BODAS Pressure sensor PR4

RE 95156
Edition: 01.2019
Replaces: 12.2018

- Thin-film measurement principle
- Measurement range
  0 ... 50 bar
  0 ... 280 bar
  0 ... 420 bar and
  0 ... 600 bar
- Ratiometric output signal 0.5 ... 4.5 V
  at 5 V supply voltage
  or SENT according to SAE J2716 JAN 2010
- Type of protection IP67 and IP69K

Features

- Tightening torque up to 45 Nm
- Shock and vibration resistant
- Very good resistance to temperature shock
- High accuracy over the complete measuring range
- Compact dimensions for all pressure ranges

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Ordering code

	01	02	03	04	05		06
BODAS	**PR4**					**/**	**10**

Type

01	Pressure sensor	**PR4**

Measurement range

02	0 ... 50 bar	**050**
	0 ... 280 bar	**280**
	0 ... 420 bar	**420**
	0 ... 600 bar	**600**

Mechanical connection		**050**	**280**	**420**	**600**	
03	G1/4 A according to DIN EN ISO 1179-2	●	●	●	–	**G**
	M14 x 1.5 according to ISO 6149-2	–	–	–	●	**M**

Electrical connection

04	Bosch Compact	**B**

Supply	**Output signal**	**050**	**280**	**420**	**600**	
05	5 ±0.25 V	0.5 ... 4.5 V ratiometric (at 5 ±0 V supply)	●	●	●	●	**05**
	5 ±0.25 V	SENT according to SAE J2716 JAN 2010	●	●	●	●	**SE**

Series

06		**10**

● = Available ○ = On request – = Not available

Available variants

Type	Material number Bulk pack (136 pieces)	Single pack
PR4 050 G B 05 / 10	R917C11189	R917A11189
PR4 050 G B SE / 10	R917C11574	R917A11574
PR4 280 G B 05 / 10	R917C05562	R917A05562
PR4 280 G B SE / 10	R917C10997	R917A10997
PR4 420 G B 05 / 10	R917C09842	R917A09842
PR4 420 G B SE / 10	R917C11558	R917A11558
PR4 600 M B 05 / 10	R917C10105	R917A10105
PR4 600 M B SE / 10	R917C11550	R917A11550

Description

This sensor is used for measuring pressure in hydraulic circuits. Due to its outstanding characteristics, it is also ideally suited for use in mobile hydraulics: shock and vibration resistance, type of protection, resistance to pressure spikes, resistance to temperature shock, EMC characteristics better than 150 V/m.

A resistance bridge is applied on a steel membrane using thin-film technology. The measurement principle uses a hermetically welded thin-film measurement cell, which ensures long-term leak resistance. The sensor signal can be directly evaluated by a BODAS controller RC.

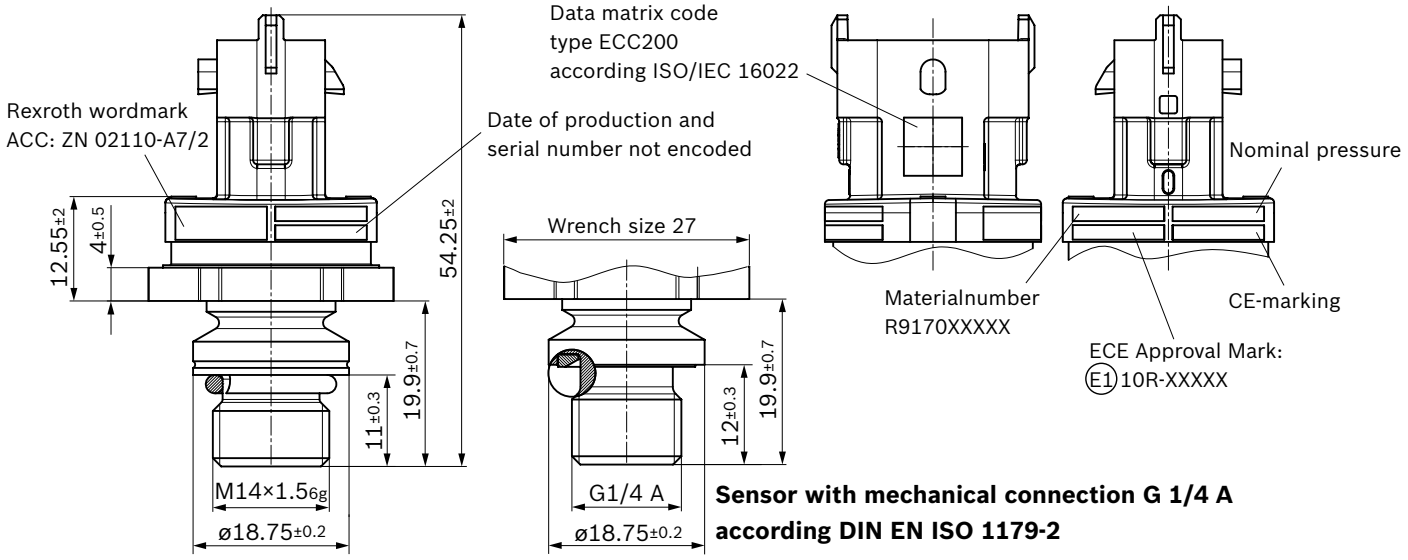
Technical data

Type PR4	**050 GB05 / GBSE**	**280 GB05 / GBSE**	**420 GB05 / GBSE**	**600 MB05 / MBSE**
Measurement range p_n	0 ... 50 bar	0 ... 280 bar	0 ... 420 bar	0 ... 600 bar
Overload limit[1] p_{max}	100 bar	400 bar	560 bar	840 bar
Bursting pressure[2][3] p_{Berst}	500 bar	2500 bar	3750 bar	4500 bar
Output signal	PR4 xxx xx 05 /10: 0.5 V ... 4.5 V, ratiometric (at 5 V supply) PR4 xxx xx SE /10: SENT according to SAE J2716 JAN 2010			
Supply voltage U_s	5 V ± 0.25 V			
Maximum supply voltage	18 V (maximum 1 h)			
Short circuit signal output to GND or supply voltage	$U_{S, short}$ = 0 ... 18 V, (max. 8 h) in case of simultaneous supply of U_S with $U_{S, short}$			
Sensor output impedance $R_{differntial}$ at 0.1 U_s < U_{out} < 0.9 U_s	typical: 5 Ω maximum: 10 Ω			
Current consumption	12 mA (at 5 V supply voltage)			
Maximum quiescent-current consumption	≤ 15 mA (at 5 V supply voltage)			
Reverse polarity protection of the supply voltage	yes (U_S ≤ 11V)			
Maximum at reverse connection	260 mA			
Connector	Bosch Compact 1.1a, 3 pin, code 1			
Parts contacting measuring materials	X5CrNiCuNb16-4			
Housing material	PBT-GF30/CrNi steel			
PR4 xxx xx 05 /10: Response time (10 ... 90 %)	≤ 1.0 ms			
PR4 xxx xx SE /10: SENT data transfer	Time till the first SENT Data transmission, min.: 1.8 ms max.: 2.2 ms			
Overall accuracy	≤ 1.5 %, refer to table "tolerance of the sensors PR4 xxx xx 05 /10" or "PR4 xxx xx SE /10"			
Ambient temperature range	–40 °C ... +140 °C			
Storage temperature range	–30 °C ... +60 °C at 0 ... 80 % relative humidity and 5 years			
Transportation conditions, Conditions deviating from the storage conditions are allowed for the transport:				
Duration, max. 48 h temperature	–40 °C ... +80 °C			
Relative humidity	0 % ... 80 %			
Service life	10000 operating hours or 15 years Different values, depending on operational conditions on request			
Pressure cycles over service life	10 million cycles			
Shock resistance	50 g (DIN EN 60068-2-27, 11 ms), 500 g (DIN EN 60068-2-27, 1 ms)			
Vibration resistance				
Amplitude of the deflection	s = 0.25 mm in the range 70 Hz ... 147 Hz			
Amplitude of the acceleration	a = 210 m/s² in the range 147 Hz ... 1350 Hz			
	a = 175 m/s² in the range 1350 Hz ... 2000 Hz			
Frequency change	0.5 octave/min			
Duration of excitation	100 h in each spatial direction with the same test specimen			
Drop test	Controlled drop from 1 m height onto concrete in accordance with ISO 16750-3. One drop event per axial direction. The component must then be fully functional or visually damaged			
CE conformity	According to EMC directive 2014/30/EU (EN ISO 14982 and EN 13309)			
E1 Type approval	UN ECE 10 Rev4			
Electromagnetic compatibility EMC	ISO 11452-2, -4, -5 as well as according to IEC 61000-4-2			
BCI up ... 200 mA	open and closed loop according ISO 11452-4 up ... 400 MHz.			
Antenna > 150 V/m	according ISO 11452-2 from 200 MHz - 3.2 GHz			
Electrical protection	Protection from voltage reversal, short circuits and undervoltage; protection from overvoltage in the defined supply voltage range			
Type of protection with installed mating connector	IP67 and IPX9K according to ISO 20653 (2006-08-15)			
Weight approx.	G 1/4 A: 48 g, M14 × 1.5 mm: 52 g			
Permissible hydraulic fluids	Mineral oil, HETG, HEPG, HEES, HFE, HFB, HFD (Other hydraulic fluids on request)			
ROHS	EU-RoHS2 compliant			

