Digital Absolute Pressure Sensor

KP253

dBAP

Digital Barometric Air Pressure Sensor IC

Data Sheet

Revision 1.1, 2015-07-29

Sense & Control

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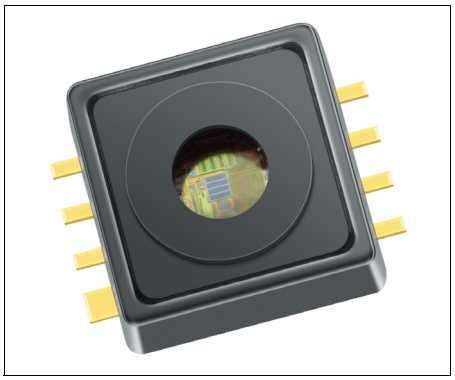
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1 Product Description



PG-DSOF-8-16

The KP253 is a miniaturized Digital Barometric Air Pressure Sensor IC based on a capacitive principle. It is surface micromachined with a monolithic integrated signal conditioning circuit implemented in BiCMOS technology.

The sensor converts a pressure into a 12-bit digital value and sends the information via the SPI interface. In addition, a temperature sensor is integrated on chip. Based on the received SPI command, the 12-bit temperature information will be transmitted via the SPI interface.

A special reliability feature is the integrated diagnostic mode, which allows testing the sensor cells as well as the signal path. This diagnosis can be simply triggered with a SPI command.

The chip is packaged in a “green” SMD housing. The sensor has been primarily developed for measuring barometric air pressure, but can also be used in other application fields. The high accuracy, high sensitivity and reliability features of the device makes it a perfect fit for advanced automotive applications as well as in industrial and consumer applications.

1.1 Features

The following features are supported by the KP253:

- High accuracy pressure sensing (± 1.0 kPa)
- 12-bit pressure resolution
- Integrated temperature sensor
- 12-bit temperature resolution
- Power-down mode for reduced power consumption
- Self diagnosis features
- “Green” 8 pin SMD housing
- Automotive qualified

1.2 Target Applications

The KP253 is designed for use in the following target applications:

- Automotive applications
- Industrial control
- Consumer applications
- Medical applications
- Weather stations, Altimeters

Product Name	Product Type	Ordering Code	Package
Digital Absolute Pressure Sensor	KP253	SP001399102	PG-DSOF-8-16

2 Functional Description

2.1 Pin Configuration

Figure 1 shows the pin configuration.

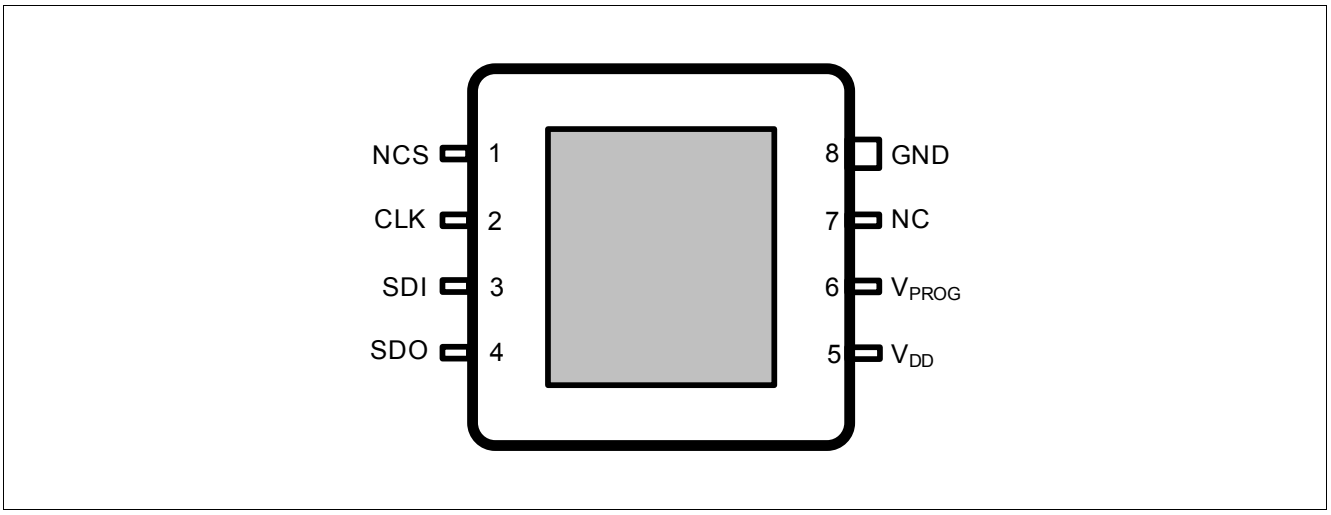


Figure 1 Pin configuration (top view, figure not to scale)

2.2 Pin Description

Table 1 shows the pin description.

Table 1 Pin description

Pin No.	Name	Function	Comment
1	NCS	Not-Chip-Select (active-low)	Communication is enabled when NCS is low
2	CLK	Serial Clock	External clock for serial communication
3	SDI	Serial Data In	Serial data input (e.g. from a controller)
4	SDO	Serial Data Out	Tri-state serial data output
5	V_{DD}	Supply voltage	–
6	V_{PROG}	Programming Voltage	Only required during E^2PROM programming
7	NC	Not Connected	Pin is not bonded
8	GND	Ground	–

2.3 Block Diagram

Figure 2 shows the functional block diagram.

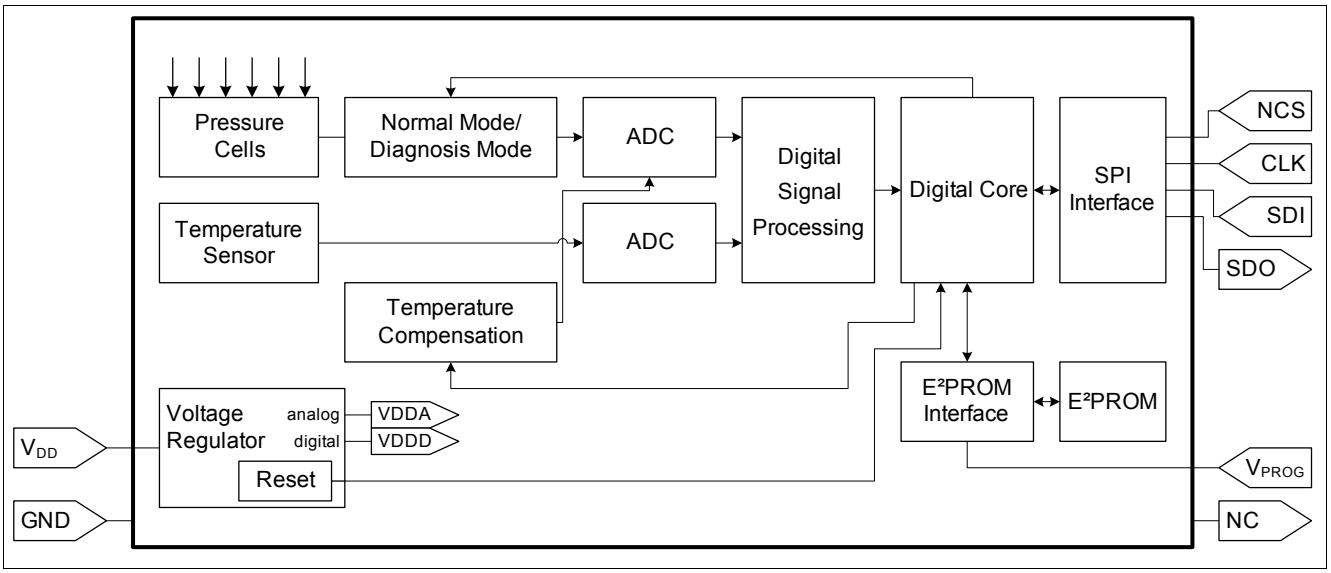


Figure 2 Functional block diagram

2.4 Transfer Function Pressure

The KP253 device is fully calibrated on delivery. The sensor has a linear transfer function between the applied pressure and the digital output signal.

