Servo-Loop Proportional Action Coefficient

P74

Category	QVN
Type 2	Unsigned decimal
No. of words	32 (36 for index K or above)

Description

Defines the proportional action coefficient of an axis or spindle speed servo-loop. This coefficient is expressed in internal current unit divided by the internal speed unit (millionths).

The values can be between 0 and 31999996. If the value specified is outside these limits, the default coefficient used by the system is 100000.

Principle

The word position corresponds to the physical address of the speed sensor.

Speed sensor physical @ or spindle @	List of words		
@ 0	Word N0		
@ 1	Word N1		
"	"	"	
@ 31	Word N31		
Spindle @ 24	Word N32		At index K or above
"	"	"	At index K or above
Spindle @ 27	Word N35		At index K or above

With the CNC software at index K or above, words N32 to N35 are used to define the maximum spindle motor speeds using the address of their position sensors. Spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

Calculation of the Proportional Action Coefficient

The speed reference is expressed in the internal unit on 18 signed bits (131071 corresponds to the maximum operating speed).

The current reference is expressed in the internal unit on 15 signed bits (16383 corresponds to the peak current reference).

K_{prop} = (Peak current ref./Maximum speed error) x 10^6

Where:
- Internal current unit (16383 corresponds to the peak current reference),
- Internal speed unit (131071 corresponds to the maximum operating speed).

Example

Set a bandwidth of 40 Hz for the speed servo-loop (on the axis with address 0), i.e. a speed gain of $40 \times 2\pi = 251\ s^{-1}$ with a motor used at a maximum speed of 3000 rpm.

For the peak current, the measured acceleration is equal to 15.000 rad/s^2.

Calculate the maximum speed error

Max. speed error = Max. acceleration/Speed gain = 15.000/251 = 59.8 rad/s.

Conversion to internal speed units

Max. speed error = 59.8 rad/s = (131071 / (3000 / 60 x 2π)) x 59.8 = 24942 internal speed units.

Calculate the proportional action coefficient

K_{pv} = 16383 / 24942 x 10^6 = 656843

Word N0	656843

5

5.12 Speed Servo-Loop Integral Action Cut-off Pulse

P75

Category	QVN
Type 2	Unsigned decimal
No. of words	32 (36 for index K or above)

Description

This parameter specifies the cutoff pulse of the speed servo-loop integral action coefficient expressed in millionths of radians per sampling period (the sampling period is set in word N1 of parameter P50).

The values can be between 0 and 1000000. If the value specified is outside these limits, the default coefficient used by the system is 10000.

Principle

The word position corresponds to the physical address of the speed sensor.

Speed sensor physical @ or spindle @	List of words		
@ 0	Word N0		
@ 1	Word N1		
"	"	"	
@ 31	Word N31		
Spindle @ 24	Word N32		At index K or above
"	"	"	
Spindle @ 27	Word N35		

With the CNC software at index K or above, words N32 to N35 are used to define the maximum spindle motor speeds using the address of their position sensors. Spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

Calculation of the Integral Action Cut-off Pulse

$$Ki\ (0.000001\ \text{rad/smp}) = 2\pi \times 10^6 \times F\ (\text{Hz}) / F_e\ (\text{Hz})$$

where F is the integral action cut-off frequency and Fe is the speed servo-loop sampling frequency.

Example

Where F = 7 Hz and F_e = 1000 Hz: Ki (0.000001 rad/smp) = 7 x 2π x 10^3 = 43982

5.13 Speed Sensor Measurement Increment Average (Motor Sensor)

P76

Category	QVN
Type 0	Signed decimal
No. of words	32 (36 for index K or above)

Description

The motor speed measurement can be generated by averaging the motor sensor measurement increments instead of from the instantaneous measurement increments.

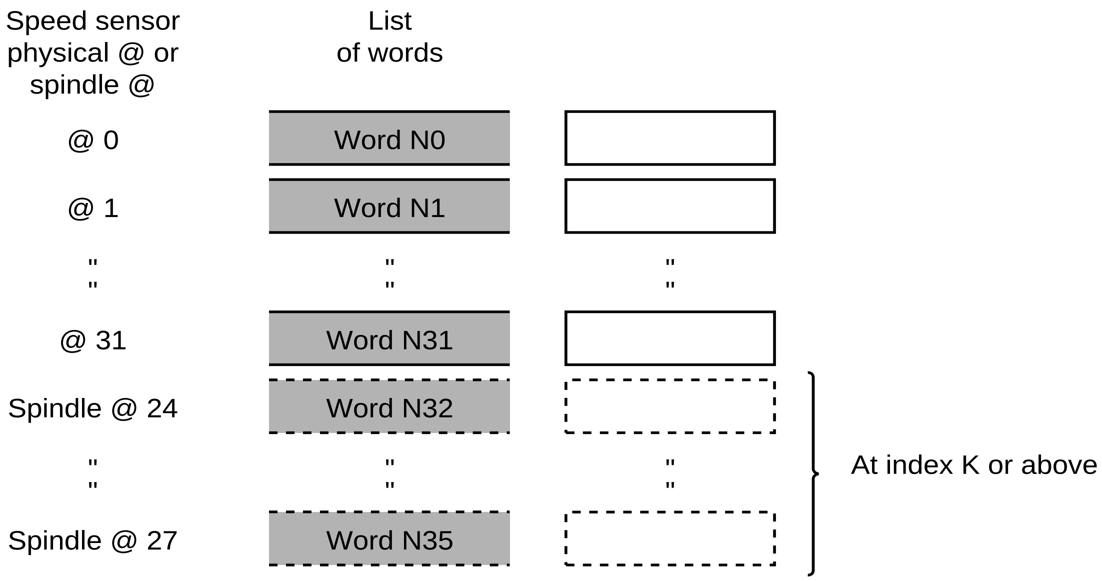
Principle

Parameter P76 sets the number (n) of past increments to be used to compute the motor speed. The possible values for n are 0, 1, 2 or 3.

n < 0 The system inhibits calculation of the average (same as n = 0)

n > 3 The system limits n to 3.

The word number corresponds to the physical address of the speed sensor.



With the CNC software at index K or above, words N32 to N35 are used to define the maximum spindle motor speeds using the address of their position sensors. Spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

5.14 Speed Measurement Filter

P77

Category	QVN
Type 5	Unsigned decimal
No. of words	32 (36 for index K or above)

Description

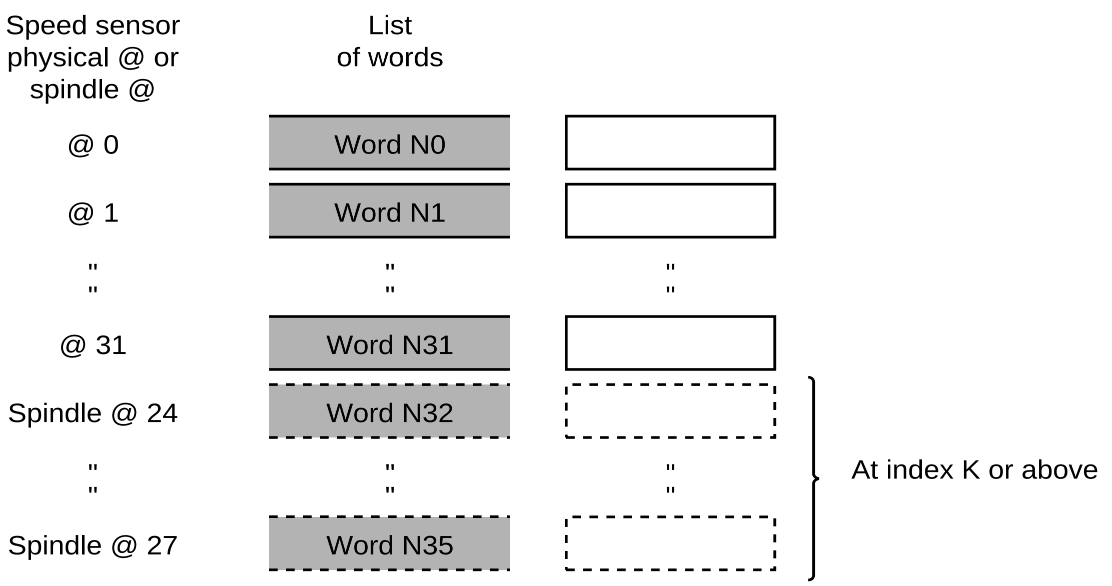
After computation of the increment average, the speed measurement can be filtered by a first-order low-pass filter. Parameter P77 specifies the filter cutoff frequency in Hz.

Minimum value: 20 Hz (any lower value inhibits action of the filter).

Maximum value: 2π / (QVN sampling period x 4): the system limits any higher value to this value.

Principle

The word number corresponds to the physical address of the speed sensor.



With the CNC software at index K or above, words N32 to N35 are used to define the maximum spindle motor speeds using the address of their position sensors. Spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

5.15 Torque Reference Filter

P78

Category	QVN
Type 5	Unsigned decimal
No. of words	32 (36 for index K or above)

Description

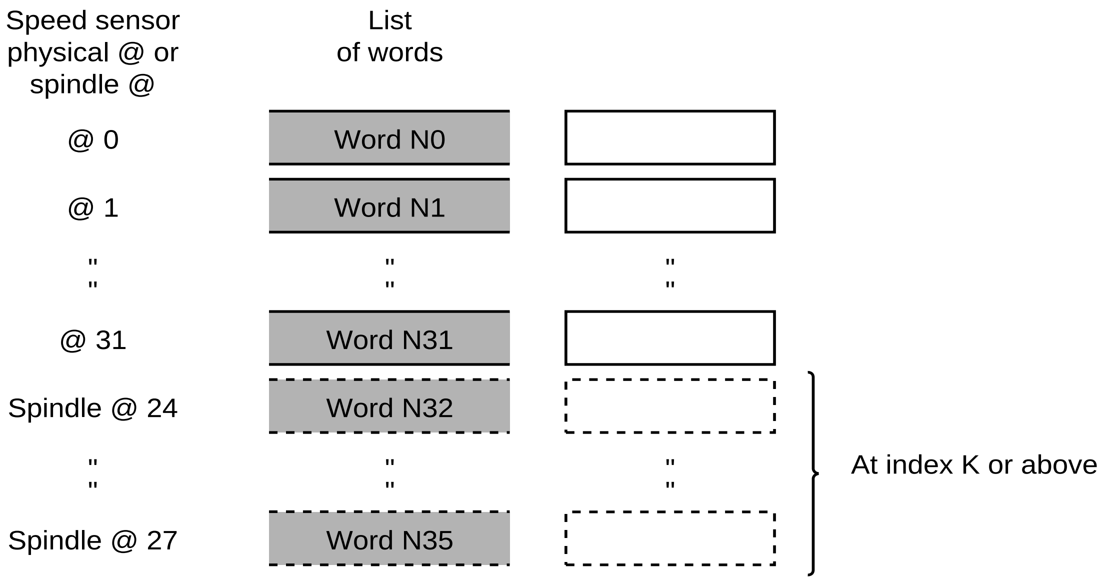
The torque reference can be filtered by a first-order low-pass filter. Parameter P78 specifies the filter cutoff frequency in Hz.

Minimum value: 20 Hz (any lower value inhibits action of the filter).

