

KP276C1505

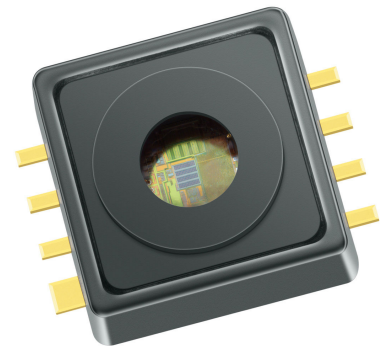
Digital Absolute Pressure Sensor

dTurboTMAP with SENT Output and Temperature Sensor Interface



Features

- Increased media robustness for current automotive requirements
- High accuracy pressure sensing ($\pm 1.03\%$ FSS)
- Integrated signal processing for external temperature sensor
- SENT protocol interface
- Real 12-bit pressure resolution
- Real 12-bit temperature resolution
- Self diagnosis features
- “Green” 8 pin SMD housing
- Automotive qualified



Potential applications

- Automotive applications, Industrial control
- Consumer applications, Medical applications

Product validation

Qualified for automotive applications.
Product validation according to AEC-Q100.

Description

The KP276C1505 is a miniaturized Digital Absolute 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 SENT protocol (SAE J2716 revised April 2016). In addition, an interface for an external negative temperature coefficient (NTC) temperature sensor is provided. The temperature information given by the NTC is also digitized into a 12-bit value and transmitted with the SENT protocol.

A special safety feature is the integrated diagnostic mode, which allows testing of the sensor cells as well as the signal path. This diagnosis is triggered by powering the device.

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

| Type | Package | Ordering Code | Marking |
|------------|---------------|---------------|------------|
| KP276C1505 | PG-DSOF-8-162 | SP002167802 | KP276C1505 |

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Functional description

1 Functional description

1.1 Pin configuration

Figure 1 shows the pin configuration.

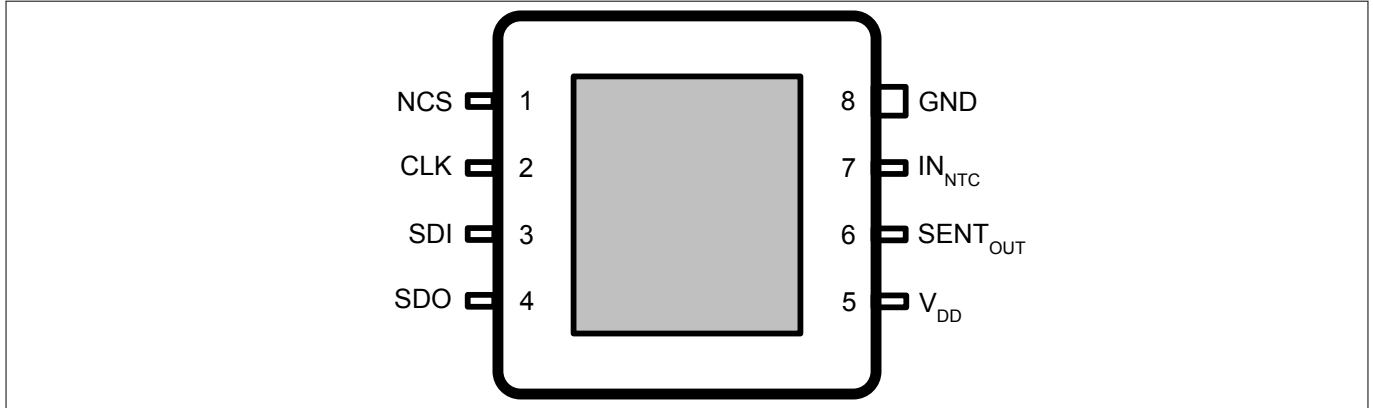


Figure 1 Pin configuration (top view, figure not to scale)

1.2 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 ¹⁾ |
| 2 | CLK | Serial Clock | External clock for serial communication ¹⁾ |
| 3 | SDI | Serial Data In | Serial data input (e.g. from a controller) ¹⁾ |
| 4 | SDO | Serial Data Out | Tri-state serial data output ¹⁾ |
| 5 | V _{DD} | Supply voltage | – |
| 6 | SENT _{OUT} | SENT output | Digital Output of the SENT Interface |
| 7 | NTC _{IN} | NTC Input | Input pin for an external NTC |
| 8 | GND | Ground | – |

¹⁾ SPI pins (Pin No. 1 - Pin No. 4) are used only during calibration and test. It is recommended to leave these pins floating in the application.

Functional description

1.3 Block Diagram

Figure 2 shows the functional block diagram.

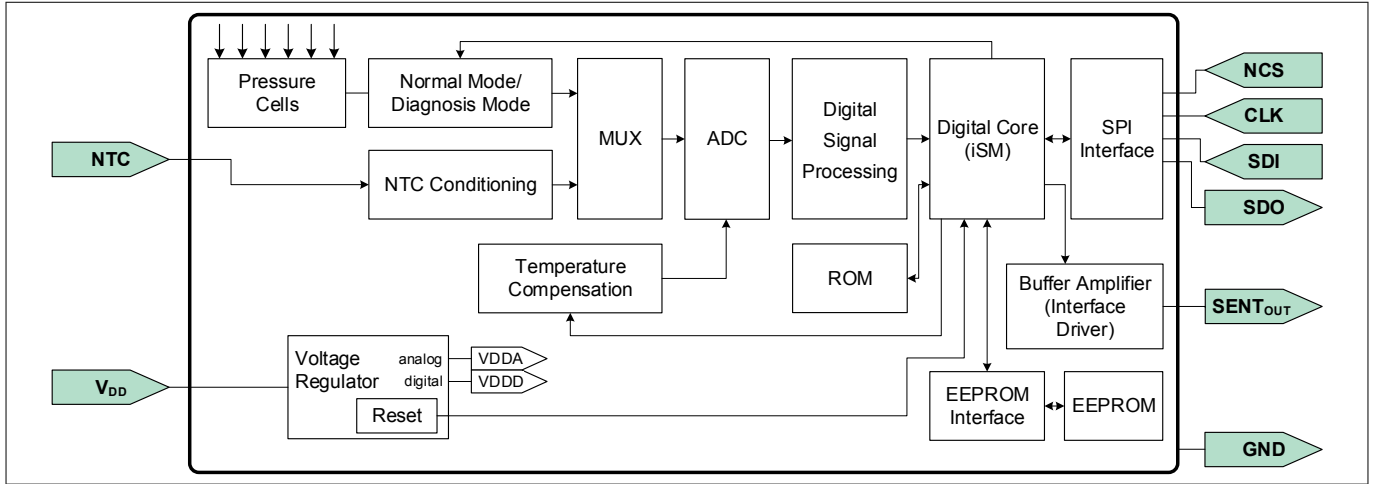


Figure 2 Functional block diagram

1.4 Transfer function pressure

The KP276C1505 device is fully calibrated on delivery. The sensor has a linear transfer function between the applied pressure and the digital output signal.