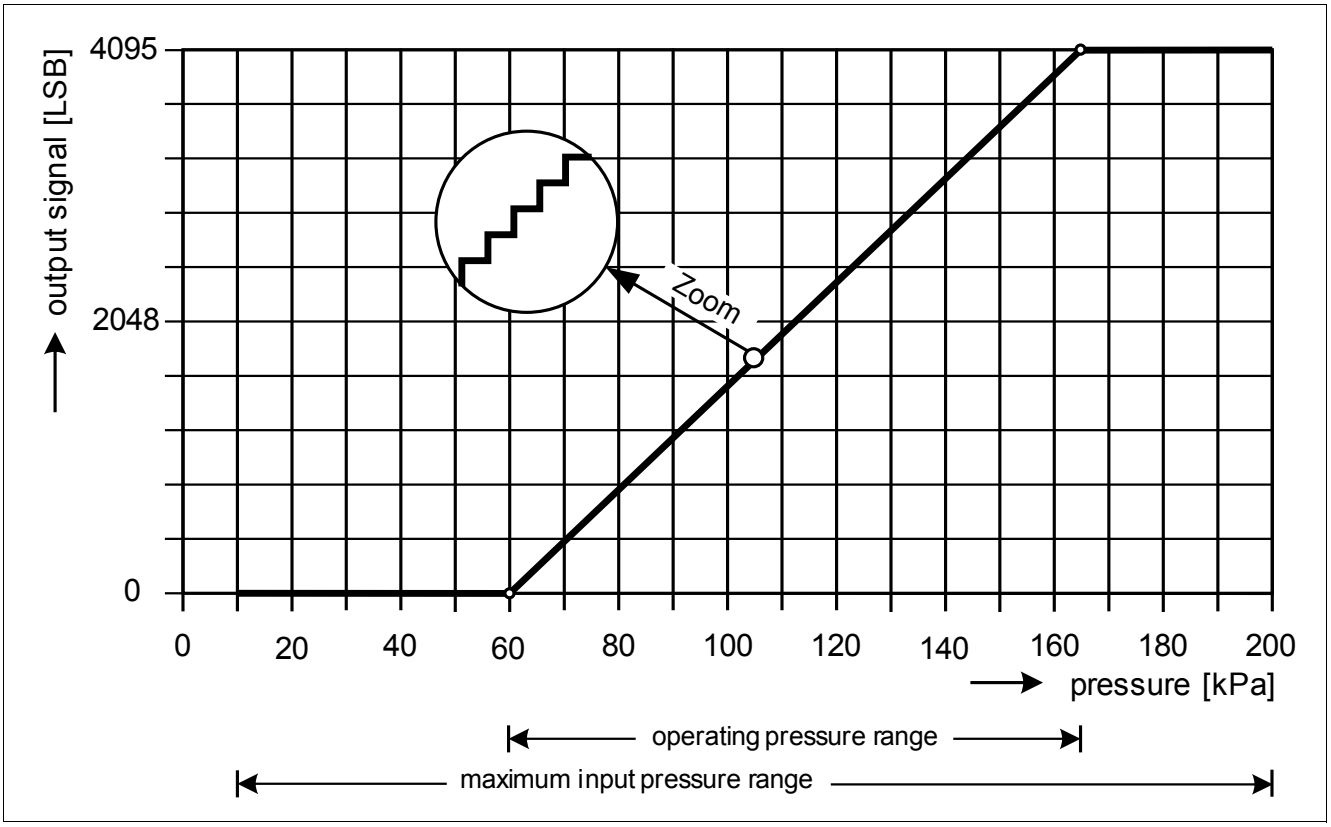


Figure 3 Pressure transfer function

2.4.1 Pressure Transfer Function Characteristics

The following calibration is adjusted with the parameters S_p and $offs_p$

$$p_{amb} = \frac{out_p - offs_p}{S_p}$$

Table 2 Pressure transfer function characteristics

Pressure			Output Code				Gain and Offset		
Symbol	**Values**	**Unit**	**Symbol**	**Values**	**Unit**		**Symbol**	**Value**	**Unit**
$p_{IN,1}$	60	kPa	$LSB_{OUT,1}$	0	LSB		Sp	39	LSB/kPa
$p_{IN,2}$	165	kPa	$LSB_{OUT,2}$	4095	LSB		offsp	-2340	LSB

Note: The points $p_{IN,1}/LSB_{OUT,1}$ and $p_{IN,2}/LSB_{OUT,2}$ define the calibrated transfer function and not the operating range. The operating pressure range is defined by the parameter 2.8 "Ambient operating pressure range" on Page 22

2.4.2 Accuracy

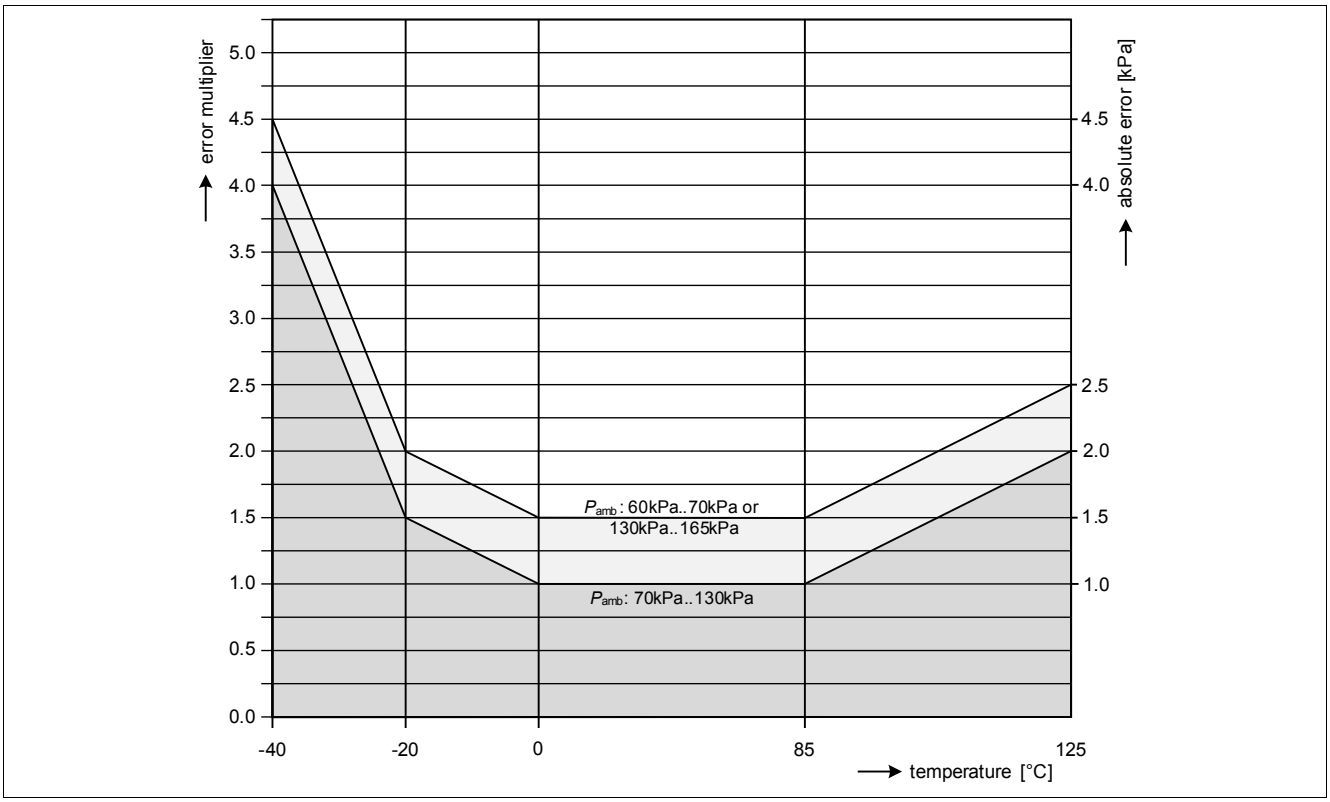


Figure 4 Accuracy for pressure acquisition

2.5 Transfer Function Temperature

Triggering the temperature command (see **Section 2.7.1.4**) the KP253 provides the ambient temperature.

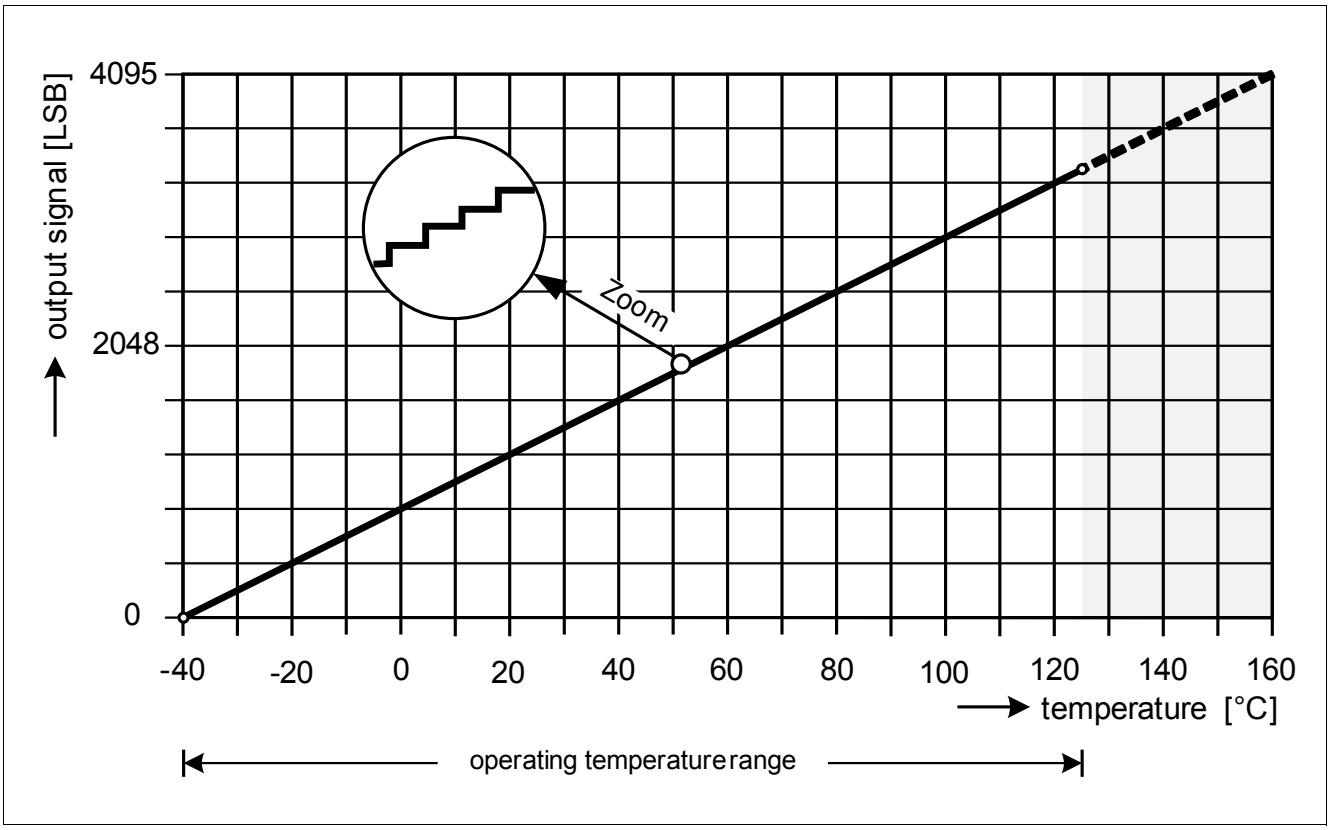


Figure 5 Temperature transfer function (V_{DD} = 5.0 V)