Maximum value: 2π/(QVN sampling period x 4): the system limits any higher value to this value.

Principle

The word number corresponds to the physical address of the speed sensor.



With the CNC software at index K or above, words N32 to N35 are used to define the maximum spindle motor speeds using the address of their position sensors. Spindle addresses 24 to 27 correspond to words N32 to N35 respectively.

5.16 Static Current Limiting

P79

Category	QVN
Type 1	16-bit decimal
No. of words	36

Description

Parameter P79 is available with software index K or above.

Parameter P79 defines the maximum current for a QVN application.

Principle

For QVN application i (i: speed sensor number), the maximum current is expressed in word Ni in tenths of an ampere.

Possible cases according to the value entered in word Ni and the maximum current of the servo-drive at address i:
- Negative value in word Ni: the maximum current is that of the servo-drive (default value -1)
- Value in word Ni < maximum current of the servo-drive at address i: the maximum current is limited to the value defined in word Ni,
- Value in word Ni $\geq$ maximum current of the servo-drive at address i: the maximum current is that of the servo-drive.

Where $I_{maximum}$, is the maximum current considering the limiting:

- The nominal current is always defined by $I_{nominal} = \frac{\sqrt{2}}{3} \times I_{maximum}$,
- The torque fault detection threshold is always defined for operation with current $I_{maximum}$ for 2 seconds.

With a switchable QVN spindle/QVN axis configuration, the maximum current defined for the spindle applies to both the spindle and axis.

The word position corresponds to the physical address of the speed sensor.

Speed sensor physical @ or spindle @	List of words	
@ 0	Word N0	
@ 1	Word N1	
"	"	"
@ 31	Word N31	
Spindle @ 24	Word N32	
"	"	"
Spindle @ 27	Word N35	

5.17 Association of a Torque Slave with a Master

P85

Category	QVN
Type 0	8-bit hexadecimal
No. of words	32

Description

Parameter P85 is available with the software at index K or above.

Parameter P85 associates a master application with a slave application.

Principle

For slave application i (i: speed sensor number) associated with master application j (j: speed sensor number), word Ni takes on value j.

The default value for each of the words is $FF (no master).

5.18 Direction of Rotation of a Torque Slave Application

P86

Category	QVN
Type 6	32-bit hexadecimal
No. of words	1

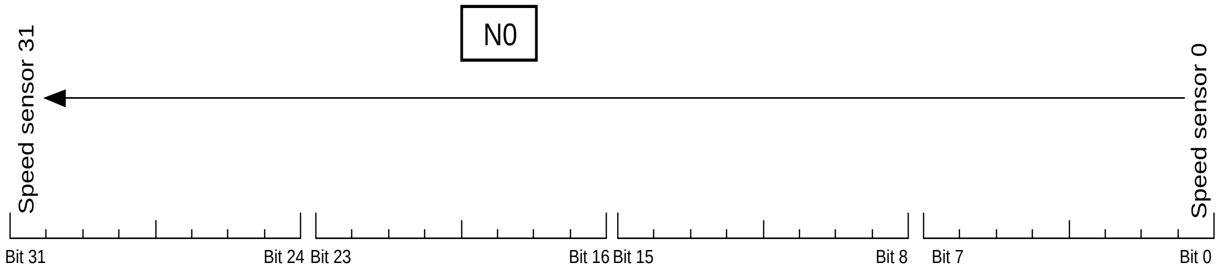
Description

Parameter P86 is available with the software at index K or above.

For a torque slave application, P86 specifies whether the slave rotates in the same direction or opposite direction from the master.

Principle

The bit position in word N0 corresponds to the physical address of the speed sensor:



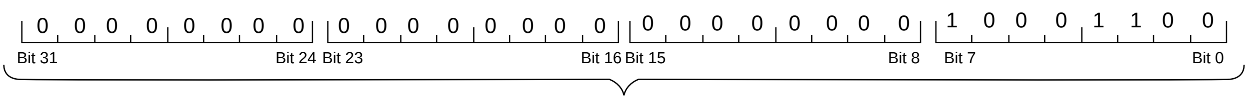
The bit is a 0 when the torque slave rotates in the same direction as the master.

The bit is a 1 when the torque slave rotates in the opposite direction from the master.

This parameter is meaningless for axes that are not torque slaves.

Example

If torque slave application 2, 3 and 7 rotate in the opposite direction from their master application:



P86 = $0000008C

Word N0	0000008C

5.19 Preload Current of a Master/Slave Pair

P87

Category	QVN
Type 1	16-bit decimal
No. of words	32

Description

Larameter P87 is available with the software at index K or above.

Parameter P87 defines a preload current for a QVN master/slave pair.

Principle

For a master QVN application i (i: speed sensor number), the magnitude and sign of the preload current is defined in word Ni. It is expressed as a signed percentage of the rated current of the master QVN application. The preload current of the slave has the same magnitude but is of the opposite sign. The maximum permissible percentage is + 30 percent.

REMARK *It is necessary to use the same maximum current limiting (parameter P79, see Sec. 5.16) for the master and slave to have the same magnitude of preload current on the master and slave.*

The word position corresponds to the physical address of the speed sensor.

Speed sensor physical @ or spindle @	List of words	
@ 0	Word N0	
@ 1	Word N1	
"	"	"
@ 31	Word N31	

5.20 Low-Pass Filter on Speed Reference

P88

Category	QVN
Type 5	Unsigned decimal
No. of words	

Description

Parameter P88 smoothes the acceleration on the load.

This parameter is documented in the setting procedure (see Chapter 7).

P89

P90

5.21 Rejection Filter on the Interpolated Speed Reference N2j : fn N2j + 1 : Zn

5.22 Rejection Filter on the Interpolated Speed Reference N2j : fd N2j + 1 : Zd

Category	QVN
Type 5	Unsigned decimal
No. of words	

Description

The filter parameters are fn, fd in Hz and Zn, Zd in thousandths.

These parameters are documented in the setting procedure (see Chapter 7).

5.23 Flexible Machine Mode Damping Coefficient

P91

Category	QVN
Type 5	Unsigned decimal
No. of words	

Description

This parameter specifies the flexible machine mode damping coefficient.

This parameter is documented in the setting procedure (see Chapter 7).

P92

P93

5.24 Speed Error Rejection Filter N2j : fn N2j + 1 : Zn

5.25 Speed Error Rejection Filter N2j : fd N2j + 1 : Zd

Category	QVN
Type 5	Unsigned decimal
No. of words	

Description

The filter parameters are fn, fd in Hz and Zn, Zd in thousandths.

These parameters are documented in the setting procedure (see Chapter 7).

5

5.26 Complementary Loop Application Frequency

P94

Category	QVN
Type 5	Unsigned decimal
No. of words	

Description

Defines the separation frequency between two complementary position loops.

The maximum permissible setting is 1/(4*CNC_RTC)
- i.e. 1000/20 = 50 Hz
- giving P94 maximum = 500 for a CNC RTC set at 5 ms.

This parameter is documented in the setting procedure (see Chapter 7).

5.27 Speed Observer - Ratio Kc/j

P116

5.28 Speed Observer - Gain for Position Estimate

P117

5.29 Speed Observer - Gain for Speed Estimate

P118

5.30 Speed Observer - Gain for Interference Estimate

P119

Category	QVN
Type 4	Unsigned decimal
No. of words	

Description

The gains are set in P117, P118 and P119.

These parameters are documented in the setting procedure (see Chapter 7).

5.31 Speed Observer - Supervision Device

P120

Category	QVN
Type 1	8-bit hexadecimal
No. of words	

Description

This parameter contains the two parameters of the supervision device, $V_{threshold}$ in rpm and K_{slope} in thousandths.

This parameter is documented in the setting procedure (see Chapter 7).

5.32 Vibration Elimination When Stopped by Processing of the Speed Measurement

P121

5.33 Vibration Elimination When Stopped by Clipping of the Proportional Gain

P122

Category	QVN
Type	
No. of words	

Description

These parameters are documented in the setting procedure (see Chapter 7).

6 PLC Variables

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6.1 Torque Enable

The bits of %W34.L are set to 0.

Variable	Mnemonic	Description
%W34.7 to %W34.0	DISC_TRQ31 to DISC_TRQ24	Torque enable on QVN axes 31 to 24 Set to enable torque. Reset to inhibit torque.
%W35.7 to %W35.0	DISC_TRQ23 to DISC_TRQ16	Torque enable on QVN axes 23 to 16 Set to enable torque. Reset to inhibit torque.
%W36.7 to %W36.0	DISC_TRQ15 to DISC_TRQ8	Torque enable on QVN axes 15 to 8 Set to enable torque. Reset to inhibit torque.
%W37.7 to %W37.0	DISC_TRQ7 to DISC_TRQ0	Torque enable on QVN axes 7 to 0 Set to enable torque. Reset to inhibit torque.

There are no equivalent bits in assembler programming or with PLCUT7. The torque is always enabled.

6.2 Speed Reference Enable

Variable	Mnemonic	Description
%W38.0	DISC_SPD	QVN axis speed reference enable Set to enable normal operation of the QVN axes. Reset to force the QVN axes speed reference low and cause braking at maximum torque.

If the speed references are inhibited, they are forced low.

At power on, the speed references are inhibited.

If a CNC error causing reset of E_CNPRET is detected, the speed reference is inhibited for the QDD axes. When the error is cancelled by a reset, the speed references are again enabled or inhibited the PLC function.

In assembler programming and with PLCUT7, bit A.113 operates in the same way.

6.3 Programming Recommendations

On an emergency stop, it is recommended to:
- Inhibits the speed reference (DISC_SPD = 0),
- Activate a feed stop so as not to generate too high a following error.

6.4 Dynamic Current Limiting

It is possible to dynamically limit the maximum current by the PLC selectively for each QVN application (torque slave excluded).

Variable	Mnemonic	Description
%WE00.B to %WE1F.B	RDUC_TRQ00 to RDUC_TRQ31	Dynamic current limiting of QVN applications 00 to 31

Where Imaximum is the maximum current taking into account the static limitation and α is the contents of the byte:

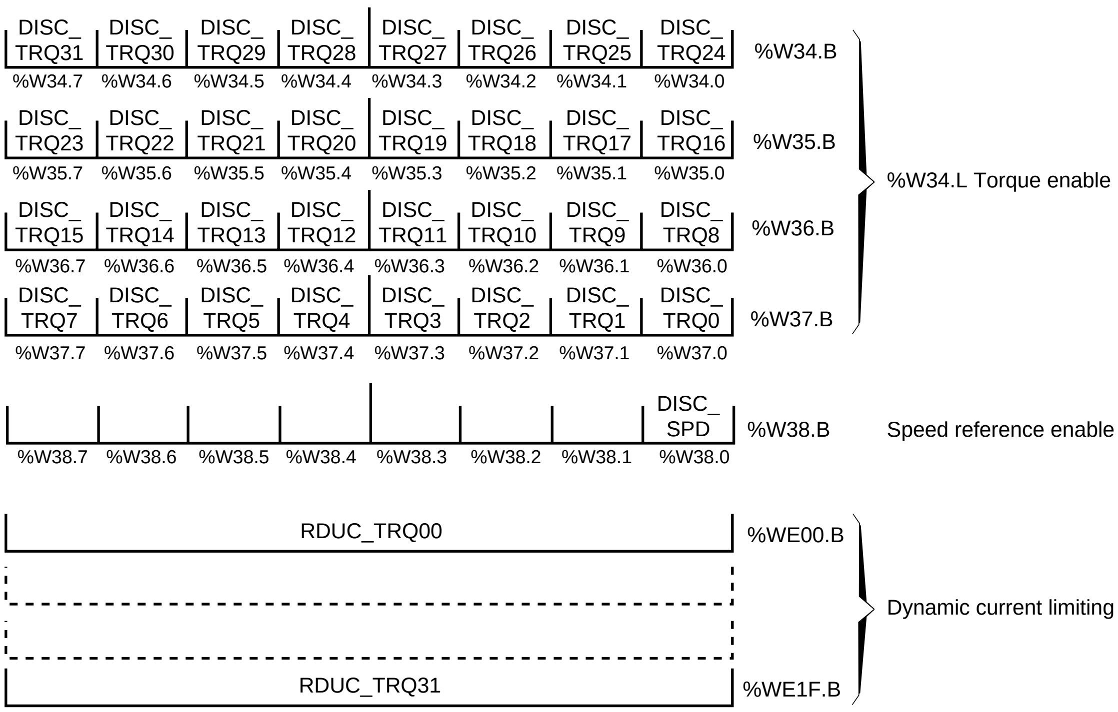
- If α is negative or zero ($00, $80 to $FF), there is no dynamic current limiting,
- If α is positive ($01 to $7F), the maximum permissible current is equal to $I_{maximum}$ x [(127 - α)/127].