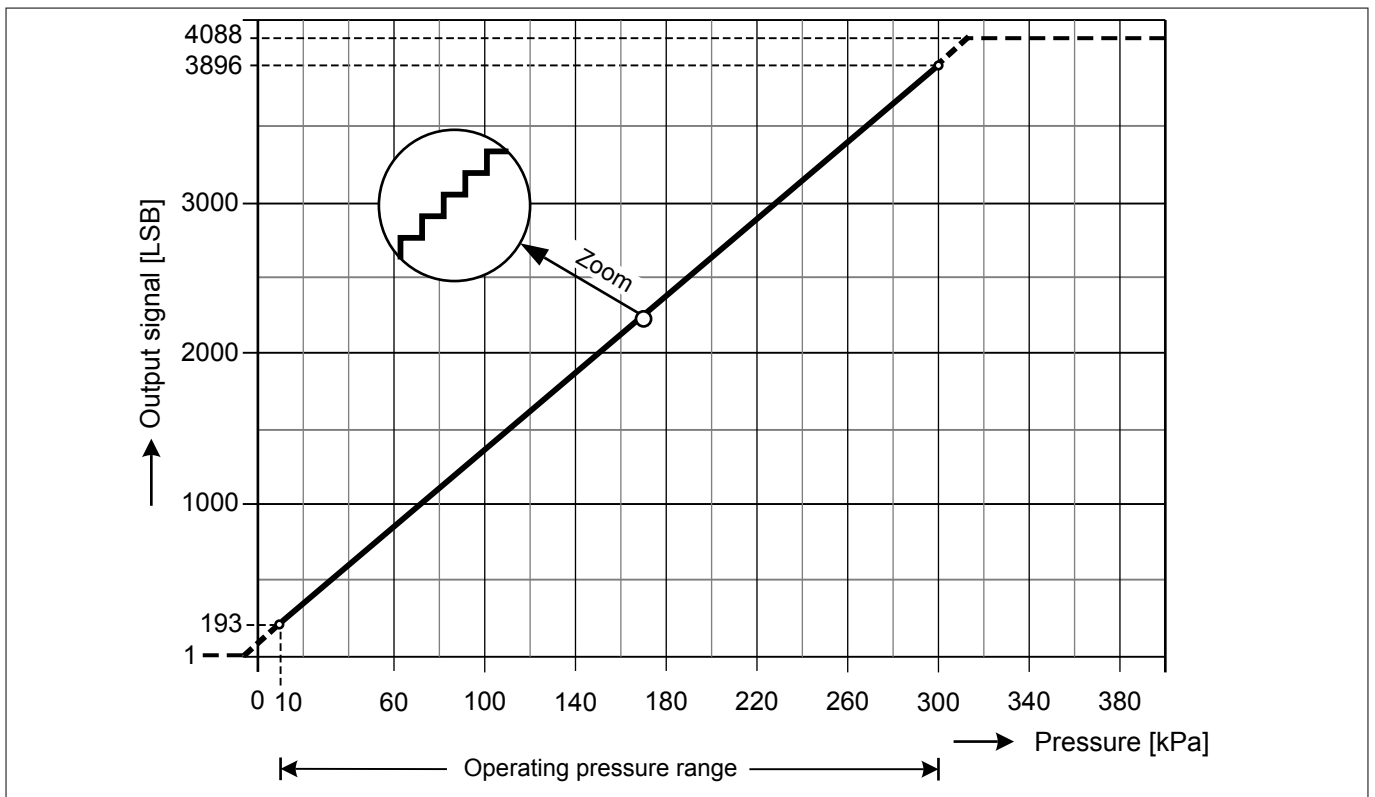


Figure 3 Pressure transfer function

Clamping

The output signal for pressure is limited internally to clamping level low (output code 1) and clamping level high (output code 4088).

Functional description

1.4.1 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

| Output Code | | | Pressure | | | Gain and Offset | | |
|-------------|--------|------|---------------|--------|------|-----------------|-------|---------|
| Symbol | Values | Unit | Symbol | Values | Unit | Symbol | Value | Unit |
| $p_{IN,1}$ | 10 | kPa | $LSB_{OUT,1}$ | 193 | LSB | S_p | 12.77 | LSB/kPa |
| $p_{IN,2}$ | 300 | kPa | $LSB_{OUT,2}$ | 3896 | LSB | $offs_p$ | 65.31 | LSB |

1.4.2 Pressure accuracy

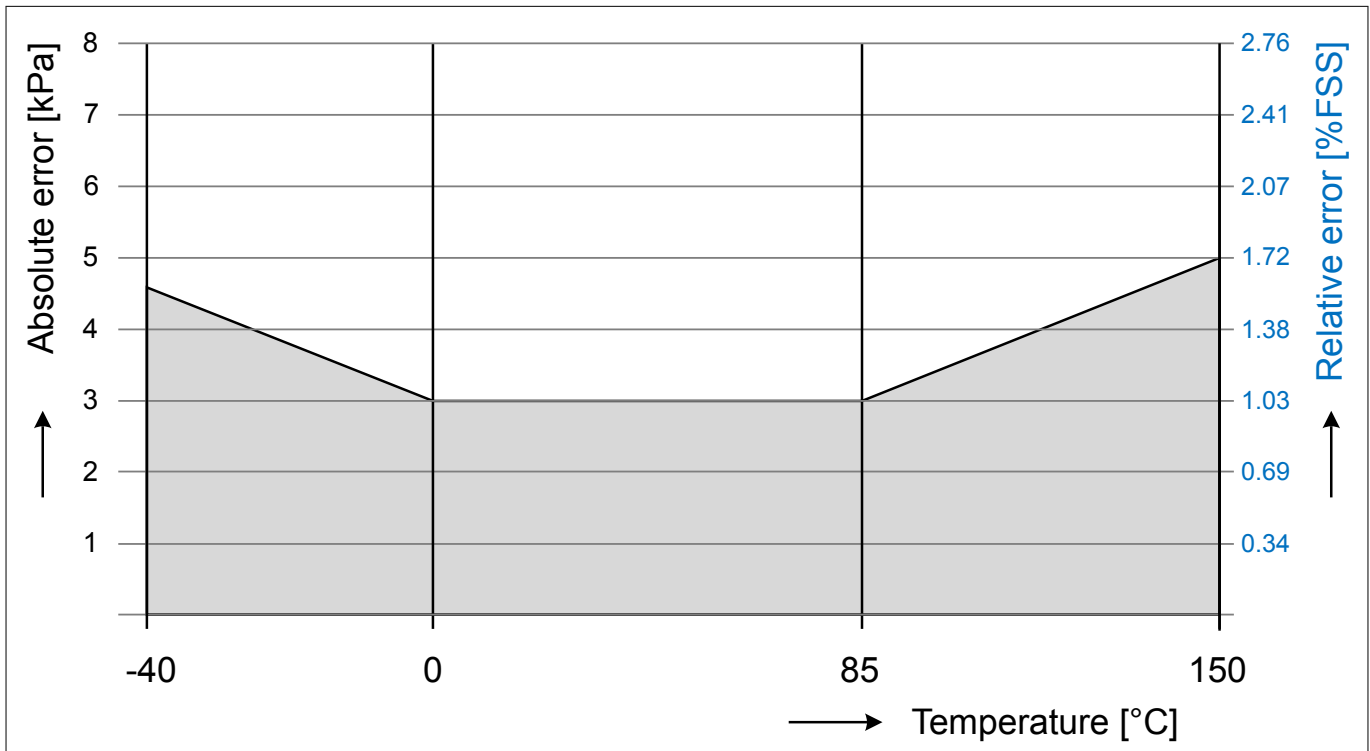


Figure 4 Accuracy for pressure acquisition

Functional description

1.5 Transfer function temperature

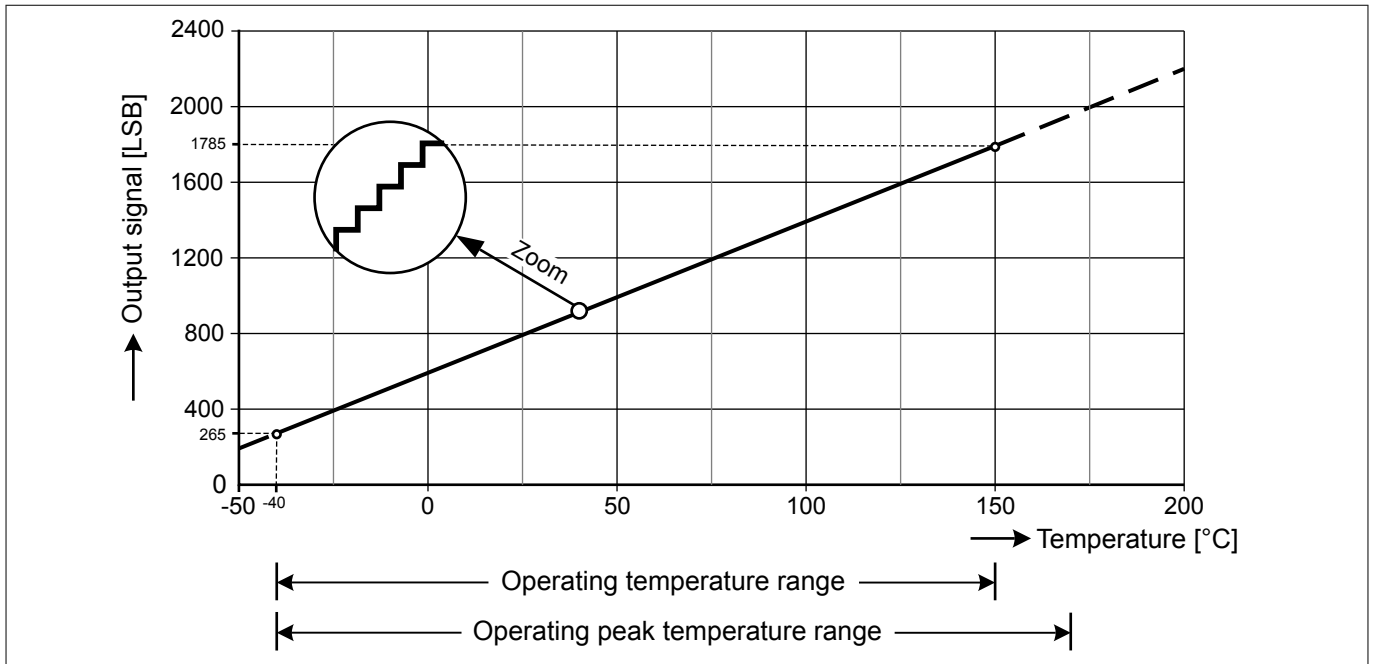


Figure 5 Temperature transfer function

1.5.1 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 |
| $T_{IN,1}$ | -40 | °C | $LSB_{OUT,1}$ | 265 | LSB | S_T | 8.0 | LSB/°C |
| $T_{IN,2}$ | 170 | °C | $LSB_{OUT,2}$ | 1945 | LSB | $offs_T$ | 585.2 | LSB |

