Bulletin MSG11-5715-677/UK

Operation Manual
Series PWDXXA-40X
Design ≥ 40

Electronics for Proportional DC Valves

Parker Hannifin
Manufacturing Germany GmbH & Co. KG
Industrial Systems Division Europe
Gutenbergstr. 38
41564 Kaarst, Germany
E-mail: isde.kaarst.support@support.parker.com

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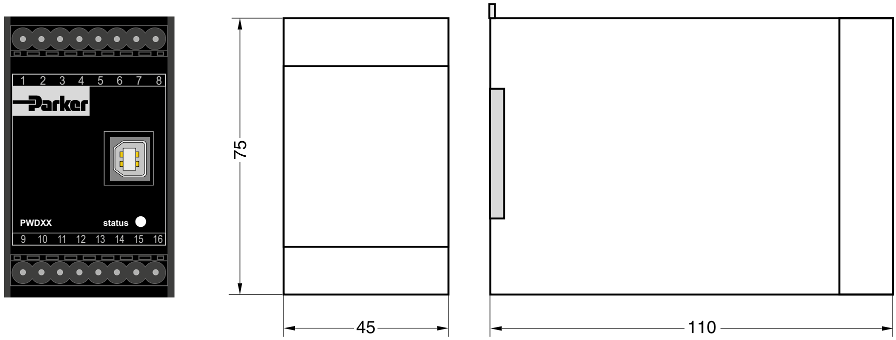
1. Introduction

Parker electronic modules PWDXXA-40X for rail mounting are compact, easy to install and provide time-saving wiring by disconnectable terminals. The digital design of the circuit results in good accuracy and optimal adaption for proportional directional control valves with position sensor by a comfortable interface program.

1.1 Front view / dimensions



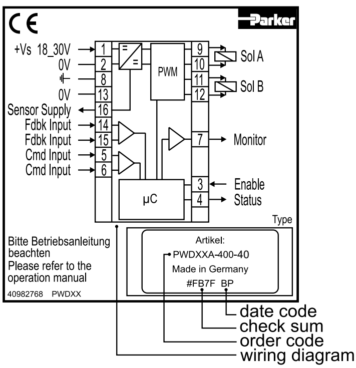
1.2 Ordering code

PWD **XX** **A** – **40** – ☐ – ☐

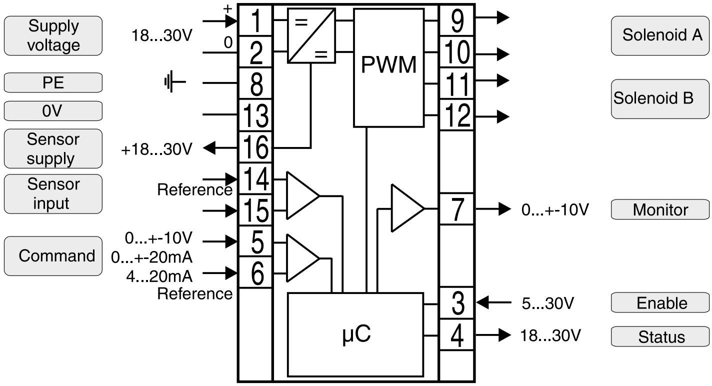
- **PWD**: Electronic module for DC valves
- **XX**: Position control universal
- **40**: Amplifier, Min/Max adjustment, accel/decel ramps, command input
- ☐: Technology function
- ☐: Design series

Code	Function
0	Standard
1	Linearization

1.3 Name plate



1.4 Block diagram



1.5 Characteristics

The described electronic unit combines all necessary functions for the optimal operation of proportional directional control valves with position sensor. The most important features are:

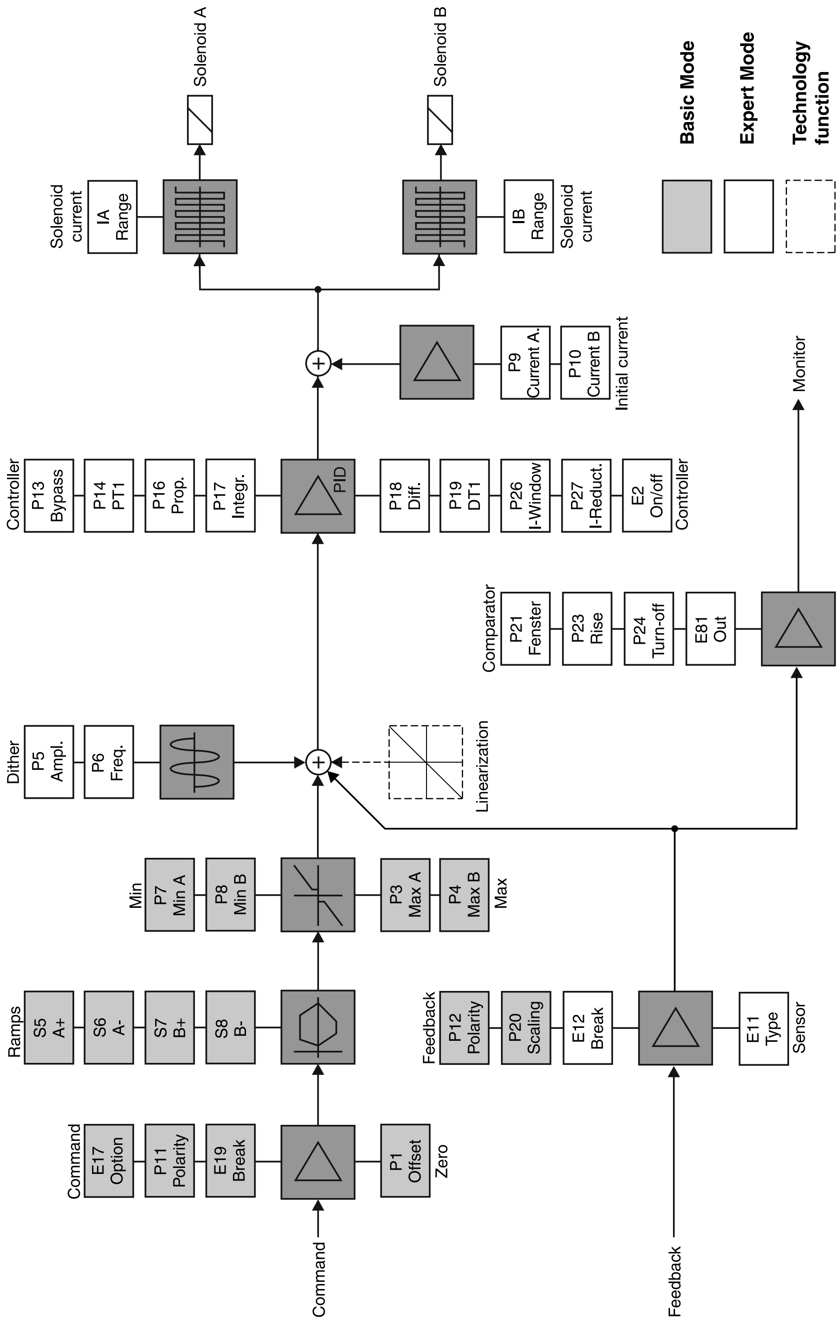
- digital circuit design
- parametrizable control as position control for valve spool or external closed loop control
- constant current control
- differential input stage with different signal options
- monitor output for spool stroke/feedback, status output
- four quadrant ramp function
- enable input for solenoid driver
- status indicator
- parametering by USB interface
- connection by disconnectable terminals
- compatible to the relevant European EMC-standards
- Comfortable PC user software, free of charge: **www.parker.com/isde** - see "Support", or directly at **www.parker.com/propxd.**
- optional technology function "linearization"

CE

1.6 Technical data

General		
Model		Module package for snap-on mounting on EN 50022 rail
Package material		Polycarbonate
Inflammability class		V0 acc. UL 94
Installation position		Any
Ambient temperature range	[°C]	-20...+60
Protection class		IP 20 acc. EN 60529
Weight	[g]	160
Electrical		
Duty ratio	[%]	100
Supply voltage	[VDC]	18...30, ripple < 5 % eff., surge free
Switch-on current typ.	[A]	22 for 0.2 mS
Current consumption max.	[A]	2.0
Pre-fusing	[A]	2.5 A medium lag
Command signal options	[V] [mA] [mA]	+10...0...-10, ripple < 0.01 % eff., surge free, Ri = 100 kOhm +20...0...-20, ripple < 0.01 % eff., surge free, Ri = 200 Ohm 4...12...20, ripple < 0.01 % eff., surge free, Ri = 200 Ohm < 3.6 mA = solenoid output off, > 3.8 mA = solenoid output on (acc. NAMUR NE43)
Input signal resolution	[%]	0.025
Differential input voltage max.	[V]	30 for terminals 5 and 6 against PE (terminal 8) 11 for terminals 5 and 6 against 0 V (terminal 2)
Sensor supply	[V]	18...30 (U_S), max. current <100 mA
Enable signal	[V]	0...2.5: Off / 5...30: On / Ri = 100 kOhm
Status signal	[V]	0...0.5: Off / Us: On / rated max. 15 mA
Monitor signal	[V]	+10...0...-10, rated max. 5 mA, signal resolution 0.4 %
Adjustment ranges Min Max Ramp Zero offset Current Initial current	[%] [%] [s] [%] [A] [%]	0...50 50...100 0...32.5 +100...-100 1.3 / 2.7 / 3.5 0...25
Interface		USB type B
EMC		EN IEC 61000-6-2, EN IEC 61000-6-4
Connection		Screw terminals 0.2...2.5 mm², disconnectable
Cable specification	[AWG] [AWG]	16 overall braid shield for supply voltage and solenoids 20 overall braid shield for sensor and signal
Cable length	[m]	50
Options		
Technology function	Code1	Software adjustable transfer function with 10 compensation points for linearization of valve behaviour.