2.5.1 Temperature Transfer Function Characteristics

The following calibration is adjusted with the parameters S_T and $offs_T$:

$$T_{amb} = \frac{out_T - offs_T}{S_T}$$

Table 3 Temperature transfer function characteristics

Temperature			Output Code				Gain and Offset		
Symbol	**Values**	**Unit**	**Symbol**	**Values**	**Unit**		**Symbol**	**Value**	**Unit**
$T_{IN,1_5.0}$ [1]	-40	°C	$LSB_{OUT,1}$	0	LSB		ST	20.48	LSB/°C
$T_{IN,2_5.0}$ [1]	160	°C	$LSB_{OUT,2}$	4095	LSB		offsT_3.3 [2] $offs_{T_5.0}$ [1]	839 819	LSB LSB

1) Valid for V_{DD} = 5.0 V
2) Valid for V_{DD} = 3.3 V

Note: The points $T_{IN,1}/LSB_{OUT,1}$ and $T_{IN,2}/LSB_{OUT,2}$ define the calibrated transfer function and not the operating range. The operating temperature range is defined by the parameter 2.7 "Operating temperature" on Page 22

2.6 Power-Down Mode

The KP253 has a special power saving feature called the Power-down mode. The sensor will enter a sleep mode where the power consumption is drastically reduced.

2.6.1 Entering Power-Down Mode

To enter the Power-down mode, the **Trigger power-down command** has to be sent to the sensor via the SPI interface. The sensor will enter the Power-down mode within some µs.

2.6.2 Exiting Power-Down Mode

To wake-up the sensor from the Power-down mode the NCS pin needs to be low during the rising edge of the CLK pin. To allow repowering of the sensor, the user needs to wait the time $t_{start-up}$ before sending the first SPI command (e.g. **Acquire pressure command**). The response of the sensor during this first command must be ignored.

With the next SPI command the pressure value from the previous acquire command will be returned.

2.7 Serial Interface

The communication and data transmission is based on a standard 16 bit serial peripheral interface (SPI).

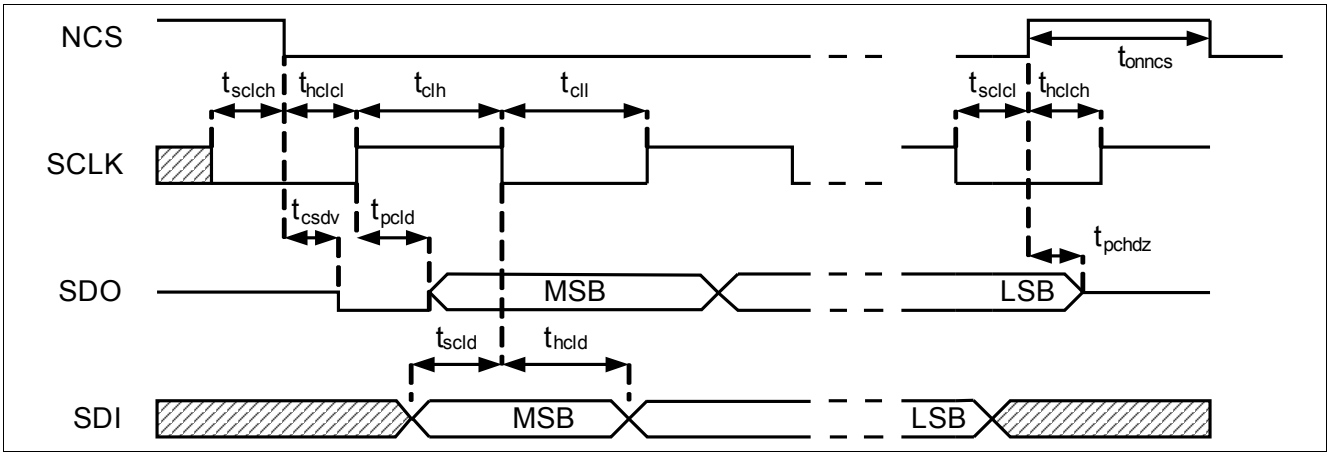


Figure 6 SPI timing

2.7.1 Commands

The following Commands are defined:

- Acquire identifier
- Acquire pressure (incl. E²PROM check and last updated Diag1 & Diag2)[1)]
- Acquire temperature (incl. E²PROM check and last updated Diag1 & Diag2)[1)]
- Trigger power-down mode (activates the power-down state)
- Trigger diagnosis (triggers Diag1 and Diag2)
- Trigger test mode (entry into test mode only occurs if this is the first command received after power up, in conjunction with a high voltage level (>10V) on pin V_{PROG})

1) Last updated diagnosis information is only available if the **Trigger diagnosis command** was sent at any time before and the diagnostic reset is not active (Reset-bit C12 = '1', see **Chapter 2.9.1**).

2.7.1.1 Command Behavior

The SPI command interpretation is based on following rules:

- The response to command N is the result of the previous command (N-1)
- The response to the first command is the identifier
- When a command (N) is sent and the processing of the previous command (N-1) has not finalized, the last command (N) will not interrupt the processing
- Max. one command is stacked (during processing a command a new received command is stacked; further received commands will overwrite the stack)
- If a command has finished, the sensor takes the next command from the stack; if no command is in the stack, the sensor goes into the pressure measurement mode
- The diagnosis command triggers the Diag1 and Diag2 measurement; during this time pressure values (including out of range information) will not be updated
- Pressure and temperature values can be updated continuously based on a parallel acquisition
- If the sensor is in the power-down state then the next command triggers the wake-up process (NCS must be low in combination with a rising SCLK edge)

2.7.1.2 Structure

The following structure is defined for an SPI command:

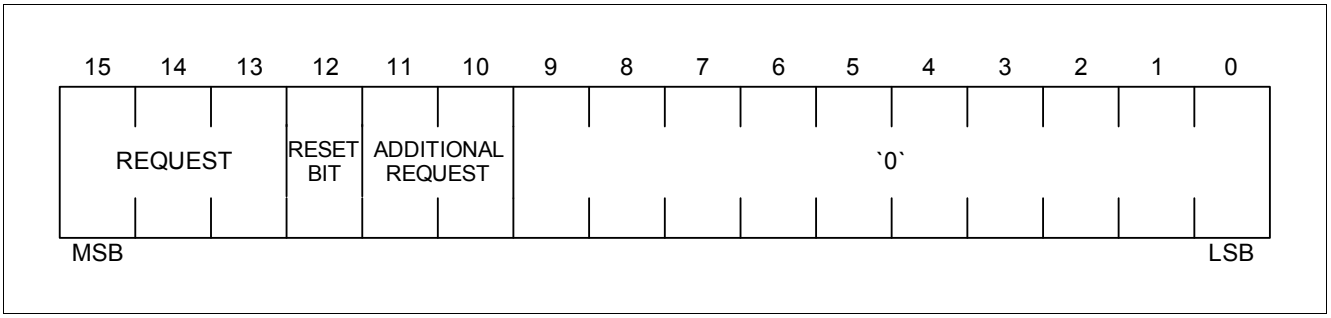


Figure 7 SPI command structure

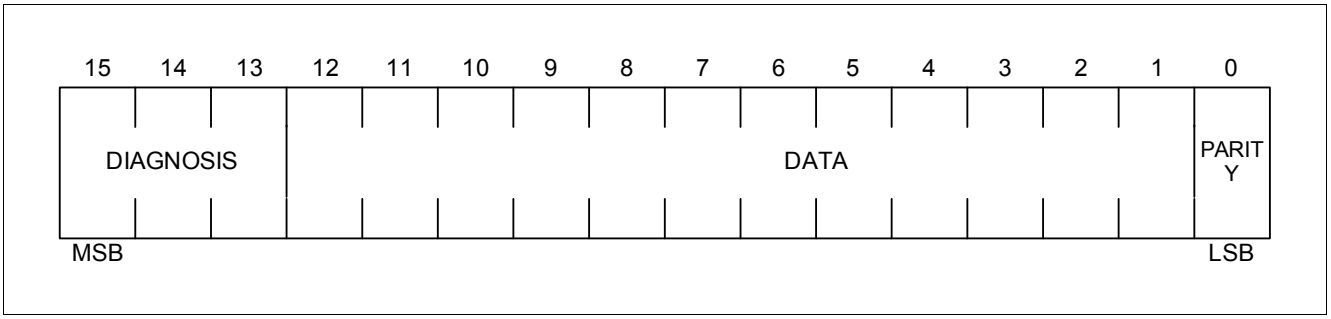


Figure 8 SPI response structure

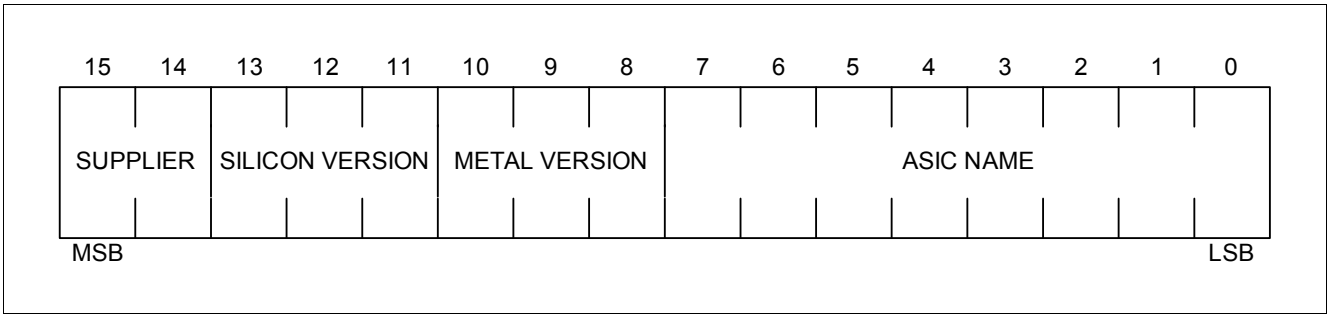


Figure 9 SPI response structure for identifier

2.7.1.3 Parity

Except for the identifier response (see **Section 2.7.1.6**) every SPI response (including the **Communication Error** response, see **Section 2.7.1.5**) includes an odd parity (LSB, [0]). The number of bits with the value one in the 16 bit response is odd (including the parity bit).