Functional description

1.6 SENT interface

The SENT interface enables communication according to the SENT (Single Edge Nibble Transmission) specification. The SENT protocol specifies the transmission of information in a series of pulses with data encoded as falling edge to falling edge periods. Each following pulse is called a nibble. The SENT interface transmits messages organized in frames. Each frame consists of several pulses which are delimited by falling edges. Each falling edge marks the start of a new nibble.

- **KP276C1505 SENT configuration shorthand definition:** SENT2016-03.0us-6dn-ppc(282.0)-esp-A.5

1.6.1 Physical layer

The physical layer provides the method of transferring digital data encoded as time between two falling edges of a signal through the communication medium. It consists of power, ground and the signal wire (see [Figure 16](#)).

The basic unit of time for the SENT interface is called a clock tick. The transmission bit rate depends on the data value sent and the sensor clock tolerance. The shortest length of a nibble pulse consists of 12 ticks (nominally 36 μs), the maximum length is 27 ticks (nominally 81 μs).

[Figure 6](#) shows the physical layer specification of a nibble.

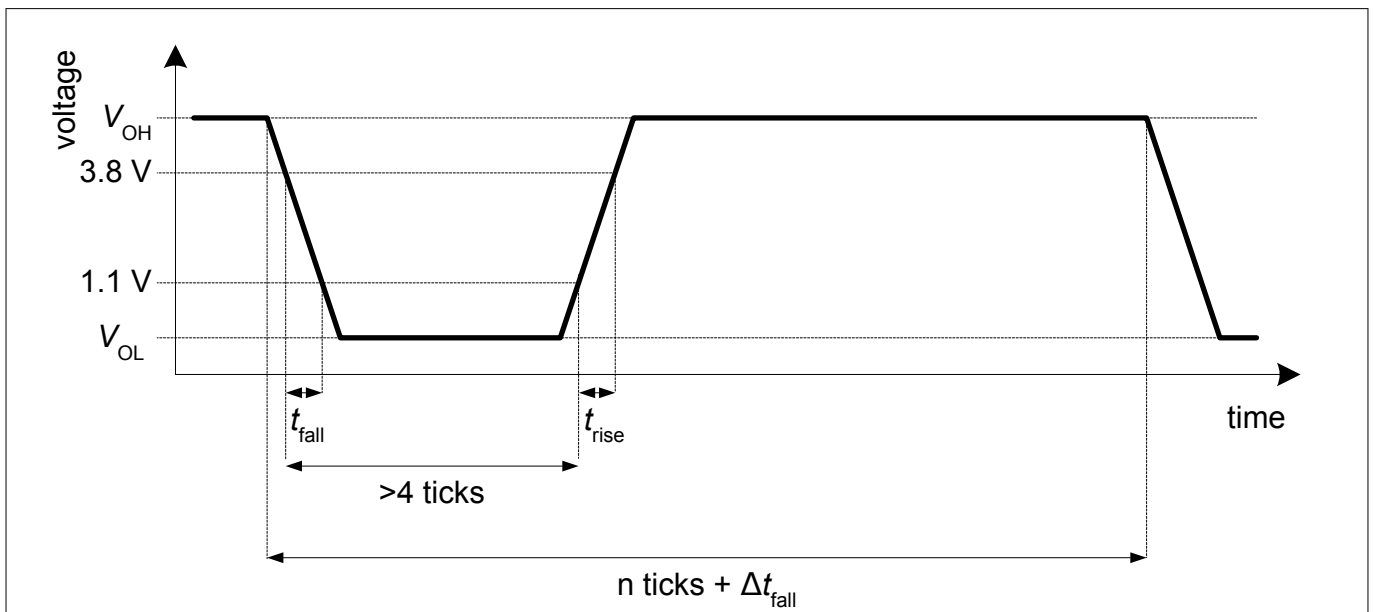


Figure 6 Physical layer specification of a nibble

1.6.2 Data link layer

The SENT interface has two channels for transmitting information:

- Fast channel
- Slow channel

The fast channel represents the information transmitted in the data pulses of the SENT frame. Within a single SENT frame a full pressure code and full NTC code is transmitted.

The slow channel represents the information transmitted within the status and serial communication nibble. On this channel information is transmitted over several SENT frames (4 bits per SENT frame). This information consists of diagnostic codes and serial messages.

The SENT frame starts with a synchronization and calibration pulse which is used by the receiver to synchronize with the frame and to create a reference for the length measurement of the following nibbles.

The synchronization pulse is followed by a status and serial communication nibble. The value coded in this nibble represents a series of 4 bits. While bit #0 and bit #1 are reserved, bit #2 and bit #3 are used to communicate serial messages.

Functional description

The message transmitted by the KP276C1505 contains two fast channels. Each channel is segmented in 3 data nibbles; every nibble includes 4 bits. The 12-bit pressure information is transmitted by the first fast channel, the 12-bit temperature information of the NTC by the second fast channel.