Dynamic current limiting applied to a master QVN application is also applied to the associated slave QVN applications.

When operating in anti-pitching mode, dynamic current limiting applied to a master QVN application has no effect on the master and slave preload currents.

When operating with a switchable QVN spindle/QVN axis configuration, the dynamic current limiting signal sent to the QVN application is switched when switching from one configuration to the other.

6.5 Exchange Area



7 DISC Digital Servocontrol Setting Procedure

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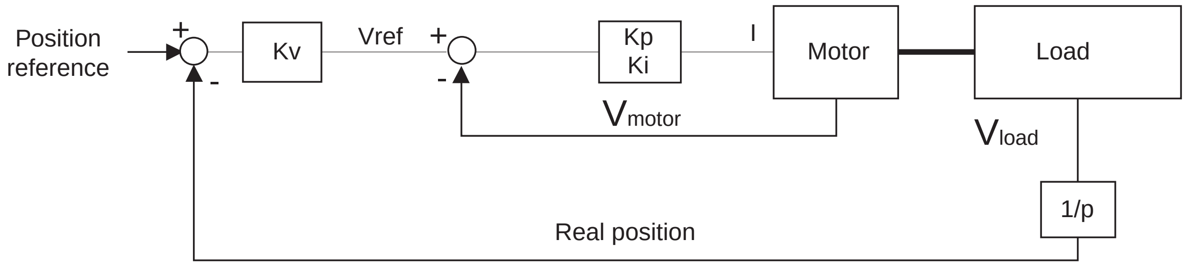
7.1 Setting Method

This section describes the steps to be followed for integration of QVN digital servodrives.

The axis addresses and axes must be declared beforehand (see Machine Parameters Manual). Initially, only the basic settings are made.

If the results are not satisfactory or to achieve high performance, the speed estimator and possibly the notch filters or flexibility compensations and vibration eliminators may be used. These are additional settings.

7.1.1 General Purpose



General diagram of a position feedback loop

The servodrive settings of a machine tool axis follow a few simple general rules:

- Set the motor speed loop with high gains to improve interference rejection
- Set the speed loop bandwidth at least four times wider than the corresponding target position bandwidth

$$\frac{K_P.K_C}{\sqrt{2}.J_{Tot}} > 4.K_V \approx 70.G_{CNC}$$

where

K_P [A_{maxi}/rad.s^{-1}]	Gain proportional to the speed loop
K_C [N.m/A_{rms}]	Motor torque constant
J_{Tot} [kg.m^2] = J_{MOT} + J_{LOAD/N^2}	Total momentum
K_V [Hz]	Target position gain
G_{CNC} [m/min/mm] =K_V/16.67	Position gain in CNC units

7.2 Basic Settings

Purpose

For a target **CNC gain G_{cnc}**, the time T_p of the first overshoot of the response to the speed loop control pulse (see glossary) must satisfy the following inequality:

$$T_{p(ms)} \leq \frac{60}{G_{cnc[(m/min)/mm]}}$$

- If time T_p of the first overshoot is not satisfactory, reduce the CNC gain.

The integral action coefficient must satisfy the inequality $K_i > 80_{[rad/s]}$

- Setting K_i too low leads to poor interference rejection and marking at the quadrant crossings.

7.2.1 Parameters of Coefficients K_p (P74) and K_i (P75) to Be Adjusted

Proportional action coefficient K_p (P74) sets the speed feedback loop bandwidth. It determines the rise time of the speed signal for a pulse type command. Its action is decisive on the stability and robustness margins at high frequencies.

Integral action coefficient K_i (P75) ensures the static accuracy of the speed in steady state and contributes to rejecting low and medium frequency interference. Its action introduces a negative phase shift and therefore reduces the stability margins at medium frequencies.

7.2.2 Initial Settings to Start the Procedure

Integral action coefficient **K_i (P75)** is set arbitrarily to 30 rad/s to obtain an error-free response in steady state.

Set proportional action coefficient **K_p (P74)** to obtain a theoretical speed loop bandwidth of around 30Hz : $\frac{K_P.K_C}{\sqrt{2}.J_{Tot}} \approx 30$ Hz.

Filter on the speed measurement: **Set** an average of two measurements by setting **P76=1**.

Other filters (low-pass filters on measurement and torque): To be inhibited: **P77=0 and P78=0**.

Word i corresponds to axis sensor address i and j+8 to spindle address j.

7.2.3 Cascade Method, Recommended for a Conventional Machine

Setting of PI Controller with Position Loop OPEN

7.2.3.1 Control and Monitoring Parameters

First set the control signal characteristics (using SETTool):
- Set the pulse amplitude to a low value, less than or equal to 5% of maximum speed.
- Set the minimum pulse width to 200 ms.

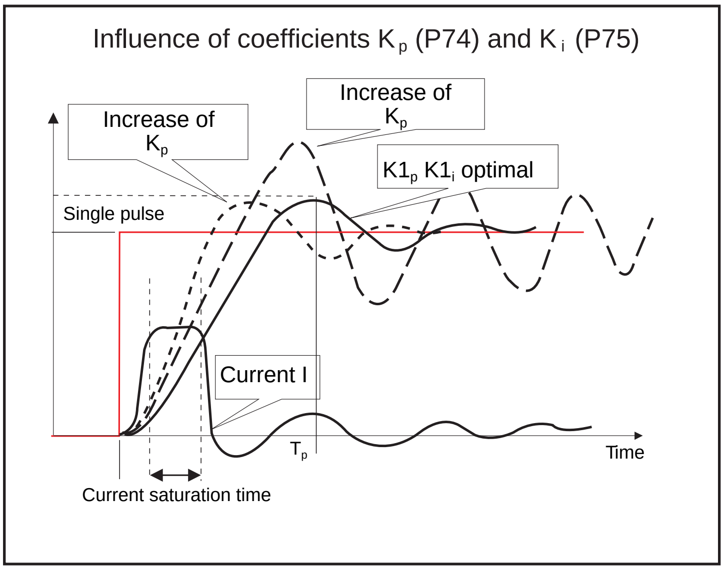
The observed parameters are:
- Motor speed
- Motor torque reference
- Axis speed (only if the axis measurement is output by an additional sensor).

7.2.3.2 Setting Procedure

Gradually adjust coefficient **K_p** (P74) to obtain:
- A rapid motor speed rise time (see glossary)
- A torque current which may be saturated during the transient phase. The maximum saturation time must be less than 20% of the speed signal rise time
- A low-noise torque current (circuit noise at frequencies between 110 and 160 Hz which may generate audible mechanical vibrations).

Then set coefficient K_i (P75) to obtain a motor response to the control pulse with an overshoot of around 30%. A three-digit setting of the coefficient is highly appreciated due to the importance of its action on the markings in the four quadrants of the ball bar traces (feedback aspect).

Influence of Coefficients K_p and K_i



Increasing coefficient K_p reduces time T_p. However, the current must not be saturated for more than 20% of the speed rise time T_r in the speed loop for speed control pulses of approximately 5% of the maximum speed (see glossary).

Too high a setting of K_p causes large amplitude noise on the motor current (interference at frequencies of 110 to 150 Hz) generating audible mechanical vibrations.

Increasing coefficient K_i reduces the steady-state error. The highest possible setting of K_i is therefore advantageous. However, too high a setting of K_i creates instability (low frequency oscillation at around 50 Hz) and a speed loop overshoot. The higher the setting of K_p, the higher the overshoot.

REMARK *The controller gives precedence to rise time over overshoot. An overshoot of 30% is fully acceptable.*

7.2.4 General Method Recommended for a Stiff Machine

Setting of PI Controller with Position Loop CLOSED

This method, more straightforward, consists of setting the speed loop gain with position feedback active.

7.2.4.1 Control and Monitoring Parameters

Movement is in Jog mode using the feed rate override potentiometer. **Set** an acquisition period of around 1 ms using SETTool.

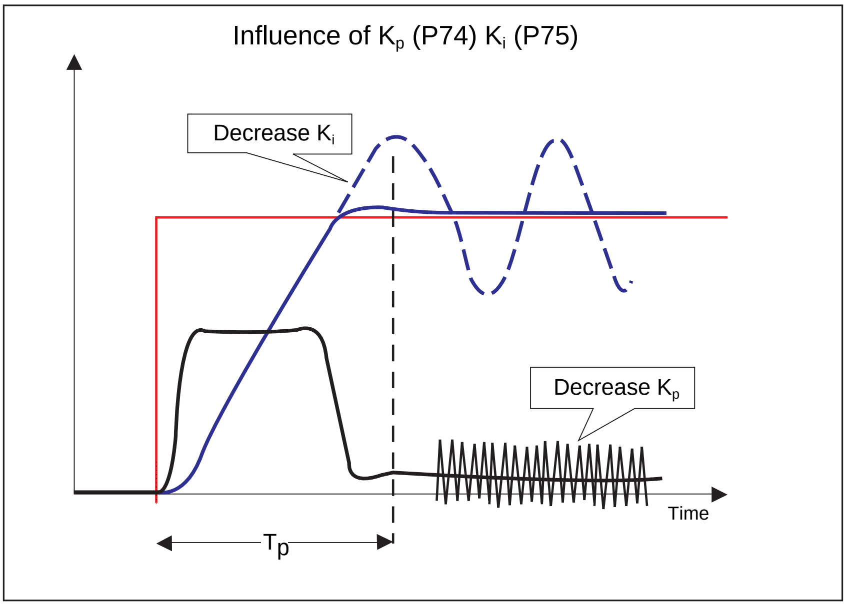
The observed parameters are:
- Motor speed
- Motor torque reference
- Axis speed (only if the axis measurement is output by an additional sensor).

7.2.4.2 Initial Setting

Use external parameters to temporarily inhibit:
- High speed machining of precision contours function **(E11012=0)**, and
- Gradual $\sin^2$ acceleration **(E11013=0)** if necessary.