1) maximum 15 minutes at p_n to p_{max}
2) maximum 15 minutes at p_n to p_{Berst}
3) The specifield bursting pressure is valid for the device only. This value does not include the mechanical interface - the thread between the sensor and the hydraulic component

Dimensions and labeling

Sensor with mechanical connection M14 × 1.5 according DIN EN ISO 6149-2



Sensor with mechanical connection G 1/4 A according DIN EN ISO 1179-2

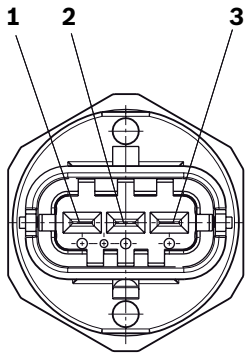
Data matrix code content

Content	Digits	Count
Material type: finished product	1	1
Material number R9170XXXXX	2-11	10
Year of production	12-13	2
Production day related to production year	14-16	3
Serial number related to production day	17-21	5
Number of production-line	22	1

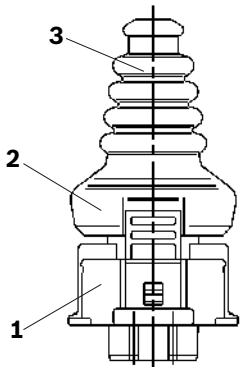
Content	Digits	Count
Number of the manufacturing plant	23-25	3
Internal Bosch Rexroth number	26-30	5
Bosch Rexroth change index	31-32	2
Bosch Rexroth drawing index	33-35	3
Empty place for CD-free sensor	36	1

Connector Bosch Compact

PIN assignment Sensor **Mating Connector**



1 Ground GND
2 Output
3 Supply voltage U_s



1 Compact 1.1a / Plug 3P / Cod. 1
2 End clip
3 Cap straight

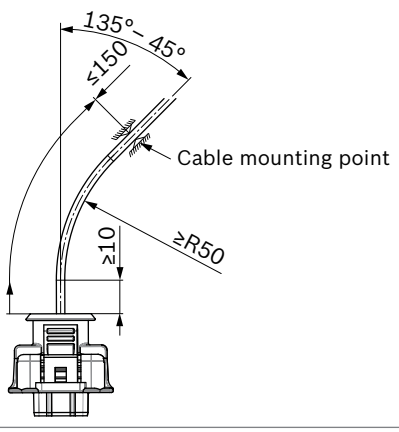
Mating connector [1)]

Mating connector sets with the following content are available under Rexroth material number R917009890 for the manual assembly of wiring harness connectors for laboratory or small-series requirements:

Designation	Number	Part number
Bosch Compact 1.1a Connector	1	1928403966
BDK 2,8 Terminal Gold for 18-20 AWG, 0.5-1.0 mm²	3	1928498054
Bosch compact cap straight	1	1928300527
BDK 2.8 / Single seal / Ø 1,2 - 2,1 mm / blue for insulation diameter 1.2 .. 2.1 mm	3	1928300599
End clip	1	1928403423

Further variants of the mating connector are available from Robert Bosch GmbH as well as via distribution.
See also the list in the drawing:
A 928 000 453 - Offer drawing compact plug 1.1

Instruction for cable guide



Required tooling [2)]

Designation	Number	Part number
Bosch crimping tool for BDK 2.8 terminal 0.5, 0.75, 1.0 sq mm wire	1	1928498161
Bosch terminal extraction tool for BDK 2.8 terminals	1	1928498167

Notes regarding assembly

In the assembly of the connectors, respect the assembly instructions for plug connections (Y 928 P00 222) and BDK 2.8 contacts (1 928 F00 025).
These assembly instructions are available on request from Bosch Rexroth.

Caution:

In the installation of the connector in the vehicle, observe the following:
The fixation of the cable harness must be done at a distance ≤ 150 mm after the outgoing cable unit at the same vibration level of the sensor.

Electrical connection

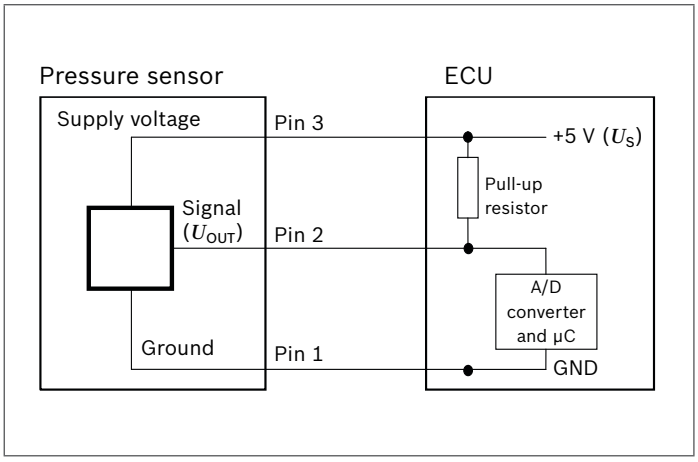
- The device may only be installed by a trained electrician.
- The national and international specifications regarding the installation of electro-technical systems must be followed.
- Voltage supply according to SELV, PELV.
- De-energize the system.
- The contacts in the plug of the sensor must not be touched during assembly work
- So called "Hot plugging" of the sensor, i.e. plugging it into a connector with existing voltage supply, is to be avoided

1) The mating connector are not included in the scope of supply. These are available from Bosch Rexroth under the corresponding material numbers.
2) The tools may be purchased from Bosch dealers or Bosch Service (www.bosch-service.com)
Drawings and further information about Bosch connectors and tools can be found on the internet: www.bosch-connectors.com

Wiring of the sensors: PR4 xxx xx 05 /10

Recommended wiring of the sensor
The sensor is to be connected to the ECU according to the following wiring diagram and provided with a supply voltage of 5 V.

▼ **Sensor wiring in the ECU**



The assignment of the connector pins of the high-pressure sensor is depicted on previous page.
The pressure sensor delivers an analog output signal that has a ratiometric relationship with the supply voltage.

Specification of the pull-up resistor:
In addition to this, a low-pass filter with a time constant of maximum 0.7 ms is to be provided in the signal path.
The electrical output of the sensor is designed such that malfunctions through cable breaks or short-circuits can be detected with the wiring shown in the representation with a pull-up resistor of 4.64 kΩ ±5 % against supply voltage.