2.7.1.4 Command Definition

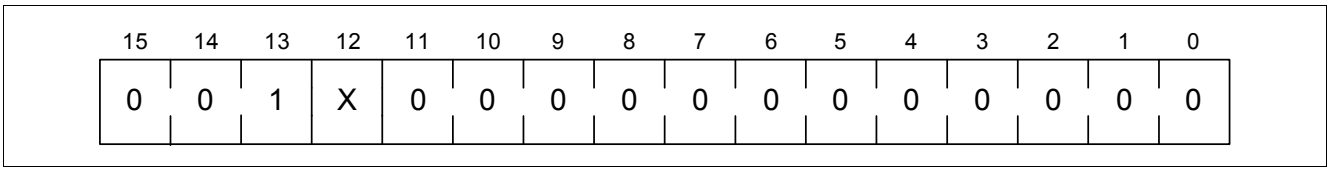


Figure 10 Acquire pressure command

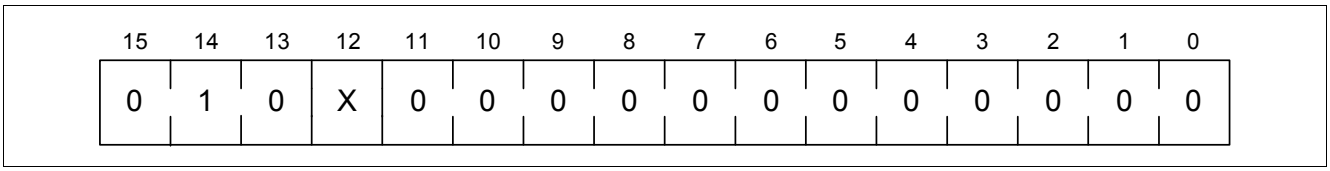


Figure 11 Acquire temperature command

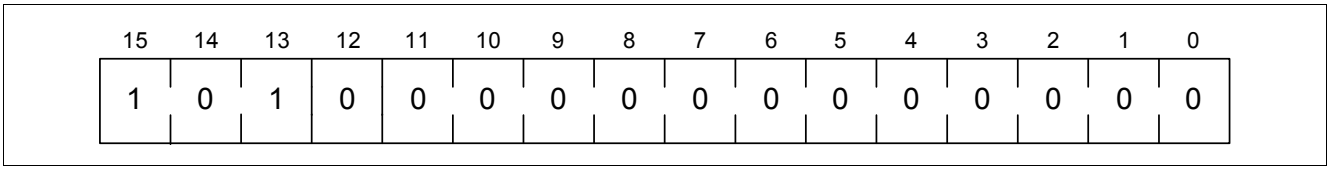


Figure 12 Trigger power-down command

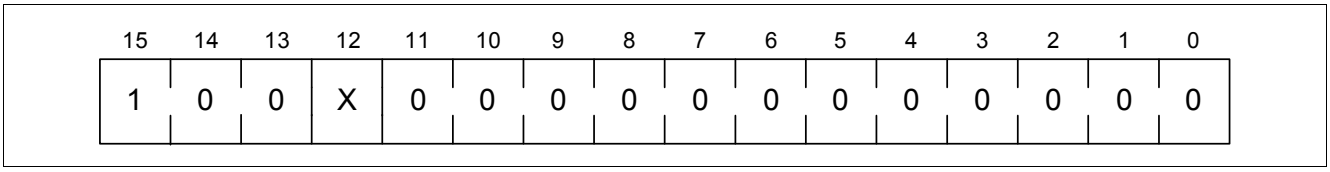


Figure 13 Trigger diagnosis command

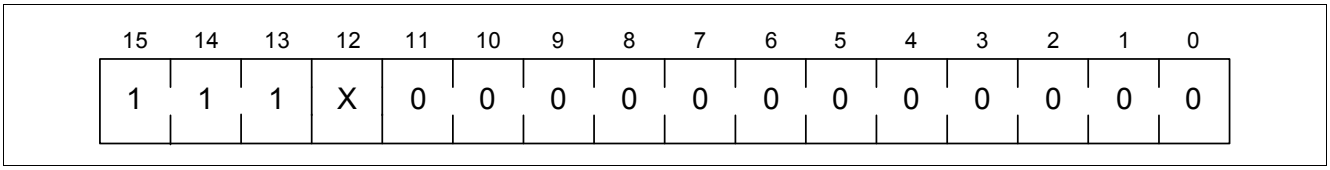


Figure 14 Acquire identifier command

Note: The Reset-bit (C12) determines how the diagnostic reset is handled. For details about the function of the Reset-bit refer to Chapter 2.9.1.

The “trigger test mode” command is only for information. The test mode is only for calibration and E²PROM programming. Both are already done during the supplier’s back-end assembly. The information should serve to avoid command for unintentional test mode operation.

Note: Additional safeguards are provided to prevent unintentional test mode operation. For test mode operation, the command must be the first command after power-up in combination with a high voltage level at pin V_{PROG}.

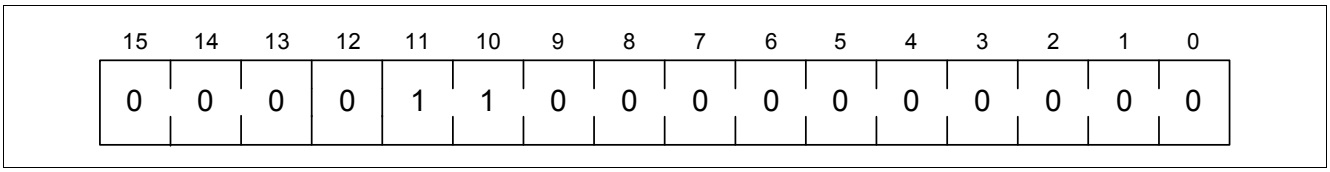


Figure 15 Trigger test mode command

2.7.1.5 Communication Error

In normal operation only the pressure, temperature, diagnosis and identifier commands are valid. Every abnormality of these commands (e.g. unused command, other value of unused bits, number of clocks not equal to 16n with n = 1, 2, 3...) will result in a communication error. The response to a detected communication error is given below.

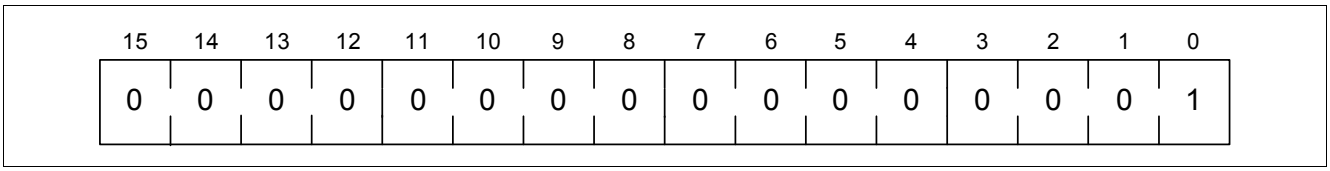


Figure 16 Response after a communication error

2.7.1.6 Identifier Response Definition

The response to an **Acquire identifier command** is a fixed value as stated below. With this response, the KP253 sensor can be indentified when operated in a bus system with several different parts.

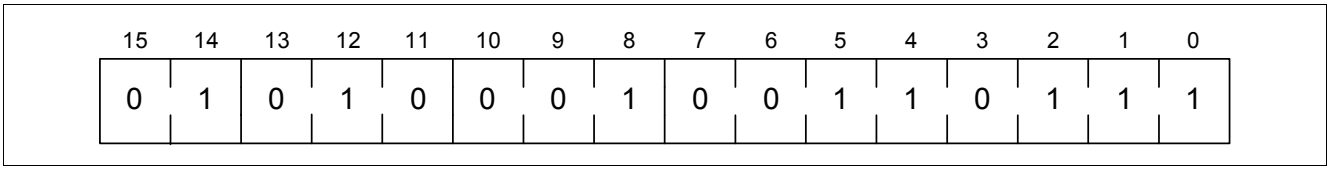


Figure 17 Identifier response definition

2.7.2 Single Device Operation

Figure 18 shows an example on how to connect a singe device to a microcontroller.

After NCS is pulled to low, the request command is sent to the sensor with the next 16 cycles of the CLK. The response of the sensor for the previous request command is returned at the same time. The SPI signal timing is shown in **Figure 19**.