1.7 Signal flow diagram



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2. Safety instructions

Please read the operation manual before installation, startup, service, repair or stocking! Paying no attention may result in damaging the electronics or incorporated system parts.

2.1 Symbols

This manual uses symbols which have to be followed accordingly:

⚠ **Instructions with regard to the warranty**

△ **Instructions with regard to possible damaging of the electronics or linked system components**

☞ **Helpful additional instructions**

2.2 Marking, name plates

Instructions applied on the electronics, i.e. wiring diagrams and name plates, must be observed and maintained legibly.

2.3 Work at the electronics

Working in the area of installation and commissioning of the electronics may only be allowed by qualified personnel. This means persons who due to education, experience and instruction, have sufficient knowledge of relevant directives and approved technical rules.

3.0 Important details

3.1 Intended usage

This operation manual is valid for module electronics PWDXXA-40X series. Any use diverging or going beyond is deemed to be as not intended. The manufacturer is not liable for warranty claims resulting from this.

3.2 Common instructions

We reserve the right of technical modifications of the described product. Illustrations and drawings within this manual are simplified representations. Due to further development, improvement and modification of the product, the illustrations might not match precisely with the described valve. The technical specifications and dimensions are not binding. No claim may resulting from it. Copyrights reserved.

3.3 Liability

The manufacturer does not assume liability for damage due to the following failures:

- incorrect mounting / installation
- improper handling
- lack of maintenance
- operation outside the specifications

⚠ Do not disassemble the electronics! In case of suspicion for a defect please return the unit to the factory.

3.4 Storage

In case of temporary storage the electronics must be protected against contamination, atmospheric exposure and mechanical damages.

4. Mounting / Installation

4.1 Scope of supply

Please check immediately after receiving the electronics, if the content is matching with the specified scope of supply. The delivery includes:

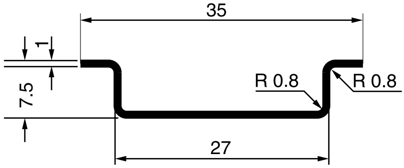
- module electronics
- operation manual

☞ Please check the delivery immediately after receiving the shipment for apparent damages due to shipping. Report shipment losses at once to the carrier, the insurance company and the supplier!

4.2 Mounting

- Compare electronics type (located on the name plate) with part list resp. circuit diagram.
- The module may be mounted in any direction.
- The module has to be mounted within a shielded environment (i.e. control cabinet).
- For mounting an assembly rail acc. EN 50022 is required.

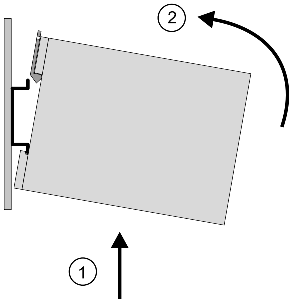
Dimensions assembly rail



Work flow for module installation

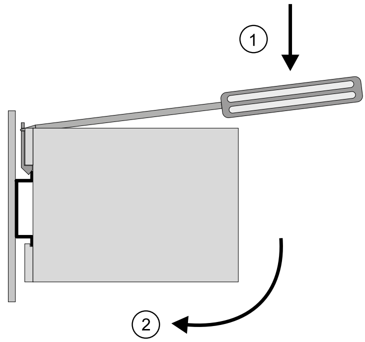
Mounting:

1. Apply the module with the assembly rail guide at the lower edge of the rail.
2. Engage the module upward.



Removing:

1. Lift the metal socket lock with a suitable screwdriver (approx. 4 x 1 mm blade) against the spring force.
2. Unmount the module at the top edge of the assembly rail.



4.3 Operation limits

The electronics may be operated within the determined limits only. Please refer to the “technical data” section.

⚠ Follow the environmental conditions! Unallowable temperatures, shock load, moisture exposure, radiation exposure, illegal electromagnetic emmissions may result in operating trouble and may lead to failure! Follow the operating limits listed in the “specifications” table!

4.4 Electrical connection

The electrical connection of the module electronics takes place by disconnectable screw terminal blocks.

☞ This easy-to-install connection type allows a fast module replacement and a visible separation of the electrical connection. An additional folding unlocking lever allows simple removing of the terminal blocks and serves at once as shock hazard protection and marking strip.

The connecting wires have to comply to the following specification:

Wire type:	hookup cable, stranded
Cross sections:	supply and solenoids min. AWG 16/1.5 mm²
	sensor and signals min. AWG 20/0.5 mm²
Wire length:	max. 50 m

☞ For wire lengths > 50 m consult factory.

Skinning length for the connection wires

The screw terminals are designed to allow termination of all kinds of copper wires without the need for preparation. Copper made wire end sleeves may usable as conductor stripping protection for the stranded wires.

⚠ Soldering of the connection wires is not permitted.

To ensure EMC-compatibility the wiring of the module has partly to be undertaken by shielded cables. Detailed information can be read from the chapter “Electrical Interfacing”.

⚠ The installation has to take place by qualified personnel! A short between individual conductors, loose wires as well as improper shield connection may result in malfunction and breakdown of the electronics resp. the connected valve!

⚠ The mounting surface of the valve has to be carefully tied to the earth grounded machine frame. The earth ground wire from terminal 8 as well as the cable shields have to be tied to the protective earth terminal within the control unit. It is necessary to use a low ohmic potential connection between control unit and machine frame to prevent earth loops (cross section min. AWG 6 / 10 mm²).

4.5 Electrical interfacing

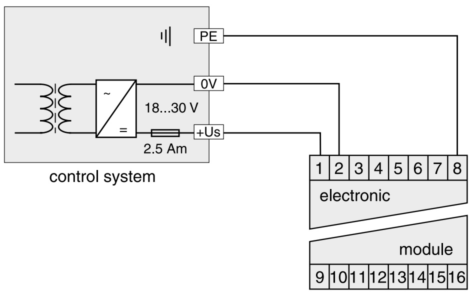
Supply Voltage:

The supply voltage for the electronics will be connected to the terminals 1 and 2 of the module electronics and has to cover the range of 18...30 V. The residual ripple may not exceed 5 % eff.

⚠ The applied power supply must comply to the relevant regulations (DIN EN 61558) and must carry a CE-mark. The operating voltage for the electronics must be free of inductive surges. Do not exceed the max. value of 30V! Non-observance of this rule may result in permanent damaging of the electronics resp. the connected valve!

⚠ The increased inrush current of the valve should be considered when selecting the power supply. A stabilized power supply with overcurrent limiting feature should not be used. Due to the inrush current of the electronics the current limit circuit may respond prematurely and create problems during energizing of the supply voltage.

Wiring diagram of supply voltage



⚠ The operation of the electronics is blocked if the supply voltage polarity is interchanged.

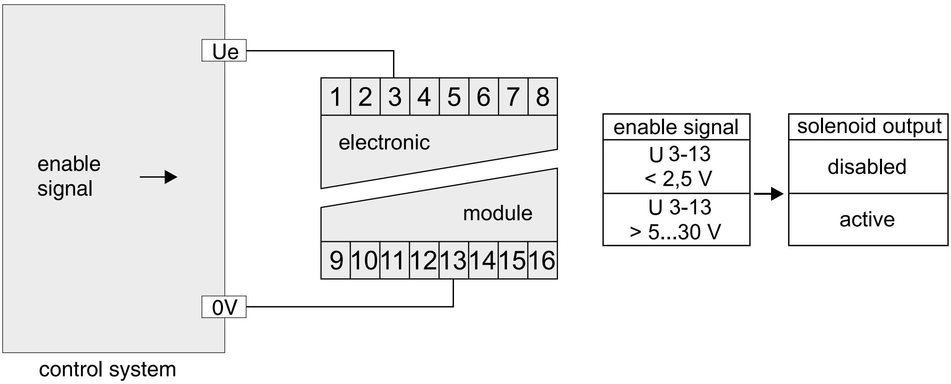
⚠ Each electronics requires a separate pre-fuse of 2.5 Amp time lag. Non-observance of this instruction may create irreparable damage of electronics resp. incorporated system parts.

Enable input

A signal voltage applied to the terminals 3 and 13 enables the solenoid output of the electronics. Continuous operation of the electronics requires a permanent voltage 5...30 V (i.e. the supply voltage). In case of disabling the signal the solenoid output of the electronics will be switched off in no time independently from the command signal value. At the same time the position controller output will be clamped. In case of restarting the enable signal, the valve spool takes its position always out of the fail safe position. Preferable the enable signal should be switched on together with the hydraulic pressure supply. This forces the valve solenoid into drop out condition when the hydraulic system is switched off, and it avoids needless heating of the actuator.

⚠ The enable function represents no safety arrangement against unwanted valve operation in terms of rules for accident prevention! To block the valve function under all conditions, more advanced steps are necessary, i.e. the installation of additional safety check valves.

Wiring diagram of enable input



Command signal input

The command signal to the valve will be connected to the terminals 5 and 6 of the difference signal input of the electronics. The connection has to be performed shielded.

The stroke of the valve spool behaves proportional to the command signal amplitude. Depending on the selected electronic parameters different versions of command signal processing are available, which are decribed below.

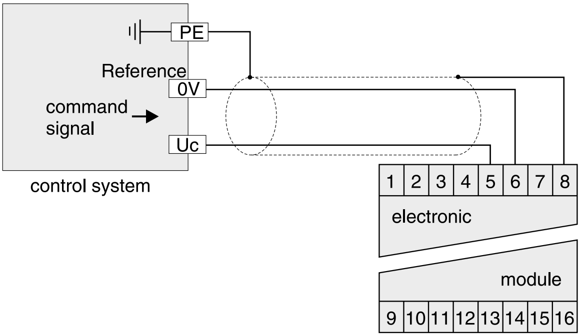
For the function description terminal 6 is assumed as signal reference (0 V).