7.2.4.3 Setting Procedure

- Gradually adjust proportional action coefficient $\mathbf{K_p}$ (P74) to the maximum gain giving an axis rise time without overshoot and the start of torque instability (the desired signal is buried in noise at frequencies between [~110 and ~180 Hz]). These noise bursts usually generate audible machine vibrations.
- Decrease gain $\mathbf{K_p}$ until obtaining an acceptable current noise < 1.5 A with no more audible mechanical vibrations.
- Gradually increase integral action coefficient K_i (P75) while checking that there is still no overshoot on the axis speed. A three-digit setting is highly appreciated (typically ~100 to 150 rad/s).
- Reenable the high speed machining of precision contours and gradual acceleration functions.



The figure above shows the influence of coefficients K_p and K_i.

7.3 Additional Settings

7.3.1 Problems in Achieving the Setting Targets

Certain problems due to the mechanical system or the measurement quality may prevent achievement of the setting targets. The most common problems are:

Mechanical: Axis backlash
Flexibility in the transmission
Speed frictions
Unsuitable inertia ratio RI = $J_{LOAD/N^2}/J_{MOTOR}$

Measurements: Insufficient resolution causing signal quantising problems.

Most of these problems result in vibrations or oscillations occurring at certain frequencies, when stopped or moving, depending on the origin of the problem.

This section details the problems encountered and suggests possible solutions.

7.3.1.1 Additional Settings Available

Reduction of QVN sampling period

The real-time clock must be set to the minimum possible value.

Speed observer

This function usually solves problems related to QVN measurement quantisation.
It is recommended to enable it.

Double position measurement

Stabilises the position loop when using direct measurement.

Damping of flexible machine modes

Notch filters

To reject resonance in or outside the speed bandwidth.

Vibration reduction when stopped

By clipping the speed loop gain.

7.3.1.2 Selection Guide

The symptoms and recommended solutions vary according to the frequency range and nature of the vibrations. The following selection guides are proposed. The frequencies are given for guidance. They are only orders of magnitude.

According to the Vibration Frequency Range

Vibration frequency [Hz]

10	50	100	150	Hz	Action	Explanation
↗ K_P					Increase K_P of the speed loop	The speed loop bandwidth must be more than four times the position loop bandwidth
	↘ K_I				Decrease K_I of the speed loop	Damp the speed loop
↘ P94	↘ P94				Use double position measurements	Backlash or flexibility
	P89 & P90				Apply a notch filter to the speed reference	Eliminate resonance **IN** the speed loop bandwidth
	P91				Damp by acceleration feedback	Transmission flexibility
			P92 & P93	P92 & P93	Apply a notch filter to the speed error	Eliminate resonance **OUTSIDE** the speed loop bandwidth
		P121 or P122	P121 or P122		Use a dead zone on the speed	Measurement quantisation. High RI

Position loop ↑ bandwidth Speed loop ↑ bandwidth

According to the Nature of the Vibration

A distinction is made between vibrations when stopped and when moving. The latter require an initial analysis by decreasing **P94** to eliminate the effect of mechanical transmission defects (backlash, flexibility). Then increase **P94** or set it to 0 to refine the damping strategies.

Vibration when stopped	Vibration when moving with P94 low	Vibration when moving with P94 low
HF: dead zone (P121 or P122) MF: Decrease K_i increase K_p, increase K_i again LF: Decrease CNC gain K_V	HF: Notch filter on speed error (P92 and P93) Decrease K_p	HF: Notch filter on speed error (P92 and P93) MF: Notch filter on speed reference (P89 and P90) P91: Stabilisation by acceleration feedback P94: Decrease P94 to eliminate the effects of the load

7.3.2 Decrease of QVN Sampling Period

Purpose

Adapt the QVN sampling period to the number of digital axes controlled.

Decreasing the speed feedback period:
- Decreases the importance of pure delays in the feedback loop
- Increases the stability margins and makes feedback stiffer.

Recommendations

Evenly distribute the number of axes among the digital cards to decrease the qvn_rtc.

For instance, on a six-axis machine, control three axes per QVN card instead of two by one card and four by another.

The sampling period must be adapted to:
- The active feedback functions
- The number of axes processed by each of the QVN cards.

The minimum sampling period has now been decreased to 250 ms.

The default sampling period is still 500 ms.

Word 1 of machine parameter P50 specifies the QVN period. It should be set to a default value of:
- 300 µs for a card controlling two axes
- 400 µs for a card controlling three axes
- 500 µs for a card controlling four axes

7.3.2.1 Measuring the Available Processing Time

This measurement is accessible from hidden command 19 of the I/O page menu (debug page). It must be made with all the required QVN functions activated (various filters, torque master/slave, etc.). The servodrives must be enabled.

Enter 19✶ on the I/O page.

The dialogue line proposes DM/PC? Enter PC [card number] ✶ (the cards are numbered from 0 to 7 from right to left).

The dialogue line proposes DM/PC? Enter DM.Y 200 V✶

The screen displays:

Symb	Field	Card	Address	Value
VAR.0	Y	1	200	85

The value is the time available for the card specified. It is a hexadecimal value in µs.

In case of axis/spindle switching, the measurement must be made in all possible cases of operation.

Repeat the measurement for all the QVN cards and record the value corresponding to the most loaded card.

7.3.2.2 Modifying the QVN Period (P50)

Based on the time available on the most loaded card, the table below shows the changes to be made to period QVN_RTC specified by word 1 of machine parameter P50.

Time available (µs) (in hexadecimal and (decimal))	Change to RTC (in µs)
< 14 (< 20)	+50
from 14 to 46 (from 20 to 70)	0
from 47 to 78 (from 71 to 120)	-50
from 79 to AA (from 121 to 170)	-100
from AB to DC (from 171 to 220)	-150
> DC (> 220)	-200

NOTE

The ratio $\frac{\text{CNC\_RTC (P50 word 0)}}{\text{QVN\_RTC (P50 word 1)}}$ must be an integer.

For instance, for a card with three axes and three speed observers, the QVN period must be set to 350 µs.

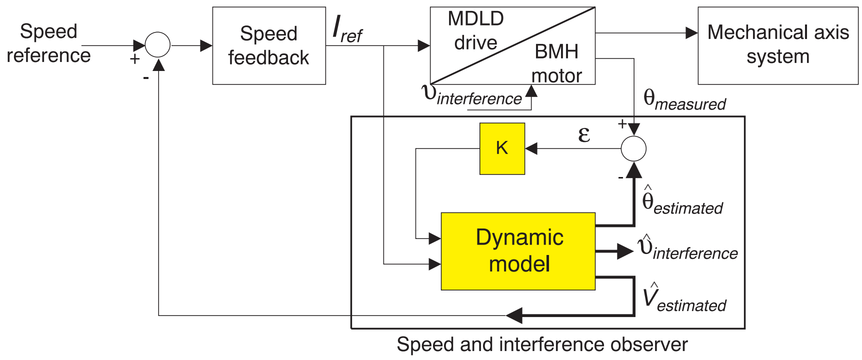
A speed observer is estimated to consume 10 µs and a notch filter 7.5 µs.

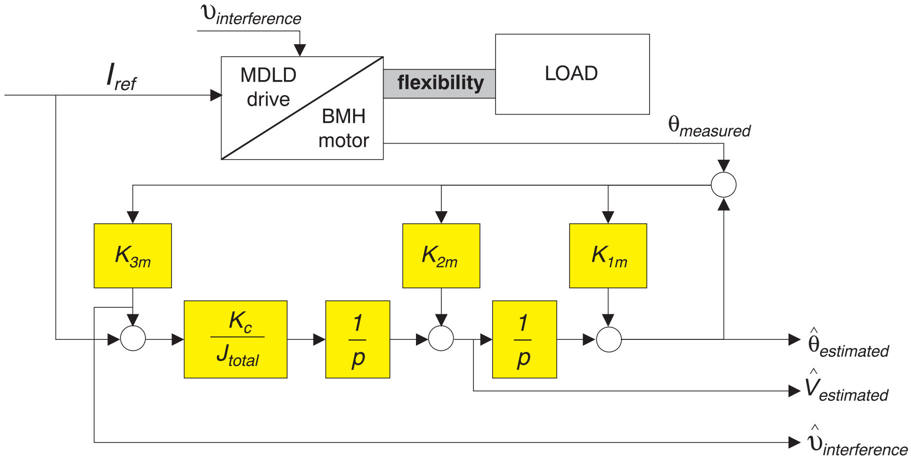
7.3.3 Speed and Interference Observer on QVN Digital Servodrive

Purpose

Improve the resolution of the speed measurement (the speed measurement is replaced by an estimator generated by observation techniques).

The standard speed measurement is replaced by the estimated speed, which has a resolution **10 to 15 times better** than that obtained by successive differentiation of the motor positions.





The monitored parameters are the speed, the rotor angle and the interference perceived by the motor.

These parameters are reconstructed using a mathematical model of the system behaviour to predict the change in the measured output (motor position).

To take into account measurement noise and the model imperfections, three corrector terms are used. They are proportional to the error ε between the measured motor speed $\theta_{measured}$ and that generated by the observer $\theta_{estimated}$ such as to achieve average convergence of $\theta_{estimated}$ to $\theta_{measured}$ and guarantee that the other parameters are asymptotically unbiased.

REMARK *The averaging and low-pass filters applied to the standard speed measurement of an axis are disabled when the observer is activated on the axis.*

The three-state observer creates filtering characterised by:
- A negligible phase shift at all measurement frequencies (contrary to a conventional filter)
- Attenuation of the high frequency components of the measurement (high frequency resonance, noise, etc)
- Two cutoff frequencies, specific to:
  - The position and speed estimators, and
  - The torque interference estimator
- A gain K_2 which sets the equivalent resolution of the speed measurement.

The tables below show the characteristics and gains of the observer in SI units based on the QVN period. The two greyed lines correspond to values suggested a priori.