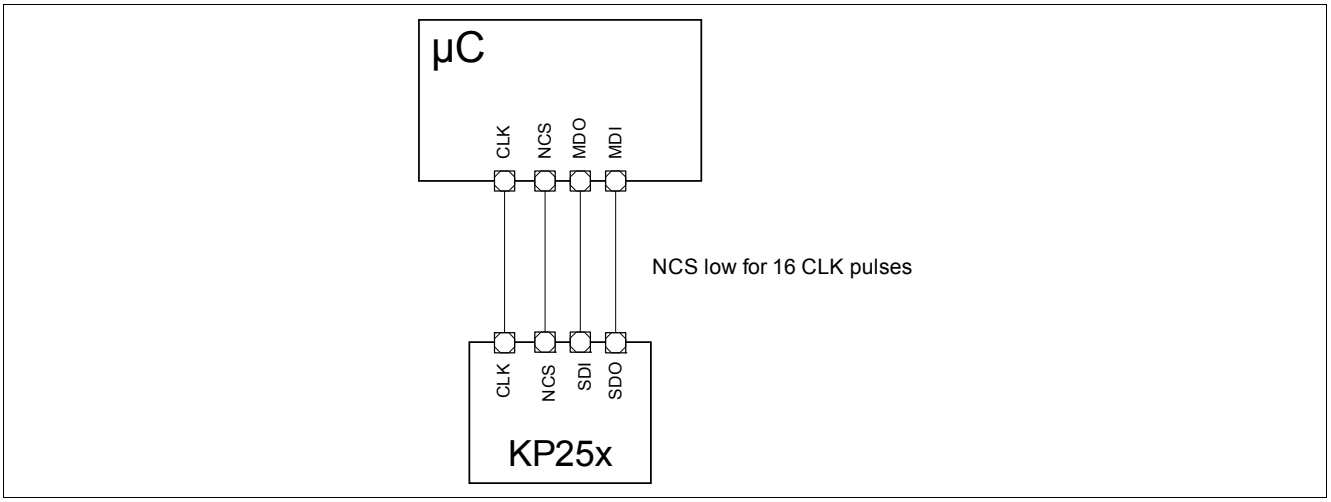


Figure 18 Example for single device operation

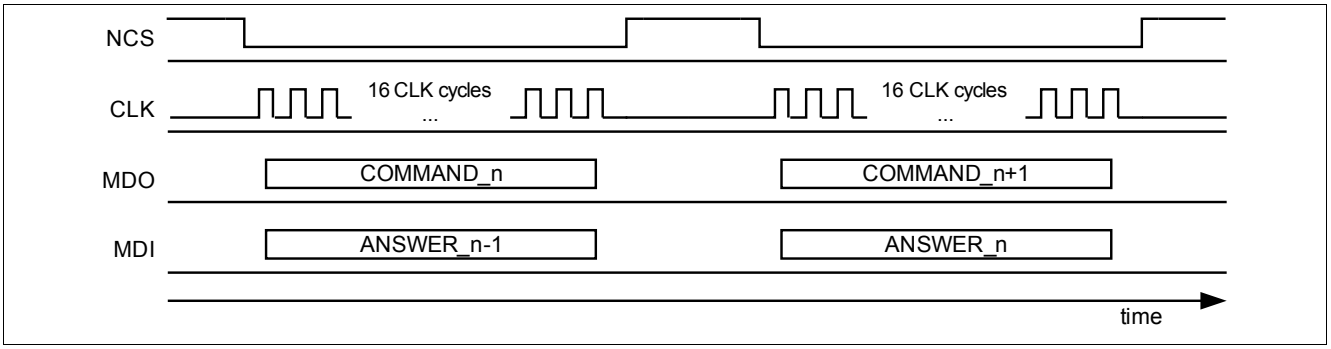


Figure 19 Example for single device signal timing

2.7.3 Daisy Chain Operation

The sensors can be connected to one SPI connection in daisy chain operation to save microcontroller pins. The number of sensors connected in daisy chain operation is unlimited.

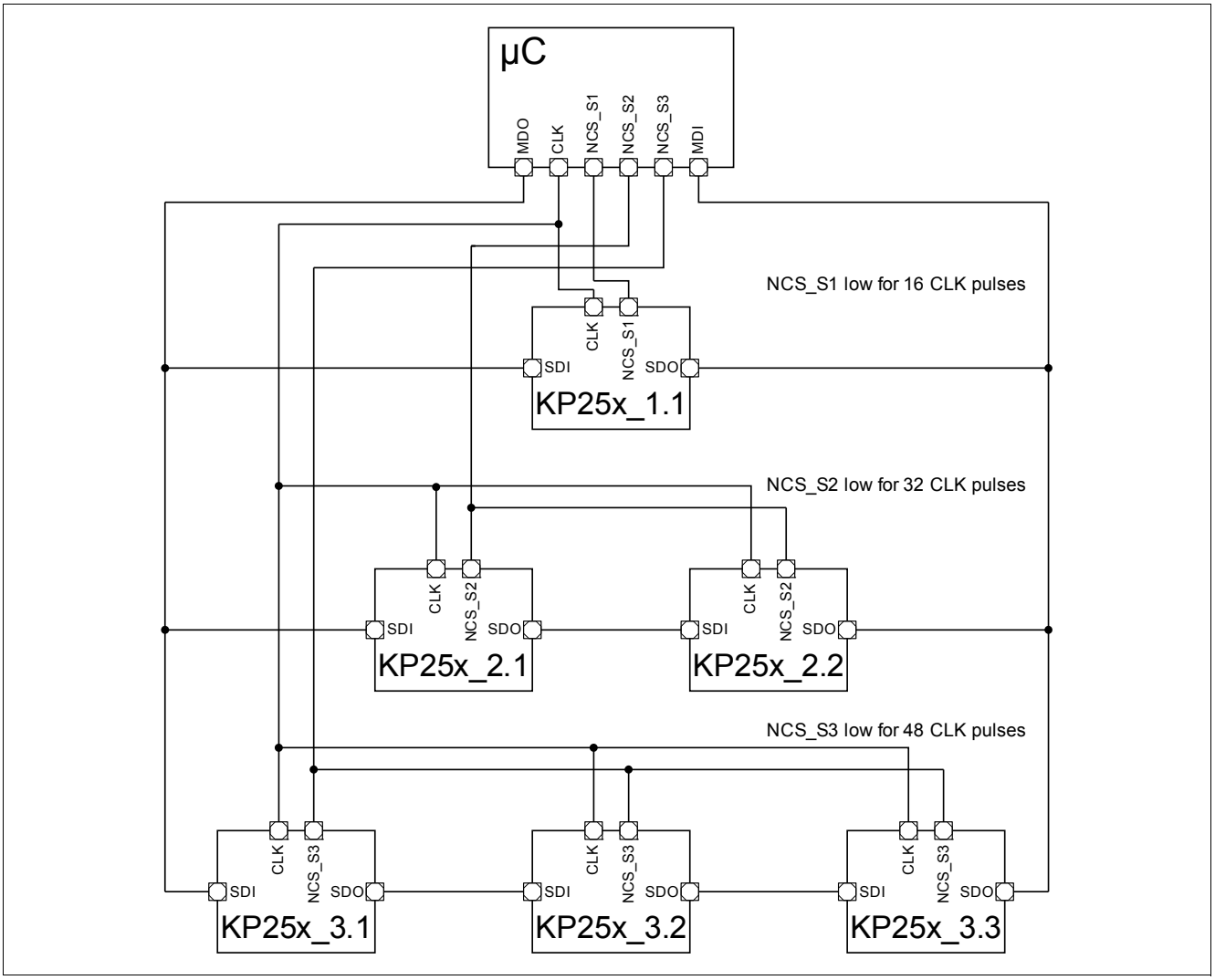


Figure 20 Example for daisy chain operation

Figure 20 shows an example of a combination of daisy chain mode and parallel operation.

Note: Not all five sensors in this example could be addressed at once. Only one branch can be addressed at once (e.g. the KP25x_2.x branch). Finally only one NCS line can be low at the same time (NCS_S1, NCS_S2 or NCS_S3).

The responding NCS line for the addressed sensor group must be low during the complete communication. During this time the provided number of clock pulses must be the multiplication result of 16 times the number of sensors in a daisy chain (e.g. 32 clock pulses for the KP25x_2.x branch in **Figure 20**)
Figure 21 shows the whole signal diagram. It is important that NCS_S2.1 and NCS_S2.2 stay at the low level during the complete transmission. Therewith the sensor is able after receiving more than 16 clock pulses without a change in the NCS signal to switch automatically in daisy chain mode (in this example the first received 16 bit input data by the sensor S2.1 will be clocked to the output of sensor S2.1 with the last 16 clock pulses).

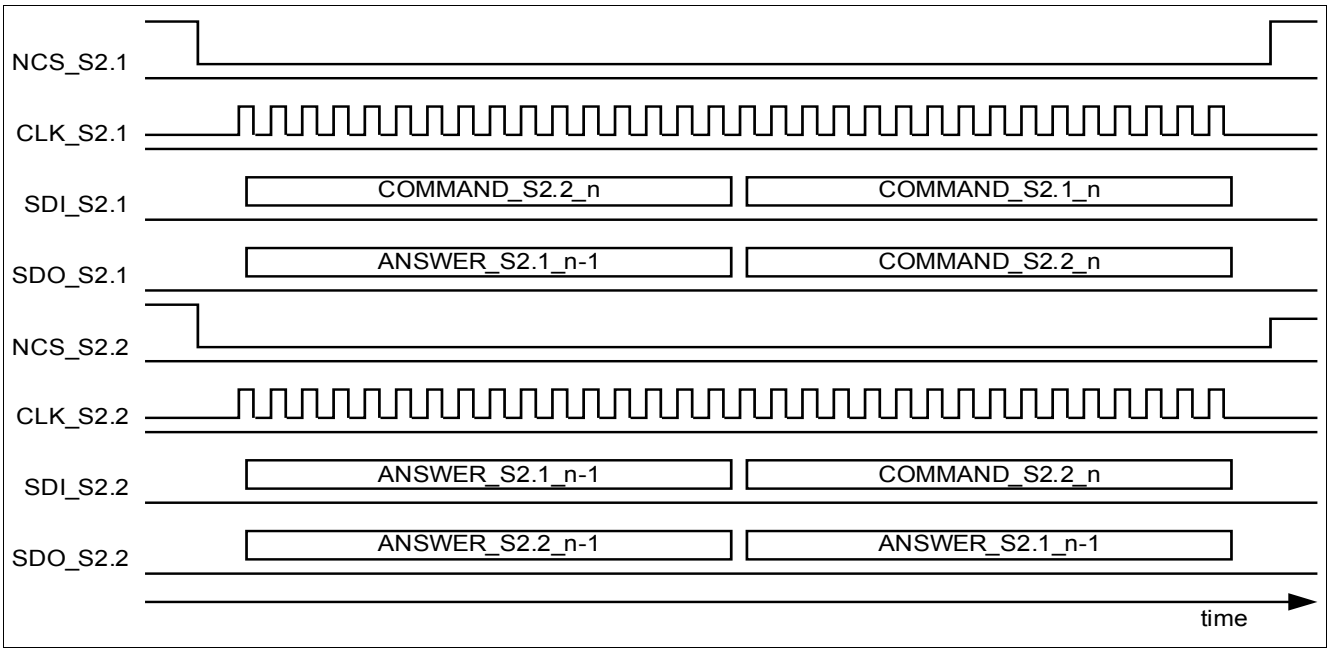


Figure 21 Example for daisy chain signal diagram

It is important that the number of clock pulses is a multiple of 16. Otherwise all commands for a daisy chain branch will be identified as invalid commands and the response of all sensors on this branch will be 01_H.