Quantity	Symbol	Value			Unit
		min	typ	max	
Pull-up resistor to U_S	$R_{Pull-up}$	4.41	4.64	4.87	kΩ

Wiring of the sensors: PR4 xxx xx SE /10

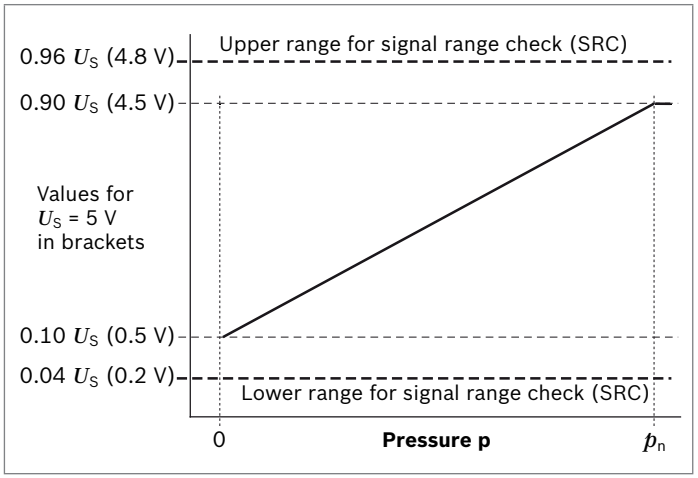
The sensor is to be connected by the control unit according to: SENT specification SAE International, "SENT-Single Edge NIBBLE Transmission for Automotive Applications", J2716 JAN 2010, January 2010 and needs to be supplied with a voltage of 5V.
The assignment of the connector pins of the high-pressure sensor deviates from the SENT standard, as described in the chapter "Pin assignment and connector bosch compact".

Characteristics of the sensors PR4 xxx xx 05 /10

Output voltage as function of the pressure
The signal output voltage is (up to the nominal pressure) calculated from the actual pressure as follows:

$U_{OUT} = (c_1 \times p + c_0) \times U_S$

where
U_{OUT} = Signal output voltage
U_S = Supply voltage (typ. 5 V)
p = Pressure [MPa]
c_0 = 0.1
c_1 = 0.8 : p_n
p_n = Nominal pressure [MPa]

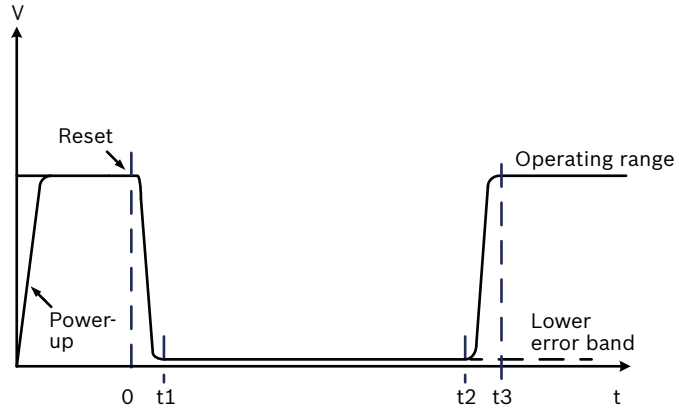


Behavior after reset and initialization for the sensors PR4 xxx xx 05 /10

In case of certain errors, a reset is triggered in the sensor. These are then generated every 400 ms. After a reset, and during the subsequent initialization of the sensor, the output is pulled to ground. If the error is still present, the output signal remains in the lower error band. In case, the error is no longer present, the output signal controls its value into the applicable operating range. The course of the output signal and the related typical time at room temperature, after the reset, are shown in diagram below.

Behavior after undervoltage and overvoltage PR4 xxx xx 05 /10
In case of undervoltage or overvoltage detection, the output is drawn to ground.

▼ **Representation of the time after reset and initialization**



Typicals [ms]	t1	t2	t3
CRC OK	0.03	0.9	1.1
CRC NOK	0.03	2.1	2.3

Error diagnosis for the sensors PR4 xxx xx 05 /10

Diagnostic ranges outside the operating range are provided for the error diagnosis (also see characteristic on page 11). Since the sensor characteristic of the upper operating range is limited, overpressure conditions can be distinguished from errors.

The coding of the response to an error in the following table is as follows:
0 = no error band and no reset
–1 = lower error band and no reset
–2 = lower error band and reset is triggered

Response of the sensor in case of error

Error description	Debounce characteristics	Error mode
Initialization, P and T not yet available		–1
Indicates that OTP Bit for final programming at Bosch of OTP Master is not set (lock-bit not set)	error is set immediately, no Reset is triggered	–1
1) Power-on complete RAM check (Read/Write) beginning of continuous ROM check 2) Online continuous ROM check continuous RAM check RAM/ROM checks DSP by Parity during each Access HW-Check of SignalProcessor (Question/Answer) signature monitoring of program counter	error is set immediately, Reset is triggered	–2
1) OTP CRC check of boot loading failed 4 times (consecutive) 2) Sum-check on trim data. Test carried out during boot loading and continuous cycle	1) error is set immediately, Reset is triggered 2) error is set immediately, Reset is triggered	–2
Test on Aquisition Chain Pressure by injection of test signal before ADC on power-up Thresholds are defined during EoL programming at Bosch for each sensor individually	error is set immediately, Reset is triggered	–2
Decimation interval error (Only possible in case of severe hardware malfunction)	no Reset, debouncing next frame	–1
Pressure Sensor element failure (Wiring Detection) 1) Power-On Common Mode at Power-On 2) Online Common Mode Current Modulation	1) error is set immeadiately, Reset is triggered 2) Reset, debouncing next frame	–2
Signal Input ADC too high, also for Sensor Element Error	no Reset, debouncing next frame	–1
Signal Input ADC too low, also for Sensor Element Error	no Reset, debouncing next frame	–1
Reference temperature input too high or low	no Reset	–1
Failure of internal temperatur sensor --> HW Defects of ADC_T or PTAT itself	no Reset	–1
Low Voltage Supply detection, programmable threshold	no Reset, debouncing next frame	–1
High Voltage Supply detection, programmable threshold	no Reset, debouncing next frame	–1

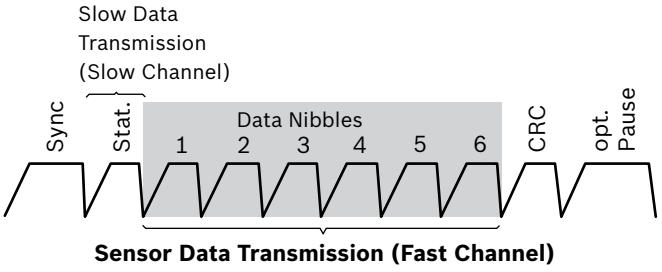
Sensor characteristics PR4 xxx xx SE /10 and SENT protocol description

SENT configuration for PR4 sensor

The PR4 xxx xx SE / 10 output setting, according the SAE J2716 standard is: P/T.

With the data nibbles 1-3 the SENT signal transmits a 12-bit data value "Fast Channel 1" (pressure).

With the data nibbles 4-6 the SENT signal transmits a 12-bit data value "Fast Channel 2" (temperature).

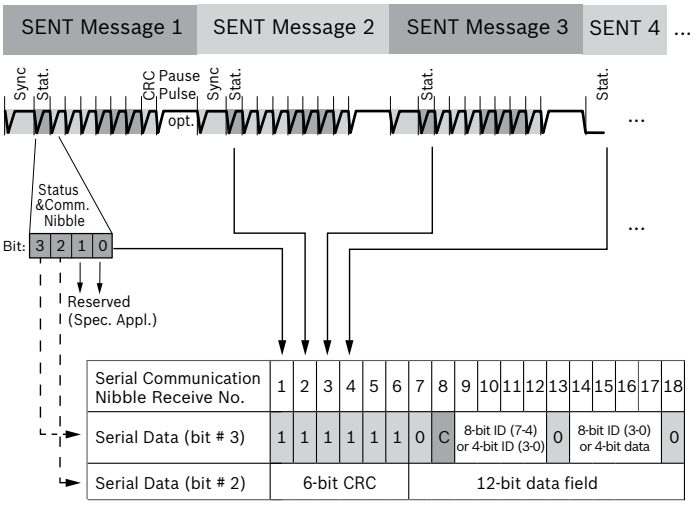


Sensor Data Transmission (Fast Channel)

Serial communication / Slow Channel / SlowData

PR4 uses the enhanced serial message format with 8-bit MsgID and 12-bit Data (config bit C=0).

In order to compose serial messages in enhanced format, two bit of each SENT message are beeing used. 18 consecutive error-free SENT messages are required to compose one serial message.



In the "slow channel / slow data", characteristic sensor data like coefficients, parameters, error information messages, OEM data, and so on are transmitted.