☞ Details are shown from the technical specifications. The parameter options for the command signal input are described in the chapter “Operating Instructions).

⚠ The command input signal needs to be filtered as well as free of inductive surges and modulations. To prevent malfunctions a high signal quality is recommended.

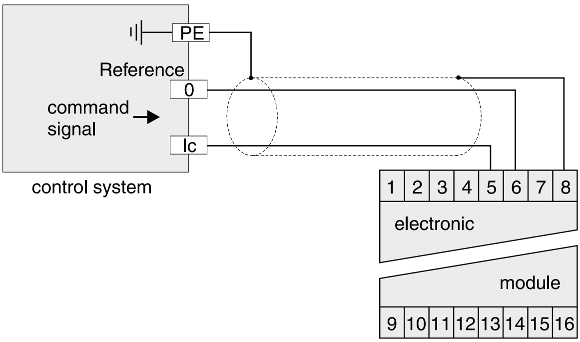
⚠ Incorrect signal amplitude levels may disturb the functionality and can damage the unit!

Wiring diagram of voltage command input +10...0...-10 V



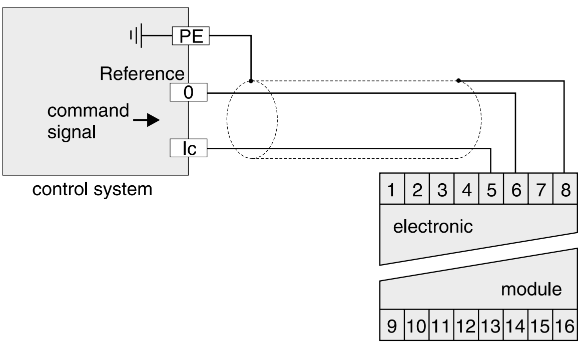
command signal	solenoid output
U 5-6 0...+10 V	11-12 B
U 5-6 0 V	0
U 5-6 0...-10 V	9-10 A

Wiring diagram of voltage command input +20...0...-20 mA



command signal	solenoid output
I 5-6 0...+20 mA	11-12 B
I 5-6 0 mA	0
I 5-6 0...-20 mA	9-10 A

Wiring diagram of current input 4...12...20 mA



command signal	solenoid output
I 5-6 12...20 mA	11-12 B
I 5-6 12 mA	0
I 5-6 4...12 mA	9-10 A
I 5-6 < 3.6 mA	solenoid output off
I 5-6 > 3.8 mA	solenoid output on

The option 4...20 mA uses the “0 mA” condition as breakdown-information. This means the presence of an evaluable failure information if the input signal line is interrupted. In this case the solenoid output will be switched off. The output will switched on when the input signal reaches a value of 3.8 mA, it switches off when the command falls below 3.6 mA. This determination follows the NAMUR-specification NE43. If necessary, the command signal cable break detection can be disabled by selecting the parameter E19. **NAMUR is an association of users of process control technology.**

Monitor output (optional comparator output)

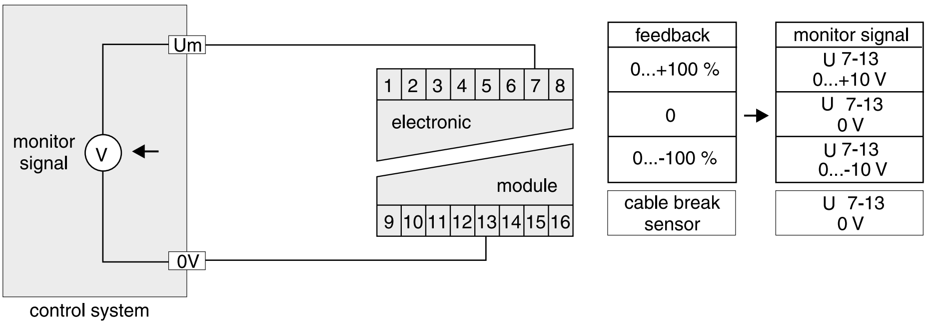
A voltage information representing the feedback signal (i.e. the valve stroke) is available from the terminals 7 and 13. Herewith a voltage span of +10 V...0...-10 V means +100...0...-100 % feedback signal range. The signal resolution of this output averages 8 bit = 0,4 %. In case of a breakdown within the sensor cable the monitor output will be switched off, provided that the feedback signal cable break detection is in use (parameter E12).

If a comparator window for the feedback signal monitoring is defined via parameter P21, the output generates a voltage signal of 0V if the upper or lower threshold is detected. Within the window the output value is typ. 10 V.

☞ The monitor output is not calibrated and represents simply a trend indicator.

⚠ The output may drive a load of max. 5 mA. Exceeding this limit leads to malfunction.

Wiring diagram of monitor output



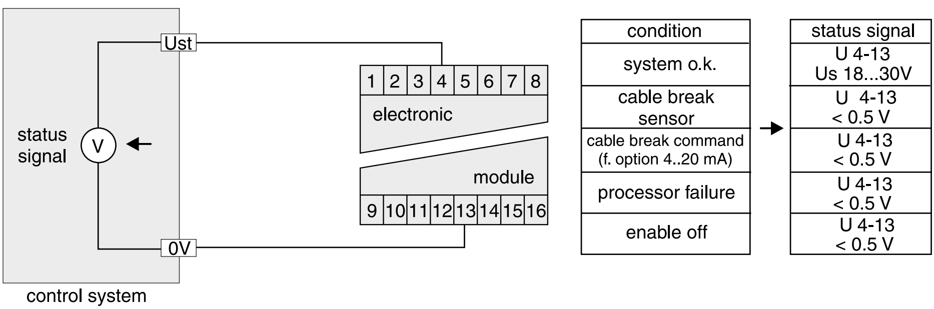
Status output

The terminals 4 and 13 distributes a signal information about the status of the electronics. The following information is available:

- feedback signal cable break (not for options voltage ±10 V / ±20 mA)
- command signal cable break (only for option 4...20 mA)
- internal processor fault
- enable off

⚠ The output may drive a load of max. 5 mA. Exceeding this limit leads to malfunction.

Wiring diagram of status output



Solenoid outputs

The valve solenoids have to be connected to the terminals 9 and 10 as well as 11 and 12, while the earth ground connection of the solenoids is made via terminal 8. The connection has to be shielded.

⚠ The solenoid connectors may not contain any protective or indication components, i.e. recovery diodes or lamps, otherwise function disturbances and permanent damages may occur to the electronics module.

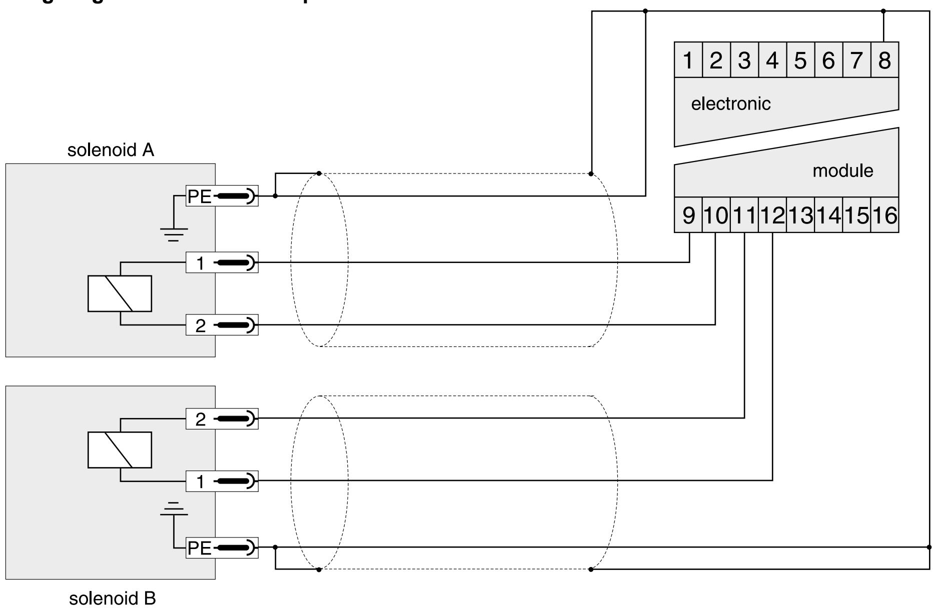
Sensor input

The sensor has to be wired to the terminals 13...16, the earth ground connection will be made via terminal 8. The connection has to be shielded. The sensor type is selectable via software parameter E11.

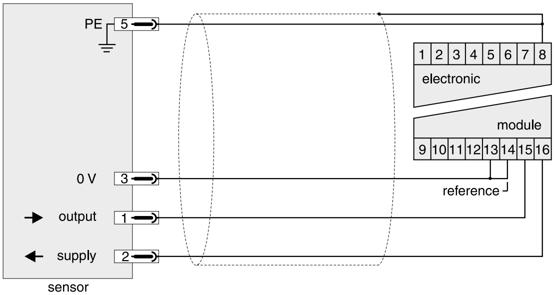
☞ The module is usable for valves of design series D*FS, RLL*R, WLL*R (standard connection). On appropriate selection of the parameter E11, sensors with other signal spans may be connected.

⚠ Connection of an unusable sensor may lead to permanent damage to the electronics module.

