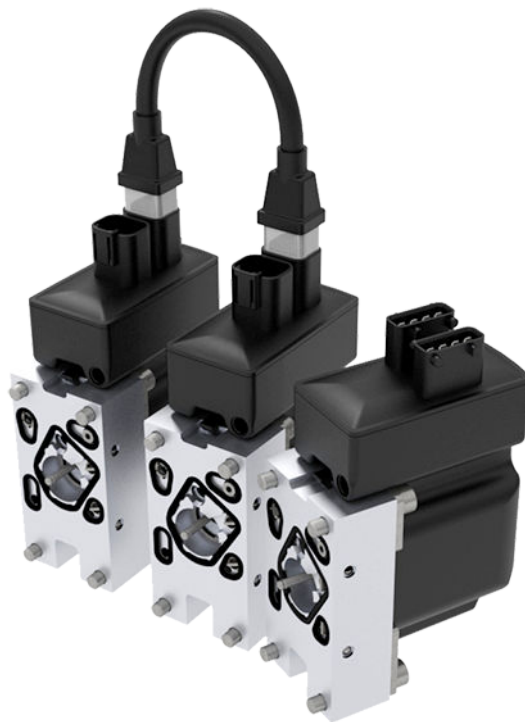


Technical Information

Proportional Valves

PVED-CC, Series 5 CANopen



Revision history

Table of revisions

Date	Changed	Rev
March 2020	Changed NodeID range notes on page 13.	0606
November 2019	Added EMC proof cable to code numbers section	0605
October 2017	Correction - AMP connector	0604
July 2017	Correction to image 'AMP 2x 4pin AMT Junior Power Timer.'	0603
March 2017	Updated AMP 2x4 drawing	0602
September 2016	Updated list of configurable parameters	0601
May 2016	Updated list of configurable parameters; Updated to Engineering Tomorrow design	0501
March 2016	List of configurable and read-only parameters updated	0401
February 2016	Configurable parameter, Temperature dependent spool timeout float addon: Ranges and defaults updated	0301
February 2016	Corrected configurable parameter range for parameter: Manufacturer Specific Set Point 8bit	0201
December 2015	First edition	0101

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Introduction

Product overview

The PVED-CC Series 5 CANopen is a high performance digital actuator for the valve families PVG 32 and PVG 100.

The PVED-CC Series 5 CANopen offers CAN bus control through loop cables simplifying the wire harness and build-in intelligence where actuator specific features tailor the actuator behavior to the exact function need.

PVED-CC CANbus code numbers

Connector type	Code number	Description
DEUTSCH	11172734	PVED-CC
	11007498	4 m cable
	11095741	4 m EMC proof cable (twisted pair)
	11007531	0.1 m loop cable
	11111916	0.3 m loop cable
	11095622	0.175 loop cable
	11007561	CAN bus terminator
AMP	11169142	PVED-CC
	157B4994	4 m cable with gray connector
	157B4995	4 m cable with black connector
	11095740	4 m EMC proof cable (twisted pair)
	157B4987	0.1 m loop cable
	11095581	0.175 m loop cable
	11163647	CAN bus terminator with gray connector
157B4988	CAN bus terminator with black connector	

Data

Operating data overview

Electrical data

Voltage		12 V _{DC}	24 V _{DC}
Current consumption	Operating	520 mA	260 mA
	Neutral - Power state	80 mA	45 mA
Energy consumption	Operating	6.24 W	6.24 W
	Neutral - Power state	1 W	1.1 W
Supply voltage (V _{bat})	Nominal	11 – 32 V _{DC}	
	Range	9 – 35.9 V _{DC}	
	Maximum ripple	5%	
CAN bus	Alive	5.5 – 36 V _{DC} *	

* PVED communicating on CAN bus, but not fully operable.

Temperature range

		Min.	Max.
Temperature	Ambient	-40°C	90°C
	Oil		
	Storage		110°C

Hydraulic data

Pilot pressure		13.5 ± 1.5 bar
Tank pressure	Continues	25 bar
	Intermittent	40 bar
Oil consumption	Electrical de-energized	0 l/min
	Spool locked position	
	Continuous changing spool position	0.7 l/min
Contamination	(ISO 4406)	23/19/16
Viscosity range	Nominal	12 – 75 mm ² /s
	Minimum	4.2 – 12 mm ² /s*
	Maximum	75 – 1000 mm ² /s

* PVED have reduced operating performance

Government regulations

Description	Standard
Low Voltage	2006/95/EC
EMC Directive	2004/108/EC
Safety	ISO4413:2010

Data

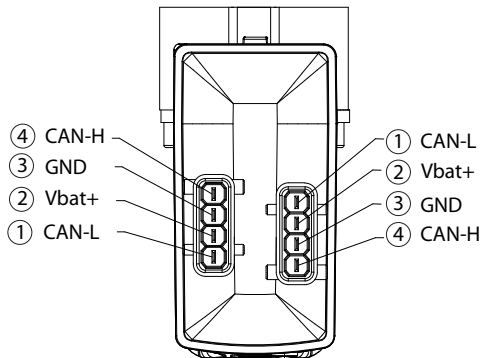
Connectors

Available 2x4 pin connectors: AMP Junior Power Timer and DEUTSCH DT06-4S-E003. Pins are internally connected in pairs between connectors. Mating connectors are not supplied by Danfoss.

AMP connector

AMP Junior Power Timer (2x4 pin)

Pinout:
1. CAN Low
2. Vbat+
3. GND
4. CAN High



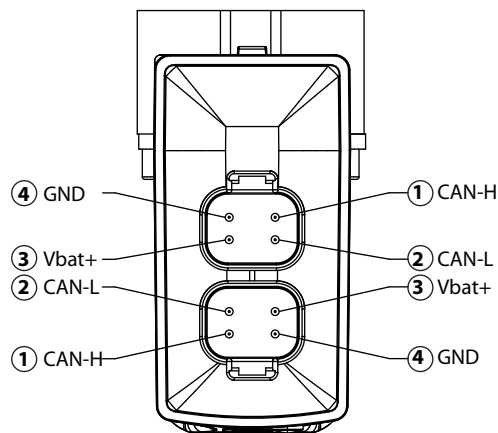
Terminal	Seal	Housing	IP rating
929930-1 (4 pcs)	828901-1 (4 pcs)	2-967059-1 (gray) or 1-967059-1 (black) *	IP66

* There is no black/gray coding of the connector

DEUTSCH connector

DT06-4S-E003 (2x4 pin)

Pinout:
1. CAN High
2. CAN Low
3. Vbat+
4. GND
IP rating: IP67; IP69K without connector