2.8 Start-up Behavior

During the start-up phase ($t_{start-up}$), there is no response on any commands.

2.9 Diagnosis

The sensor is able to detect automatically the following malfunctions:

- Signal path check (Diag1)
- Sensor cell check (Diag2)
- E^2PROM check

If a malfunction is detected, the responding diagnosis code is sent with the next response.

Note: The Diag1 and Diag2 test can only be triggered by a separate SPI command.

If more than one test fails, only that diagnosis code with the highest priority will be sent.

Table 4 Diagnosis codes

Failure	Priority	Diagnosis Code		
E^2PROM: FEC error	1	1	0	0
Acquisition chain failure: Diag1[1)]	2	0	1	0
Sensor cell failure: Diag2[1)]	3	0	0	1
No error		0	1	1

1) Note: This diagnosis code is not valid until a self diagnosis is triggered by sending the **Trigger diagnosis command**.

2.9.1 Diagnostic Reset

The Reset-bit (C12) of a SPI command allows using different reset strategies:

- C12 = ‘0‘: All detected failures will be reset (with the exeption of FEC error
- C12 = ‘1‘: A detected failure will not be reset

Reset of FEC error is not possible. Once FEC error is detected and transmitted it remains until supply reset.

2.9.1.1 Reset-bit C12 = ‘0‘

A detected failure is only transmitted by the responding diagnosis code as long as the failure is present. The diagnosis code will be reset after once transmitted. Only if the failure is detected again, the diagnosis code will be transmitted again with the next response.

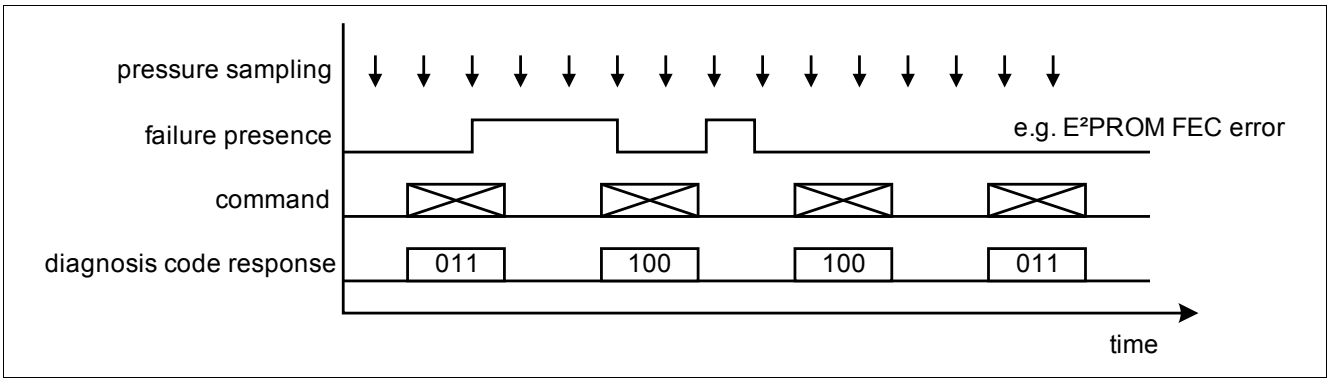


Figure 22 Example for reset strategy Reset-bit C12 = ‘0‘

2.9.1.2 Reset-bit C12 = ‘1‘

Once a failure is detected the responding diagnosis code will be transmitted as long as:

- A failure with a higher priority is not detected
- The sensor is not reset (power down)
- Independent of the presence of the failure

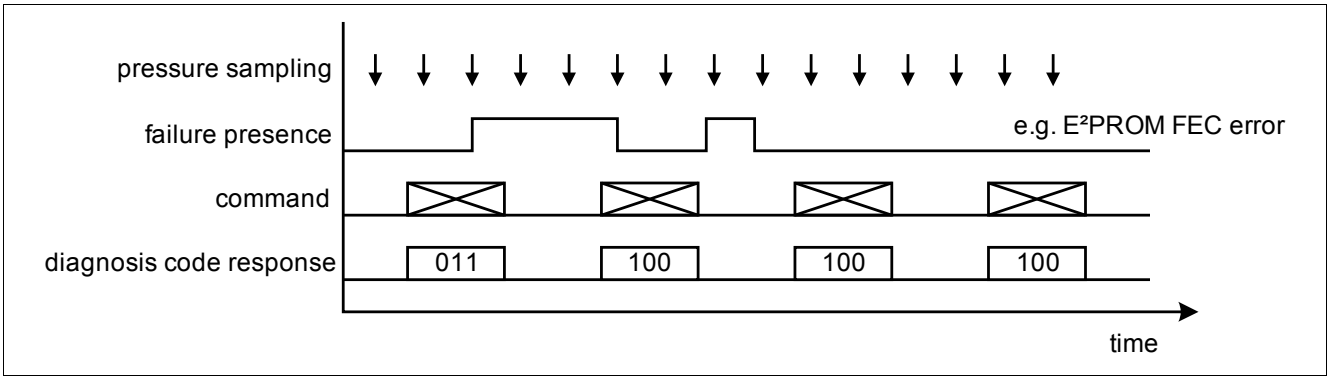


Figure 23 Example for reset strategy Reset-bit C12 = ‘1‘

2.9.2 Pressure out of Range

If the pressure value falls below the lower limit or exceeds the higher limit the pressure value will be clipped. The limits are defined in **Table 10 “Transfer function” on Page 25**.

2.9.3 Diag1

The Diag1 test checks the functionality of the signal path. Therefore the inputs of the sigma delta ADC are shorted. Afterwards, the system response is compared with the expected range (~ 50% of full scale range). If the system response is out of range, the diagnosis code is set.

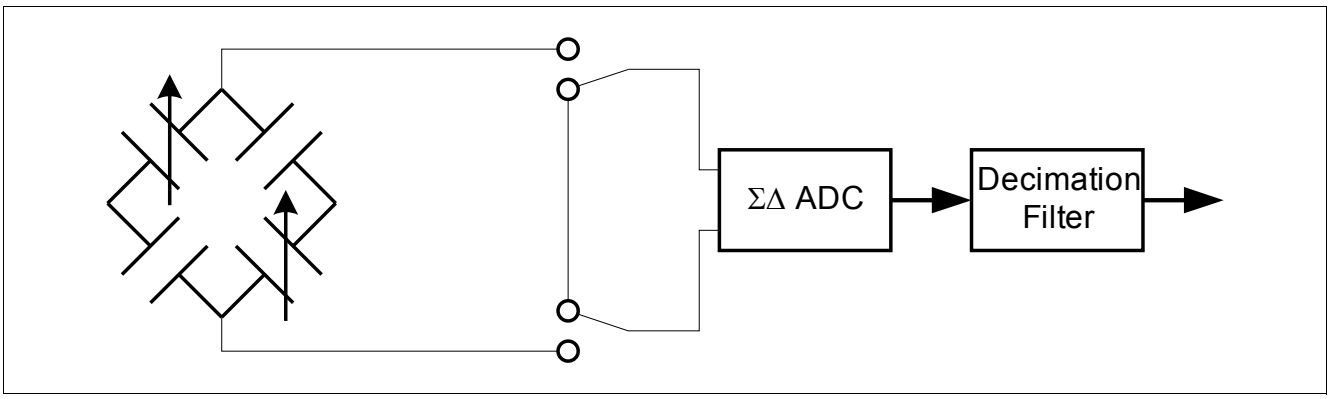


Figure 24 Diag1 functionality

2.9.4 Diag2

The Diag2 test checks the functionality of the pressure sensor cells. Therefore a malfunction (e.g. broken membrane) can be detected. The KP253 pressure sensing element is made of 2 measuring cells and 2 reference cells. In the normal mode these four cells are connected in a Wheatstone bridge configuration. In the Diag2 mode, the connection of the cells is modified as shown in **Figure 25**.