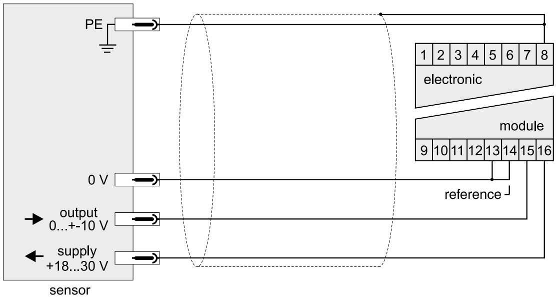
Wiring diagram of solenoid output



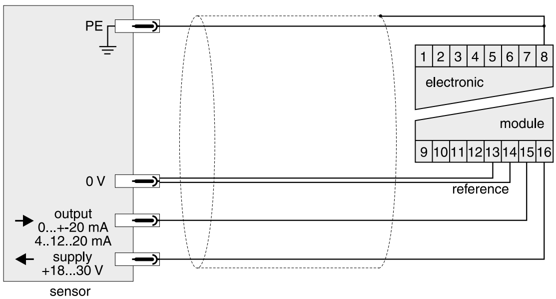
Wiring diagram of standard sensor input (Parker valves)



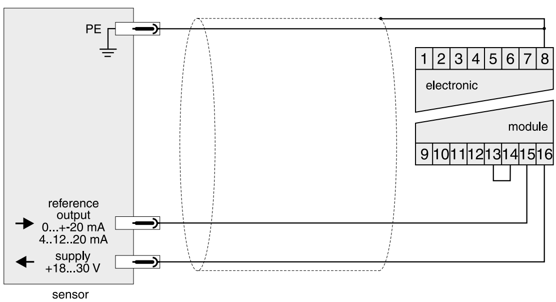
Wiring diagram of sensor input 0...±10 V



Wiring diagram of sensor input 0...±20 mA / 4...12...20 mA, 3-wire

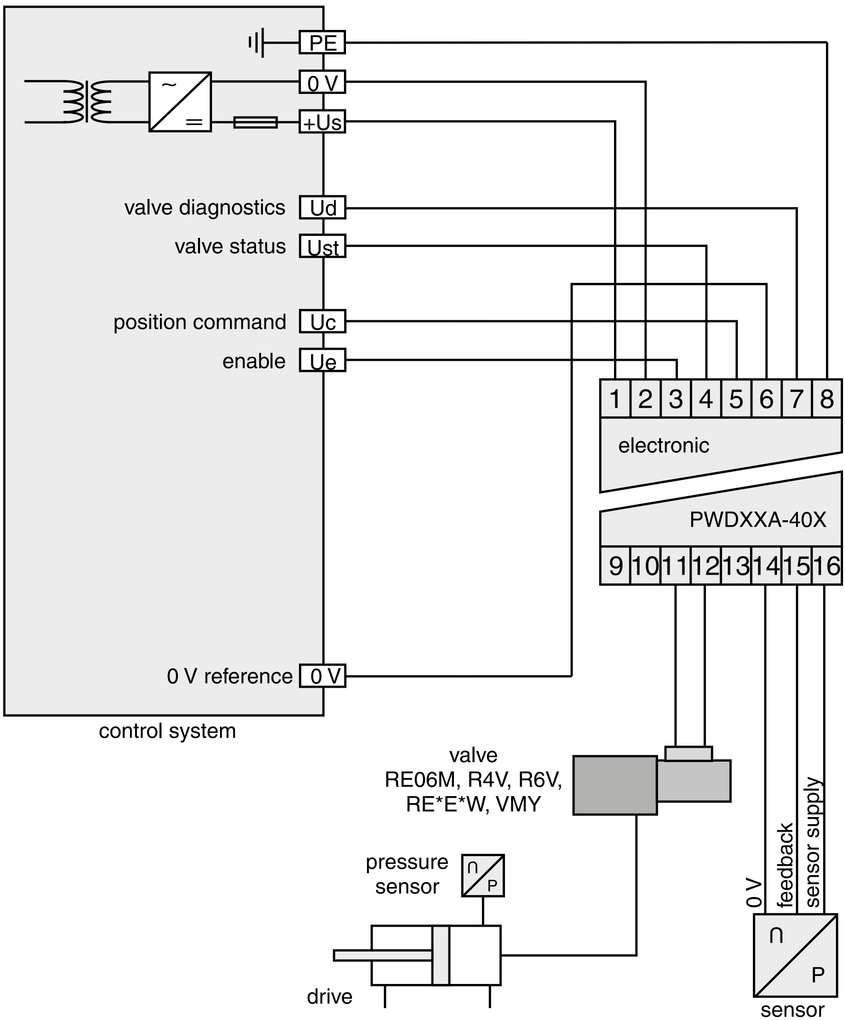


Wiring diagram of sensor input 0...±20 mA / 4...12...20 mA, 2-wire



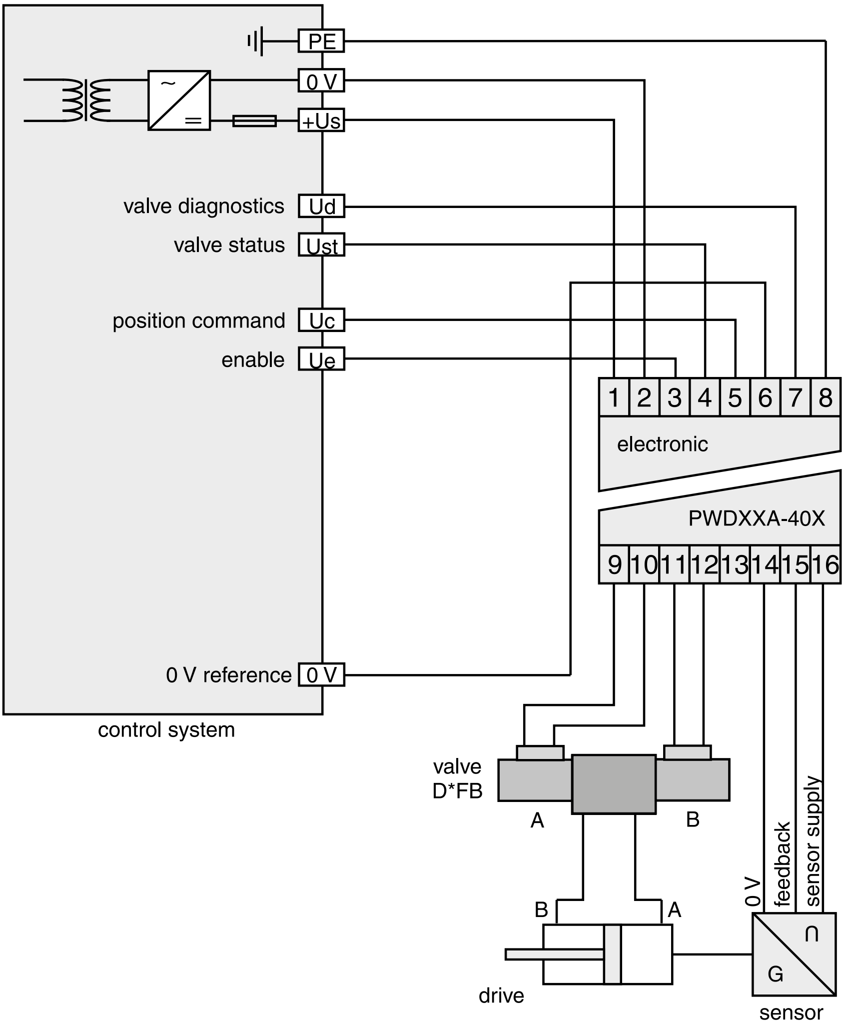
Example 1:

Closed loop pressure control within a hydraulic cylinder, performed utilizing a proportional pressure control valve with external electronic (RE06M, R4V, R6V, RE*E*W, VMY). Command preset via external control signal.



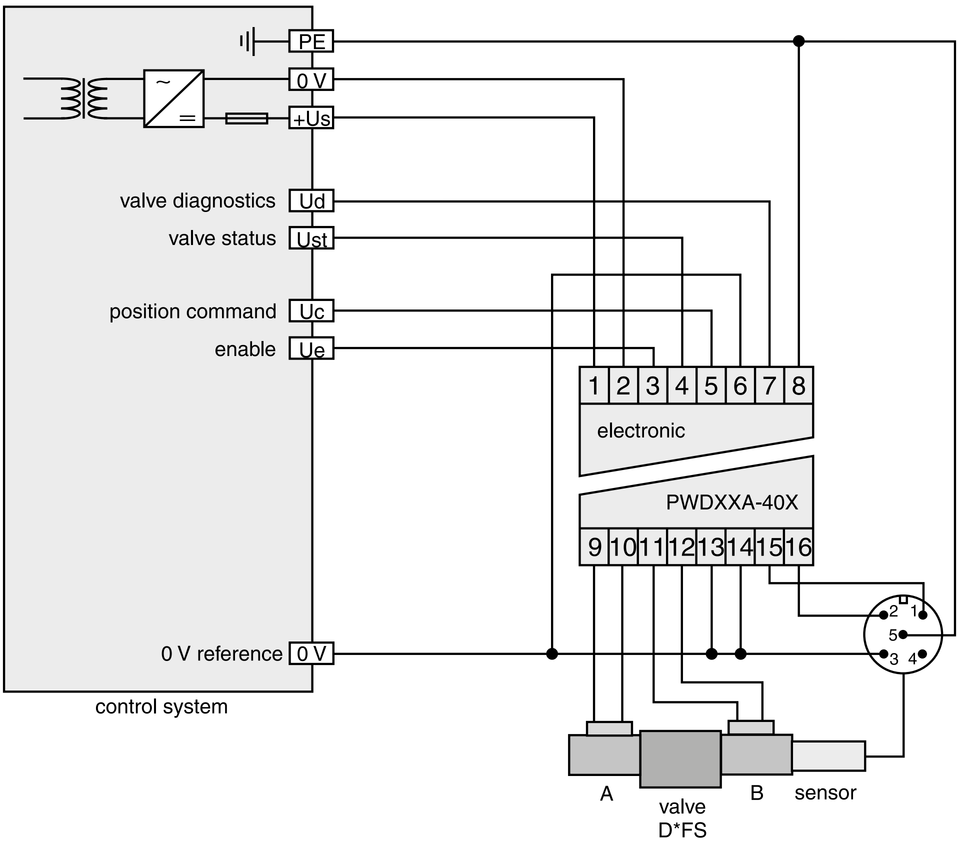
Example 2:

Closed loop position control of a hydraulic cylinder, utilizing a proportional directional control valve with external electronics (D*FB). Command preset via external control signal.