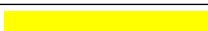


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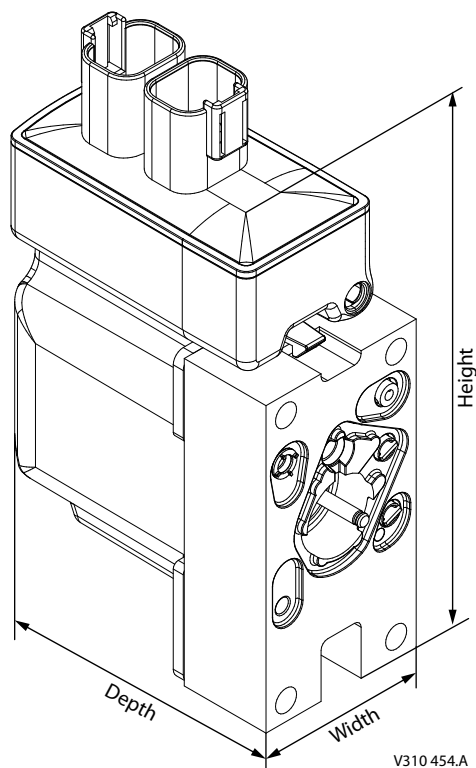
Data

LED coloring for PVED-CC Series 5

LED Characteristic

Color	LED Characteristic	Description
Green constant		No error – Actuating
Green flashing @ 1.5 Hz		Neutral – Power save
Red constant		Internal error
Red flashing @ 1.5 Hz		External or Float error
Yellow		Disable mode

Physical dimensions

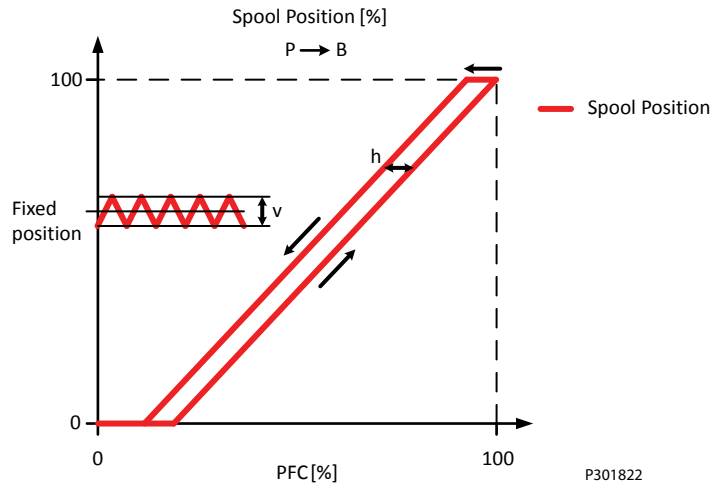


Depth		Width		Height*	
85 mm	[3.35 in]	45 mm	[1.77 in]	116 mm	[4.57 in]

* Excluding connector height

Data

PVED-CC Hysteresis and Ripple

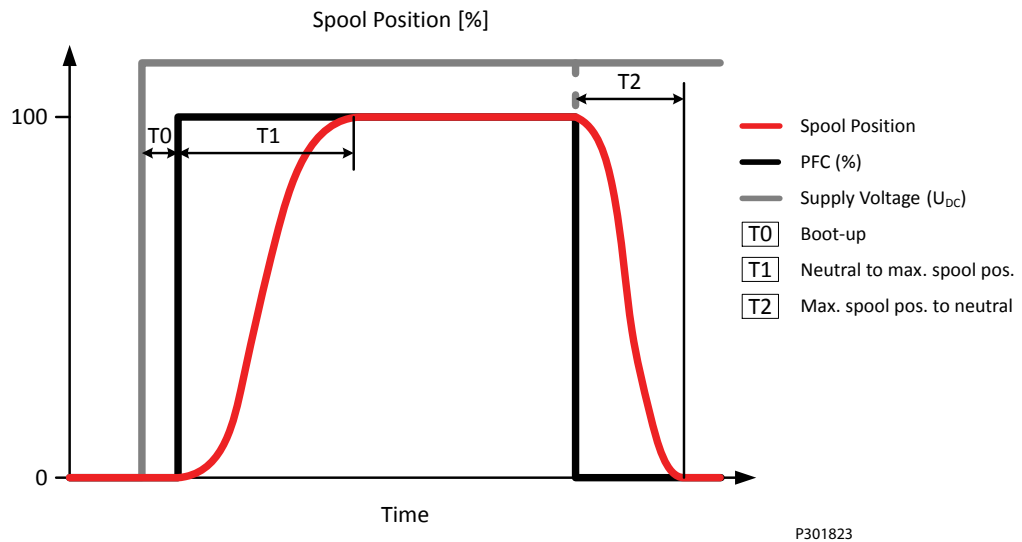


Definition of hysteresis

Hysteresis (h)	Rated [%]	1.45%
Steady state ripple at constant command signal	Rated [%]	0.29%

PVED-CC Reaction Times

Reaction times



Definition of Step Response

Reaction	Time (nominal)
T0 – Boot-up	440 ms*
T1 – Constant PFC command	177 ms
T2 – Constant PFC command	114 ms

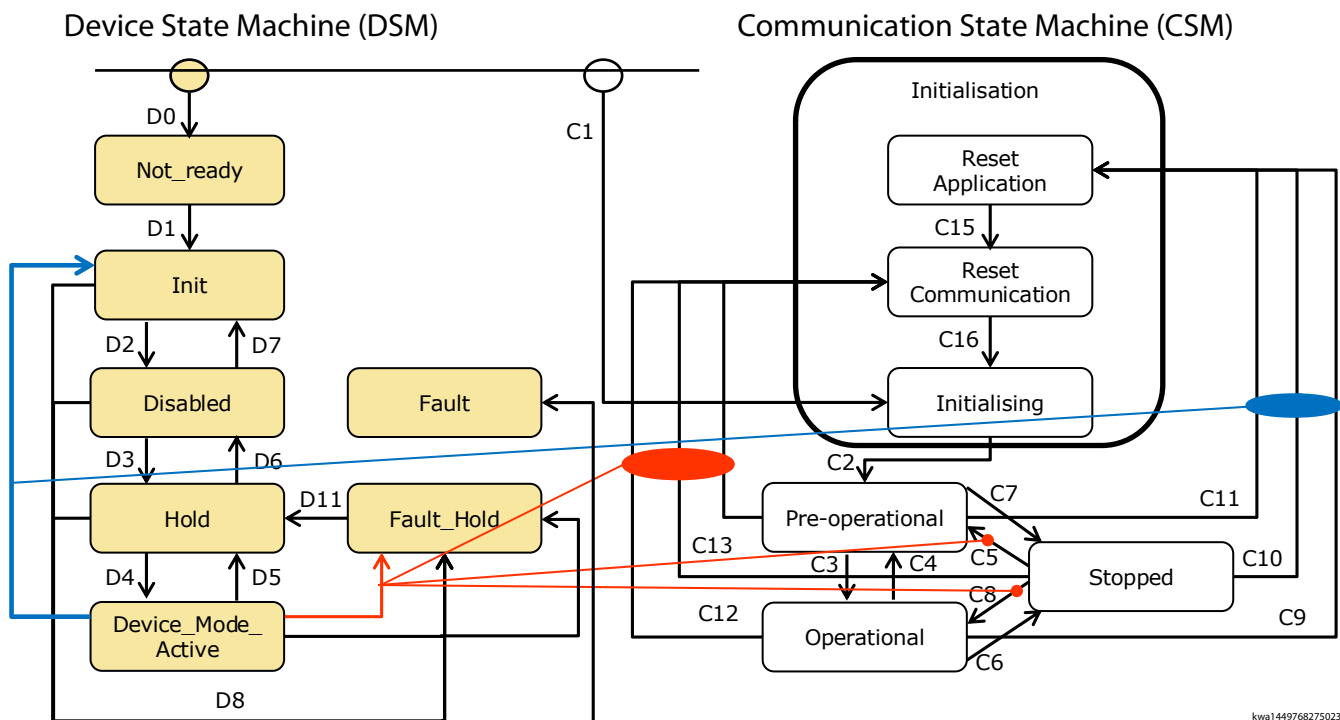
* Including Power-On-Self-Test (POST) and safety sub-system initialization.