The sensor is delivered with the following settings:

Main Sensor Settings	**050 PR4 xxx xx SE /10**	**280 PR4 xxx xx SE /10**	**420 PR4 xxx xx SE /10**	**600 PR4 xxx xx SE /10**
Pressure offset (P2) / Nominal pressure (P3)[1)]	0 bar in relative pressure mode / 050 bar	0 bar in relative pressure mode / 280 bar	0 bar in relative pressure mode / 420 bar	0 bar in relative pressure mode / 600 bar
Maximal pressure for error - flag	62,5 bar +/-5 %	350 bar +/-5 %	525 bar +/-5 %	750 bar +/-5 %
Output - setting	P/T			
Tick length	3 µs			
Variable frame length	false			
Maximal temperature for error - flag	160 °C typically +/- 20 Kelvin (full functionality only guaranteed up to 140 °C)			
Number of data nibbles	6			
Pause pulse	Yes (constant "frame length")			
Serial protocol	Enhanced serial protocol with 8 bit ID and 12 bit data			
Fast channel 1	Pressure 12 bit			
Fast channel 2	Temperature 12 bit			
Length of one Fast Data Message	0,846 ms +/-10 %			
One Slow Data Message (18 Fast Data Messages)	15,2 ms +/-10 %			
8 Slow Data Messages (Diag)	121,6 ms +/-10 %			
All 32 Slow Data Messages	486,4 ms +/-10 %			

"Configuration Shorthand" nach J2716 JAN 2010

Transfer function of the signals of the sensor PR4 xxx xx SE /10

Transfer function pressure measurement signal

The measured pressure is transmitted as a digital value according to the SENT specification J2716 JAN 2010 according to the following function in fast channel 1 (measured values are contained in the fast channel). The coefficients and other values are transmitted in the slow channel, refer to the table on page 12.

Measured pressure: $p_{ist} = \frac{p_{OUT,code} - c_0}{k}$

Transfer function pressure: $p_{OUT,code} = k \times p + c_0$

Where:

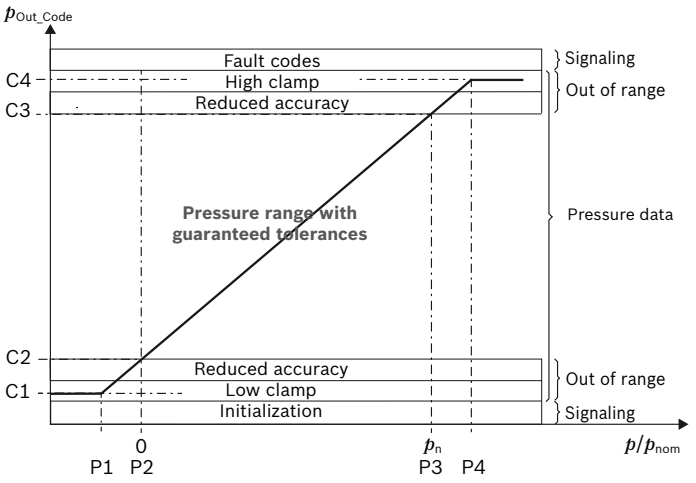
$p_{OUT,code}$ = digital 12 bit data value

p = pressure [kPa] (remark: 1kPa = 0,01bar)

Slope: $k = \frac{(Y2-Y1)}{(X2-X1)} = \frac{(C3-C2)}{(P3-P2)}$

Offset: $c_0 = Y1 - \frac{(Y2-Y1)}{(X2-X1)} \times X1 = C2 - \frac{(C3-C2)}{(P3-P2)} \times P2 = C2$

▼ **Transfer characteristic for the pressure as 12-bit data values**



1) The specific calculation rule for the nominal pressure P3 results from the 12-bit value X2 from the slow channel data as follows: The least significant 3 bits as power of ten, the higher-order (9) bits as the mantissa.
Example for X2 = 0x156: The nominal pressure corresponds to 42e6 [Pa] = 420bar.

The assignment of digital value to pressure is shown in the following table 'Pressure characteristic parameter', the accuracy of the sensor is defined in the section Tolerances on temperature, pressure and life of the sensor PR4 xxx xx SE /10.

Characteristic parameters pressure

Parameter	050 0261.547.023 HPS5 50 bar	280 0261.547.010 HPS5 280 bar	420 0261.547.021 HPS5 420 bar	600 0261.547.015 HPS5 600 bar
P_1	-259249 Pa	-1451796 Pa	-2177694 Pa	-3110991Pa
P_2 (X1)	0 Pa (0x0)	0 Pa (0x0)	0 Pa (0x0)	0 Pa (0x0)
P_3 (X2)	5000000 Pa (0x195)	28000000 Pa (0xE6)	42000000 Pa (0x156)	60000000 Pa (0x1E6)
P_4	5259249 Pa	29451796 Pa	44177694 Pa	63110991 Pa
C_1 (Low clamp)	1 LSB	1 LSB	1 LSB	1 LSB
C_2 (Y1, c_0)	193 LSB	193 LSB	193 LSB	193 LSB
C_3 (Y2)	3896 LSB	3896 LSB	3896 LSB	3896 LSB
C_4 (High clamp)	4088 LSB	4088 LSB	4088 LSB	4088 LSB
k	74,06 LSB/bar	13,225 LSB/bar	8,8167 LSB/bar	6,1717 LSB/bar
c_0	193 LSB	193 LSB	193 LSB	193 LSB

Temperature measurement transfer function

The sensor measures the temperature in the ASIC (application-specific integrated circuit). According to the SENT specification J2716 JAN 2010, the temperature characteristic is encoded as a 12-bit signal for slow and fast channel:

Measured temperature:

$$T_{ist} = K \times \frac{T_{OUT,code}}{round} \times 8 + 200$$

Temperature transfer function:

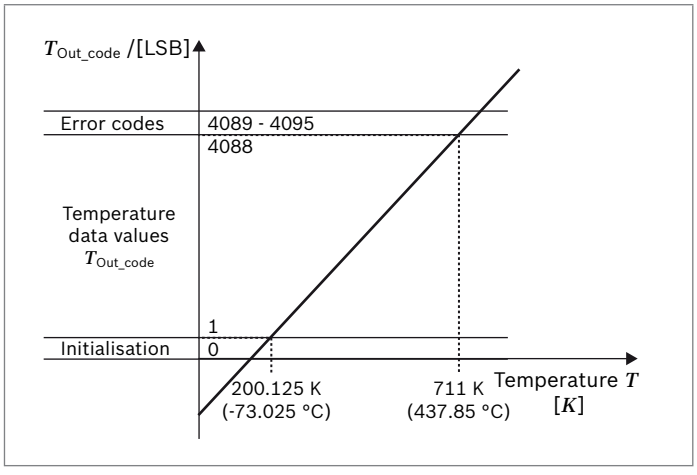
$$T_{OUT,code} = 8 \times round \frac{T_{ist} - 200K}{K}$$

where:

T_{ist} = Temperature in Kelvin $[K]$

$T_{OUT,code}$ = digital 12 bit data value

▼ **Transfer characteristic of the temperature values $[K]$ into 12-bit data values**



Maximum temperature until sending an error message:
160 °C typical +/- 20 Kelvin

Supply voltage measurement transfer function

According to the SENT specification J2716 JAN 2010, the supply voltage is encoded as a 12-bit signal for slow channel:

Measured supply voltage:

$$U_{ist} = \frac{U_{Val} \times V}{round \times 100}$$

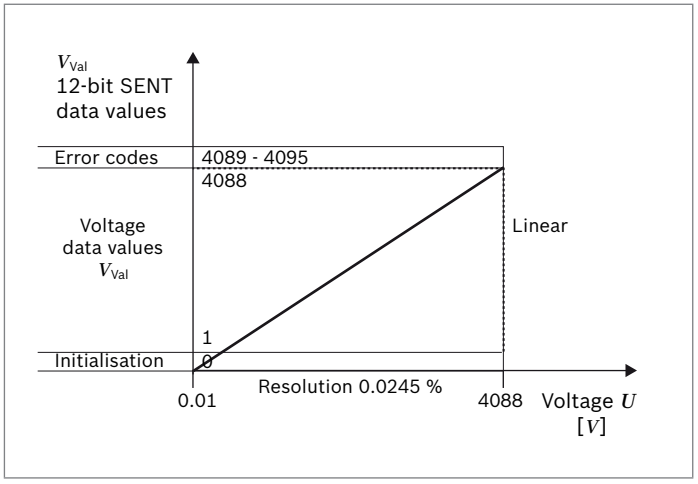
Supply voltage transfer function:

$$U_{Val} = 100 \times round \frac{U_{ist}}{V}$$

where:

U_{Val} = digital 12 bit data value

U_{ist} = Voltage range in V



Threshold for the overvoltage error message:
5,65 +/- 0,15 V

Threshold for the undervoltage error message:
4,35 +/- 0,15V

SENT-Slow Channel Messages Order, meaning and values

In the slow channel, this information is submitted in the order given as a continous (repeating) sequence.