Example 3:

Closed loop position control of a hydraulic cylinder, performed via proportional directional control valve with external electronic (D*FS). Command preset via external control signal.



5. Operating instructions

Basically the electronics performs the task of converting a command signal into a proportional control value via the connected valve with the highest possible dynamic. For these purposes the input value will be electronically compared with the feedback of the process value (i.e. the spool position) within the module. The signal difference feeds a position controller, that in turn provides via a power amplifier stage the required current for the solenoids of the valve.

5.1 Operating software program

ProPxD parameterizing software:

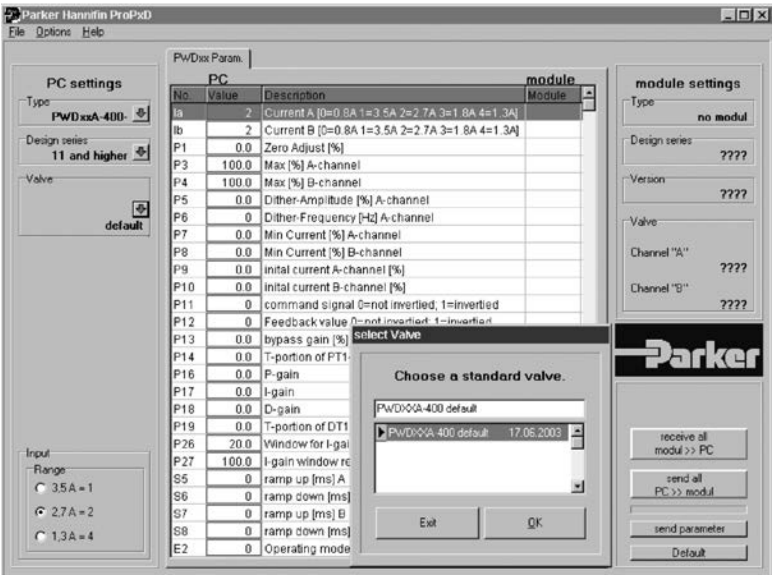
The ProPxD software permits comfortable parameter setting for the module electronics. Via the clearly arranged entry mask the parameters can be noticed and modified. Storage of complete parameter sets to floppy or hard disk is possible as well as printout or record as a text file for further documentation. Stored parameter sets may be loaded anytime and transmitted to the module electronics in the same manner as the basic parameters which are available for all usable valve series. Inside the electronics a nonvolatile memory stores the data with the option for recalling or modification.

⚠ The connected valve may not operated before loading an appropriate parameter set from the PC into the module electronics!

Features

- comfortable editing of all parameters
- depiction and documentation of parameter sets
- storage and loading of optimized parameter adjustments
- executable with all actual Windows® operating systems from Windows® XP upwards
- plain communication between PC and electronics via USB interface
- Comfortable PC user software, free of charge: **www.parker.com/isde** - see "Support", or directly at **www.parker.com/propxd.**

ProPxD screenshot



Hardware requirements

- PC with operating system from Windows® XP upwards
- USB interface
- display resolution min. 800 x 600
- storage requirement approx. 4 MB

☞ It is recommended to select “small fonts” at the display setting, otherwise distortion of the display may occur.

After connecting the module to the computer via a USB cable, Windows recognizes the module and installs a USB serial port. This port must be selected in ProPxD under Options-Interface.

The COM port is displayed in the Windows device manager under "Ports (COM & LPT)" as USB Serial Port (COMx). If there are several USB serial ports in the device manager, the USB serial port of the module can be identified by unplugging the module cable - the corresponding entry in the device manager disappears. If it is plugged in again, the entry with the corresponding USB serial port appears again.

5.2 Program installation

Please check before installation if the above hardware requirements are met. If your PC has already stored an older version of the “ProPxD” program, it has to be deinstalled by using the Windows® - system control feature.

Program installation sequence

- Terminate the execution of other programs.
- Insert ProPxD-software CD.
- Execute the file “setup.exe”.
- Follow the instructions on the screen.

Answer the question, if an older version should be overwritten, with “ok”. During the installation you may change destination drive resp. installation path, if needed (i.e. if the storage space on drive “c” is not sufficient).

Please answer also “ok” if at the end of the installation the program reports any system information. After successful installation the desktop display shows the ProPxD icon for starting the program.

Software operating

⚠ Incorrect settings may lead to malfunction! In case of parameter changes shut the drive down!

Brief instruction for first startup

- Connect the module electronics to the supply voltage.
- Connect the module to a PC via USB cable.
- Click on the ProPxD icon to start the operating program.
- After displaying the program resp. data base version a program window opens and the connected electronics will be automatically identified (possibly a manual identification via the button “Receive all” is necessary).
- Select the desired version via the menu “Options/Optionen” with the menu item “Language/ Sprache”.
- Select the engaged valve from the provided type table via the menu “Options” and the item “Valve type”.
- Subsequently the program inserts the valve specific default parameters into the parameter table.
- Individual parameters may be selected via mouse or the arrow buttons at the center of the program screen.
- Parameter changes are possible via mouse or the arrow buttons on the bottom left within the program screen, also the parameter values may be edited via the keyboard.
- Modified parameters will be stored via the “Enter” key or via the button “Update list”.
- After completing of all modifications, the entire parameter set may be transmitted to the electronics via the button “send all”, also the parameters will be nonvolatile stored.
- The chosen parameters may be optionally stored on the PC via the “File” menu with the menu item “Save as”, data retrieving is always possible via the function “Load out of database”

Extended functions

The user software is shared into 2 parameter ranges:

- basic mode
- expert mode

For normal startup the basic mode is absolutely sufficient. It permits the setting of all **application** specific parameters to match the valve function with the task setting, the **valve** specific parameters will be selected from the valve library. In case of special applications the valve parameters may be adapted via the expert mode.

The operating mode may be selected from the “Options” menu and remains after termination and re-start of the program.

⚠ Changing of expert parameters is only permitted for qualified personnel.

To prevent an unauthorized access for the expert mode, a password is requested. The name is “parker” and cannot be changed. Thus additionally to the button “Default” for loading of the default parameters, the button “Send parameter” appears in the “Expert”-operating mode. This button transmits only the setting of one single parameter to the connected module electronics. Thus a quick tuning of single parameters is permitted during the setup.

☞ A horizontal bar graph readout between the communication buttons shows the data transfer state.

Additional to the device parameters, the electronics stores also the device types, selected from the valve library. Via the button “receive all” the valve parameters will be read out of the electronics and stored including the valve type. If expert parameters will be modified and transfered, the valve information memory inside the electronics will be erased and the word “customized” is shown within the valve display area. Via an arrow button located beside the view boxes of “Type”, “Design series” and “Valve”, the corresponding selection table may be reached directly.

☞ Because the ProPxD program has also offline (i.e. without connection to the electronics) functionality, a manual pre-selection of the parameters is possible. After selection of the electronics type via the menu “Options” the parameters may be set and stored for later transmission. Note the design series while selection of the electronics!

The “File” menu provides the functions “Printer setup”, “Print preview” and “Print”. The print preview includes the option for parameter set storage as text file (format .txt) prior to further processing. The “Options” menu provides also the selection of the virtual COM port via the menu item “Port”. Via the menu item “Load out of database” previously stored parameter sets may be loaded.

5.4 Adjustment parameters

The available parameters may be divided into multiple groups and are characterized by different letters:

S-parameters	internal commands and ramps
P-parameters	operating parameters
E-parameters	extended parameters
I-parameters	solenoid current parameters

Parameter overview for basic mode

Parameter	Description	Unit	Parameter range		Default setting
			from	up to	
S5	ramp accel. channel A	ms	0	32500	0
S6	ramp decel. channel A	ms	0	32500	0
S7	ramp accel. channel B	ms	0	32500	0
S6	ramp decel. channel B	ms	0	32500	0
P1	zero	%	-100.0	+100.0	0.0
P3	MAX channel A	%	50.0	100.0	100.0
P4	MAX channel B	%	50.0	100.0	100.0
P7	MIN channel A	%	0.0	50.0	0.0
P8	MIN channel B	%	0.0	50.0	0.0
P11	polarity command	–	0	1	0
P12	polarity feedback	–	0	1	0
E17	option command	–	1 = ±10 V 2 = ±20 mA 3 = 4 ... 20 mA		1 = ±10 V
E19	cable break detection command	–	0	±10 V: 0 ±20 mA: 0 4 ... 20 mA: 1	0

Individual description of basic parameters

S5 ramp accel. channel A	Adjustment of ramp rate for increasing of valve side A. To avoid switching noise.
S6 ramp decel. channel A	Adjustment of ramp rate for decreasing of valve side A. To avoid switching noise.
S7 ramp accel. channel B	Adjustment of ramp rate for decreasing of valve side B. To avoid switching noise.
S8 ramp decel. channel B	Adjustment of ramp rate for decreasing of valve side B. To avoid switching noise.
P1 offset	Adjustment of zero position shifting (offset). To compensate for unbalances within the zero position of the valve.
P3 MAX channel A	Adjustment of maximum stroke for valve side A at 100 % command signal. To match the command signal span to the valve operating range.
P4 MAX channel B	Adjustment of maximum stroke for valve side B at 100 % command signal. To match the command signal span to the valve operating range.
P7 MIN channel A	Adjustment of stroke step for valve side A at 0,1 % command signal. To compensate for the overlap of the valve spool.
P8 MIN channel B	Adjustment of stroke step for valve side B at 0,1 % command signal. To compensate for the overlap of the valve spool.
P11 command signal polarity	Adjustment of the command signal polarity. To match the command signal polarity to the valve operating direction.
P12 feedback signal polarity	Adjustment of the feedback signal polarity. To match the sensor signal polarity to the solenoid polarity of the valve.
E17 type of com. signal device	Adjustment of the command signal option. To match the command signal input to the input signal mode.
E19 cable break detection command	Adjustment of the operating mode for the command cable break detection. To turn on resp. off the cable break detection for the command signal at a selected command signal option of 4...20 mA.