Selection of Settings

- **The line used as default is the second greyed line** which provides the best bandwidth of the speed estimator
- If the target gains are small and the requirements on the speed variation are high, use the first greyed line which provides a better speed resolution

Cutoff frequency of the position/ speed estimator	Cutoff pulse of the interference estimator	Speed measurement resolution	K1m Gain assigned to the speed estimator	K2m Gain assigned to the speed estimator	K3m Gain assigned to the interference estimator
For a QVN_RTC = 0.5 ms (table 1)					
77 Hz	146 rad/s	0.20 rpm	0.335	0.034 s-1	14020 s-2
110 Hz	74 rad/s	0.35 rpm	0.404	0.052 s-1	13270 s-2
154 Hz	37 rad/s	0.58 rpm	0.503	0.0869 s-1	12120 s-2
218 Hz	18 rad/s	1 rpm	0.620	0.147 s-1	10600 s-2
For a QVN_RTC = 0.45 ms (table 2)					
77 Hz	162 rad/s	0.17 rpm	0.311	0.029 s-1	14270 s-2
109 Hz	82 rad/s	0.3 rpm	0.375	0.0438 s-1	13590 s-2
154 Hz	41 rad/s	0.53 rpm	0.468	0.0732 s-1	12540 s-2
218 Hz	20 rad/s	0.9 rpm	0.582	0.125 s-1	11110 s-2
For a QVN_RTC = 0.4 ms (table 3)					
77 Hz	182 rad/s	0.17 rpm	0.287	0.024 s-1	14520 s-2
109 Hz	92 rad/s	0.28 rpm	0.344	0.036 s-1	13920 s-2
154 Hz	46 rad/s	0.49 rpm	0.431	0.06 s-1	12970 s-2
218 Hz	23 rad/s	0.86 rpm	0.541	0.104 s-1	11650 s-2
For a QVN_RTC = 0.35 ms (table 4)					
77 Hz	207 rad/s	0.19 rpm	0.261	0.0197 s-1	14780 s-2
109 Hz	105 rad/s	0.28 rpm	0.310	0.0290 s-1	14260 s-2
154 Hz	53 rad/s	0.46 rpm	0.391	0.048 s-1	13420 s-2
218 Hz	26 rad/s	0.80 rpm	0.495	0.084 s-1	12220 s-2
For a QVN_RTC = 0.30 ms (table 5)					
77 Hz	238 rad/s	0.17 rpm	0.234	0.0156 s-1	15040 s-2
109 Hz	122 rad/s	0.25 rpm	0.280	0.0224 s-1	14610 s-2
154 Hz	61 rad/s	0.41 rpm	0.350	0.037 s-1	13880 s-2
218 Hz	31 rad/s	0.72 rpm	0.444	0.065 s-1	12810 s-2

7.3.3.1 Description of New Parameters P116, P117, P118 and P119

The gains are set in three CNC machine parameters.

Parameter P117: Includes 32 words relative to gain K1m used to estimate the rotor position.

Case of an axis: for speed sensor address i, word Ni contains K1m in millionths.

Case of a QVN spindle: for speed sensor address j, word Nj+8 contains K1m in millionths.

Parameter P118: Includes 32 words relative to gain K2m used to estimate the rotor speed (unit s-1).

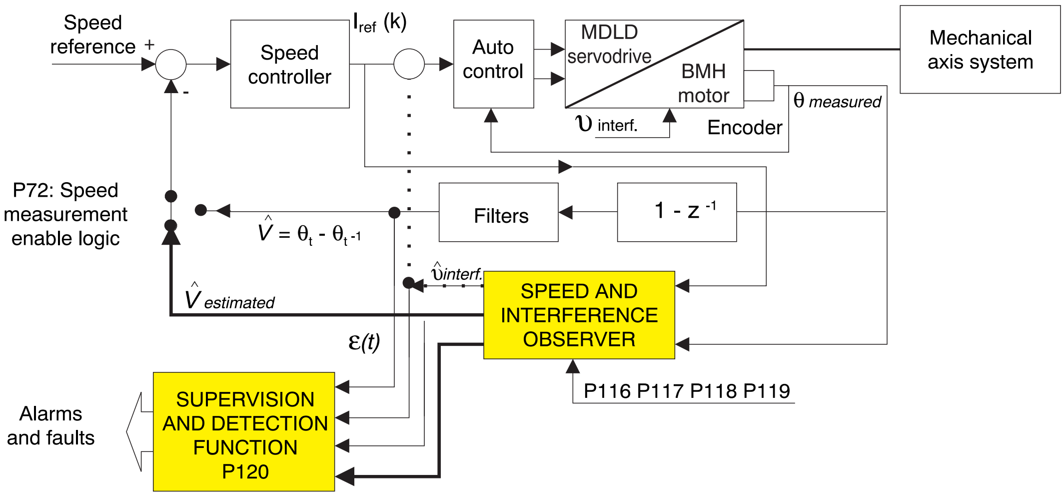
Case of an axis: for speed sensor address i, word Ni contains K2m in millionths.

Case of a QVN spindle: for speed sensor address j, word Nj+8 contains K2m in millionths.

Parameter P119: Includes 32 words relative to gain K3m used to estimate the interference perceived by the motor (unit s-2).

Case of an axis: for speed sensor address i, word Ni contains K_{3m} in <u>units</u>

Case of a spindle: for speed sensor address j, word Nj_{+8} contains K_{3m} in <u>units.</u>



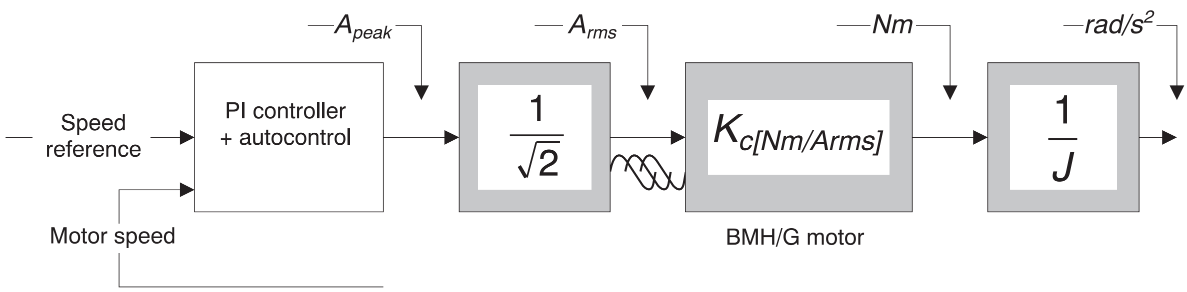
Functional diagram of feedback loop with use of a speed observer

The behaviour model requires knowing ratio K_C/J of the motor torque constant to the total inertia seen by the motor.

Parameter P116: Describes this ratio K_C/J in tens of **Nm/Arms/Kgm²**. This parameter contains 32 words.

Case of an axis: for speed sensor address i, word Ni contains K_C/J relating torque to acceleration

Case of a QVN spindle: for speed sensor address j, word Nj_{+8} contains K_C/J.



7.3.3.2 Activation and Use of the Speed Observer

Activation of the Filter

The speed observer is active after initialisation of the CNC if coefficient **K_c/J is different from zero** (P116 Ni > 0).

If one of the following conditions is not satisfied at initialisation, the filter is inoperative:
- The maximum rating of the drive Ic > 0 (P79 Ni)
- Gains K_{1m} and K_{2m} are less than 1

$$\frac{I_c}{16383} \times \frac{K_c}{J\sqrt{2}} \times T^2 \times \frac{1.8 \times 10^6}{2\pi} < 1 \quad \text{and} \quad \frac{16383}{I_c} \times \frac{J\sqrt{2}}{K_c} \times \frac{2\pi}{1.8 \times 10^6} K_{3m} < 1$$ (internal check of coefficients).

Use of the Filter: Parameter P72

Parameter P72: Use of the estimated speed in the feedback of the speed loop defined words N2 and N3.

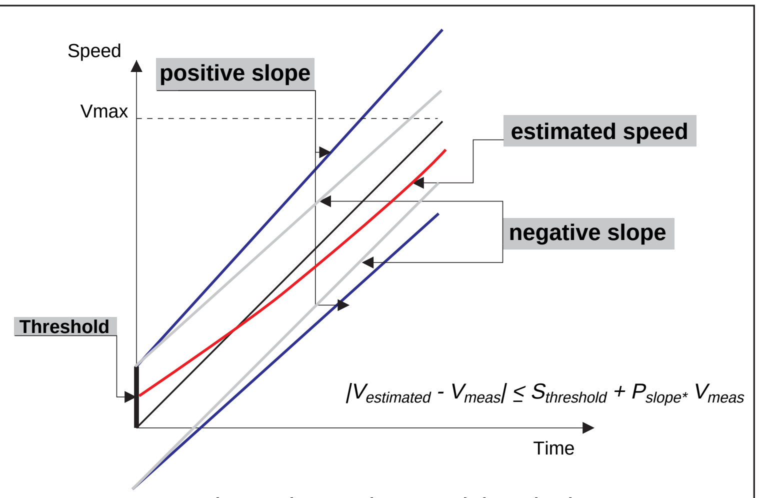
Word N2: Measured speed replaced by observed speed and activation of the speed monitoring system (**for axes**). The bit position corresponds to the speed sensor address.

Word N3: Measured speed replaced by observed speed and activation of the speed monitoring system (**for QVN spindles**). For the spindle at address j, setting of bit j-24 of word N3 activates the speed observer.

7.3.3.3 Supervision Device

A **supervision device** monitors the speed within a speed cone defined by a threshold and a slope.

Parameter P120: Includes 64 words, representing the speed threshold in rpm and the slope in thousandths applied to the supervision device speed signal. Words N2i and N2i+1 correspond to speed sensor address i.



Estimated speed supervision device

The permissible values of $V_{threshold}$ are positive and limited to 40 percent of the maximum motor speed (P73).

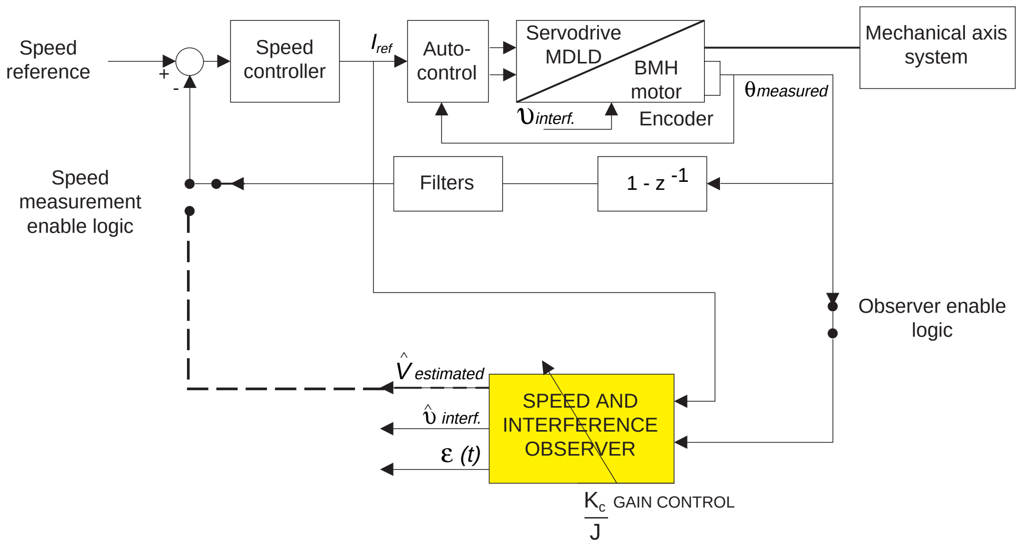
The value of coefficient K_{slope} can be:
- Zero: The maximum permissible error is constant at all speeds
- Positive: The maximum permissible error increases with the speed
- Negative: The maximum permissible error decreases with the speed.

The recommended values are: $V_{threshold}$ around 100 rpm, K_{slope} close to 2% of Vmax.

If the speed error between the estimated and measured speed is greater than the permissible error, the QVN returns error "245" associated with the message "Speed estimator".

The two probable causes of error are:
- A speed threshold $V_{threshold}$ and a coefficient K_{slope} too severe: relax the supervision requirements
- Estimator incorrectly set: adjust the setting of $\frac{K_c}{J}$ or gains $\boldsymbol{K_{1m}}$ $\boldsymbol{K_{2m}}$ $\boldsymbol{K_{3m}}$

7.3.3.4 Integration of the Speed Observer



Functional diagram during speed and interference observer adjustment

Known Parameters of the Moving Assembly

The input data are:

- Ratio $\dfrac{K_{c[Nm/Arms]}}{Jmot}$ associated with each of the motors (see motor characteristic)

- Inertia ratio $Ri = \dfrac{J_{load}}{J_{motor}}$. The permissible real values are 0 < Ri < 19.