Message ID	Message order	Meaning	Hexadecimal value (decimal value)
0x01	1	Diagnostic Error Codes / Error and Status Codes	See table page 14 Error Codes[1)]
0x03	2	Channel 1 / 2 Sensor type Data values for the sensor types are defined in Table D.4 in J2716 JAN 2010	0x7 (7)
0x04	3	Configuration Code Detailed specification of sensor type defined in Message 03 (Material number)	2)
0x05	4	Manufacturer Code Specific codes are assigned by the SAE SENT Task Force (B for Bosch)	0x42 (66)
0x06	5	SENT Standard Revision SENT J2716 JAN 2010	0x3 (3)
0x23	6	Supplementary data channel Bosch Codes: Internal Reference Temperature (PTAT/Diode) (TIC)	1)
0x1C	7	Supplementary Data Channel Supply Voltage	1)
0x82	8	Bosch-specific Information	1)
0x01	9	Diagnostic Error Codes / Error and Status Codes	See table page 14 Error Codes[1)]
0x07	10	Fast channel 1 Characteristic X1 [P2] Physical unit and encoding defined in application-specific appendices: Pressure transfer characteristic function (Channel 1)	0x0 (0)
0x08	11	Fast channel 1 Characteristic X2 [P3] (Exponent + Mantisse = nominal measurement range)	2)
0x09	12	Fast channel 1 Characteristic Y1 [LSB]	193 LSB
0x0A	13	Fast channel 1 Characteristic Y2 [LSB]	3896 LSB
0x83	14	Configurable Message 1	0x1 (1)
0x84	15	Configurable Message 2	0x2 (2)
0x85	16	Configurable Message 3	0x3 (3)
0x01	17	Diagnostic Error Codes / Error and Status Codes	See table page 14 Error Codes[1)]
0x29	18	Sensor ID #1 12-bit for 48-Bit Serial Number	3)
0x2A	19	Sensor ID #2 12-bit for 48-Bit Serial Number	3)
0x2B	20	Sensor ID #3 12-bit for 48-Bit Serial Number	3)
0x2C	21	Sensor ID #4 12-bit for 48-Bit Serial Number	3)
0x80	22	IIR Lowpass Filter Setting	(0)
0x81	23	Supplier Info #2 Bosch Rexroth part number, coded (part1)	3)
0x90	24	Bosch Rexroth-specific Information	0x0 (0)
0x01	25	Diagnostic Error Codes / Error and Status Codes	See table page 14 Error Codes[1)]
0x91	26	Bosch Rexroth-specific Information	0x0 (0)
0x92	27	Bosch Rexroth-specific Information	0x0 (0)
0x93	28	Bosch Rexroth-specific Information	0x0 (0)
0x94	29	Bosch Rexroth-specific Information	0x0 (0)
0x95	30	Bosch Rexroth-specific Information	0x0 (0)
0x96	31	Bosch Rexroth-specific Information	0x0 (0)
0x97	32	Bosch Rexroth-specific Information	0x0 (0)

1) Variable values

2) Depending on the pressure range and sensor type, this means the data changes for each material number.

3) Changes for each sensor

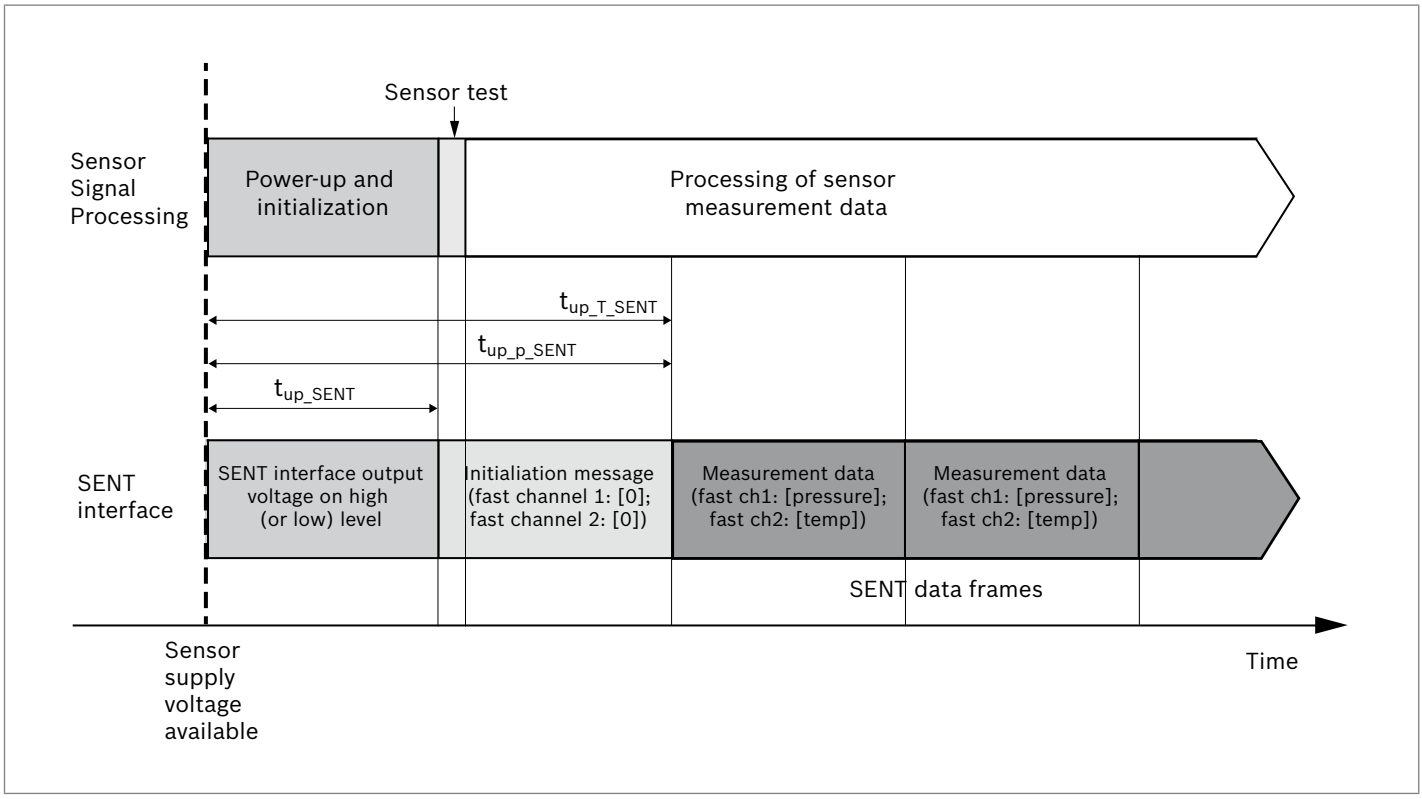
Default = 0

Response after a reset and following initialization of the Sensor PR4 xxx xx SE /10

For certain faults (see 'Fault diagnosis for sensor PR4 xxx xx SE /10') a reset is triggered in the sensor. After a reset and during the subsequent initialization of the sensor, the SENT message "Initialization 0" is sent exactly once as soon as the transmission is possible. As soon as pressure values and temperature values are available, they are sent.

There are two types of resets:
Hard-Resets: are executed immediately upon request.
Soft-Resets: are not executed until error conditions are still present after approx. 400 ms after power-on and the cause of the error could be reported under ID1 in the slow channel.
The attempt to initiate a reset within 400ms after power-on results in a continuous transmission of ID1 until the error condition is omitted or the reset is triggered after 400ms.