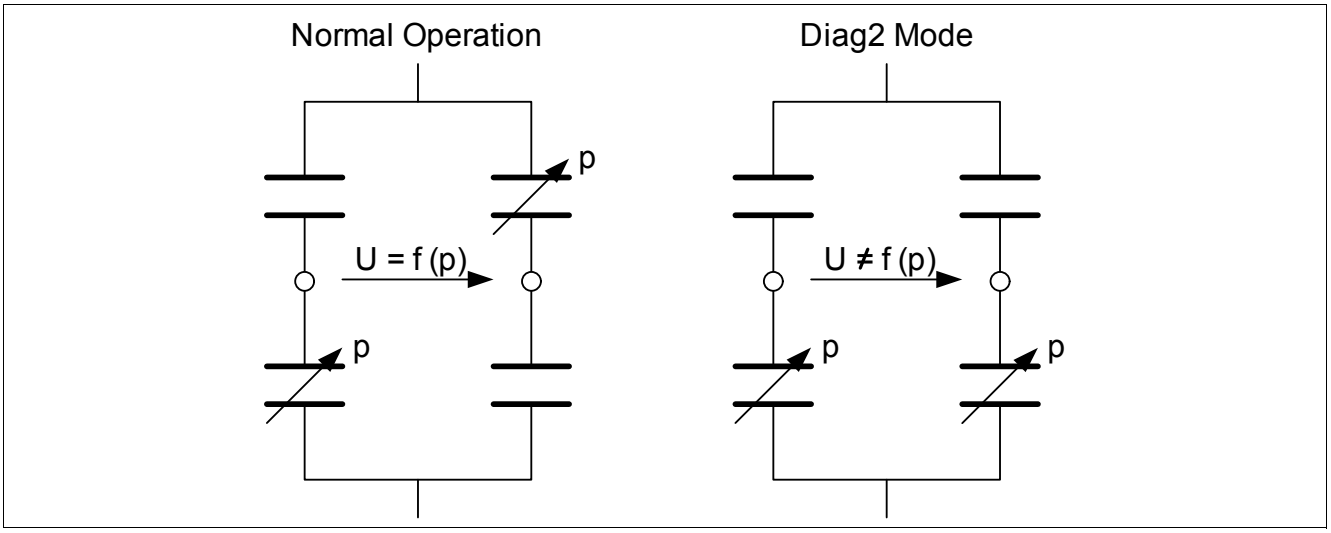


Figure 25 Diag2 functionality

2.9.5 E²PROM Check

During the initialization phase, and after receiving a SPI command, the content of the E²PROM cells is copied into the corresponding E²PROM registers. Thereby, a parity check is done based on the parity row and column. A one bit error is corrected by the forward error correction. Any additional bit error results in an FECerror. In that case the diagnosis code 1 will be transmitted with the next response

3 Specification

3.1 Application Circuit Example

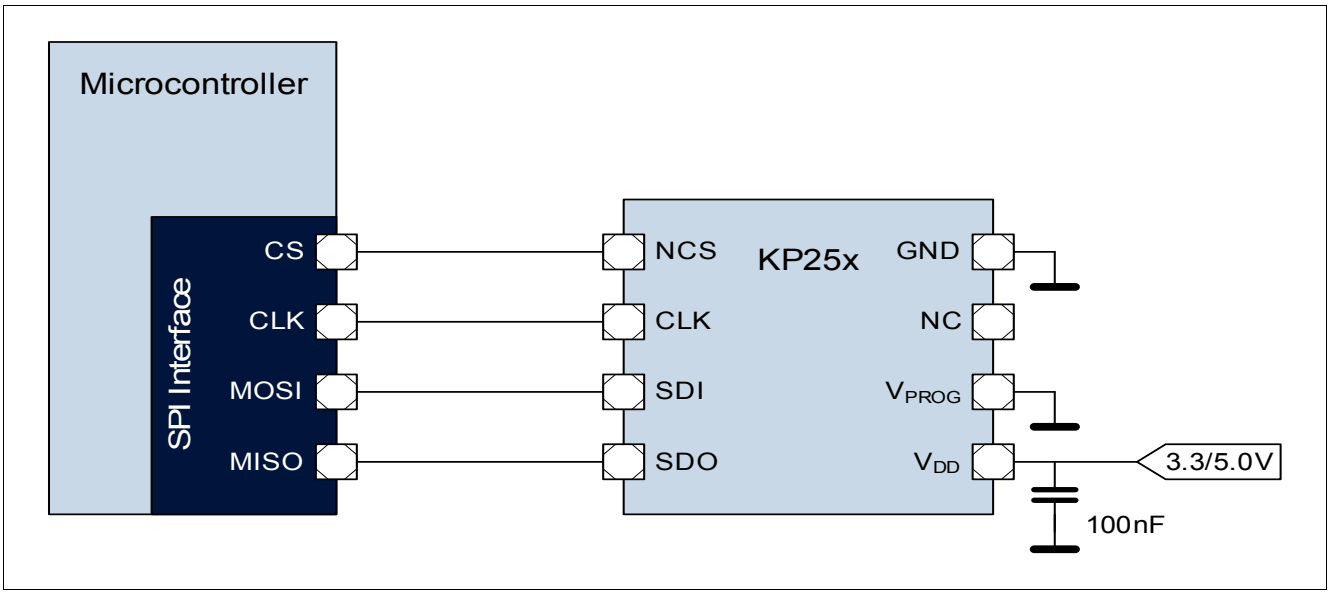


Figure 26 Application circuit example

Table 5 Component values

Component	Symbol	Values			Unit
		Min.	Typ.	Max.	
Supply Blocking Capacitor[1)]	C_1	30[2)]	100	–	nF

1) The use of a blocking capacitor with a nominal value of 100nF is mandatory; any drift or tolerances in capacity of standard capacitors are already considered. To avoid any measurement inaccuracy the supply blocking capacitor has to be placed as close as possible to the VDD pin, at least the distance must be less than 10 mm.

2) The minimum capacity including any variations or drift over lifetime must not undershoot this value.

3.2 Absolute Maximum Ratings

Table 6 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Voltage on any pin	V_{max}	-0.3	–	5.5 6.0	V V	– Limited time: Max. 300 s	1.1
Voltage at output pins	V_{max_out}	-0.3	–	VDD + 0.3	V	–	1.2
Storage temperature	T_S	-40	–	125	°C	–	1.3
Thermal resistance	$R_{thj\text{-}pin}$	–	–	180	K/W	Thermal resistance between the die and the pins	1.4
Maximum input pressure	p_{amb_max}	10	–	200 600	kPa kPa	 Limited time: Max. 300 s	1.5

Attention: Stresses above the max. values listed in Table 6 "Absolute maximum ratings" may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the integrated circuit.

3.3 Operating Range

The following operating conditions must not be exceeded in order to ensure correct operation of the device. All parameters specified in the following sections refer to these operating conditions, unless noted otherwise.

Table 7 Operating range

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Supply voltage	$V_{DD3.3}$ $V_{DD5.0}$	3.135 4.75	– –	3.475 5.25	V V		2.1
Supply voltage power up/power down gradient	V_{grad}	1E-5	–	1E4	V/ms		2.2
Input voltage for low level at pins NCS, CLK & SDI	V_{low_in}	-0.3	–	0.8	V		2.3
Input voltage for high level at pins NCS, CLK & SDI	V_{high_in}	2.0	–	5.5	V	Even with the supply voltage of $V_{DD3.3_min}$ the max. input voltage V_{high_in} is allowed; back biasing will not happen	2.4
Output voltage for low level at pin SDO	V_{low_out}	–	–	0.4	V	Test current at pin SDO is 2.0mA	2.5
Output voltage for high level at pin SDO	V_{high_out}	VDDx.x - 0.4	–	VDDx.x	V	Test current at pin SDO is 1.5mA	2.6
Operating temperature	T_a	-40	–	+125	°C		2.7
Ambient operating pressure range	p_{amb}	60	–	165	kPa		2.8
Lifetime[1)]	t_{live}	15	–	–	years		2.9

1) The life time shall be considered as anticipation with regard to the product that shall not extend the agreed warranty period.

3.4 Characteristics

Product characteristics involve the spread of values guaranteed within the specified voltage and ambient temperature range. Typical characteristics are the median of the production.

Table 8 Electrical characteristics

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Supply current into VDD	I_{VDD}	–	–	10.0	mA		3.1a
Supply current into VDD during Power-down mode	I_{VDD_PD}	–	–	12.0	µA		3.1b
Internal pressure update rate	f_{update}	150	–	–	kHz		3.2
Pressure signal path settling time	t_{path_pres}	–	–	5	ms		3.3a
Temperature signal path settling time	t_{path_pres}	–	–	15	ms		3.3b
Start-up time	$t_{start\text{-}up}$	–	–	5	ms	no response on SPI commands during the start-up time	3.4
Resolution of pressure transmission	n_{res_pres}	n.a.	12	n.a.	bits		3.5
Resolution of temperature transmission	n_{res_temp}	n.a.	12	n.a.	bits		3.6
Capacitive load at pins NCS, CLK & SDI	C_{load_in}	–	–	14	pF		3.7
Capacitive load at pin SDO	C_{load_out}	–	–	19	pF		3.8
Tri state leakage current	I_{SDO}	-5	–	5	µA	NCS = high V_{DD} = 5V	3.9
Hysteresis of input voltage at pins NCS, CLK & SDI	V_{SPI_Hys}	200	–	–	mV		3.10
Current sink for NCS, CLK & SDI (each pin)	I_{SPI_in}	-100 –	– –	-5 5	µA µA	@ V_{low_in} = 0 V @ V_{high_in} = 5 V no back biasing	3.11