Communication

State machine

The PVED-CC Series 5 CANopen operates according to the device state machine defined in VDMAPROP chapter 5.2 and the CANopen communication state machine defined in CiA301 chapter 9.4.

Relationship between the state machines



kwa1449768275023

State transition overview

Device state machine transitions

Transition number	Transition	Device control word
D1	Not_Ready to Init	Automatic transition after boot-up
D8	Any state to Fault Hold and Fault	Automatic transition on active fault occurrence
D2	Init to Disabled	0b1001 0x09
D3	Disabled to Hold	0b1011 0x0B
D4	Hold to Device_Mode_Active	0b1111 0xFF
D5	Device_Mode_Active to Hold	0b1011 0x0B
D6	Hold to Disabled	0b1001 0x09
D7	Disabled to Init	0b1000 0x08
D11	Fault_Hold to Hold	0b1011 / 0b0011 0x0B / 0x03

Communication

Communication state machine transitions

CSM transition	DSM impact
C14, C13 and C12	Change to Fault_Hold
C5	Change to Fault_Hold
C8	Change to Fault_Hold
C9, C10 and C11	Change to Init

Actuator behavior dependent on state

State	Transmit TPDO	Spool monitoring	Spool is controlled by PVED-CC	Setpoint timeguarding
Not_Ready	N/A			
Init	Yes	Yes	No	No
Disabled	Yes	Yes	No	No
Hold	Yes	Yes	No	No
Device_Mode_Active (CAN controlled)	Yes	Yes	Yes	Yes
Device_Mode_Active (Hand operation)	Yes	No	No	No
Fault_Disabled	Yes	No	No	No
Fault_Hold	Yes	No	No	No

PVEC-CC CANopen message overview

Message ID	Message type	Translation	Direction (from controller)	Timing
0x700 + nodeID*	Boot-up protocol on page 11	Boot-up message on CANbus	Rx	On power-up
0x000	NMT services on page 11	Network Management	Tx	Controller dependant
0x7E5	Layer Setting Service (LSS) on page 11	Layer Setting Service command	Tx	Controller dependent
0x7E4	Layer Setting Service (LSS) on page 11	Layer Setting Service response	Rx	On request
0x200 + nodeID*	RxPDO1 on page 17	Read Process Data Object 1	Tx	Controller dependent
0x300 + nodeID*	RxPDO2 on page 17	Read Process Data Object 2	Tx	Controller dependent
0x180 + nodeID*	TxPDO1 on page 18	Transmit Process Data Object 1	Rx	Configurable
0x280 + nodeID*	TxPDO2 on page 18	Transmit Process Data2	Rx	Configurable
0x600 + nodeID*	SDO command on page 23	Service Data Object command	Tx	Controller dependent
0x580 + nodeID*	SDO response on page 23	Service Data Object response	Rx	On request
0x080	Sync message on page 21	Synchronize message	Tx	Controller dependent
0x700 + nodeID*	PVED-CC heartbeat protocol on page 21	Heartbeat message	Rx	Once at power-up/configurable
0x080 + nodeID*	Emergency producer on page 21	Emergency message	Rx	Event triggered

* nodeID range: 0x01 to 0x7E

Communication

Network Management (NMT)

Boot-up protocol

Upon power-up the PVED will log onto the CAN bus network by broadcasting the nodeID it has been given upon parametrization.

Frame format

Msg ID	DLC	Byte 0
0x700 + nodeID	1	NMT State
		0x00

NMT services

NMT messages are used to navigate the Communication State Machine (CSM).

Frame format

Msg ID	DLC	Byte 0	Byte 1
0x000	2	NMT Command specifier	Destination nodeID

NMT data

Byte 0	NMT Command specifier	Enter Operational mode (CAN controlled) = 0x01
		Enter Stopped mode = 0x02
		Enter Preoperational mode = 0x80
		Reset application = 0x81
		Reset communication = 0x82
Byte 1	Destination nodeID	Slave nodeID of the PVED-CC CANopen 0x00 for global messages

Layer Setting Service (LSS)

LSS is used to parametrize the nodeID and bit timing as well as inquire vendor ID, code number, revision and serial number of the PVED.

LSS mode works only in Stopped Mode.

PVED-CC switch state global

This is an unconfirmed service that sets the device to LSS configuration mode.

Frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Mode*	Reserved					
		0x04		0x00	0x00	0x00	0x00	0x00	0x00

* 0x00 Switch to LSS wait state, 0x01 Switch to LSS configuration mode.

PVED-CC switch state selective

This switches LSS slave device into LSS configuration state by using the LSS address consisting of vendor ID, Product code, revision number and serial number.

Communication

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Vendor ID				Reserved		
		0x40					0x00	0x00	0x00
0x7E5	8	CS	Product code				Reserved		
		0x41					0x00	0x00	0x00
0x7E5	8	CS	Revision number				Reserved		
		0x42					0x00	0x00	0x00
0x7E5	8	CS	Serial number				Reserved		
		0x43					0x00	0x00	0x00

Response frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	Reserved						
		0x44	0x00	0x00	0x00	0x00	0x00	0x00	0x00

LSS switch state selective data

CS 0x40	Byte 0	CS (0x40)
	Byte 1	Vendor ID OD 1018, sub 0x01
	Byte 2	
	Byte 3	
	Byte 4	
	Byte 5	Reserved (0x00)
	Byte 6	
Byte 7		
CS 0x41	Byte 0	CS (0x41)
	Byte 1	Product code OD 1018, sub 0x02
	Byte 2	
	Byte 3	
	Byte 4	
	Byte 5	Reserved (0x00)
	Byte 6	
Byte 7		
CS 0x42	Byte 0	CS (0x42)
	Byte 1	Revision number OD 1018, sub 0x03
	Byte 2	
	Byte 3	
	Byte 4	
	Byte 5	Reserved (0x00)
	Byte 6	
Byte 7		

Communication

LSS switch state selective data (continued)

CS 0x43	Byte 0	CS (0x43)
	Byte 1	Serial number OD 1018, sub 0x04
	Byte 2	
	Byte 3	
	Byte 4	
	Byte 5	Reserved (0x00)
	Byte 6	
	Byte 7	

Inquire nodeID

By this command the PVED nodeID can be inquired.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x5E	0x00	0x00	0x00	0x00	0x00	0x00	0x00

NodeID range: 0x01 to 0x7E. 0x20 is used as spare part nodeID.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	NodeID*	Reserved					
		0x5E		0x00	0x00	0x00	0x00	0x00	0x00

* NodeID range: 0x01 to 0x7E.