Response after a reset of the Sensor PR4 xxx xx SE /10
Values for the indicated times are available on request and are made available by Bosch Rexroth



Behavior after undervoltage and overvoltage of the sensor PR4 xxx xx SE /10
The sensor PR4 xxx xx SE /10 can detect an undervoltage or overvoltage in the supply line. An undervoltage is detected when the supply voltage drops below a measured voltage threshold (U_{mess} under).

Overvoltage is detected when the supply voltage is above a voltage threshold (U_{mess} over).
The undervoltage / overvoltage detection is designed in such a way that continuous undervoltage / overvoltage (e.g. due to damaged cables or plug-in connections) and temporary undervoltage / overvoltage are detected.

Error diagnosis for Sensor PR4 xxx xx SE /10

For fault diagnosis, fault codes are transmitted in the fast channel instead of data values (pressure or temperature), these are shown in the following table.

Transmitted error codes on the fast channel

Transmission	Description PR4 xxx xx SE /10
4095	Used for the production stage (e.g. if errors occurred during the manufacturing process)
4094	Unused
4093	Unused
4092	Unused
4091	Error indication sensor element and front end pressure measuring of sensor element and front-end error
4090	Error signal processing and signal perimeter
4089	Error message is sent due to reduced accuracy or reliability of the pressure signal
0	The initialization message is transmitted during the sensor initialization phase until valid measurement values are available (minimum one time after reset)

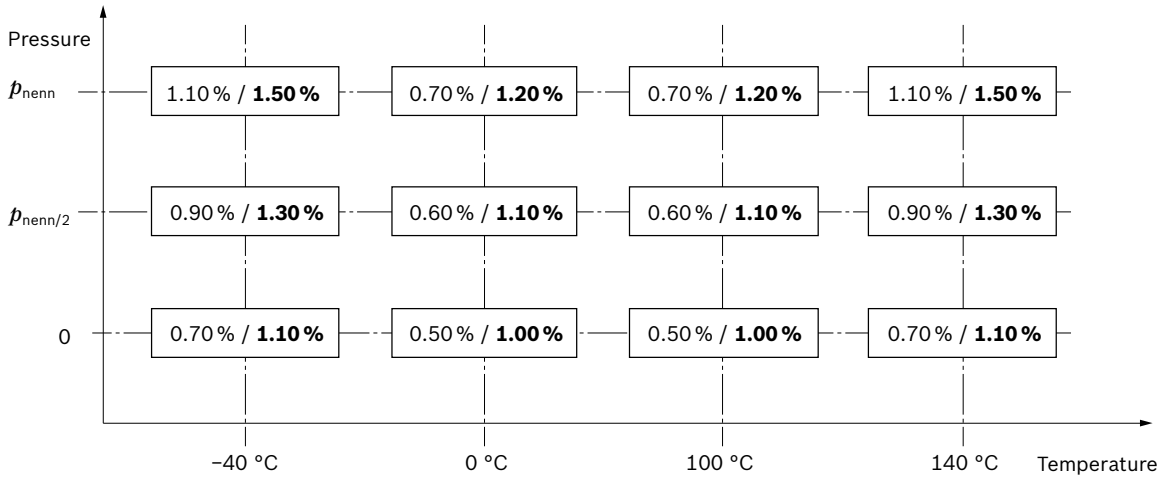
Hint: Error indicator bits and serial message data (Massage ID 01) carry additional information.

A further error detailing is described via information sent in the slow channel. The assignment of the errors between fast channel and slow channel as well as the associated priorities are shown in the following table.

Error description	Slow channel error codes [dec]	SENT fast channel 1 error codes [dec]	SENT fast channel 2 error codes [dec]	Channel 1 error bit 0 of status nibble	Channel 2 error bit 0 of status nibble	Internal reference temperature (PTAT/Diode) Supplementary data channel #4,1 error codes [dec]	Sensor supply voltage Supplementary data channel #3,1 error codes [dec]	Reset after slow channel error message if set to 1 [bin]	Fast channel 1 measurement data priority (measured value is transmitted at FC rather than error)	Fast channel 2 measurement data priority (measured value is transmitted at FC rather than error)
Initialization (P and T not yet available)	0	0	0	0	0			0		
Factory use only (OTP bits not set)	0	4095	4095	1	1	4095	4095	0		
Error during initial or cycling HW check (RAM/ROM)	2070	4090	4090	1	1	4090	4090	1		
Error during initial CRC or cyclic trim data check	3	4090	4090	1	1	4090	4090	1		
Error during injection self test on power-up	2049	4091		1	0			1		
Internal timing error (buffer overflow)	2076	4089		1	0			0		
Sensor element error (FC1, pressure)	2064	4091		1	0			1		
Signal input ADC too high (FC1, pressure)	1	4091		1	0			1		
Signal input ADC too low (FC1, pressure)	2	4091		1	0			1		
Reference temperature input to high or low	2067	4091	4091	1	1	4091		0		
Failure of internal temperature sensor	2067	4091		1	0	4091		0		
Low voltage supply (threshold exceeded)	32	4089	4089	1	1	4089		0	1	1
High voltage supply (threshold exceeded)	33	4089	4089	1	1	4089		0	1	1
ASIC temperature high (threshold exceeded)	34	4089	4089	1	1		4089	0	1	1
Pressure above or below limit for error flag	2056			1	0			0		
Overflows or saturation in supply voltage path (measurement possibly unreliable or wrong)	2079			0	0		4089	0		
Overflows or saturation in signal paths (pressure, temperature, supply voltage)	2075			1	1			0		

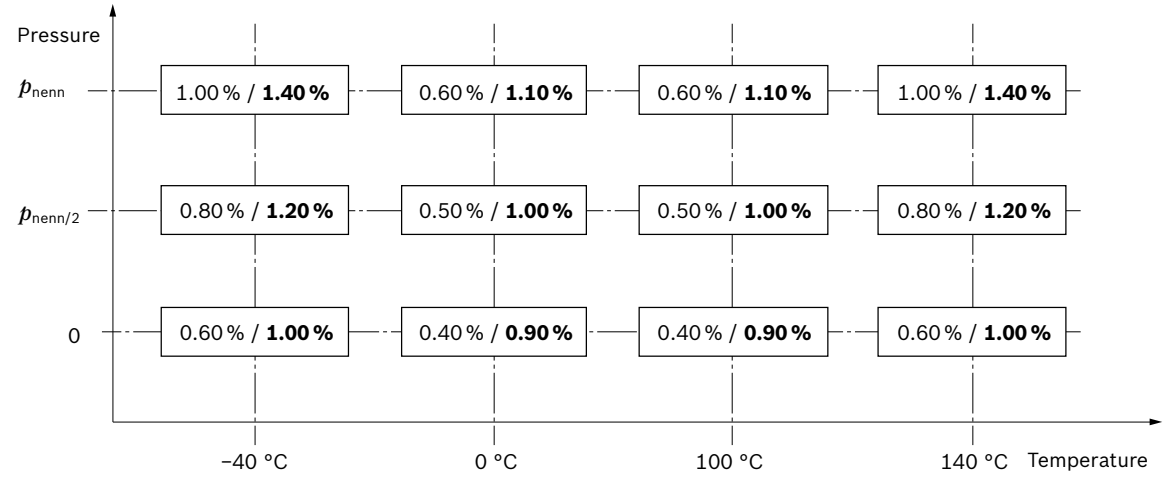
Tolerances of the sensors PR4 xxx xx 05 /10

The tolerance for the pressure measurement is given in % FS = "full scale". FS denotes the sensor nominal pressure p_{nenn} or the usable range (4 V). The relative tolerance is dependent on the pressure and temperature, and increases over the service lifetime. Here, the service lifetime encompasses the entire lifetime. The tolerances for new parts are statistically observed with 3 s per manufacturing batch. Delivery of 100 % sorted products is permitted. After lifetime the tolerance for new parts can broaden to the values given in the diagram. Here the given tolerances also represent the 3 s limit.



Tolerances of the sensor PR4 xxx xx SE /10

The tolerance for the pressure measurement is given in % FS = "full scale". FS denotes the sensor nominal pressure p_{nenn} or the usable range. The relative tolerance is dependent on the pressure and temperature, and increases over the service lifetime. Here, the service lifetime encompasses the entire lifetime. The tolerances for new parts are statistically observed with 3 s per manufacturing batch. Delivery of 100 % sorted products is permitted. After lifetime the tolerance for new parts can broaden to the values given in the diagram. Here the given tolerances also represent the 3 s limit.