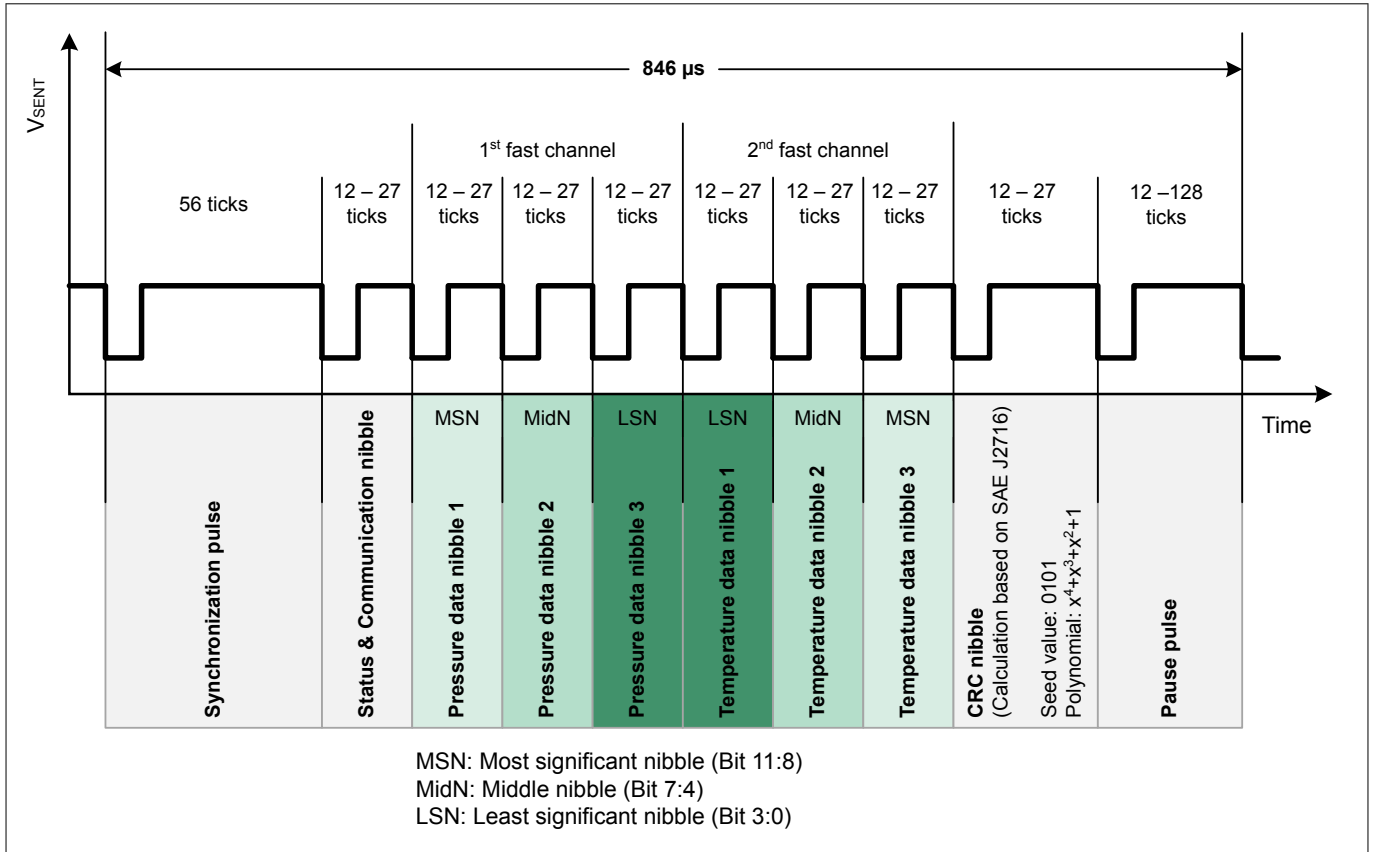


Figure 7 Message transmission

The pause pulse is used to create a SENT transmission with a constant frame length of 282 clock ticks (846 μs).

1.6.2.1 Nibble specification

A nibble contains 4-bit data content. The length of a nibble defines the content of the 4 bits. The global timing of a nibble is based on ticks. The length of a tick is specified as 3 μs.

The following formula defines the number of ticks (n_{ticks}) based on the nibble content ($data_{nibble}$):

$$n_{ticks} = 12 + data_{nibble}$$

Figure 8 shows the nibble timing.

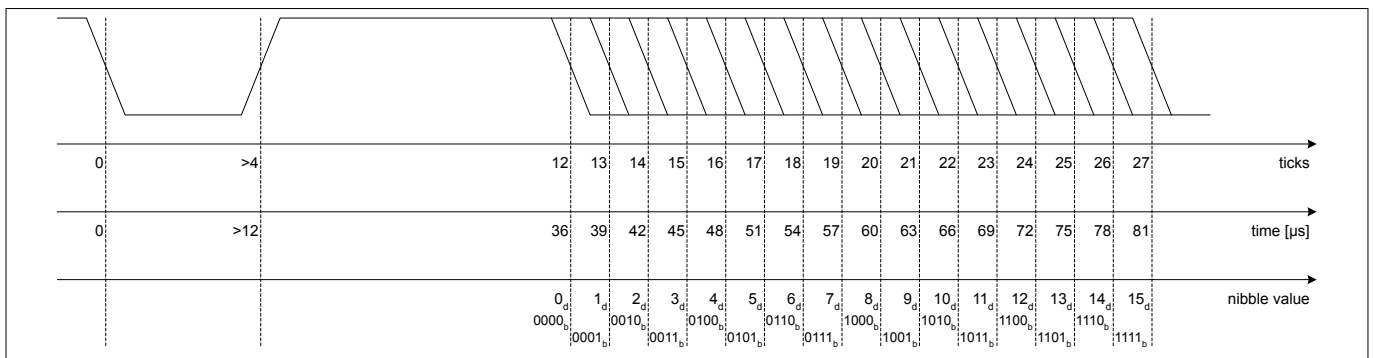


Figure 8 Nibble timing

Functional description

1.6.2.2 Status and communication nibble

This nibble is reserved to enable the sensor to transmit different information such as part numbers or error code information. The nibble is defined in the following table:

Table 4 Status nibble description

| Status Nibble Bit | Function |
|-------------------|---|
| 0 | Fast channel-1 error flag |
| 1 | Fast channel-2 error flag |
| 2 | Serial message bit: Serial message data bit |
| 3 | Serial message bit: Serial message data bit and indicates the start of a serial message |

The serial message channel (slow message channel) is implemented as enhanced serial message format.

1.6.2.3 Enhanced serial message format

Bit #2 and #3 of the status and communication nibble are used for serial data transmission. A serial message stretches over 18 consecutive SENT data messages. All 18 messages must be successfully received for the serial value to be valid.

The frame start of a serial message is indicated by the unique pattern “111110” in bit #3 of the status and communication nibble, **Figure 10**. The first “1” in a series of six “1” (after a “0”) indicates the first nibble of a serial message. Serial data bit #3 of serial communication nibble 1 - nibble 6 are set to “1”, Serial data bit #3 of serial communication nibbles 7, 13 and 18 are set to “0”.

The serial message contains 20 bits of payload data. The communication is defined by the configuration bit (serial data bit #3, serial communication nibble No. 8), configuration bit = 0”:

- 12-bit data and 8-bit message ID

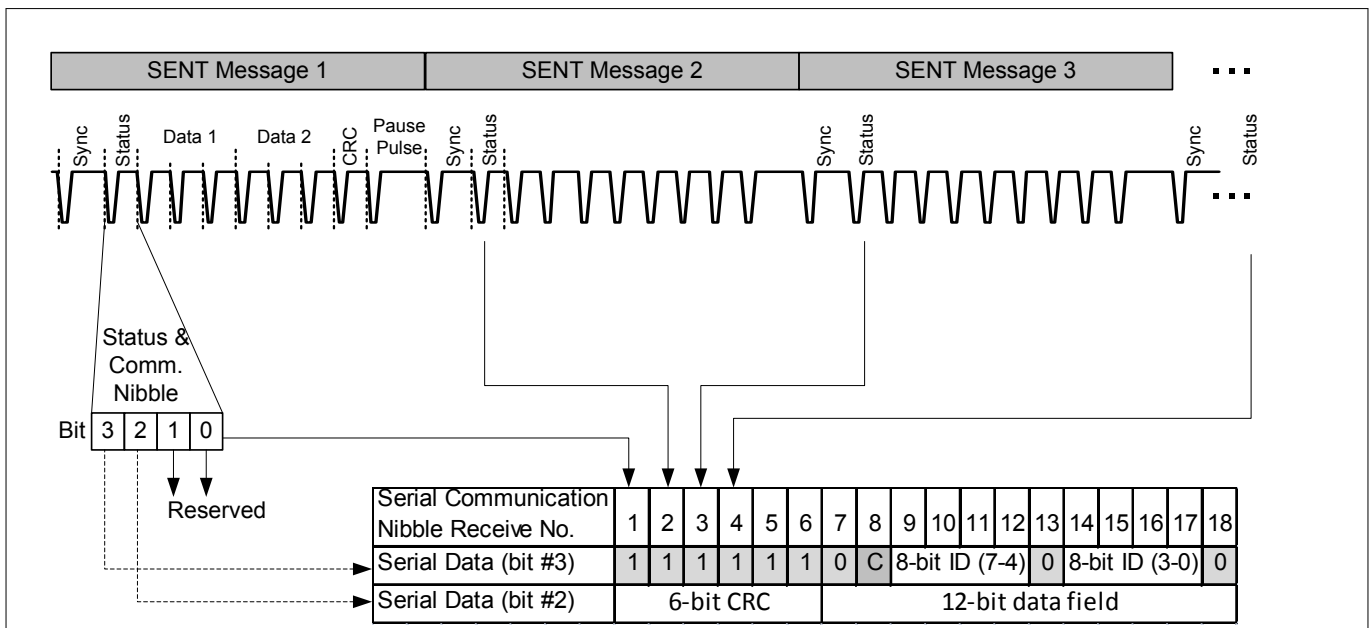


Figure 9 Construction of enhanced serial data message from 18 SENT messages

All data (data field, message ID and CRC) that is transmitted in the serial message channel is sent in the order MSB to LSB.