Configure nodeID

With this command the PVED as LSS slave is configured to the new nodeID.

Response frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	nodeID*	Reserved					
		0x11		0x00	0x00	0x00	0x00	0x00	0x00

* NodeID range: 0x01 to 0x7E. 0x20 is used as spare part nodeID.

Response frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	Error code*	Reserved					
		0x11		0x00	0x00	0x00	0x00	0x00	0x00

* 0x00 no error, 0x01 NodeID out of range.

Configure bit timing

With this command the baud rate can be changed from default 250kbps.

Communication

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Table selector	Table index*	Reserved				
		0x13	0x00		0x00	0x00	0x00	0x00	0x00

* 0x00= 1000kbps, 0x02 = 500kbps, 0x03 = 250kbps (default), 0x04 = 125kbps

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	Error code*	Reserved					
		0x13		0x00	0x00	0x00	0x00	0x00	0x00

* 0x00 no error, 0x01 Bit rate not supported.

Activate bit timing parameters

This service activates simultaneously the bit rate at the LSS communication interface of all CANopen devices in the network.

LSS Cmd

COB-ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Switch Delay		Reserved				
		0x15	LSB	MSB	0x00	0x00	0x00	0x00	0x00

Each LSS slave device copies the pending bit rate to the active bit rate value, after 'Switch Delay' (given in ms, in multiples of 1 ms) has elapsed. Therefore in response to this service device changes its bit rate after 'Switch Delay'.

PVED-CC store configurations

By this command the configured local layer settings are stored to EEPROM.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x17	0x00	0x00	0x00	0x00	0x00	0x00	0x00

NodeID range: 0x01 to 0x7E

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	Error code*	Reserved					
		0x5E		0x00	0x00	0x00	0x00	0x00	0x00

* 0x00 no error, 0x01 storage configuration not supported, 0x02 storage media access error.

Inquire vendor ID

By this command the PVED vendor ID can be inquired.

Communication

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x5A	0x00	0x00	0x00	0x00	0x00	0x00	0x00

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	
0x7E4	8	CS	Vendor ID				Reserved			
		0x5A	0x19	0x00	0x00	0x01	0x00	0x00	0x00	0x00

Inquire product code number

By this command the PVED product code can be inquired.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x5B	0x00	0x00	0x00	0x00	0x00	0x00	0x00

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	
0x7E4	8	CS	Product Code				Reserved			
		0x5B					0x00	0x00	0x00	

Inquire revision number

By this command the PVED revision number can be inquired.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x5C	0x00	0x00	0x00	0x00	0x00	0x00	0x00

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	
0x7E4	8	CS	Revision Number				Reserved			
		0x5C					0x00	0x00	0x00	

Inquire serial number

By this command the PVED serial number can be inquired.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x5D	0x00	0x00	0x00	0x00	0x00	0x00	0x00

Communication

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	Serial Number				Reserved		
		0x5D					0x00	0x00	0x00

Serial number conversion key

The serial number is read from byte 1 to 4 as a hexadecimal number ordered from LSB to MSB.

Converting the hexadecimal serial number to decimal number will give the serial number in the following layout:

ww yy d ssss

ww week of the year (1-52)

yy year

d day of the week (1-7)

ssss running unique number of the day (0000 – 9999)

As an example:

Week = 41 (ww = 41)

Year = 2015 (yy = 15)

Day = Thursday (d = 4) Unique number = 5574 (ssss = 5574)

The serial number is combined to 411545574.

Serial number converted to hexadecimal = 1887AFE6

The serial number response to the inquire serial number command from the master will then be:

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	0x5D	0xE6	0xAF	0x87	0x18	0x00	0x00	0x00

PVED-CC identify non-configured remote slave

By this command the master can identify any slaves that got stuck in NMT initialization and therefore are not configured (meaning do not have an active nodeID). Only non-configured slaves will respond to the command.

Request frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E5	8	CS	Reserved						
		0x4C	0x00	0x00	0x00	0x00	0x00	0x00	0x00

Response frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x7E4	8	CS	Reserved						
		0x50	0x00	0x00	0x00	0x00	0x00	0x00	0x00

Fastscan

The PVED supports Fastscan according to CiA 305.

Communication

Process Data Object (PDO)

The PVED support two RxPDO messages as well as send out two TxPDO messages.

The PVED requires periodical RxPDO messages containing process data inputs.

Based on the transmission type configured the PVED can send out TxPDO containing process data.

RxPDO1

The RxPDO1 is, by default, mapped to the following two process data inputs:

- Dummy object (OD 0x3472)
- Vpoc Set Point (OD 0x6300 sub 0x01)

Frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x200 + nodeID	8	Dummy object		Vpoc Set Point (Set point)*		Reserved			
						0x00	0x00	0x00	0x00

* Range: -16384 to 16384 (corresponding to -100% to 100% spool travel), Float state = 32767 or - 32767.

The valve behavior to setpoint messages and the time guarding of RxPDO1 is configured in OD 0x1400.

RxPDO1 behavior

OD 0x1400, sub 0x01	COB-ID	COB-ID to control the PVED
OD 0x1400, sub 0x02	Transmission Type	Range: 0x00 to 0xF0 (synchronies, used together with Sync messages as trigger for sending PDO)
		Default: 0xFF event driven (asynchronies)
OD 0x1400, sub 0x05	Event Timer	Timeout of the RPDO message

RxPDO2

The RxPDO2 is, by default, mapped to the following two process data inputs:

- Device Control Word (OD 0x6040)
- Device Mode (OD 0x6042)

Frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x300 + nodeID	8	Device Control Word		Device Mode*	Reserved				
					0x00	0x00	0x00	0x00	0x00

* 0x01 CAN controlled, 0x02 hand operational mode.

The valve behavior to setpoint messages and the time guarding of RxPDO2 is configured in OD 0x1401.