Tolerances of the temperature measurement PR4 xxx xx SE /10

Internal temperature measurement on ASIC:
CPK[1] ≥ 1,67 short term and
CPK[1] ≥ 1,33 long term

Temperature	New part	Life
- 40°C	± 10 K	± 12 K
30°C	± 5 K	± 7 K
100°C	± 5 K	± 7 K
140°C	± 9 K	± 11 K

Tolerances of the supply voltage measurement PR4 xxx xx SE /10

The high-pressure sensor transmits the level of the power supply with a tolerance of ± 150 mV.

Installation instructions

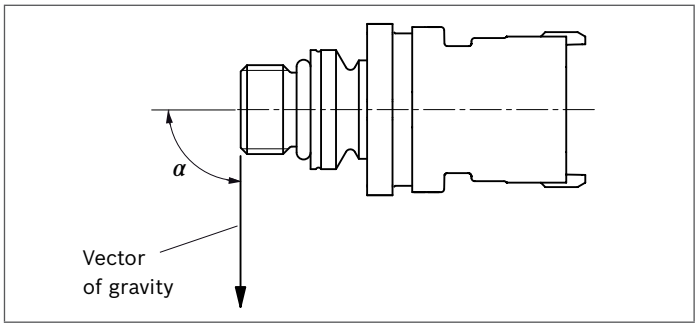
Mounting

Mounting process of sensor must be ensured by customer by adequate validation.
Bosch Rexroth recommends to wet the surface of thread and tightening plane of pressure sensor completely with Oil or Molykote WI5 prior to mounting.

To prevent accumulation of lubricant in the pressure port application of lubricant by spraying while pressure port facing downwards is recommended.

Recommended position:
α = ± (0 ...90°) to acceleration of gravity

Other mounting position, after acceptance of DC-MH and corresponding design of the machanical interface.



Mechanical connection

- Before installing and removing the device, make certain that the system is not pressurized.

Tightening torque

Before mounting the PR4 pressure sensor, check the specifield tightening torque of the hydraulic pump, motor or valve block.
If the torque for mounting the sensor in the respective hydraulic component is not specifield use a torque of 35 ±5 Nm for the sensors with the G1/4 thread up to 420 bar and 45 Nm ± 5 Nm for the 600 bar sensors with the M14 x 1,5 mm thread.
Do not exceed the maximum tightening torque of: 45 ±5 Nm.

Operating conditions - temperatures

The sensor is designed for use in hydraulic components (direct motor attachment) and the corresponding ambient temperatures with a typical temperature distribution:

Temperature	Distribution
–40 °C	6 %
23 °C	20 %
85 °C	65 %
135 °C	8 %
140 °C	1 %

Storage conditions

The pressure sensor is to be stored under the following conditions:

Temperature range	–30 °C ... +60 °C
Rel. humidity	0 ... 80 % r. h.
Maximum storage duration after the delivery by the Bosch production plant	5 years

The sensor has to be kept under dry and dust-free storage conditions. It is important to ensure that there is no contamination due to liquid or solid media in the connector area or on the threaded fitting. Sulfurous atmospheres have to be avoided for silver-plated connector pins.
These storage conditions do not lead to any change in the properties and the functioning of the high-pressure sensor. After the maximum storage duration is exceeded, the sensors must be sent back to Bosch Rexroth AG for inspection or testing.

Transportation conditions

Conditions deviating from the storage conditions are allowed for the transport:

Duration	max. 48 h
Temperature	–40 °C ... +80 °C
Relative humidity	0 % ... 80 %

1) CPK = process capability indize

Manufacturer confirmation of PR4 $MTTF_D$-values

The $MTTF_D$-values were determined in accordance with ISO 13849-1:2008-12, Appendix D, Parts Count Method, and the specified temperature profiles below.

Ambient temperature Control unit [°C]	Self-heating [°C]	Temperature profile, Operating time share [%]						
		1	2	3	4	5	6	7
10	10	100	0	0	0	0	0	0
20	10	0	100	0	0	0	0	0
30	10	0	0	100	0	0	0	0
40	10	0	0	0	100	0	0	0
50	10	0	0	0	0	100	0	0
60	10	0	0	0	0	0	100	0
70	10	0	0	0	0	0	0	100
80	10	0	0	0	0	0	0	0
90	10	0	0	0	0	0	0	0
100	10	0	0	0	0	0	0	0
110	10	0	0	0	0	0	0	0
120	10	0	0	0	0	0	0	0
130	10	0	0	0	0	0	0	0
140	10	0	0	0	0	0	0	0
$MTTF_D$-value [years] with one operating time of	4h use per day	71601	51998	37273	26434	18552	12869	8806
	8h use per day	44751	32499	23295	16521	11595	8043	5504
	16h use per day	25597	18589	13325	9450	6632	4601	3148
	24h use per day	17900	12999	9318	6608	4638	3217	2202

Ambient temperature Control unit [°C]	Self-heating [°C]	Temperature profile, Operating time share [%]							
		8	9	10	11	12	13	14	15
-40	10	0	0	0	0	0	0	0	6
10	10	0	0	0	0	0	0	0	0
20	10	0	0	0	0	0	0	0	0
23	10	0	0	0	0	0	0	0	20
30	10	0	0	0	0	0	0	0	0
40	10	0	0	0	0	0	0	0	0
50	10	0	0	0	0	0	0	0	0
60	10	0	0	0	0	0	0	0	0
70	10	0	0	0	0	0	0	0	0
80	10	100	0	0	0	0	0	0	0
85	10	0	0	0	0	0	0	0	65
90	10	0	100	0	0	0	0	0	0
100	10	0	0	100	0	0	0	0	0
110	10	0	0	0	100	0	0	0	0
120	10	0	0	0	0	100	0	0	0
130	10	0	0	0	0	0	100	0	0
135	10	0	0	0	0	0	0	0	8
140	10	0	0	0	0	0	0	100	1
$MTTF_D$-value [years] with one operating time of	4h use per day	5933	3930	2559	1639	1034	644	397	3106
	8h use per day	3708	2456	1599	1025	647	403	248	1941
	16h use per day	2121	1405	915	586	370	230	142	1110
	24h use per day	1483	982	640	410	259	161	99	776

Assessment of Safety Principles

List of the safety principles that must be to taken into account in the higher-level system.

Chapter	Basic safety principles	Remarks	Technology	Area of use	Rating
A.1.5	Suitable mounting	For the application of screw locks, observe the manufacturer's application notes. Overstraining can be avoided by applying a suitable torque limiting method.	Mechanical system	Components	Installation of the sensor protected for the intended use as described in the data sheet. The described loads must not be exceeded and the installation conditions must be observed by the customer.
C.1.5	Suitable mounting	For the application e.g. of screw locks, fittings, adhesives, clamping rings, observe the manufacturer's application notes. Overstraining can be avoided by applying a suitable torque limiting method.	Hydraulic system	Components	Installation of the sensor protected for the intended use as described in the data sheet. The described loads must not be exceeded and the installation conditions must be observed by the customer.
D.1.6	Application of the principle of energy separation (GS-BGIA-M13: Off-load current principle, spring, return spring)	A safe condition is achieved by separating all important equipment from the energy source, e.g. by using a normally closed (NC) contact for inputs (contact and position switches) and a normally open (NO) contact for relays [see also EN 292-2:1991 (ISO/TR 12100-2:1992), 3.7.1]. There can be exceptions in some cases, e.g. if a failure of the electrical supply represents an additional hazard. Time-delaying functions may be necessary to ensure that a safe status of the system is achieved [see EN 60204-1:1997 (IEC 60204-1:1997), 9.2.2].	Electrical system	Components	The safe state is reached when the signal is in the error band. This is the case when the power supply is disconnected from the sensor.
A.1.7	Limitation of the range of ambient parameters	These parameters are e.g. temperature, humidity, impurities at the installation site. Observe the manufacturer's application notes.	Mechanical system	Components	The ambient parameters specified in the data sheet must be observed.
D.1.7	Suppression of voltage peaks	A set up for suppressing voltage peaks (an RC element, a diode or a varistor) must be used parallel to the applied load but not parallel to the contacts. NOTE: A diode increases the switching off time.	Electrical system	Components	The sensor is designed so that the peak voltages described in the data sheet do not damage the sensor or keep the sensor within the specification. The higher-level system must avoid voltage peaks.