Functional description

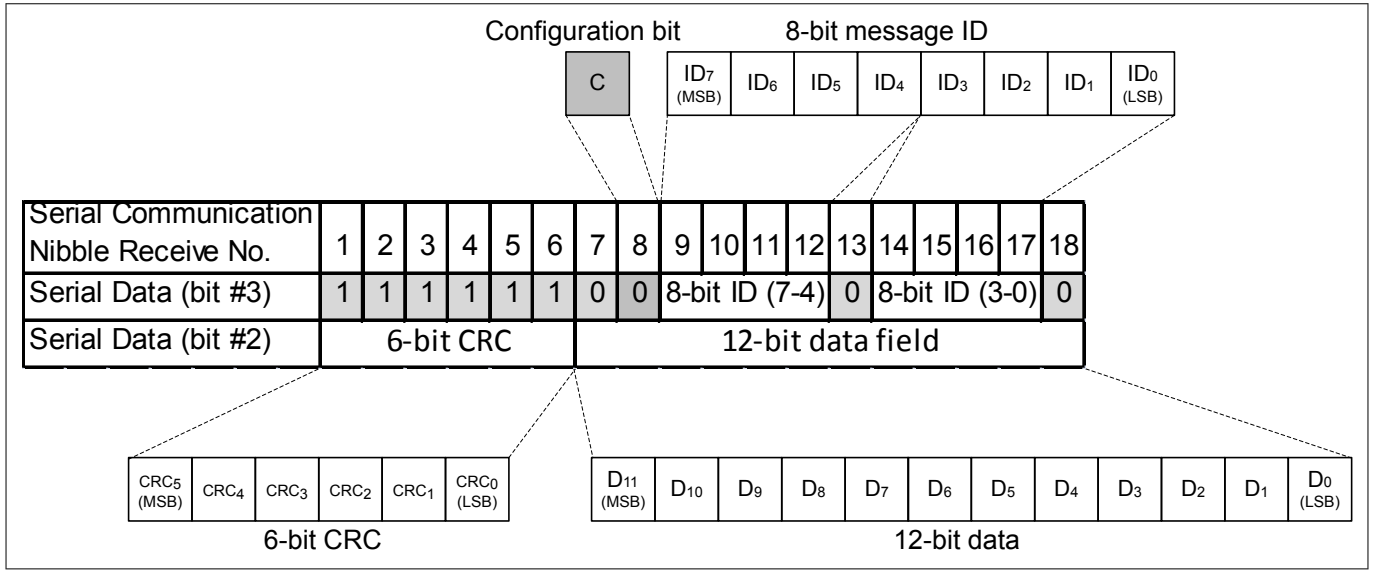


Figure 10 Enhanced serial message format with 12-bit data field and 8-bit message ID

Functional description

1.6.2.4 Enhanced serial message data

The following 28 serial messages are transmitted over the slow channel and continuously repeated:

Table 5 Slow message channel data

| Message Number | Message ID | Definition | 12-bit data | EEPROM programmable |
|----------------|------------|--|-------------|---------------------|
| 1 | \$01 | Diagnostic error codes | – | – |
| 2 | \$03 | Sensor type Channel 1/2 Pressure/ Temperature | 0x007 | no |
| 3 | \$04 | Configuration Code | 0x001 | no |
| 4 | \$05 | Manufacturer Code | 0x056 | no |
| 5 | \$06 | SENT standard version | 0x004 | no |
| 6 | \$07 | Fast channel 1 characteristic $X1$, ($X1=p_{IN,1}$) | 0x053 | yes |
| 7 | \$08 | Fast channel 1 characteristic $X2$, ($X2=p_{IN,2}$) | 0x0F4 | yes |
| 8 | \$01 | Diagnostic error codes | – | – |
| 9 | \$81 | Defined by OEM/Supplier | 0x000 | no |
| 10 | \$23 | Supplementary data channel #4,1, reference temperature (NTC temperature) | 0x000 | no |
| 11 | \$09 | Fast channel characteristic $Y1$, default | 0x0C1 | no |
| 12 | \$0A | Fast channel characteristic $Y2$, default | 0xF38 | no |
| 13 | \$29 | Sensor ID #1 | | yes |
| 14 | \$80 | Defined by OEM/Supplier | 0x000 | no |
| 15 | \$01 | Diagnostic error codes | – | – |
| 16 | \$2A | Sensor ID #2 | | yes |
| 17 | \$2B | Sensor ID #3 | | yes |
| 18 | \$2C | Sensor ID #4 | | yes |
| 19 | \$82 | OEM/Supplier | 0x000 | no |
| 20 | \$90 | OEM part number | 0x590 | yes |
| 21 | \$91 | OEM part number | 0x66B | yes |
| 22 | \$01 | Diagnostic error codes | – | – |
| 23 | \$92 | OEM part number | 0x590 | no |
| 24 | \$93 | OEM part number | 0x550 | no |
| 25 | \$94 | OEM part number | 0x951 | yes |
| 26 | \$95 | OEM part number | 0x000 | yes |
| 27 | \$96 | OEM part number | 0x000 | yes |
| 28 | \$97 | OEM part number | 0x000 | yes |

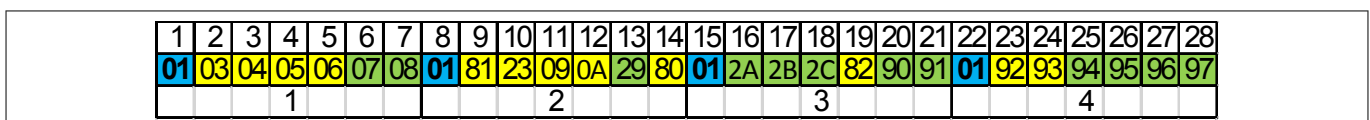


Figure 11 ESM cycle

Functional description

1.6.3 Pressure channel output codes

Table 6 gives an overview about the pressure channel data content.

Table 6 Pressure channel data content

| Code [dec] | Code [bin] | Data Nibble 1 | Data Nibble 2 | Data Nibble 3 | Description |
|------------|----------------|---------------|---------------|---------------|----------------------|
| 0 | 0000 0000 0000 | 12 ticks | 12 ticks | 12 ticks | Invalid value |
| 1 | 0000 0000 0001 | 12 ticks | 12 ticks | 13 ticks | Clamping low |
| 2 | 0000 0000 0010 | 12 ticks | 12 ticks | 14 ticks | Min. pressure output |
| ... | ... | ... | ... | ... | ... |
| 4087 | 1111 1111 0111 | 27 ticks | 27 ticks | 19 ticks | Max. pressure output |
| 4088 | 1111 1111 1000 | 27 ticks | 27 ticks | 20 ticks | Clamping high |
| 4089 | 1111 1111 1001 | 27 ticks | 27 ticks | 21 ticks | Invalid value |
| 4090 | 1111 1111 1010 | 27 ticks | 27 ticks | 22 ticks | Diagnostic error |
| 4091 | 1111 1111 1011 | 27 ticks | 27 ticks | 23 ticks | Invalid value |
| 4092 | 1111 1111 1100 | 27 ticks | 27 ticks | 24 ticks | Invalid value |
| 4093 | 1111 1111 1101 | 27 ticks | 27 ticks | 25 ticks | Invalid value |
| 4094 | 1111 1111 1110 | 27 ticks | 27 ticks | 26 ticks | Invalid value |
| 4095 | 1111 1111 1111 | 27 ticks | 27 ticks | 27 ticks | Invalid value |

Table 7 Error indication for pressure channel

| Pressure kPa | Fast channel 1 LSB | Slow channel ID\$01 | Status Nibble Bit 0 | Description |
|----------------------|-----------------------------------|---------------------|---------------------|-------------------------|
| $P < -4.9$ | 1 | 002 _H | 1 | Clamping low |
| $-4.9 \leq P < 10$ | $2 \leq \text{code} \leq 192$ | 002 _H | 0 | Reduced signal accuracy |
| $10 \leq P \leq 300$ | $193 \leq \text{code} \leq 3896$ | 000 _H | 0 | Signal range |
| $300 < P \leq 314.9$ | $3897 \leq \text{code} \leq 4087$ | 001 _H | 0 | Reduced signal accuracy |
| $314.9 < P$ | 4088 | 001 _H | 1 | Clamping high |

Note: Status Nibble Bit #0 is calculated at start of every frame. Status value for slow channel is calculated at start of every slow channel status message (ID\$01).

Functional description

1.6.4 Temperature channel output codes

Table 8 gives an overview about the temperature channel data content.