RxPDO2 behavior

OD 0x1401, sub 0x01	COB-ID	COB-ID to control the PVED
OD 0x1401, sub 0x02	Transmission Type	Range: 0x00 to 0xF0 (synchronies, used together with Sync messages as trigger for sending PDO)
		Default: 0xFF event driven (asynchronies)
OD 0x1401, sub 0x05	Event Timer	Timeout of the RPDO message

Controlling a PVED using RxPDO1

The PVED can be controlled in one of two ways:

- Activating a single PVED with a single CANbus message

Communication

- For activating a single PVED the RxPDO COB-ID must be COB-ID + PVED nodeID (default = 0x200 + nodeID/0x300 + nodeID for RxPDO1 and RxPDO2 respectively)
- For activating multiple PVED's with a single message they must all have the same COB-ID (default = 0x200/0x300 for RxPDO1 and RxPDO2 respectively) and be mapped to listen to a specific byte in the RxPDO that contain their setpoints.
- Creating a mapping that will activate multiple PVED's with a single CANbus message

TxPDO1

The TxPDO1 is, by default, mapped to the following two process data outputs:

- Device Status Word, DSW (OD 0x6041)
- Vpoc Actual Value, Spool Position (OD 0x6301, sub 0x01)

Frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3
0x180 + nodeID	4	Device Status Word		Vpoc Actual Value (Spool position)*	

* Range: -16384 to 16384 (corresponding to -100 to 100% spool travel).

The behavior of TxPDO1 is configured in OD 0x1800.

TxPDO1 behavior

OD 0x1800, sub 0x02	Transmission Type	Range: 0x00 to 0xF0 (synchronies, used together with Sync messages as trigger for sending PDO) Default: 0xFF event driven (asynchronies)
OD 0x1800, sub 0x03	Inhibit time (used with synchronies transmission time)	Minimum time between two consecutive TxPDO1
OD 0x1800, sub 0x05	Transmission Time (used with synchronies transmission time)	Maximum time between two consecutive TxPDO1

TxPDO2

The TxPDO2 is, by default, mapped to the following four process data outputs:

- Demand value (OD 0x6310)
- Manufacturer specific spool position actual value – 8bit (OD 0x3301)
- Manufacturer specific spool position actual inverted value – 8bit (OD 0x3302)
- Manufacturer specific spool position actual value – 16bit (OD 0x3304)

Frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
0x280 + nodeID	6	Demand value		Manufacturer specific spool position actual value – 8bit	Manufacturer specific spool position actual inverted value – 8bit	Manufacturer specific spool position actual value – 16bit	

TxPDO2 data

Byte 0	Demand value -1000 to 1000 corresponding to -100% to 100% spool travel
Byte 1	
Byte 2	Manufacturer specific spool position actual value – 8bit -127 to 127 corresponding to -100% to 100% spool travel
Byte 3	Manufacturer specific spool position actual inverted value – 8bit -127 to 127 corresponding to -100% to 100% spool travel

Communication

TxPDO2 data (continued)

Byte 4	Manufacturer specific spool position actual value – 16bit -1000 to 1000 corresponding to -100% to 100% spool travel Float represented by value 0
Byte 5	

The behavior of TxPDO2 is configured in OD 0x1801.

TxPDO2 behavior

OD 0x1801, sub 0x02	Transmission Type	Range: 0x00 to 0xF0 (synchronies, used together with Sync messages as trigger for sending PDO)
		Default: 0xFF event driven (asynchronies)
OD 0x1801, sub 0x03	Inhibit time (used with synchronies transmission time)	Minimum time between two consecutive TxPDO2
OD 0x1801, sub 0x05	Transmission Time (used with synchronies transmission time)	Maximum time between two consecutive TxPDO2

PDO mapping

The following procedure is recommended for changing the mapping of a PDO. It makes use of SDO commands to perform the mapping.

1. Disable the PDO by setting PDO Parameter, Object Dictionary sub 0x01, bit 31 to 0x01
2. Disable mapping by setting PDO Mapping, Object Dictionary sub 0x00 to 0x00
3. Modify the mapping in PDO Mapping, Object Dictionary
4. Create the PDO by setting PDO Parameter, Object Dictionary sub 0x01, bit 31 to 0x00

PDO mapping example

The following example shows how to map `vpoc_actual_value` and `PCB_temperature` to TPDO1 for a PVED with `nodeID = 0x20` to TxPDO1.

1. DisableTxPDO1

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x620	8	Control Byte	OD Index		OD sub index	Data			
		0x23	0x00	0x18	0x01	0xA0	0x01	0x00	0x80

Response from PVED

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x5A0	8	Control Byte	OD Index		OD sub index	Data			
		0x60	0x00	0x18	0x01	0x00	0x00	0x00	0x00

2. Disable mapping

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x620	8	Control Byte	OD Index		OD sub index	Data			
		0x2F	0x00	0x1A	0x00	0x00	0x00	0x00	0x00

Response from PVED

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x5A0	8	Control Byte	OD Index		OD sub index	Data			
		0x60	0x00	0x1A	0x00	0x00	0x00	0x00	0x00

Communication

3. Modify mapping: a) Map parameter `vpoc_actual_value`, 16bit (0x6301, sub 0x01)

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x620	8	Control Byte	OD Index		OD sub index	Data			
		0x23	0x00	0x1A	0x01	0x10	0x01	0x01	0x63

Response from PVED

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x5A0	8	Control Byte	OD Index		OD sub index	Data			
		0x60	0x00	0x1A	0x01	0x00	0x00	0x00	0x00

3. Modify mapping: b) Map parameter `PCB_temperature`, 16bit (0x3468, sub 0x00)

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x620	8	Control Byte	OD Index		OD sub index	Data			
		0x23	0x00	0x1A	0x02	0x10	0x00	0x68	0x34

Response from PVED

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x5A0	8	Control Byte	OD Index		OD sub index	Data			
		0x60	0x00	0x1A	0x02	0x00	0x00	0x00	0x00

3. Modify mapping: c) Map 2 entries (`vpoc_actual_value` and `PCB_temperature`)

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x620	8	Control Byte	OD Index		OD sub index	Data			
		0x2F	0x00	0x1A	0x00	0x02	0x00	0x00	0x00

Response from PVED

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x5A0	8	Control Byte	OD Index		OD sub index	Data			
		0x60	0x00	0x1A	0x00	0x00	0x00	0x00	0x00

4. Create the TxPDO1 with new mapping

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x620	8	Control Byte	OD Index		OD sub index	Data			
		0x23	0x00	0x18	0x01	0xA0	0x01	0x00	0x40

Response from PVED

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x5A0	8	Control Byte	OD Index		OD sub index	Data			
		0x60	0x00	0x18	0x01	0x00	0x00	0x00	0x00

Resulting new TxPDO1

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3
0x1A0	4	Vpoc_actual_value		PCB_temperature	

Communication

Sync message

The PVED uses the Sync message as trigger for sending TxPDO when transmission type is configured as Synchronies.

Number of consecutive Sync messages between TxPDO transmitted is configured in TxPDO Object Dictionaries.