The table of required observer characteristics (see tables below).

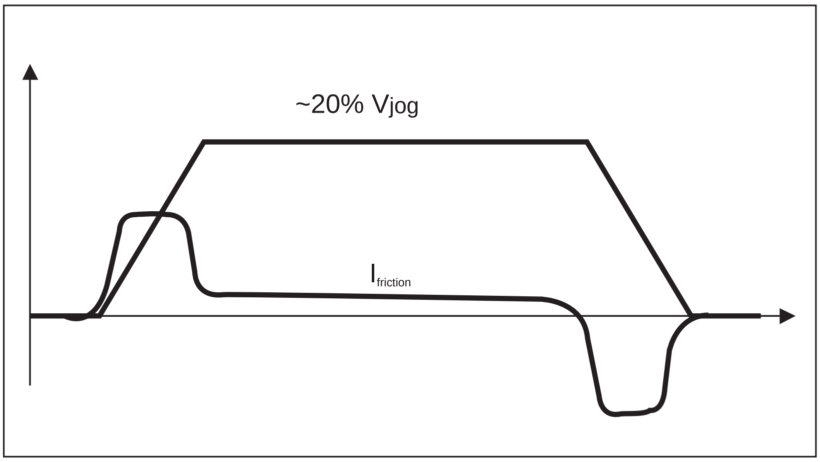
These data are used to determine:

- Ratio $\dfrac{K_{c[Nm/Arms]}}{J} = \dfrac{K_{c[Nm/Arms]}}{Jmot * (Ri + 1)}$.
- The three gains K_{1m} K_{2m} *and* K_{3m} (see characteristic table).

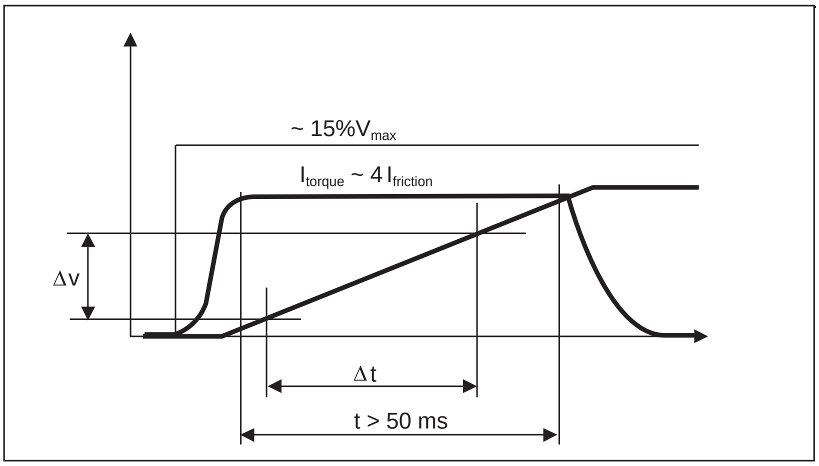
Unknown Parameters of the Moving Assembly

Experimental determination of the gain $\dfrac{K_{c[Nm/Arms]}}{J} = \dfrac{K_{c[Nm/Arms]}}{Jmot * (Ri + 1)}$ under SETTool:

- In feedback mode, measure the friction current $I_{frict\_[Apeak]}$ during movement at stabilised speed (approximately 20% of the jog speed).



- Limit the maximum torque current I_{c_sat} (**P79**) to approximately four times I_{frict}, decreasing the speed loop proportional and integral action coefficients if necessary. If dry friction is negligible, clip the torque current to approximately I_{rated}/ 6.
- Apply a speed control pulse equal to 15% of maximum speed to saturate the current for a significant time (e.g. 50 ms) then measure the acceleration (2.π.ΔV/60)/ΔT over time interval ΔT (in s) at saturated current (ΔV is the speed variation in rpm during time interval ΔT).



- The gain $\frac{K_{c[Nm/Arms]}}{J} = \frac{K_{c[Nm/Arms]}}{Jmot * (Ri + 1)}$ is approximately equal to:

$$\frac{K_{c[Nm/Arms]}}{J} = \frac{2.\pi.\Delta V_{rpm}\sqrt{2}}{60.\,\Delta T.(I_{c\_sat} - I_{frict.})}$$

- The estimated gain includes a relative error less than 5 percent.

7.3.4 Improving the Accuracy and Stability of an Axis

7.3.4.1 Application

Maximum positioning accuracy is obtained by direct measurement on the moving part rather than on the motor. This automatically takes into account the defects of the moving assembly (backlash, play in screw threads or rack).

However, most adjustment problems are due to imperfections of the mechanical transmission system between the motor, load generator and load, i.e. the part to be moved, whose position is measured. Transmission backlash and elasticity cause a phase lag between the load applied and its effect on the measurement which leads to feedback instability.

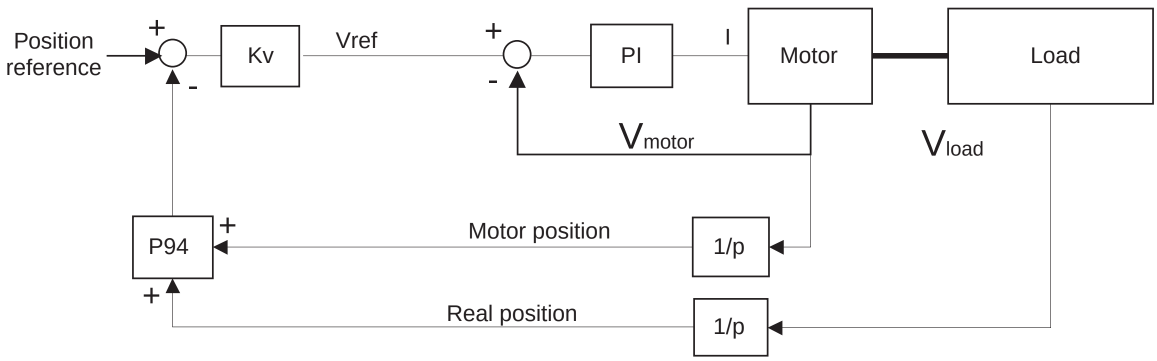
Double position measurement uses both the position output by the motor sensor and that output by a sensor related to the load in a settable proportion. It is used to ensure isolation from the load and the negative effects of defects of the moving assembly.

In certain extreme cases, double position measurement may be the only way of stabilising the position loop of an axis.

However, it should be noted that the strategy of using **P94** degrades feedback performance since the information from the axis encoder is not fully used. This may be visible on ball-bar quadrant marking.

7.3.4.2 Double Position Measurement

The solution proposed consists of using the two outputs from the motor sensor and the load sensor with two complementary position loops:



- A first **rapid** and **stable** position loop with the motor position sensor
- A second **accurate** position loop with measurement of the load position.

P94 specifies the frequency separating the two complementary loops.

Axis sensor feedback predominant	**P94**	**Motor** sensor feedback predominant

7.3.4.3 Machine Parameter P94

Parameter P94 specifies the separation frequency between the two complementary position loops in **tenths of a Hertz**. The maximum permissible setting is 1/(4*CNC_RTC), i.e. 1000/20 = 50 Hz, i.e. a maximum setting of P94 = 500 for a CNC_RTC of 5 ms.

If the setting of **P94 is low**, motor feedback predominates: the loop is stable but risks being inaccurate.

Axis sensor feedback predominant	**P94**	**Motor** sensor feedback predominant

If the setting of **P94 is high**, axis feedback predominates: the loop is accurate but risks being unstable.

Axis sensor feedback predominant	**P94**	**Motor** sensor feedback predominant

If **P94 = 0**, the function is disabled and only the **axis** sensor output is used.

If P94 is different from zero, the function is activated when power is applied.

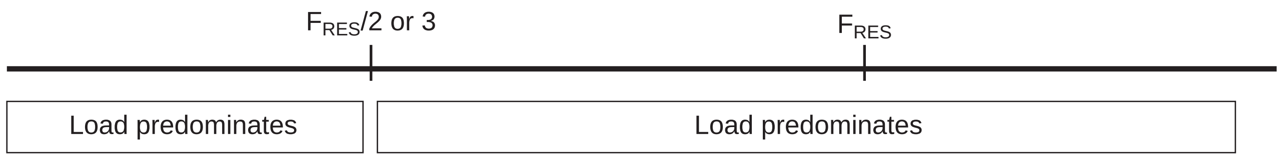
7.3.4.4 Methodology

Start the CNC with a low setting of P94 (e.g. P94 = 50, i.e. 5 Hz) so that motor feedback predominates.

Use SETTool to observe the position of the load.

Increase P94 until the position loop becomes unstable. Then decrease P94 by approximately 20%.

Case of a resonance: If the mechanical problem is a known resonance at F_{res}, **P94** can be set to filter the destabilising component of the axis sensor feedback above F_{res}/2 or 3.



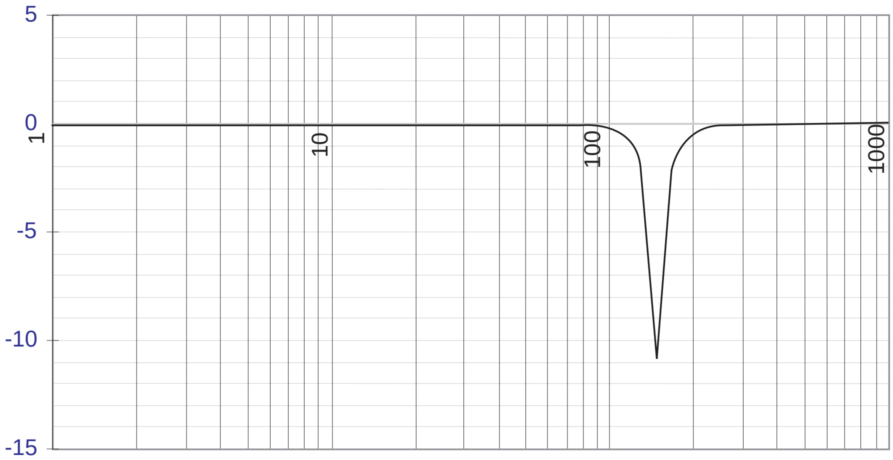
$$P94 = 10\,\frac{F_{RES}}{2 \text{ or } 3} = \frac{F_{RES}}{3 \text{ or } 5}$$

7.3.5 Notch Filters

Two notch filters are available to stabilise the load in presence of mechanical resonance. They operate on the speed error for resonance at frequencies outside the speed loop bandwidth or on the speed reference for resonance at frequencies in the speed loop bandwidth.

7.3.5.1 Notch Filter on Speed Error

Purpose: Stabilise the load in presence of mechanical resonance at a frequency outside the speed loop bandwidth.



Case of a speed loop **WITH** overshoot:

The approximate bandwidth is determined from the expression $T_p * \omega_c \cong 4.5$ *(see glossary)*, yielding

$$f_c \approx \frac{4.5}{2\pi} * \frac{1}{T_p} \cong \frac{1}{1.4T_p}$$

Case of a speed loop **WITHOUT** overshoot:

The bandwidth can be estimated from the response time to a low amplitude control pulse at 95% of the final speed:

$f_c = \frac{1}{2t_r}$ or based on the gains $f_c \approx \frac{1}{2\pi} \frac{K_p K_c}{\sqrt{2}J_{tot}}$

In both cases the speed or current oscillation frequency must be > $2f_c$

If the cause of the phenomenon is mechanical resonance, the oscillation period is independent of the speed. However, it may vary slightly with the machine position during the test.