Table 8 Temperature channel data content

| Code [dec] | Code [bin] | Data Nibble 3 | Data Nibble 2 | Data Nibble 1 | Description |
|------------|----------------|---------------|---------------|---------------|--|
| 0 | 0000 0000 0000 | 12 ticks | 12 ticks | 12 ticks | Initialization |
| 1 | 0000 0000 0001 | 12 ticks | 12 ticks | 13 ticks | Clamping low (-73°C) |
| ... | ... | ... | ... | ... | ... |
| 185 | 0000 1011 1001 | 12 ticks | 23 ticks | 21 ticks | Min. temperature ²⁾ (-50°C) |
| ... | ... | ... | ... | ... | ... |
| 2025 | 0111 1110 1001 | 19 ticks | 26 ticks | 21 ticks | Max. temperature ²⁾ (180°C) |
| ... | ... | ... | ... | ... | ... |
| 4088 | 1111 1111 1000 | 27 ticks | 27 ticks | 20 ticks | Clamping high (438°C) |
| 4089 | 1111 1111 1001 | 27 ticks | 27 ticks | 21 ticks | Invalid value |
| 4090 | 1111 1111 1010 | 27 ticks | 27 ticks | 22 ticks | Diagnostic error |
| 4091 | 1111 1111 1011 | 27 ticks | 27 ticks | 23 ticks | Invalid value |
| 4092 | 1111 1111 1100 | 27 ticks | 27 ticks | 24 ticks | Invalid value |
| 4093 | 1111 1111 1101 | 27 ticks | 27 ticks | 25 ticks | Invalid value |
| 4094 | 1111 1111 1110 | 27 ticks | 27 ticks | 26 ticks | Invalid value |
| 4095 | 1111 1111 1111 | 27 ticks | 27 ticks | 27 ticks | Invalid value |

Table 9 Error indication for temperature channel

| Temperature ²⁾ °C | Fast channel 2 LSB | Slow channel ID\$01 | Status Nibble Bit 1 | Description |
|------------------------------|--------------------|---------------------|---------------------|----------------------|
| T < -50 | code < 185 | 805 _H | 1 | Temperature too low |
| -50 ≤ T < -40 | 185 ≤ code ≤ 265 | 000 _H | 0 | Accuracy undefined |
| -40 ≤ T ≤ 170 | 266 ≤ code ≤ 1945 | 000 _H | 0 | Temperature range |
| 170 < T ≤ 180 | 1946 ≤ code ≤ 2025 | 000 _H | 0 | Accuracy undefined |
| T > 180 | code > 2025 | 804 _H | 1 | Temperature too high |

Notes:

1. The output code for fast channel 2 is limited by the NTC resistance value.
2. Status Nibble Bit #1 is calculated at start of every frame. Status value for slow channel is calculated at start of every slow channel status message (ID\$01).

²⁾ Min/max temperature output depends on external NTC due to limitation of measurement range for NTC resistance, see **Table 18**

Functional description

1.6.5 Diagnostic Error Codes

After power on, a system self check is started. During this initialization phase the following internal sensor checks are performed:

- Pressure out of range
- Signal path check (Diag1)
- Sensor cell check (Diag2)
- EEPROM check

The signal range is continuously monitored and “Signal out of range” is transmitted with every SENT frame. Pressure out of range is transmitted over fast channel1, temperature out of range is transmitted over fast channel2.

If an internal malfunction is detected, the error code 4090 is transmitted over fast channel1 and fast channel2. The error type is transmitted over the slow message channel (Diagnostic Error Code), see [Table 10](#). If more than one error is detected, only the diagnosis code with the highest priority will be sent.

Table 10 Diagnostic Error Codes

| Description | Priority ³⁾ | Fast Channel1 Code | Fast Channel2 Code | Diagnostic Error Code |
|---------------------------------|------------------------|--------------------|--------------------|---------------------------|
| Normal Operation/Initialization | | channel1 data | channel2 data | 000 _H no error |
| Internal Error | 5 | 4090 | 4090 | A05 _H |
| Pressure out of range high | 4 | 4088 | channel2 data | 001 _H |
| Pressure out of range low | 3 | 1 | channel2 data | 002 _H |
| Temperature out of range high | 2 | channel1 data | >2025 | 804 _H |
| Temperature out of range low | 1 | channel1 data | <185 | 805 _H |

Note: Diagnostic error code is updated with start of every new status message ID.

1.6.5.1 Signal out of range

The signal ranges are monitored during normal operation mode. If the pressure value is below the minimum operating pressure range or exceeds the maximum operating pressure range the error code “Pressure out of range low/high” is transmitted. The limits are defined in [Table 7](#).

If the NTC temperature is below the minimum operating temperature or NTC resistor exceeds the maximum resistance value of NTC “Temperature out of range low” is transmitted. If the NTC temperature exceeds the maximum operating temperature or NTC resistor is below minimum resistance value the error code “Temperature out of range high” is transmitted. The limits are defined in [Table 9](#), the resistance values of NTC are defined in [Table 18](#).

1.6.5.2 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 diagnostic error code “Internal Error” is set.

³ Priority 5: high, priority 1: low

Functional description

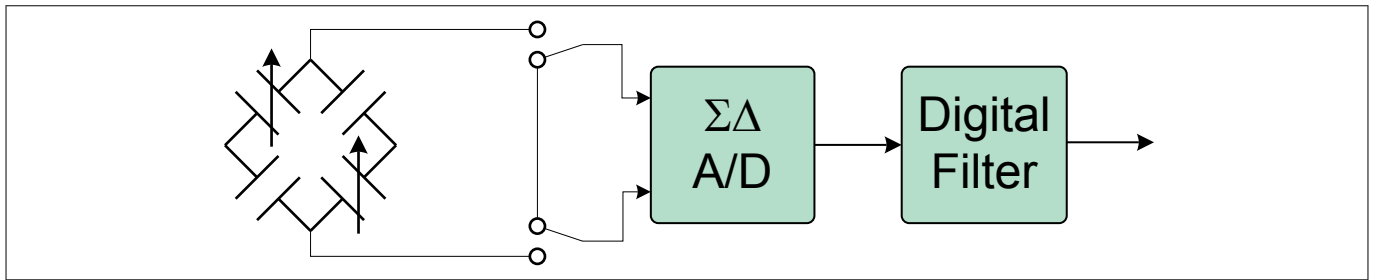


Figure 12 **Diag1 functionality**

1.6.5.3 **Diag2**

The Diag2 test checks the functionality of the pressure sensor cells. Therefore a malfunction (e.g. broken membrane) can be detected. The KP276C1505 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 13**. If Diag2 value is out of range, the diagnostic error code “Internal Error” is set.

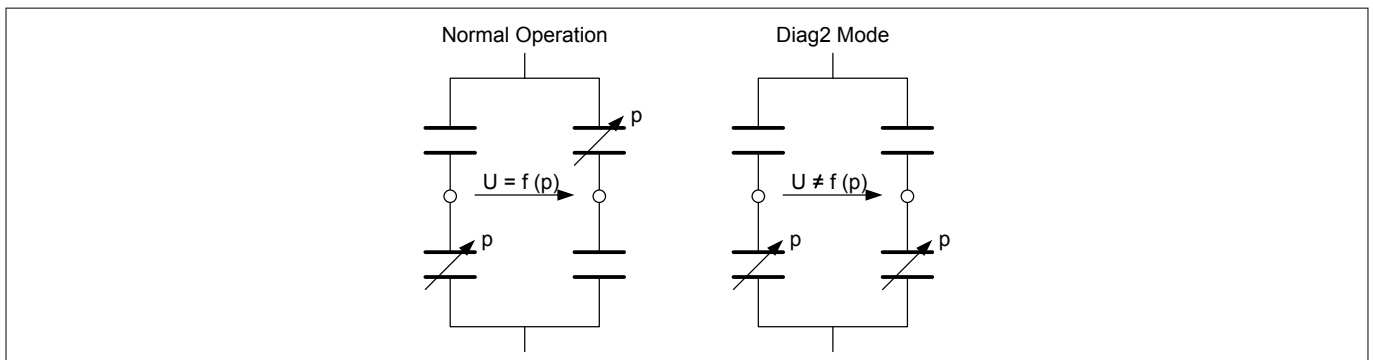


Figure 13 **Diag2 functionality**

1.6.5.4 **EEPROM Check**

During the initialization phase the content of the EEPROM cells is copied into the corresponding EEPROM 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 “Internal Error”.