Sync frame format

Msg ID	DLC
0x80	0

PVED-CC heartbeat protocol

The PVED supports heartbeat protocol for error control services.

Heartbeat mechanism can be established by configuring the PVED as a heartbeat producer in OD 0x1017. Resolution is 10ms and value 0 will disable heartbeat producer.

Heartbeat frame format

Msg ID	DLC	Byte 0
0x700 + nodeID	1	State

Heartbeat data

Byte 0	State
	0x00 = Bootup
	0x04 = Stopped
	0x05 = Operational
	0x7F = Preoperational

Emergency messages

Emergency producer

Emergency messages are used to broadcast diagnostic codes to the CANbus network.

Emergency producer frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x080 + nodeID	8	Emergency Code	Error Register	Occurrence Counter	Fault ID	Reserved			Severity Level

Emergency producer data

Byte 0	EMCY code*								
Byte 1									
Byte 2	Error register*								
Byte 3	Occurrence Counter			Number of times the active fault has appeared previously					
Byte 4	Fault ID*								
Byte 5	Reserved (0x00)								
Byte 6									

Communication

Emergency producer data (continued)

Byte 7	Severity level*	0x00 = Info
		0x10 = Warning
		0x20 = Critical
		0x30 = Severe

* Refer to the [PVED-CC \(CANopen\) Diagnostics log](#) on page 28 for more information on specific faults.

Emergency severity level

Severity level	DSM transition	Action and recovery
Info (0x00)	No change	The PVED does not take any action
Warning (0x10)	Fault_Hold	Shutdown of PVED until the fault is no longer active
Critical (0x20)	Fault	Shutdown of PVED. Power reset needed after fault is no longer active
Severe (0x30)	Fault	

PVED emergency consumer

The PVED uses Emergency Consumer as emergency stop message from external sources.

The Emergency consumer is configured in OD0x1028 and has 14 allowed slots.

Emergency consumer frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Emergency producer ID	8	Emergency Code		Error Register	MSEF	Internal Error Code	Reserved		Severity Level (don't care)

Emergency consumer data

Byte 0	EMCY code
Byte 1	
Byte 2	Error register
Byte 3	Manufacturer Specific Error Field
Byte 4	Fault ID
Byte 5	Reserved (0x00)
Byte 6	
Byte 7	Severity level (don't care)

Parameters

Service Data Object (SDO)

SDO provide access to entries into the Object Dictionary.

SDO command

SDO command frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x600 + nodeID	8	Control Byte	OD index		OD sub index	Data			

SDO command data

Byte 0	Control Byte	0x2F: write 1 byte data
		0x2B: write 2 byte data
		0x23: write 4 byte data
		0x22: write 4 byte or less
		0x40: read command
Byte 1	Object Dictionary index	
Byte 2		
Byte 3	Object Dictionary sub-index	
Byte 4	Data (LSB first) Must always be 0x00 for SDO read command!	
Byte 5		
Byte 6		
Byte 7		

SDO response

SDO response frame format

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x580 + nodeID	8	Control Byte	OD index		OD sub index	Data			

SDO response data

Byte 0	Control Byte	0x43: SDO read acknowledge
		0x60: SDO write acknowledge
		0x80: SDO abort
Byte 1	Object Dictionary index	
Byte 2		
Byte 3	Object Dictionary sub-index	
Byte 4	Data (LSB first)	If Control byte = 0x43. Data read in OD
Byte 5		If Control byte = 0x60, Data = 0x00
Byte 6		If Control byte = 0x80, Data = SDO abort codes acc. CiA 301
Byte 7		

Parameters

List of configurable parameters

Configurable parameters

Parameter	Object Dictionary	Sub index	Description	Range	Default
Heartbeat	0x1017	—	Time between heartbeat messages transmitted from the PVED	Resolution: 10ms	1000 ms
				0-1000ms	
				0-100	
				0x00 - 0x64	
Emergency Consumer	0x1028	0x01 - 0x0E	Emergency Consumer ID of external sources to which PVED must react with a fault	0x81 - 0xFF	0x81 - 0x8E
Emergency Consumer no. Obj.	0x1028	0x00	No. of Emergency Consumers to which PVED must react with a fault	0x00 - 0xFF	0
RPDO1 parameters	0x1400	0x01	COB-ID for RPDO1	0x181 - 0x57F	0x200 + nodeID
		0x02	Transmission type for RDPO1	0x0 - 0xFF	0xFF
		0x05	Timeout for receiving RPDO1	0x0 - 0xFFFF	0x00
RPDO1 mapping	0x1600	0x01	Mapping of the RPDO1	0x1000 - 0x9FFF	0x30010
		0x02		0x1000 - 0x9FFF	0x63000110
RPOD2 parameters	0x1401	0x01	COB-ID for RPDO2	0x181 - 0x57F	0x300 + nodeID
		0x02	Transmission type for RDPO2	0x0 - 0xFF	0xFF
		0x05	Timeout for receiving RDPO2	0x0 - 0xFFFF	0x00
RPDO2 mapping	0x1601	0x01	Mapping of RPDO2	0x1000 - 0x9FFF	0x60400010
		0x02		0x1000 - 0x9FFF	0x60420008
TPDO1	0x1800	0x01	Message ID for TPDO1	0x181 - 0x1FF	0x180 + nodeID
		0x02	Transmission type. Synchronies or asynchronies (event driven) transmission of TPDO	0x0 - 0xFF	0xFF (event driven)
		0x03	Inhibit time. Minimum between two TPDO if event driven	0x0 - 0xFFFF	0x00
		0x05	Event timer. Maximum time between two TPDO if event driven	0x0 - 0xFFFF	0x64
TPDO1 mapping	0x1A00	0x01	Mapping of TPDO1	0x1000 - 0x9FFF	0x60410010
		0x02		0x1000 - 0x9FFF	0x63010110
TPDO2	0x1801	0x01	Message ID for TPDO2	0x281 - 0x2FF	0x280 + nodeID
		0x02	Transmission type. Synchronies or asynchronies (event driven) transmission of TPDO	0x0 - 0xFF	0xFF (event driven)
		0x03	Inhibit time. Minimum between two TPDO if event driven	0x0 - 0xFFFF	0x00
		0x05	Event timer. Maximum time between two TPDO if event driven	0x0 - 0xFFFF	0x64

Parameters

Configurable parameters (continued)