Chapter	Basic safety principles	Remarks	Technology	Area of use	Rating
D.1.9	Compatibility	Application of components that are suitable for the applied voltages and currents (power supply unit).	Electrical system	Components	The sensor is designed so that the voltages and currents described in the data sheet are protected under the loads and installation situations described there. The higher-level system must comply with the specified voltages and currents.
C.1.13	Suitable temperature range	This must be taken into account throughout the system.	Hydraulic system	Components	The sensor is designed so that the temperature loads described in the data sheet do not damage the sensor or keep the sensor within the specification. The specified temperature range must be observed.
A.1.14	Suitable protection against penetration of liquids and dust	Observe the IP protection type [see EN 60529 (IEC 60529)].	Mechanical system	Components	The sensor is protected against the intrusion of fluids or dust. The specified protection classes must be observed.

Chapter	Well-tried safety principles	Remarks	Technology	Area of use	Rating
D.3.4	Energy limitation	A condensator must be used to supply a limited amount of energy, e.g. when using a time cycle controller.	Electrical system	Components	The supply voltage described in the data sheet must be observed.
D.3.5	Limiting electrical parameters	Limiting of the voltage, current, energy or frequencies to avoid an unsafe status, e.g. by torque limitation, offset/time-limited running and reduced speed.	Electrical system	Components	The supply voltage described in the data sheet must be observed.
D.3.6	Avoidance of undefined conditions	Undefined conditions in the control system must be avoided. The design of the control system shall be such that the condition of the control system, e.g. outputs, can be predetermined during normal operation and under all expected operating conditions.	Electrical system	Components	In the case of an error, the sensor signal goes into the error band (safe state) as described in the data sheet.
D.3.8	Status orientation in the case of failures	If possible, all equipment/circuits should enter a safe condition or be safe to operate.	Electrical system	Components	In the case of an error, the sensor signal goes into the error band (safe state) as described in the data sheet.
D.3.9	Directed failure	If it is possible to implement, components or systems should be used whose types of failure are known in advance [see EN 292-2:1991 (ISO/TR 12100-.2:1992), 3.7.4].	Electrical system	Components	In the case of an error, the sensor signal goes into the error band (safe state) as described in the data sheet.

Safety instructions

General instructions

- Before finalizing your design, request a binding installation drawing.
- The proposed circuits do not imply any technical liability for the system on the part of Bosch Rexroth.
- It is not permissible to open the sensor or to modify or repair the sensor. Modifications or repairs to the wiring could result in dangerous malfunctions.
- Only allow pressure measurement devices to be installed by trained and specialist personnel who are authorized by the system owner.
- Only install pressure gauges by trained personnel who are authorized by the system owner.
- Connections must only be opened while in a depressurized state!
- The sensor may only be assembled/disassembled in a depressurized and deenergized state.
- In order to prevent damage at the sensor and to maintain its unobjectionable functioning, professional air bleed of the hydraulic system is required.
- System developments, installation and commissioning of electronic systems for controlling hydraulic drives must only be carried out by trained and experienced specialists who are sufficiently familiar with both the components used and with the complete system.
- While commissioning the sensor, the machine may pose unforeseen dangers. Before commissioning the system, you must therefore ensure that the vehicle and the hydraulic system are in a safe condition.
- Make sure that nobody is in the machine's danger zone.
- No defective or incorrectly functioning components may be used. If the sensor should fail or demonstrate faulty operation, it must be replaced.
- Residual measurement materials in unmounted pressure measurement devices could endanger people, the environment and equipment. Take appropriate precautionary measures.
- In spite of taking great care in preparing this document, all conceivable application cases could not be taken into account. If information is lacking for your specific application, please contact Bosch Rexroth.

Notes on the installation location and position

- Do not install the sensor close to parts that generate considerable heat (e.g. exhaust).
- Wires are to be routed with sufficient distance from hot or moving vehicle parts.
- A sufficiently large distance to radio systems must be maintained.
- The connector of the sensor is to be unplugged during electrical welding and painting operations.
- Electrostatic painting of the sensor is not allowed (hazard: ESD damage).
- Cables/wires must be sealed individually to prevent water from entering the device.
- Make sure, by appropriate installation of the sensor, that no water is gathering the sensor measuring element. This might result to a malfunction of the measuring signal (freezing condition, in worst case: crack of measuring element).

Notes on transport and storage

- Please inspect the device for any damages which may have occurred during transport. If there are obvious signs of damage, please immediately inform the transport company and Bosch Rexroth.
- If it is dropped, the sensor must not be used any longer as invisible damage could have a negative impact on reliability.

Notes on wiring and circuitry

- Use twisted pair wires to connect the pressure sensor.
- Use short wires to avoid voltage drop along the lines and choose wires with bigger gauge in case of longer distances between the sensor and the electronic.
- We recommend to use shielded wire to increase the signal quality. Connect the shield on one side, either to the machine or the vehicle ground or to the electronic via a short low resistance connection.
- The mating connector of the sensor must not be plugged or unplugged, if the electrical system of the machine is energized.
- The sensor wires are sensitive to radiation interference. For this reason, the following measures should be taken when operating the sensor:
  - Sensor wires should be attached as far away as possible from large electric machines.
  - If the signal requirements are satisfied, it is possible to extend the sensor cable.Wires from the sensor to the electronics must not be routed close to other power-conducting lines in the machine or vehicle.
- The wiring harness should be fixated mechanically in the area in which the sensor is installed (spacing < 150 mm). The wiring harness should be fixated so that in-phase excitation with the sensor occurs (e.g. at the sensor mounting points).

- If possible, wires should be routed in the vehicle interior. If the wires are routed outside the vehicle, make sure that they are securely fixed.
- Wires must not rub against edges and must not be routed through sharp-edged ducts without protection.
- Bosch Rexroth warranty will cover the function of the connector system only in the case of combination with harness connector system parts according to this data sheet.
- Use only the appropriate tooling to crimp and mount the mating connector.

Attention:
Use harness connector for protection against water ingress.

- First cable mounting point max. 150 mm after the plug (straight cable length). It must be located on the sensor carrier.
- Angle of bending the cable (deviation from straight line) between cable exit at sensor and first mounting point, 20° ... 90°.
- Admissible bending radius of the cable up to the first cable mouting point: $R \geq 50$ mm.
- Installation instructions see also corresponding offer drawing.

Intended use

- The sensor is designed for use in mobile working machines provided no limitations/restrictions are made to certain application areas in this data sheet.
- Prior to installation, commissioning and operation, make certain that the correct pressure measurement device was selected with respect to measurement range, design and – based on the specific measurement conditions – parts which are in contact with measuring materials (corrosion). Furthermore, the respective national safety regulations are to be observed.
- Operation of the sensor must generally occur within the operating ranges specified and released in this data sheet, particularly with regard to voltage, temperature, vibration, shock and other described environmental influences.
- If required, install a throttle, that limit possible pressure peaks. Attention should be also paid to side effects e.g. cavitation. Ensure that there will be no cavitation in any point of operation.
- Use outside of the specified and released boundary conditions may result in danger to life and/or cause damage to components which could result in consequential damage to the mobile working machine.
- Failure to observe the respective specifications may result in serious bodily injury and/or property damage.

Improper use

- Any use of the sensor other than that described in chapter “Intended use” is considered to be improper.
- Use in explosive areas is not permissible.
- Damages which result from improper use and/or from unauthorized, interference in the component not described in this data sheet render all warranty and liability claims with respect to the manufacturer void.

Use in safety-related functions

- The customer is responsible for performing a risk analysis of the mobile working machine and determining the possible safety-related functions.
- In safety-related applications, the customer is responsible for taking suitable measures for ensuring safety (sensor redundancy, plausibility check, emergency switch, etc.).
- Product data that is necessary to assess the safety of the machine are listed in this data sheet.

Further information

- Further information about the sensor can be found at www.boschrexroth.com/mobile-electronics.
- The sensor must be disposed according the national regulations of your country.

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