Machine Parameters

Parameters P92 and P93 specify the filter.

The word number corresponds to motor sensor i for axes and j+8 for spindles.

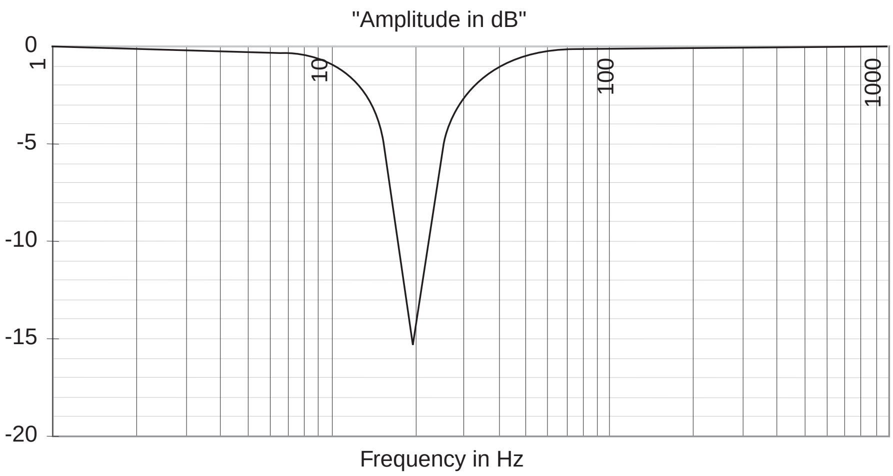
Methodology

- Measure the motor current or speed oscillation period T using SETTool. Determine the frequency F = 1/T
- Enter the measured frequency as filter cutoff frequency fo at maximum attenuation
- Set the -3 dB bandwidth to f_0
- Set the attenuation to -10 dB
- Set the calculated values in parameters P92 and P93 (see Sec. 7.4)
- Check the filter efficiency by a new recording with SETTool
- If interference subsists, the attenuation can be increased to -30 dB.

7.3.5.2 Notch Filter on Speed Reference

Purpose

Stabilise the load in presence of low frequency mechanical resonance in the speed loop bandwidth (~[10-25 Hz] in the example).



Machine Parameters

Parameters P89 and P90 specify the filter.

The word number corresponds to motor sensor i for axes and j+8 for spindles.

Methodology

Use SETTool to observe:

- The motor speed or motor current if the load influences the motor
- The load speed if the load does not influence the motor (case of unsuitable inertia ratio)
- Measure the motor current or speed oscillation period T using SETTool. Determine the frequency F = 1/T
- Enter the measured frequency as filter cutoff frequency f_0 at maximum attenuation
- Set the -3 dB bandwidth to f_0
- Set the attenuation to between -10 and -15 dB
- Check that the filter phase shift does not exceed 20 to 30 degrees (see Sec. 7.3.5.3)
- Set the calculated values in parameters P89 and P90 (see Sec. 7.4)
- Check the filter efficiency by a new recording with SETTool
- If interference subsists, the attenuation can be increased to -30 dB.

- If necessary, increase the attenuation within the limit permitted by the phase shift.

The filter phase shift increases with the bandwidth and especially with the attenuation. The wider the bandwidth, the more rapidly the filter acts at low frequencies.

7.3.5.3 Determination of Parameters {P89, P90} {P92, P93}

Parameters P89, P90, P92 and P93 are determined using the NOTCH-d.XLS Excel worksheet by entering the characteristics of the interference to be eliminated in the cells provided
- Cutoff frequency F_c relative to maximum attenuation
- -3 dB bandwidth centred on the cutoff frequency (typical bandwidth = F_c)
- Amplitude of the attenuation in dB at the cutoff frequency (-10 to -15 dB).

Procedure
- Fill in cells A2, B2, C2 (cutoff frequency, bandwidth, attenuation)
- Fill in cell C7 (required position gain in m/min/mm)
- Set cell D2 to zero (high-frequency attenuation)
- Set cell E5 to zero (gain correction)
- Fine-tune the result by adjusting the gain correction as follows:
  - In the TOOL menu, select TARGET VALUE
  - Fill in the CELL TO BE SPECIFIED field by clicking cell D5 (gain_digit.hf)
  - Fill in the VALUE TO BE REACHED field by clicking cell D2 (Att_HF(dB))
  - Fill in the CELL TO BE MODIFIED field by clicking cell E5 (correct_gain).
  - Click OK. The process may last several minutes.

7

REMARK *The macro called by <Ctrl+m> automatically adjusts the HF gain.*
To use this function, set cell D2 to zero.

The parameter values are given in cells B19 to B22.

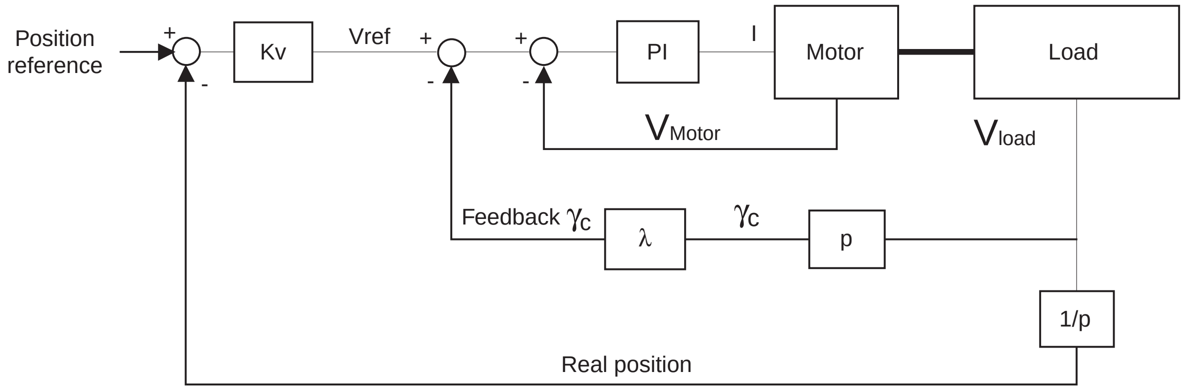
Precaution

For the filter on the speed reference, make sure the phase shift at the position loop cutoff frequency specified in cell E23 is less than 20 to 30 degrees. This may require decreasing the attenuation or bandwidth.

7.3.6 Damping the Flexible Modes of the Machine

When the speed loop bandwidth is large, the machine risks vibrating at the frequency of its flexible mode.

Active damping of the machine can be achieved by load acceleration feedback determined by differentiating the machine speed read on a load sensor.



7.3.6.1 Wiring Requirement

The load and motor sensors must both be connected to the same QVN card.

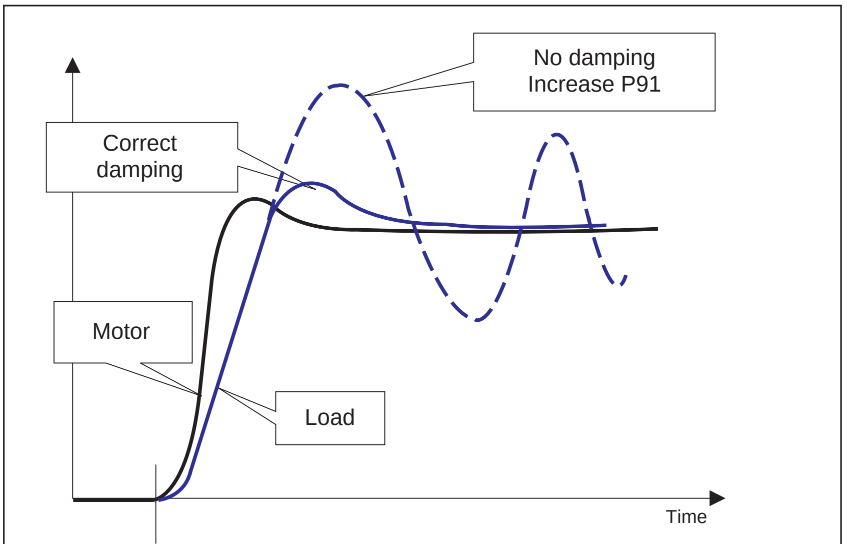
REMARK QVN cards accommodate only incremental encoders.

7.3.6.2 Machine Parameter P91

Parameter P91 specifies the damping coefficient of the flexible mode of the machine.
Word i corresponds to axis sensor address i and word j+8 to spindle address j.
The permissible setting in thousandths ranges from 0 (no damping) to 1000 (maximum damping).

If **P91** is different from zero, the function is activated at power on.

7.3.6.3 Methodology



Influence of P91

Use SETTool to observe the motor speed and load speed.

Increase P91 until damping of the flexible mode is correct.

Observe the motor current. If the load measurement quantisation effect is large, set filtering of the load speed (the available filters are the same as those dedicated to the motor speed):
- Averaging on the load speed measurement: average of **P76Ni** values (i: load sensor address)
- First-order low-pass filter on load speed measurement: **P77Ni** contains the cutoff frequency in Hz (i: load sensor address).

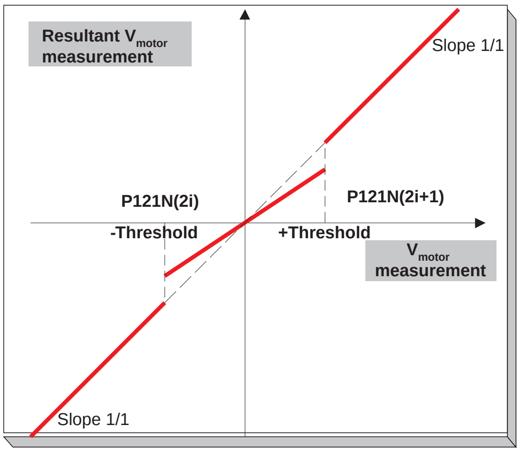
7.3.7 Vibration Reduction/Elimination When Stopped

Speed measurement quantisation phenomena are directly amplified by the proportional action coefficient of the feedback loop. Torque current spikes whose amplitude is directly related to gain Kp are then transmitted to the power components (drive/motor).

A vibration can then arise in the motor feedback loop when stopped. The typical vibration frequency is around 100 Hz {90 - 120 Hz}.

7.3.7.1 Vibration Elimination When Stopped by Speed Measurement Processing (P121)

Description of the Function



Non-linear measurement processing in the speed loop feedback system

To reduce the vibration amplitude efficiently when stopped while preserving a high proportional action gain, the speed measurement related to proportional action gain Kp is weighted by a coefficient equal to less than 1 when the **speed measurement** is below a threshold.

Parameter P121

Case of a QVN Axis

P121N2i: Speed threshold (in tenths of rpm), where i is the motor speed sensor address

- For an averaged, filtered speed measurement, the threshold is typically given by the speed measurement resolution, i.e. 1/(300*qvn_rtc[in sec]) rpm.
- For an estimated motor speed measurement, the threshold is set to a value close to the apparent resolution of the estimator, i.e. approximately 1/(300*qvn_rtc[in sec]) rpm.