Table 9 SPI timing

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Clock frequency of SPI interface	f_{SPI}	0.1	–	5	MHz	No limitation with lower frequencies, but not subject to production test	4.1
Transmission speed at SDO (20% - 80%)	t_{SDO_trans}	5 5	– –	30 50	ns ns	V_{SDO} = 5V & C_{load} = 50pF V_{SDO} = 5V & C_{load} = 150pF	4.2
Clock high time	t_{clh}	75	–	–	ns		4.3
Clock low time	t_{cll}	75	–	–	ns		4.4
NCS filter time[1)]	t_{fNCS}	10	–	60	ns	Pulses below the NCS filter time will be ignored	4.5
Delay between NCS falling edge and SDO changing from tri-state to low	t_{csdv}	–	–	75	ns		4.6
Delay between CLK rising edge and start SDO data	t_{pcld}	–	–	50	ns	incl. t_{SDO_trans}	4.7
Delay between CLK low and start NCS low	t_{sclch}	75	–	–	ns		4.8
Delay between NCS low and rising edge 1st CLK pulse	t_{hclcl}	75	–	–	ns		4.9
Time between start SDI data and falling edge CLK	t_{scld}	15	–	–	ns		4.10
Time between falling edge CLK and end SDI data	t_{hcld}	15	–	–	ns		4.11
Delay between falling edge lst CLK pulse and rising edge NCS	t_{sclcl}	100	–	–	ns		4.12
Delay between rising edge NCS and rising edge CLK pulse	t_{hclch}	100	–	–	ns		4.13

Table 9 SPI timing (cont'd)

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Delay between rising edge NCS and end SDO data	t_{pchdz}	–	–	75	ns		4.14
Time between rising edge NCS and falling edge next NCS	t_{onncs}	300	–	–	ns		4.15

1) not subject to production test - verified by characterization/design

Table 10 Transfer function

Parameter	Symbol	Values			Unit	Note or Test Condition	Number
		Min.	Typ.	Max.			
Sensitivity pressure	Sp	–	39	–	LSB /kPa		5.1
Offset pressure	offsp	–	-2340	–	LSB		5.2
Sensitivity temperature	ST	–	20.48	–	LSB /°C		5.3
Offset temperature	offsT_3.3 $offs_{T_5.0}$	– –	839 819	– –	LSB LSB	VDD = 3.3 V V_{DD} = 5.0 V	5.4
Accuracy pressure central temperature range	acc_{p_Tmid} 	-1.0 -1.5	– –	1.0 1.5	kPa kPa	0°C - 85°C P_{amb}: 70 ... 130 kPa P_{amb}: 60 ... 70 kPa or 130 ... 165 kPa	5.5a
Accuracy pressure low temperature range	acc_{p_Tlow} 	-1.5 -2.0	– –	1.5 2.0	kPa kPa	@-20°C P_{amb}: 70 ... 130 kPa P_{amb}: 60 ... 70 kPa or 130 ... 165 kPa	5.5b
Accuracy pressure high temperature range	acc_{p_Thigh} 	-2.0 -2.5	– –	2.0 2.5	kPa kPa	@125°C P_{amb}: 70 ... 130 kPa P_{amb}: 60 ... 70 kPa or 130 ... 165 kPa	5.5c
Accuracy temperature	acc_T	-5.0	–	5.0	°C	-40°C - 125°C accuracy is referenced to the ambient temperature	5.6
Pressure out of range: Low	p_{low} p_{low_d}	– –	60 0_d	– –	kPa LSB	Accuracy not considered	5.7
Pressure out of range: High	p_{high} p_{high_d}	– –	165 4095_d	– –	kPa LSB	Accuracy not considered	5.8

4 Package Information

For passivation the sensor is covered with a transparent gel.

4.1 PG-DSOF-8-16 Outline

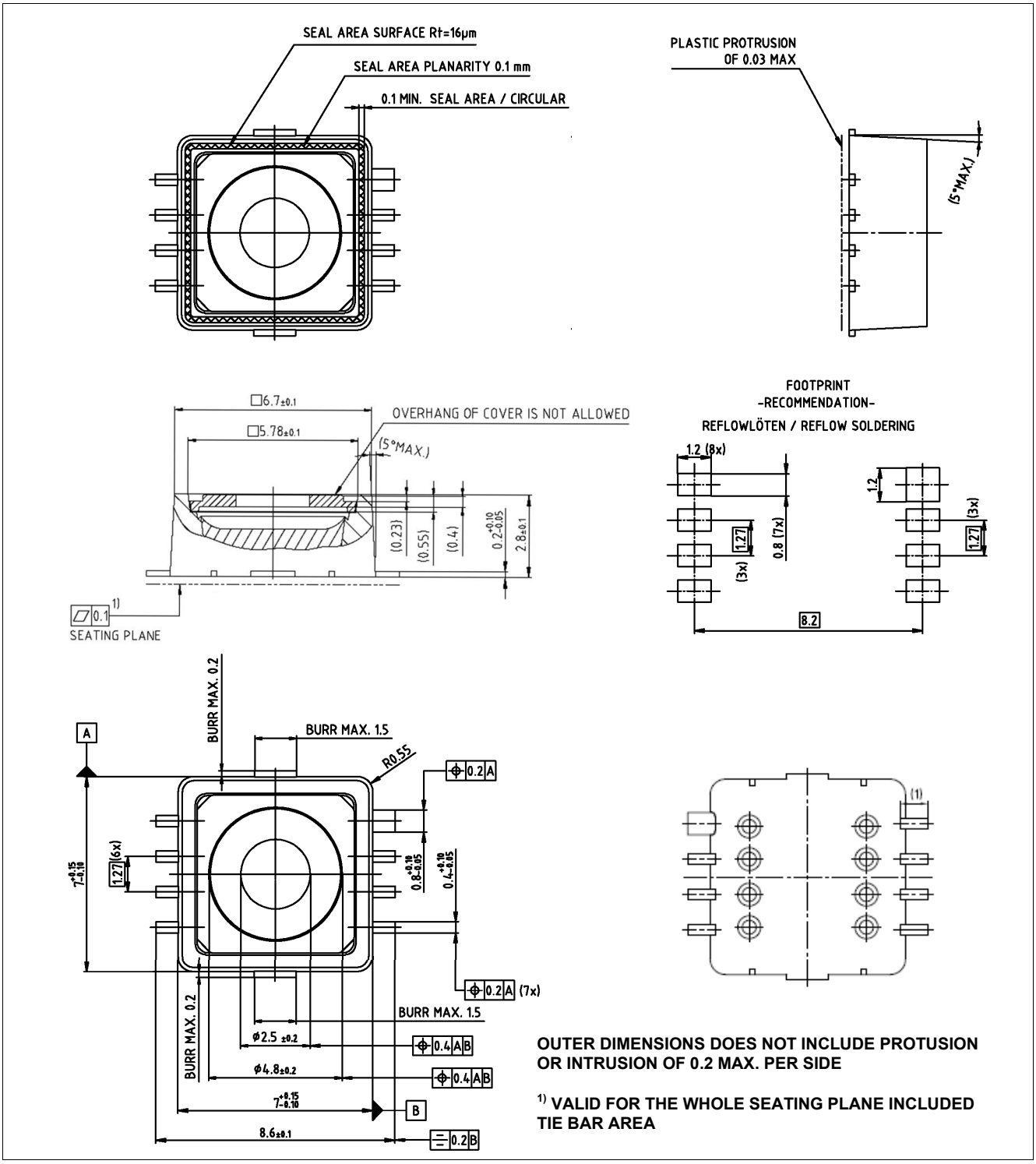


Figure 27 Package outline

Green Product (RoHS compliant)

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

4.2 Identification Code

The identification code is provided in a machine readable format. The date and sales code are provided in human readable format.

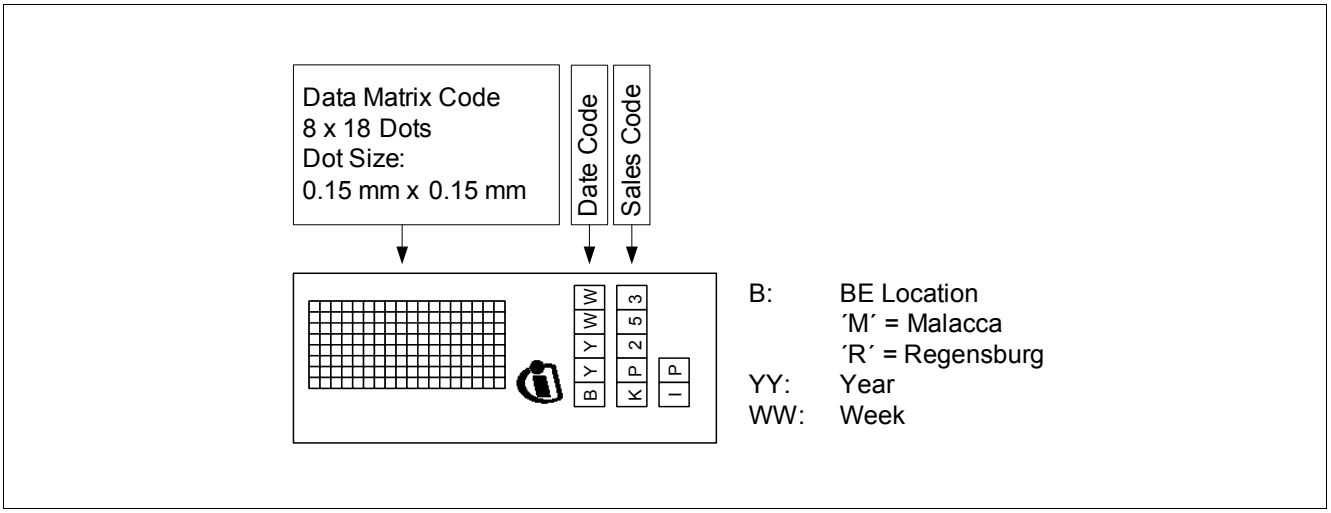


Figure 28 Identification code

The identification code for the KP253 is on the same side of the package as pin 8 (GND).

For further information on alternative packages, please visit our website:
http://www.infineon.com/packages.

Dimensions in mm

5 Revision History

KP253 Digital Absolute Pressure Sensor

Revision History: 2015-07-29, Revision 1.1

Previous Revision: Revision 1.0

Page	Subjects (major changes since last revision)
	Design improvement, new ordering code and marking

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