Parameter overview for expert mode

Parameter	Description	Unit	Parameter range from	Parameter range up to	Default setting
P5	dither amplitude	%	0	10.0	0
P6	dither frequncy	Hz	0	300	0
P9	quiescent current channel A	%	0	25.0	0
P10	quiescent current channel B	%	0	25.0	0
P13	bypass gain	–	0	100.0	0
P14	T-portion PT1-element	–	0	100.0	0
P16	P-portion	–	0	100.0	0
P17	I-portion	–	0	100.0	0
P18	D-portion	–	-100.0	+100.0	0
P19	T-portion DT1-element	–	0	100.0	0
P20	feedback scaling	%	0	200.0	100.0
P21	comparator function window	%	0	200.0	0
P23	comparator rise delay time	ms	0	10000	0
P24	comparator turn-off delay time	ms	0	10000	0
P26	window I-portion	-	0	200.0	20.0
P27	reduct. window I-portion	-	0	100.0	100.0
E2	closed loop control	–	0 = inactive (open loop) 1 = active (int. closed loop) 2 = active (ext. closed loop)		0 = inaktiv
E11	position transducer type	–	1 = ±10 V 2 = ±20 mA 3 = 4-20 mA bipolar 4 = D1FC/WLL NG06 5 = D3FC/WLL NG10 6 = RLL NG06 7 = D31FS 8 = D41FS 9 = D81FS 10 = D91FS 11 = D111FS 12 = 4-20 mA unipolar 13 = TEL 50/70 14 = TEL 90/125		1 = ±10 V
E12	cable break detection feedback	–	0	voltage: 0 current ±20 mA: 0 current 4-20 mA: 1	0 = voltage
E25	MIN operating threshold	–	0 = 1 % 1 = 0.01 %		0 = 1 %
IA	solenoid current channel A	–	1 = 3.5 A 2 = 2.7 A 4 = 1.3 A		4 = 1.3 A
IB	solenoid current channel B	–	1 = 3.5 A 2 = 2.7 A 4 = 1.3 A		4 = 1.3 A
J2	Compability mode	–	0 = off (fast) 1 = on (Design <20)		0 = off
E81	Function "Sensor supply" pin	–	0 = Sensor supply 1 = Comparator out		0

Individual description of expert parameters

P5 dither amplitude	Adjustment of dither amplitude. To reduce the influence of solenoid friction.
P6 dither frequency	Adjustment of dither frequency. To match the dither signal to the valve dynamic.
P9 initial current channel A	Adjustment of the bias current for the solenoid of the valve side A. To compensate for the solenoid initial current.
P10 initial current channel B	Adjustment of the bias current for the solenoid of the valve side B. To compensate for the solenoid initial current.
P13 bypass gain	Adjustment of the bypass gain for the controller. To improve the control dynamic.
P14 T-portion of PT1	Adjustment of the integral action time for the PT1-portion of the controller. To attenuate for the P-portion.
P16 P-portion	Adjustment of the P-portion for the controller. For the basic tuning of the controller.
P17 I-portion	Adjustment of the I-portion for the controller. To reduce the control failure.
P18 D-portion	Adjustment of the D-portion for the controller. To improve the control dynamic.
P19 T-portion of DT1	Adjustment of the pre-hold time for the DT1-portion of the controller. To attenuate for the D-portion.
P20 feedback scaling	Adjustment of the scaling factor for the feedback signal. To match the feedback signal span to the operating range.
P21 window for comparator function	Adjustment of the comparator window for the feedback monitoring. To adjust the feedback monitoring range.
P23 comparator rise delay time	Adjustment of the comparator rise delay time. To delay the rise threshold for the comparator function.
P24 comparator turn-off delay time	Adjustment of the comparator turn-off delay time. To delay the turn-off threshold for the comparator function.
P26 window for I-gain activation	Adjustment of the I-portion active range in terms of the control difference. To limit the I-portion on a certain range.
P27 I-gain window reduction	Adjustment of the I-portion outside the window in terms of the control difference. To match the response behaviour to the I-portion.
E2 control mode	Adjustment of the operating mode for the controller. To select the control function.
E11 type of feedback device	Adjustment of the feedback device type. To match the feedback input to the signal device features.
E12 cable break detection feedback	Adjustment of the operating mode for the feedback cable break detection. To turn on resp. off of the cable break detection for the feedback signal.
E25 MIN operating threshold	Adjustment of the MIN operating threshold. To match the response sensitivity for the MIN-stroke step.
IA nominal current solenoid A	Adjustment of the maximum current for the solenoid of the valve side A. To match the solenoid output to the nominal current of the solenoid.
IB nominal current solenoid B	Adjustment of the maximum current for the solenoid of the valve side B. To match the solenoid output to the nominal current of the solenoid.
J2 Compability mode	Adjustment of the control cycle. To adapt the cycle time to design version <20.
E81 Funktion "Sensor supply" pin	Adjustment of the "Sensor supply" pin. To select the function sensor supply or comparator out.

5.5 Guideline for closed loop applications

Practical guidelines for the adjustment of the control parameters are summarized below. They are divided into different application categories and include common rules of thumb.

☞ The commissioning of a closed loop systems requires detailed knowledge of process control technology. Therefore on-site works support is recommended.

⚠ An incorrect wiring resp. parameter setting may lead to malfunction and permanent damaging of electronics and drive system!

5.5.1 Application: Closed loop systems for position

Introduction

The electronics uses a feedback control loop which automatically adjusts the electrical input to the valve amplifier to move the drive to a commanded position. At the heart of this feedback loop is a digital controller which computes and updates the signal output (set value output) every one millisecond. The controller has adjustable coefficients, which must be set by the user for the particular application.

The controller provides a standard PID control capability plus extra features you can use to improve the performance beyond the limits of PID.

Basic information for the control algorithm

Why tuning?

The controller can be used with valves that vary greatly in flow capacity, frequency response, saturation and deadband, with different kinds of load, and with cylinders of any area and stroke. The user must adjust the control coefficients for the specific system. There are no fixed sets of values for the controller coefficients that will handle every situation well.

The electronics utilizes a “PID” controller for its basic control action. The name PID comes from the fact that the controller output is the sum of three terms, called proportional (P), integral (I) and derivative D), each with a user adjustable coefficient. The user software provides therefore the parameters P16 (P), P17 (I) and P18 (D).

P - P16
This term provides an immediate output signal, proportional to the error between commanded and measured position. If this parameter is set too high, sustained oscillations may occur. If it is set too low, accuracy and speed of response may be poor.

I - P17
This term causes the output to change at a rate proportional to the error in measured position over time (integration time), in a direction to drive the steady state error to zero. P17 is active within a window, which might be adjustable by parameter P26. P26 shall be adjusted in the way that the window lies near the final position or in the stationary range of the drive. A too higher value of P17 causes oscillations, in addition to which the selection of a too lower value may result in a slow action.

D - P18
The D-term provides an output proportional to the rate of change of the measured drive position. Depending on the polarity of the parameter prefix, this term causes damping or acceleration. For hydraulic drives this term should be set to a low value.

Parameter ranges

The controller provides two parameter ranges of **BASIC** and **EXPERT**. The **BASIC** mode serves for adjustment of the fundamental function parameters, while the application specific setting of the control coefficients may be made via the **EXPERT** mode. The operating mode is selected via the menu **OPTIONS**.

Simple tuning of a position control loop

Before trying anything complicated, you should adjust the proportional gain, accessible by P16. In many cases this coefficient will be all you need, and you will not have to bother with any of the other control features. If you do need the other features, you cannot adjust them properly without first adjusting the P-gain. Adjusting the P-gain is done by setting all the other control coefficients P13 – 19 as well as P26 and P27 to zero and increasing P16 to the highest value that does not result in sustained oscillations of the drive position.

Guarantee of control functionality

Before the tuning of the control loop may be commenced, the functionality of the control circuit must be ensured. As previously mentioned, the controller compares command and feedback signal and adjusts the electrical input to the valve amplifier to move the drive to the commanded position. To ensure this functionality, the polarities of command and feedback signal must be equal.

How can the functionality of the control loop be achieved?

At first you should set off the control loop (set parameter E2 to value 0 = open loop and transmit to the electronic) and cause the drive via manual control to the middle of the cylinder stroke. Afterwards adjust at first the control coefficients as described in chapter “Simple tuning of a position control loop” (P16 at 10 %) as well as the parameter E2 at 2 = external closed loop and transmit to the electronic. If this results in a rapid movement of the drive to an end position, the polarities are incorrect. Access now the parameter P12 = feedback signal polarity, change the value and transmit the data. The drive should be adjustable and remain in its position when you switch on the closed loop control via parameter E2. Now you should preset position commands and supervise the drive movement. If the drive even tough is running in closed loop mode, but the direction of the movement is not as required, you have to change the polarities of both command and feedback signal via the parameters P11 and P12. After that the drive is running as desired, you can continue with tuning of the loop.

Tuning of the closed loop control

1. Create a suitable tuning test profile – otherwise it may be difficult for you to tell how good the system response is (the test profile may also be generated by an upstreamed electronic module PZD00A-40X). The test profile should so programmed to causing the drive to move from the start position with the desired maximum acceleration and velocity to the required final position. In the final position the drive should be commanded to dwell, that will give you enough time to watch the load position to see if it oscillates or remains stationary. This should be followed by returning of the drive to the start position, where the dwell in position may also be evaluated.
2. Check once more to be sure that P17 and P18 are set to zero.
3. Adjust P16 to a low value, i.e. 10 %, and try the system on the test profile.