P121N2i+1: Coefficient applied to the motor speed ratio below the threshold [in thousandths], where i is the motor sensor address. Typical value 70%, i.e. P121N2i+1 = 700.

Examples for an axis

qvn_rtc [s]	Apparent resolution of V_{meas}	Measurement type	P121N2i	P121N2i+1
0.0004	~ 8.4 rpm	position Δ	**> 84**	**700**
0.0005	~ 6.7 rpm	position Δ	**> 67**	**700**
0.0004	~ 0.5 rpm	observer	**> 5**	**700**
0.0005	~ 0.6 rpm	observer	**> 6**	**700**

Case of a QVN Spindle

P121N2(j+8): Speed threshold (in tenths of rpm),
where j is the spindle speed sensor address (j∈{24,...,27}).

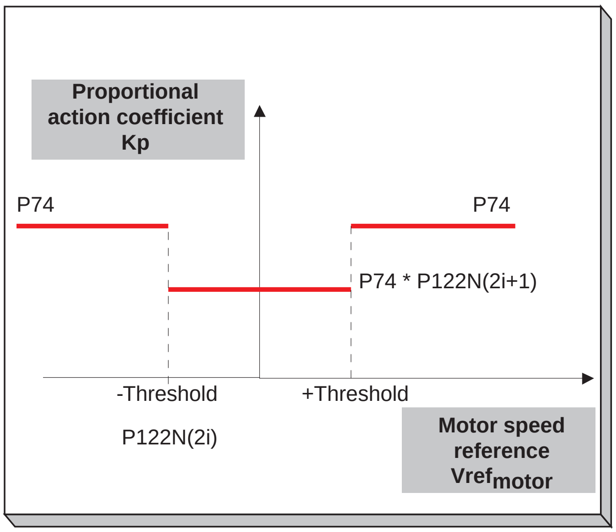
P121N2(j+8)+1: Coefficient applied to the motor speed ratio below the threshold [in thousandths],
where j is the spindle sensor address.

If the parameter associated with the **speed measurement threshold** is different from zero, the function is activated.

7.3.7.2 Vibration Elimination When Stopped by Decrease of the Proportional Gain (P122)

Description of the Function

To reduce the vibration amplitude efficiently when stopped while preserving a high proportional action gain, the proportional action coefficient is decreased when the speed **reference** falls below a threshold.



Parameter P122

Case of a QVN Axis

P122N2i: Speed reference threshold (in tenths of rpm). The typical value is the apparent speed measurement resolution

P121N2i+1: Ratio applied to speed loop proportional action coefficient when the speed reference is below the threshold. Typical value 70%.

Case of a QVN Spindle

P122N2(j+8): Speed reference threshold (in tenths of rpm), where j is the spindle speed sensor address ($j \in \{24,...,27\}$).

P122N2(j+8)+1: Ratio applied to the speed loop proportional action coefficient when the speed reference is below the threshold in thousandths], where j is the spindle sensor address.

If the parameter associated with the speed reference threshold is different from zero, the function is activated.

7.3.8 Low-Pass Filter on the Speed Reference

Purpose: Smooth the load acceleration.

7.3.8.1 Machine Parameter P88

Parameter P88: f_c is the cutoff frequency in hertz of the first-order filter.

The cutoff frequency must satisfy the following inequality:

$f_{cutoff[Hz]} \geq 4. \frac{1000}{60} . \frac{G_{CNC[(m/min)/mm]}}{2\pi}$ to smooth the acceleration of the load without degrading the position loop stability (speed overshoot).

Note: Maximum permissible value = $\frac{1}{4^{*}\ Htr\_QVN}$

The use of this filter must not compromise the CNC gain requirements stated by the customer.

Word i corresponds to axis sensor address i and word j+8 to spindle address j.

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7.4 Dynamic Parameter Modification in QVN

Dynamic modification of the machine parameter images facilitates adjustment of the settings while making it possible to see the effect of the modification without having to reset the machine.

Dynamic modification does not change the parameter settings in the EEPROM but only the value in internal units used by the QVN card. When modification is completed, the settings must be included in the machine parameters by means of utility 5.

When the system is reset, the parameter settings in the EEPROM are used.

Parameter modification is carried out by programming operator OV1 with the following arguments:
/ @ position sensor address
/ @ speed sensor address
/ parameter number
/ ... parameter setting
/ ... parameter setting
/ ...

The parameter setting arguments are expressed in the same unit and order as those used in utility 5.

Each argument can be a numerical value, an L variable, an external parameter or a symbolic variable.

The following parameters can currently be modified in internal units in QVN:

P20, P21	
P76	Number of terms of the position sensor speed measurement averager
P77	Position sensor speed measurement filter cutoff frequency
P88	Frequency of low-pass filter on speed reference
P89, P90	Notch filter on speed reference
P91	Flexibility compensation
P92, P93	Notch filter on speed error
P94	Double position measurement
P116, P117, P118, P119	Speed and interference observer
P120	Observer supervision
P121	Non-linearity on speed
P122	Gain clipping

7.4.1 Programming Notes

Certain functions are specified by a group of several parameters. Each parameter can have several arguments.

A change in one parameter of a group can be carried out by specifying any parameter of the group, but all the arguments of all the parameters must be specified.

The table below shows the syntax used for each group.

Parameter	Syntax	Permissible settings (else programming error)	Disable setting	Maximum settings in internal units
P20, P21	/20/ setting P20 / setting P21	P20 (0,1) P21 : > 0		
P88	/88/parameter setting	≥ 0 and ≤ 65535	0	1Hz, Fsmp QVN/4
P76	/76/setting	≥ 0	0	0.7
P77	/77/setting	≥ 0 or ≤ 65536	< 20	20Hz,F_{QVN}/4
P89, P90	/89/ fn/ zn/ fd/ zd or /90/ fn/ zn/ fd/ zd	Same conditions as for initialisation	fn = 0, zn = 0, fd = 0, zd = 0	
P91	/91/setting	0 < setting < 1000	None	
P92, P93	/92/ fn/ zn/ fd/ zd or /93/ fn/ zn/ fd/ zd	Same conditions as for initialisation	fn = 0, zn = 0, fd = 0, zd = 0	
P94	/94/setting	0 < setting ≤ 65536	0	0.1Hz,F_{CNC}/4
P116, P117, P118, P119	/116/Kc/J/K1m/K2m/K3m Or /117/Kc/J/K1m/K2m/K3m Or /118/Kc/J/K1m/K2m/K3m Or /119/Kc/J/K1m/K2m/K3m	Same conditions as for initialisation	None	
P120	/120/Vthreshold/Kslope	≥ -65535 and ≤ 65535		Maximum settings same as for initialisation
P121	/121/threshold/ratio	Same conditions as for initialisation	Threshold = 0	
P122	/122/threshold/ratio	Same conditions as for initialisation	Threshold = 0	

If the settings programmed do not satisfy the requirements (programming error 93), the corresponding parameters of the QVN application remain unchanged.

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7.4.2 Example

The example concerns the QVN application controlled by QVN card 0 using an additional position sensor:

position sensor @ = 5

speed sensor @ = 25

The programme below sets the parameters for various functions.

%100

(QVN parameter modification on request)

(Low-pass filter on speed reference)

N10 OV1/5/25/88/70

(Notch filter on speed reference: f_n, z_n, f_d, z_n)

N20 OV1/5/25/89/100/20/96/300

(Speed observer: Kc/J, K_{1m}, K_{2m}, K_{3m})

N30 OV1/5/25/116/70833/ 238900/12300/8657

(Speed observer: $V_{threshold}$ and K_{slope})

N40 OV1/5/25/120/80/300

(Notch filter on speed error: f_n, z_n, f_d, z_n)

N50 OV1/5/25/92/200/20/198/300

(Load acceleration feedback: 0.5 encoded as 500/1000)

N60 OV1/5/25/91/500

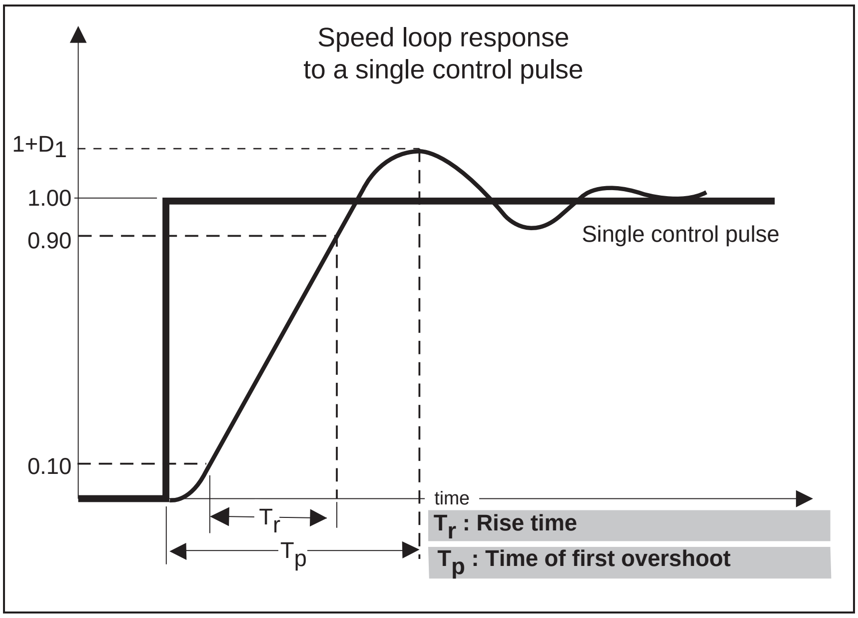
(Averaging filter on two consecutive values for the load speed)

N70 OV1/5/-1/76/1 (see remark)

M2

REMARK *If the parameter is used with the load sensor (case of P76 and P77), the motor speed sensor address argument must be set to -1.*

7.5 Glossary



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T_r: Rise time

Time between 10% and 90% of the final value of a signal assumed to be only slightly damped.

T_p: Overshoot time (peak time)

Time of the first overshoot of the response measured from the start of the control pulse.

Relation between T_p, the speed loop -3 dB cutoff pulse ω_c and the CNC position gain:

ω_c is the -3 dB cutoff pulse of the speed loop, i.e. ?c is the speed loop bandwidth. An overshoot of 30% is tolerated.

The function relating T_p to ω_c is $\boxed{T_p \,.\, \omega_c \cong 4.5}$

The time T_p of the first overshoot is therefore a very good indicator of the speed loop bandwidth.

For correct closed loop operation, the speed loop bandwidth ω_c must be 4 to 5 times higher than the position gain K_v.

The function relating time T_p to the CNC gain is:

$$T_p = \frac{4.5}{\omega_c} \leq \frac{4.5}{4.5\ K_v} = \frac{1}{K_v} = \frac{60_{[s]}}{1000.G_{CNC}} = \frac{60_{[ms]}}{G_{CNC[(m/min)/mm]}}$$

The time Tp of the first overshoot can therefore be used to estimate the maximum possible position gain:

$$G_{CNC[(m/min)/mm]} \leq \frac{60}{T_{p(ms)}}$$

The speed loop bandwidth must be:

$$\omega_c = 4{,}5K_v = \frac{4500G_{CNC[(m/min)/mm]}}{60}$$