1.6.6 **Definition of Pressure signal path latency**

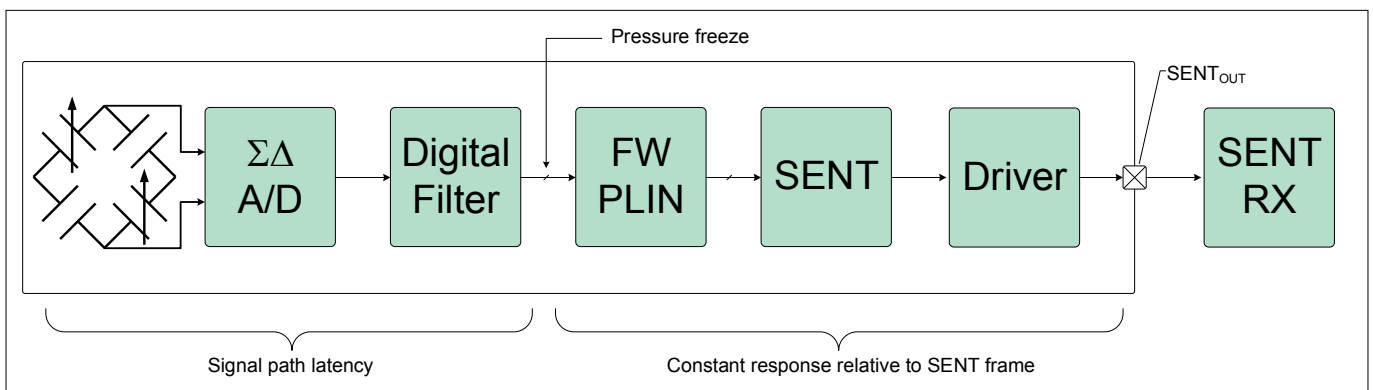


Figure 14 **Pressure signal path latency t_{path_pres} (pressure settling time)**

The pressure value is calculated at start of the SENT frame and is transmitted once per frame.

Functional description

1.7 External temperature sensor

The KP276C1505 can be connected to an external temperature sensor at pin NTC_{IN} . The internal signal processing of the KP276C1505 makes it a perfect fit for using standard NTC temperature sensors. To avoid errors through self heating of the NTC, the power consumption is limited.

1.7.1 Linearization of the external temperature sensor transfer function

The resistance of NTC thermistors is a nonlinear function of the temperature. The used method for mathematical modelling of the resistance R versus temperature T is the **Steinhart-Hart Equation**:

$$\frac{1}{T} = A + B(\ln(R)) + C(\ln(R))^3$$

The Steinhart-Hart coefficients for a selected NTC are coded in the EEPROM. Evaluation of accuracy is included for the following thermistor:

Table 11 NTC characteristics example

| | | | | | Steinhart-Hart coefficients | | |
|-----|--------------------|-----------------|--------------------|-----------------|-----------------------------|------------|------------|
| | $R_{min} [\Omega]$ | $T [^{\circ}C]$ | $R_{max} [\Omega]$ | $T [^{\circ}C]$ | A | B | C |
| NTC | 102 | 170 | 107300 | -40 | 1.0211E-03 | 2.6434E-04 | 1.3405E-07 |

Note: The resistance range of the NTC is limited, see [Table 18](#).

1.7.2 Accuracy for NTC signal processing

The accuracy of the signal processing for external temperature sensors depends on the resistance value and the nonlinearity of the connected NTC. In [Figure 15](#) the absolute error is displayed graphically, all errors due to the integrated signal processing are considered.

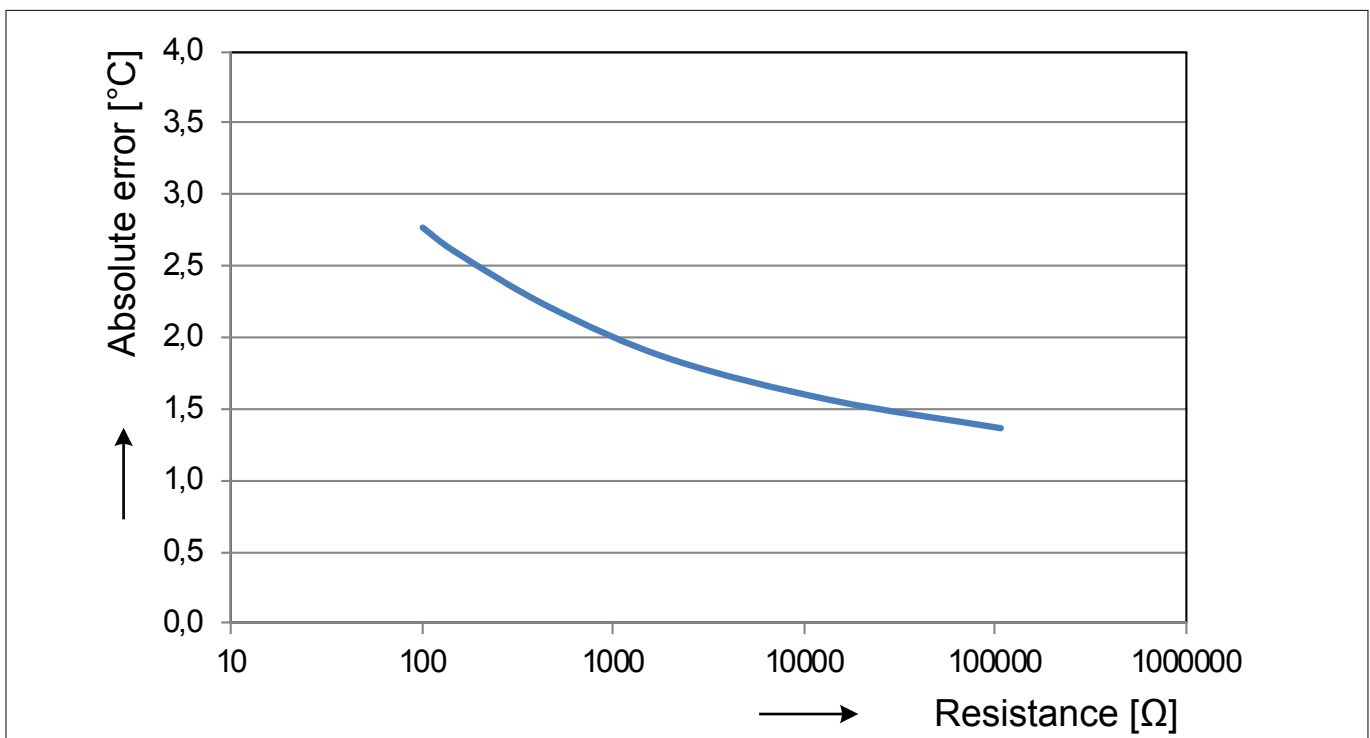


Figure 15 Accuracy for signal processing of NTC

Specification

2 Specification

2.1 Application circuit example

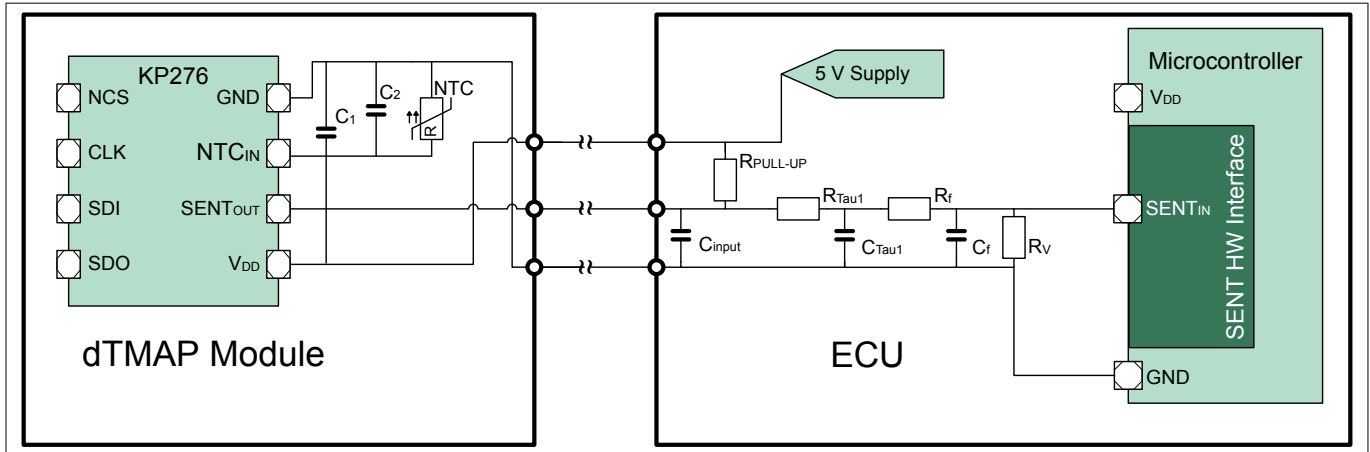


Figure 16 Application circuit example

Table 12 Component values

| Component | Symbol | Values | | | Unit |
|---|---------------|--------|------|------|------------|
| | | Min. | Typ. | Max. | |
| Supply Blocking Capacitor | C_1 | 30 | 100 | - | nF |
| NTC Capacitor | C_2 | - | 330 | - | pF |
| Pull-up Resistor | $R_{PULL-UP}$ | 10 | - | 55 | k Ω |
| Parasitic Input Capacitor | C_{input} | - | - | 0.1 | nF |
| Low Pass Resistor | R_{Tau1} | 448 | 560 | 672 | Ω |
| Low Pass Capacitor | C_{Tau1} | 1.54 | 2.2 | 2.86 | nF |
| Low Pass Resistor - second stage | R_f | 4 | - | - | k Ω |
| Low Pass Capacitor - second stage | C_f | - | 47 | - | pF |
| optional resistor | R_v | - | 100 | - | k Ω |
| Filter Time Constant - first stage, determined by R_{Tau1} and C_{Tau1} | $Tau1$ | 0.74 | - | 1.73 | μs |
| Filter Time Constant - second stage, determined by R_v , R_f and C_f | $Tau2$ | 0.6 | - | 1.4 | μs |