Observe the result of the test. There are three possible outcomes:

The drive oscillates continuously

- Stop the system quickly. Reduce the P16-value to ½ of the initial guess, and try again.

The drive overshoots, but stops after one or two oscillations

- Reduce the P16-value to ¾ of the initial guess, and try again.

The drive reaches the commanded position with no overshoot

- The system is usable with the estimated value of P-gain. You should experiment with stepwise increasing of the P16-value to see how high a value the system will tolerate. Accuracy and response are improved by high values, but do not allow permanent oscillation!

4. You have now completed the basic tuning for your control loop. The next step is to test the performance of the system to see if it meets your requirements. If not, the electronic has additional control features you can use to improve performance, as explained below.

The table below gives information, which approaches may be embarked if typical problems with position control loops appear.

Problem	Solution
Position error too large, when drive is stationary	Use parameter **P17 = I-gain** (only active if P26 > 0)
Repeatable position error by using a valve with overlap/hysteresis	Use dead band compensation feature **P7 = MIN channel A** resp. **P8 = MIN channel B**
Position error too large when following constant velocity position command	Use parameter **P13 = bypass gain**
Slow, small amplitude, position oscillation	Use integrator window **P26 = window I-gain**
Disappointingly low P-gain	Check the frequency response of the valve and position transducer, or possibly the drive resonant frequency (s. items below)
Response too slow	Be sure **P16 = p-gain** is adjusted high enough (s. also previous items)
Unexplainable problems	Check the setting of all parameters

Improving system performance

Using the parameter P17 = I-gain
The integrator gain (abbreviated I) can be adjusted to reduce or eliminate the error between the commanded position and the position measured by the feedback transducer, subject to the command remaining constant. Higher values of I-gain will cause the response to be slower and more prone to oscillation with the combined effect of a reduced stationary error. Lower values will require an extended time to reach zero steady state error. This parameter is only active if a window (> 0) is defined via P26.

Elimination of slow, small amplitude oscillation in position

Because of friction and other imperfections, use of the I-gain sometimes causes a slow, small amplitude oscillation in load position. This is an entirely different problem from the vigorous oscillations that occur when the P-gain is set too high. The electronic provides a “Window” feature (sometimes called “in-position-window”) to solve this problem. Select the parameter P26. Stepwise increasing of the window size to a large enough value will stop the slow oscillations.

Repeatable position error too large because of valve dead band or hysteresis

Utilization of the integrated dead band compensation coefficient enables this effect to be reduced or eliminated. There are separate adjustable parameters P7 and P8 for both valve sides. This feature generates constant correction signals which will be active for the dedicated valve site if a signal occurs on the command signal input. As a result this will cause the valve to “Jump“ through the overlap region of the spool.

Increasing load stiffness

“Load stiffness” is the term given to the resistance of the servo loop to deflection of the drive by external forces. Adjusting P16 to the highest practical value is important.

Disappointing control loop function

The higher the value of P-gain that can be used, the better is the static and dynamic performance of the system. You may not have any direct need for fast response, but may still need a high value of P to reduce static error, reduce following error or increase actuator stiffness. High values of P cause faster system response, whether you need it or not. As the system frequency response gets too close to the frequency response of one of your components, the system response becomes oscillatory.

- **Valve**
  The frequency response of the valve can be obtained from the datasheets. As a first guess, it needs to be at least twice the system frequency response.
- **Position transducer**
  Some analog output transducers will present problems because of filtering intended to smooth the output. To ensure the best system dynamic, sensors with integrated D/A-converter should operate with a high sampling rate. Magnetostrictive transducers with digital output often have a low sampling rate, because an interaction with the achievable resolution. Please obtain detailed information from the transducer supplier.
- **Drive**
  There is a mode of mechanical vibration created by the mass of the load and the compressibility of the hydraulic fluid in the whole system. This frequency is often surprisingly low when using long stroke cylinders.

Update rate of the controller

The controller updates the electrical output to the valve at 1000 Hz. This rate is fast enough to have negligible effect in almost all hydraulic applications, but it does set an absolute limit on the response of the system.

- **Position transducer accuracy and resolution**

A control system is no better than its transducer. Here are points to watch for:

- **Absolute accuracy**
  The controller positions the load as closely as possible to the position measured by the feedback transducer. The absolute accuracy of the measured position is determined by the transducer.
- **Resolution**
  The electronics cannot position the load more accurately than the resolution of the transducer. Be sure the resolution of your sensor is adequate. When using a true analog transducer (analog measurement principle and analog output), the resolution is limited by the utilized A/D-converter, which is 12 bit (1/4096 = 0.025 %).
- **Installation**
  The installation of the position transducer plays a most important rule for the proper functionality of the closed loop control. By all means it has to be secured, that the mounting of transducer and actuating device provides absolute freedom from vibration and clearance effects. This is most important even for the commonly expected velocities and accelerations. Also, the transducer has to be laid out for the dynamic requirements.

5.5.2 Application: Closed loop systems for pressure (via pressure control valves)

Introduction

The electronics uses a feedback control loop which automatically adjusts the electrical input to the valve amplifier that the commanded pressure appears. At the heart of this feedback loop is a digital controller which computes and updates the signal output (set value output) with a one millisecond update time. The controller has adjustable coefficients, which must be set by the user for the particular application.

The controller provides a standard PID control capability plus extra features which may be utilized to improve the performance beyond the limits of PID.

Basic information for the control algorithm

Why tuning?

The controller can be used with valves that vary greatly in flow capacity, frequency response, saturation, dead band, load, and cylinders with a variety of area and stroke. The user must adjust the control coefficients for their specific system. There are no fixed sets of values for the controller coefficients that will handle every situation.

The electronics uses a “PID” controller for its basic control action. The name PID comes from the fact that the controller output is the sum of three terms, called proportional (P), integral (I) and derivative D), each with a user adjustable coefficient. The user software provides therefore the parameters P16 (P), P17 (I) and P18 (D).

P - P16

This term provides an immediate output signal, proportional to the error between commanded and measured pressure. If this parameter is set too high, sustained oscillations may occur. If it is set too low, accuracy and speed of response may be poor.

I - P17

This term causes the output to change at a rate proportional to the error in measured pressure, in a direction to drive the steady state error to zero. P17 is active when a window will be leaving, which might be adjustable by parameter P26. P26 shall be adjusted in the way that the window lies near the final pressure. A too low a value of P17 causes low frequency oscillations, with a too higher value the required pressure may be reached too slowly.

D - P18

The D-term provides an output proportional to the rate of change of the measured pressure. Depending on the polarity of the parameter prefix, this term causes damping or accelerating. For hydraulic drives this term should be set to a very low value.

Parameter ranges

The controller provides two parameter ranges, of course the operating modes **BASIC** and **EXPERT**. Herewith the **BASIC** mode serves for adjustment of the fundamental function parameters, while the application specific setting of the control coefficients may be done via the **EXPERT** mode. The operating mode may be selected via the menu **OPTIONS**.

Simple tuning of a pressure control loop

Before trying anything complicated, you should adjust the bypass gain, accessible by P13. Herewith a “feedforward” of the output will be achieved, the PID-control loop will be “bypassed”. For this adjustment all other control parameters P14 –19 as well as P26 and P27 has to be set to zero. Then P13 will be increased accordingly, until the feedback signal appears 10...20% below the command signal . Mostly a setup value of 40...50% is practicable. Following is the adjusting of the proportional gain, accessible by P16.

Adjusting the P-gain is done by increasing P16 to the highest value that does not result in sustained oscillations of the pressure. In many cases this two coefficients will be all you need, and you will not have to bother with any of the other control features. If you do need the other features, you cannot adjust them properly without first adjusting the P-gain.

Guarantee of control functionality

Before the tuning of the control loop may be started, the functionality of the control circuit must be ensured. As previously mentioned, the controller compares command and feedback signal and adjusts the electrical input to the valve amplifier to achieve the commanded pressure. To ensure this functionality, the polarities of command and feedback signal must be equal.

How can the functionality of the control loop be achieved?

At first you should set off the control loop (set parameter E2 to value 0 = open loop and transmit to the electronic) and cause the pressure via manual control to the middle of the system pressure. Next adjust the control coefficients as described in chapter "Simple tuning of a pressure control loop" (P16 at 10%) as well as the parameter E2 at 2 = external closed loop and transmit to the electronic. If this results in a jump of the pressure into its minimum or maximum final value, the polarities are incorrect. Access the parameter P12 = feedback signal polarity, change the value and transmit the data. By now the pressure should be adjustable and must remain on its value when you switch on the closed loop control via parameter E2. The next task will be to preset the pressue command and monitor the pressure behavior. If the pressure even tough is running in closed loop mode, the behavior of the pressure rise and fall is not as required, it is necessary to change the polarities of both command and feedback signal via the parameters P11 and P12. The control loop should now be running as desired, you can continue with tuning of the loop.

Tuning of the closed loop control

1. Create a suitable tuning test profile – otherwise it may be difficult for you to tell how good the system response is (the test profile may also be generated by an up-stream electronic module PZD00A-40X). The test profile should start causing the system from the circulation pressure with the desired maximum acceleration and velocity to the required final pressure. At the final pressure the system should remain for a while, that will give you enough time to watch the pressure value to see if it oscillates or remains stationary. This should be followed by returning of the pressue to the start value, where the stationary value may also be evaluated.
2. Check once more to be sure that P17 and P18 are set to zero.
3. Adjust P16 to a low value, i.e. 10 %, and run the system using the test profile. Observe the result of the test. There are three possible outcomes:

- The pressure oscillates continuously

  Stop the system quickly. Reduce the P16-value to ½ of the initial guess, and try again.
- The pressure overshoots, but stops after one or two oscillations

  Reduce the P16-value to ¾ of the initial guess, and try again.
- The pressure reaches the commanded value with no overshoot

  The system is usable with the estimated value of P-gain. You should experiment with stepwise increasing of the P16-value to see how high a value the system will tolerate. Accuracy and response are improved by high values, but do not allow permanent oscillation!