Parameter	Object Dictionary	Sub index	Description	Range	Default
TPDO2 mapping	0x1A01	0x01	Mapping of TPDO2	0x1000 - 0x9FFF	0x34800010
		0x02		0x1000 - 0x9FFF	0x33010008
		0x03		0x1000 - 0x9FFF	0x33020008
		0x04		0x1000 - 0x9FFF	0x33040010
Scaling – Extend	0x3454	-	Scaling of the spool stroke. 100% scaling = 7mm spool stroke	0-100%	100
				0-250	250
				0x00 - 0xFA	0xFA
Scaling - Retract	0x3455	-	Scaling of the spool stroke. 100% scaling = 7mm spool stroke	0-100%	100%
				0 250	250
				0x00 - 0xFA	0xFA
Dead band offset – Extend	0x3456	-	Spool stroke upon receiving smallest set point	0-100%	0%
				0-100	0
				0x00-0x64	0x00
Dead band offset – Retract	0x3457	-	Spool stroke upon receiving smallest set point	0-100%	0%
				0-100	0
				0x00 - 0x64	0x64
Ramp up - Extend	0x3458	-	Time to stroke spool from, neutral to full stroke (full stroke is defined by the scaling parameter)	0-4000ms	0ms
				0-250	0
				0x00 - 0xFA	0x00
Ramp down - Extend	0x3459	-	Time to stroke spool from, neutral to full stroke (full stroke is defined by the scaling parameter)	0-4000ms	0ms
				0-250	0
				0x00-0xFA	0x00
Ramp up – Retract	0x3460	-	Time to stroke spool from, neutral to full stroke (full stroke is defined by the scaling parameter)	0-4000ms	0ms
				0-250	0
				0x00-0xFA	0x00
Ramp down - Retract	0x3461	-	Time to stroke spool from, neutral to full stroke (full stroke is defined by the scaling parameter)	0-4000ms	0ms
				0-250	0
				0x00-0xFA	0x00
Invert port	0x3462	-	Inverts setpoint command	Inverted/not inverted	Not inverted
Float Threshold	0x3463	-	Minimum setpoint command needed to be received by the PVED before allowed to enter float	0-100%	0%
				0-250	0
				0x00-0xFA	0x00
Float ramp time	0x347A	-	Ramp time from full flow to float position. Valid range: 0-500ms Default: 0 = ramping disabled	0-500ms	0ms
				0-500	0
				0x00-0x1F4	0x00
Power Save	0x3464	-	Reduce power consumption by making the PVED enter a sleep mode when in neutral (time delay configurable)	ON/OFF	ON

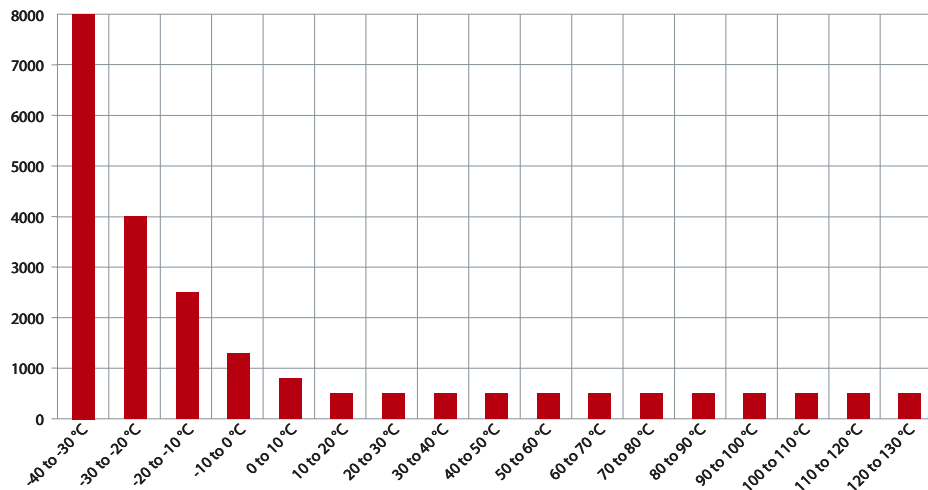
Parameters

Configurable parameters (continued)

Parameter	Object Dictionary	Sub index	Description	Range	Default
Power Save entry delay	0x3465	—	Time the spool has to stay in neutral position before power save mode is entered	0-8000ms	500ms
				0-80	5
				0x00-0x50	0x05
Low voltage reaction delay*	—	—	Time from voltage drops below acceptable limit (9VDC) to EMCY message is transmitted	0-2000ms	1000ms
				0-20	10
				0x00-0x14	0x0A
Temperature dependent spool timeout*	—	—	Allowed time to stroke the spool from full stroke to neutral in a 100C temperature interval from -40 to + 1300C	0x00-0xFF	See graph below
Temperature dependent spool timeout float add-on*	—	—	Time added to temperature dependent timeout to reach float position	0-100%	100
				0-255	255
				0x00-0xFF	0xFF
Baud rate	—	—	Communication baud rate	125kBd	250kBd
				250kBd	
				500kBd	
				1000kBd	

* Only configurable via PVED Series 5 PLUS+1® Service Tool.

Timeout as function of temperature



P301 824A

After changing one or more parameters the new data must be saved to the EEPROM with an SDO save command.

Msg ID	DLC	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
0x600 + nodeID	8	0x23	0x10	0x10	0x01	0x73	0x61	0x76	0x65

Parameters

List of read-only parameters

Parameter	Object Dictionary	Sub index	Description	Range
Current PCB temperature	0x3468	—	Temperature of the PCB measured by the onboard temperature sensor in °C (°F)	-40° C to 120° C (-40° F to 248° F)
				0-65535
				0x00-0xFFFF
Battery voltage	0x3469	—	Battery voltage measured by the PVED in steps of 0.1 V	9 V to 35.5 V
				0-65535
				0x00-0x163
8 bit dummy object	0x0002	—	The dummy unsigned 8 bit object to map in RxPDO	—
16 bit dummy object	0x0003	—	The dummy unsigned 16 bit object to map in RxPDO	—
32 bit dummy object	0x0004	—	The dummy unsigned 32 bit object to map in RxPDO	—

Diagnosis

PVED-CC (CANopen) Diagnostics log

The PVED-CC Series 5 CANopen contains a diagnostic log that saves occurrence of all faults listed below. The faults are transmitted onto the CANbus through EMCY messages upon occurrence and previously active faults can be inquired through SDO message to the EDS. The complete list of active and previously active faults can be seen in the PLUS+1® Service Tool.

Faults

Fault ID	Fault	Description	EMCY code	Severity	Error register
0	Software Initialization fault	Software could not initialize. Check that no active errors are present on CAN bus.	0x6200	Severe	0x81
1	Internal calculation fault	Actuator component fault	0x6201	Severe	0x81
2	Parameter truncation change	Value of parameter changed due to truncation	0x6203	Severe	0x81
3	Interpolation fault	Actuator components fault	0x6204	Severe	0x81
4	Supply voltage above upper limit	Actuator supply voltage above specified upper limit. Please ensure sufficient power supply	0x3411	Warning	0x05
5	Supply voltage below lower limit	Actuator supply voltage below specified lower limit. Please ensure sufficient power supply	0x3412	Warning	0x05
6	5V PSU out of range	Actuator component fault	0x3414	Severe	0x05
7	Spool position calculation fault	Actuator component fault	0x620B	Severe	0x81
8	V reference signal out of range	Actuator component fault	0x3413	Severe	0x05
9	GND signal unstable	Actuator component fault	0x3415	Severe	0x05
10	Demodulator A: signal out of range	Actuator component fault	0x5235	Severe	0x21
11	Demodulator B: signal out of range	Actuator component fault	0x5236	Severe	0x21
12	Handshake not received by safeUC	Actuator component fault	0x610D	Severe	0x81
13	Transducer signal frequency out of range	Actuator component fault	0x610E	Severe	0x81
14	Safety demodulator A: signal out of range	Actuator component fault	0x6108	Severe	0x81
15	Safety demodulator B: signal out of range	Actuator component fault	0x6109	Severe	0x81
16	Safety –controller PSU out of range	Actuator component fault	0x610F	Severe	0x81
17	Safety-controller: voltage reference out of range	Actuator component fault	0x6110	Severe	0x81
18	Safety-controller fuse bit fault	Actuator component fault	0x6101	Severe	0x81
19	Safety-controller spool position cross validation fault	Actuator component fault	0x610A	Severe	0x81
20	Safety switch state fault	Actuator component fault. Not able to perform safe operation!	0x6111	Severe	0x81
21	Safety-controller initialization fault	Actuator component fault	0x6211	Severe	0x81
22	Safety switch status fault	Actuator component fault. Not able to perform safe operation!	0x6112	Severe	0x81
23	Handshake not received by mainUC	Actuator component fault	0x6205	Severe	0x81
24	Handshake bootup fault	Actuator component fault	0x6113	Warning	0x81

Diagnosis

Faults (continued)

Fault ID	Fault	Description	EMCY code	Severity	Error register
25	POST fault	Power On Self-Test failed. Actuator cannot start up	0x620C	Severe	0x81
26	Safety controller task scheduling	Actuator component fault	0x6114	Severe	0x81
27	Spool position cross validation fault	Actuator component fault	0x8006	Severe	0x81
28	Memory (RAM) corrupted	Actuator component fault	0x5511	Severe	0x81
29	Memory (EEPROM) invalid parameter	One or more configured EEPROM parameters out of specified range	0x6322	Severe	0x81
30	Memory (Flash) corrupted	Actuator component fault	0x5521	Severe	0x81
31	SPI communication fault	Actuator component fault	0x5002	Critical	0x81
32	Fault overload	More than three faults were raised simultaneously	0xFF06	Severe	0x81
33	PWM calibration	Actuator component fault	0x6323	Severe	0x81
34	Memory (EEPROM) communication fault	Actuator component fault	0x5532	Severe	0x81
35	PSM operation fault	Actuator component fault	0x6209	Severe	0x81
36	Config sector CRC fault	Actuator component fault	0x5533	Severe	0x81
37	Diagnostic sector CRC fault	Actuator component fault	0x5536	Info	0x81
38	PSM buffer overload	Actuator component fault	0x620A	Severe	0x81
39	Average operating temp above limit	The average detected operating temperature is above the upper limit specified	0x4227	Warning	0x09
40	Current temp above upper limit	The current temperature the actuator operates in is above specified operation limit	Critical	0x4224	0x09
41	Current temp below lower limit	The current temperature the actuator operates in is below specified operation limit	0x4225	Critical	0x09
42	Main spool cannot return to neutral	Main spool cannot return back to neutral by neutral command setpoint	0x8310	Critical	0x81
43	Float not reached	Main spool cannot reach float position	0x8311	Critical	0x81
44	Main spool not in neutral at bootup	Main spool not at neutral position in the module at time of bootup	0x8307	Critical	0x81
45	Actual main spool position exceeds set point received	Main spool stroke further away from neutral than demanded by setpoint (dependent on timeout value)	0x8312	Critical	0x81
46	Transducer signal frequency out of range	Actuator component fault	0x5237	Severe	0x21
47	SPI buffer overload	Actuator component fault	0x620F	Info	0x81
48	SPI communication fault	Actuator component fault	0x6210	Severe	0x81
49	Loss and recovery of CAN bus connection	CAN bus connection to the actuator failed but recovered. Please verify connection	0x8140	Warning	0x11
50	Flow command not received within timeout period	RPDO not received by the actuator before timeout specified	0x8003	Warning	0x91
51	Safety switch status fault	Actuator component fault. Not able to perform safe operation!	0x6212	Severe	0x81

Diagnosis

Faults (continued)

Fault ID	Fault	Description	EMCY code	Severity	Error register
52	Float threshold setpoint not given	Setpoint less than float threshold given when commanded into float position	0x8313	Warning	0x81
53	Solenoid driver validation fault	Actuator component fault	0x6213	Critical	0x81
54	Stack usage >90%	Actuator component fault	0x620D	Critical	0x81
55	CRC fault	The Operator has not approved the data change	0x5537	Severe	0x81
56	Invalid hardware version	Actuator component fault	0x5001	Severe	0x81
57	COMM: running number validation	The running number for communication between controller and actuator could not be validated	0x809	Critical	0x91
58	Corrupted data received by Inlet actuator	CRC or DLC data received from Inlet actuator is corrupted	0x8008	Critical	0x91
59	TPDO from Work Function actuator not received within timeout period	TPDO not received from Work Function actuators by Inlet actuator before timeout specified	Warning	0x8001	0x91
60	RPDO received invalid	RPDO input received by actuator is invalid	Warning	0x8211	0x11
61	RPDO not received within timeout period	RPDO not received by actuator before timeout specified	Warning	0x81FF	0x11

Diagnostic history

In addition to the diagnostic log, the PVED-CC Series 5 CANopen holds a record of the last 16 faults occurred. The faults are stored in a FIFO buffer.

Besides the fault code the history also contains more information on the behavior and state of the valve upon fault occurrence. The diagnostic history can be seen in the PLUS+1[®] Service Tool.

Parameter	Description
Fault ID	ID number of the fault raised
Valve State	State of device upon fault occurrence
Current set point	Set point upon fault occurrence
Current spool position	Spool position upon fault occurrence
Battery voltage	Battery voltage upon fault occurrence
Operating time	Operating time upon fault occurrence*
Setpoint and spool position history	Last 9 setpoint and spool positions prior to fault occurrence
Temperature	Temperature upon fault occurrence [†]

* Operating time is logged every 6 minutes when the power to the PVED is ON

[†] Temperature is either received through PGN: VFT or onboard PCB temperature sensor

Temperature histogram

The PVED-CC Series 5 CANopen logs the temperature and time each 6 minutes. This temperature record is used to make a temperature histogram.

The temperature used is the one received in the PGN: Vehicle Fluid Temperature. If no PGN:VFT is received the PVED uses the onboard PCB temperature sensor.

The Temperature Histogram can be seen in the PLUS+1[®] Service Tool.

Products we offer:

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- Gear motors
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