4. You have now completed the basic tuning for your control loop. The next step is to test the performance of the system to see if it meets your requirements. If not, the electronics has additional control features that may be used to improve performance, as explained below.

The table below gives information, which approaches may be embarked if typical problems with pressure control loops appear.

Problem	Solution
Variation error too large, when pressure command remains constant	Use parameter **P17 = I-gain** (only effective for P26 >0)
Repeatable deviation by using a valve with overlap/hysteresis	Use deadband compensation feature **P7 = MIN channel A**
Sequence error too large when following pressure command profile	Use parameter P13 = bypass gain
Disappointingly low P-gain	Check the frequency response of valve and pressure transducer, and the system resonant frequency (s. items below)
Response too slow	Be sure **P16 = p-gain** is adjusted high enough (s. also previous items) and check the flow capacity of the valve
In explainable problems	Check the setting of all parameters

Improving system performance

Using the parameter P17 = I-gain

The integrator gain (abbreviated I) can be adjusted to reduce or eliminate the error between the commanded pressure and the feedback pressure measured by the transducer, when the command is constant. Higher values of I-gain will cause a better error reduction while the response will be longer. This parameter is only effective if a window (>0) is defined via P26.

Eliminating a slow, small amplitude oscillation in stationary condition

Due to the possible effects of friction and or other application variables, use of the I-gain sometimes causes a slow, small amplitude oscillation in the stationary condition. This is a different problem from the vigorous oscillations that occur when the P-gain is set too high. The electronics provide a “Window” feature (sometimes called “in-position-window”) to solve this problem. In this case the integrator operates only within this window. Select this option via parameter P26. Step increases of the window size will eliminate the oscillation.

Increasing load stiffness

“Load stiffness” is the term for the resistance of the servo loop characteristics to deflection by external forces. Adjusting P16 to the highest practical value is important.

Disappointing control loop function

The higher the value of P-gain that can be used, the better is the static and dynamic performance of the system. You may not have any direct need for fast response, but may still need a high value of P to reduce static error, reduce following error or increase load stiffness. High values of P cause faster system response, whether you need it or not. As the system frequency response gets too close to the frequency response of one of your components, the system response becomes oscillatory.

- **Valve**
  The frequency response of the valve can be obtained from the datasheets. As a first guess, it needs to be at least twice the system frequency response.
- **Pressure transducer**
  Some analog output transducers will present problems due to the use of filters intended to smooth the output. To ensure best system dynamics, sensors with integrated D/A-converter should operate with a high sampling rate. Magnetostrictive transducers with digital output often have a low sampling rate, causing an interaction with the achievable resolution. Please obtain detailed information from the transducer supplier.
- **System**
  The cutoff frequency will be determined by mass and compressibility of the hydraulic media in the entire system (cylinder, piping, valves). Mostly the value is quite low, particularly for the usage of large system volumes.

Pay attention for pressure peaks!

High pressure peaks may occur particularly at closed loop pressure controls systems. Therefore the dynamic pressure behavior should be investigated after the controller tuning utilizing a data aquisition device such as a storage oscilloscope. If the measured pressure peaks exceed the system design hardware specification, reductions may be achieved by adjustment of the control parameters.

Update rate of the controller

The controller updates the electrical output to the valve at 1000 Hz. This rate is fast enough to have negligible effect in almost all hydraulic applications, but it does set an absolute limit on the response of the system.

Pressure transducer accuracy and resolution

A control system is no better than its transducer. Here are points to watch for:

- **Absolute accuracy**
  The controller adjusts the system as closely as possible to the pressure measured by the feedback device. The absolute accuracy of the measured pressure is also determined by the transducer. On the other hand, die signal span of the transducer should be oversized to achieve a safe operation even if pressure peaks appeared. For example a system pressure of 300 bar requires a sensor with 400bar nominal pressure. This results in a value of 75 % for the feedback scaling P20 (300 bar means 75 % of 400 bar).
- **Resolution**
  The electronics is unable to set a pressure more accurately than the resolution of the transducer. Be sure the resolution of your sensor is adequate. When using a true analog transducer (analog measurement principle and analog output), the resolution is limited by the utilized A/D-converter, which is 12 bit (1/4096 = 0.025 %).
- **Installation**
  The installation of a pressure transducer plays an important role in the proper functionality of a closed loop pressure control system. The pressure transducer should be located as close to the point of control as is practical.

  Example: A closed loop pressure control is required for a given hydraulic cylinder. In this case the pressure control valve and transducer should be mounted close together, otherwise poor closed loop control will result.

Error messages
Malfunctions when using the ProPxD software program will be indicated via appropriate failure messages.

Failure messages and corrective actions

Failure message	Description/corrective action
The Com Port is not available!	Terminate the other program, or quit the message and select another RS-232C port via the menu “Options > Port”. Afterwards reconnect the null modem cable.
Unable to open COM port	Com port is not available. Quit the message and select another virtual port via the menu “Options > Port”.
There is no module connected or the communication is disturbed!	No data exchange possible. Either the electronics has been removed, the port is mismatched, or the connection will be disturbed by strong electrical fields. Check if the Com port is set for “9600, 8, 1. none, none” via the menu “Options > Port”.
Wrong password!	Retype the password, notice the exact spelling (case sensitivity).
Wrong input!	An unvalid character or a value outside the permitted range has been used at parameter entry.
Keep the entered parameters?	During parameter loading from the electronics module memory the preset parameters from the left hand screen display may be rejected or maintained.
The chosen module isn´t the same as the connected hardware!	In principle, parameters dedicated to a type which deviates from the connected electronics module may be edited. However, for data transmitting the correct module has to be connected. If parameters will be loaded from a module which deviates from the selected one, the parameters from the left hand side screen display of the program will be overwritten.
file name.pxd already exists. Do you want to replace the file?	The file name already exists within the indicated directory. Select another name, another directory or overwrite the existing file with “OK”.

6. Maintenance

Periodical maintenance is essential for the longevity of the unit and guarantees reliability and availability.

The following properties of the electronics have to be checked in continuous short time intervals:

- tight fit on the mounting rail
- tight fit of the disconnectable terminals
- tight fit of the terminal screws
- environmental temperature level
- supply voltage level
- cleanliness of the ambience

⚠ Service work may only be carried out by qualified personnel. Detailed knowledge of the machine functions concerning switching on and off as well as of the required safety relevant technical tasks is necessary!

7. Trouble-shooting

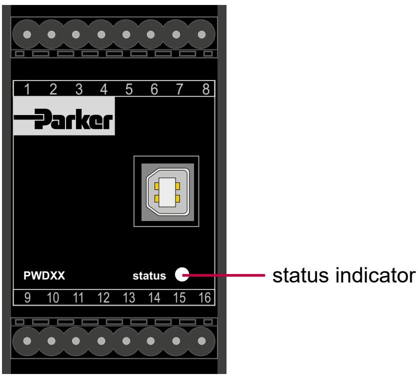
Basis of trouble-shooting is always a systematic approach. At first the following questions have to be checked:

- Are there practical experiences with similar failures?
- Have system adjustments been changed?

☞ In either case the available diagnostic options should be used. The electronics permits a diagnostic of the valve function via the monitor output. The status output monitors the working condition of the electronics, an additional visual status results from an LED indicator.

Afterwards starting of trouble-shooting by means of a priority list of the **most likely** reasons.

Location of status indicator



Function assignment

Operating condition	LED-display
no failure	green
no supply voltage	off
no enable signal	yellow
cable break feedback sensor (not for options voltage / +-20 mA)	red
cable break command signal (only for option 4...20 mA)	red
internal processor fault	red

generally no function	high frequent oscillation	low frequent oscillation	one way operation only	spool stroke variations at unchanging command	operates too ruggedly	spool stroke too low	drifting without command	possible reasons for malfunction	corrective actions
x								too low system / pilot pressure	check hydraulic pump resp. motor, pressure / relief valves
x		x	x	x		x		drive overloaded	reduce pressure resp. speed, increase valve size
x		x	x	x	x	x	x	valve contaminated	clean pressure fluid, filter / flush valve
				x		x		hydraulic fluid too viscous / too cold	change fluid grade, provide operational temperature
x		x	x					too low oil level within tank	refill pressure fluid
				x		x		filter contaminated	clean resp. replace filter
x		x				x	x	electronic supply voltage too low	keep supply voltage range
	x							electronic supply voltage contains too much ripple	reduce ripple
x			x			x		command signal too low	increase command signal
	x							command signal contains too much ripple	reduce ripple
x								enable signal too low	keep enable signal range
x	x	x	x	x	x	x	x	incorrect electronic parameters	check parameters
x	x			x	x	x	x	electronic terminals contaminated	clean terminals
x			x					interrupted cable at electronic or valve	fix cable
x	x	x	x	x		x	x	wiring sequence incorrect	correct wiring sequence
	x			x			x	cables partly or totally without shielding	change cable grade
x			x					electronic defective	keep characteristics, check wiring, replace electronic
x			x				x	valve solenoid defective	check solenoids resp. wiring, replace valve
x								valve sensor defective	check sensor resp. wiring, replace valve

△ For suspect of a sluggish spool the valve may be flushed with clean pressure fluid.

⚠ Trouble-shooting in a hydraulic system requires in either case a systematic approach. The work may exclusively be performed by qualified personnel, as it requires detailed knowledge about function and construction of the system. Reversals or dissassemblings may not be taken imprudently! Prior to the works it has to be clarified, if the system has been operated properly until the failure occured.