Note: For the application PCB-layout, it is mandatory to route the NTC GND wire in such a way that the chip current or any other current does not run through any of the NTC input connections. Star ground connection is recommended for the NTC-GND and GND of the supply source. This will reduce the additional external voltage drop that could influence the external NTC accuracy.

Specification

2.2 Application circuit example for EMC

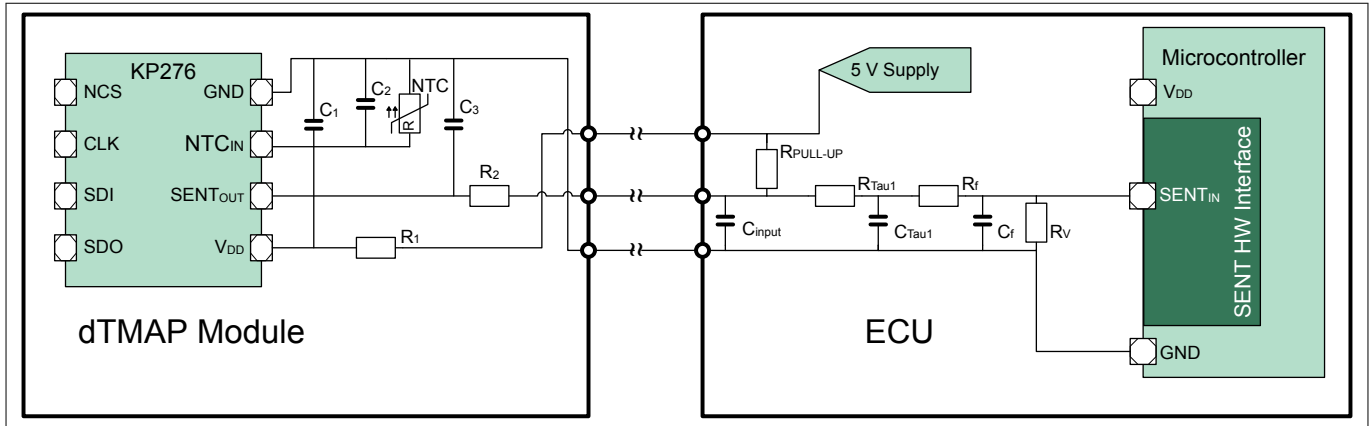


Figure 17 Application circuit example for pulse immunity

Table 13 Component values

| Component | Symbol | Values | | | Unit |
|---------------------------|--------|--------|------|------|----------|
| | | Min. | Typ. | Max. | |
| Supply Blocking Capacitor | C_1 | - | 330 | - | nF |
| NTC Capacitor | C_2 | - | 330 | - | pF |
| SENT Filter Capacitor | C_3 | - | 1 | - | nF |
| Supply Filter Resistor | R_1 | - | 10 | - | Ω |
| SENT Filter Resistor | R_2 | - | 100 | - | Ω |

For pulse immunity an EMC filter consisting of a capacitor (C_3) followed by a resistor in series (R_2) with the $SENT_{OUT}$ pin is recommended to attenuate RF energy coupled on the external signal line. In addition a filter consisting of the adapted supply capacitor (C_1) followed by a resistor in series (R_1) with the supply pin is recommended to attenuate RF energy coupled on the external supply line.

Specification

2.3 Absolute maximum ratings

Table 14 Absolute maximum ratings

| Parameter | Symbol | Values | | | Unit | Note | Number |
|-------------------------------|----------------|--------|------|------|------|--|--------|
| | | Min. | Typ. | Max. | | | |
| Voltage on GND & $SENT_{OUT}$ | V_{max} | -0.3 | - | 16 | V | - | 1.1 |
| Voltage on V_{DD} | V_{max_VDD} | -16 | - | 16 | V | Reverse polarity protection against supply | 1.2 |
| Storage temperature | T_S | -40 | - | 150 | °C | - | 1.3 |
| Maximum input pressure | p_{amb_max} | - | - | 500 | kPa | - | 1.4 |
| | | | | 600 | kPa | Limited time: Max. 300 s | |
| ESD robustness | V_{ESD} | - | - | 4 | kV | Pins: VDD, GND, $SENT_{OUT}$, NTC_{IN} (Human Body Model R= 1.5 kΩ, C= 100 pF) | 1.5 |
| | | | | 2 | kV | Pins: NCS, CLK, SDI, SDO (Human Body Model R= 1.5 kΩ, C= 100 pF) | |

Attention: Stresses above the max. values listed in [Table 14](#) 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.

Note: The voltage on $SENT_{OUT}$ must not exceed the voltage on the V_{DD} pin.

Specification

2.4 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 15 Operating range

| Parameter | Symbol | Values | | | Unit | Note | Number |
|---|-----------------|----------------|------|----------|------|---|--------|
| | | Min. | Typ. | Max. | | | |
| Supply voltage | V_{DD} | 4.5 | 5.0 | 5.5 | 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} | -3.0 | - | 0.8 | V | - | 2.3 |
| Input voltage for high level at pins NCS, CLK & SDI | V_{high_in} | 2.0 | - | 3 | V | - | 2.4 |
| Output voltage for low level at pin SDO | V_{low_out} | - | - | 0.4 | V | Test current at pin SDO is 1.5 mA | 2.5 |
| Output voltage for high level at pin SDO | V_{high_out} | $V_{DD} - 0.4$ | - | V_{DD} | V | Test current at pin SDO is 1.5 mA | 2.6 |
| Operating temperature | T_a | -40 | - | 150 | °C | - | 2.7 |
| Operating peak temperature | T_{a_peak} | - | - | 170 | °C | Limited time: Max. 20 min. | 2.8 |
| Ambient operating pressure range | p_{amb} | 10 | - | 300 | kPa | - | 2.9 |
| Thermal resistance | $R_{thj-amb}$ | - | 167 | - | K/W | Thermal resistance between the die and T_{amb} (measured acc. JESD51-2) | 2.10 |

Attention: *The KP27x is sensitive to light incident to the pressure port. The specification “Accuracy pressure” (see [Table 18](#)) is valid for an illuminance of less than 1 lx. At higher illuminance, a higher pressure error may occur.*

Specification

2.5 Characteristics

Product characteristics involve the spread of values specified within the operating range. Typical characteristics are the median of the production.

Table 16 General characteristics

| Parameter | Symbol | Values | | | Unit | Note | Number |
|--|----------------------|--------|------|------|------|--|--------|
| | | Min. | Typ. | Max. | | | |
| Supply current into VDD ⁴⁾ | I_{VDD} | - | 9 | - | mA | No NTC and no SENT filter connected | 3.1 |
| | | - | - | 15 | mA | NTC shorted to GND and SENT filter connected | |
| Internal pressure update rate | f_{update} | - | 250 | - | kHz | - | 3.2 |
| Pressure signal path latency ⁵⁾ | t_{path_pres} | - | 1 | 2 | ms | - | 3.3 |
| Temperature signal path latency | t_{path_temp} | - | 153 | 580 | ms | NTC update rate | 3.4 |
| Start-up time Pressure ⁶⁾ | $t_{start-up_pres}$ | - | 10 | - | ms | For pressure channel | 3.5 |
| Start-up time Temperature | $t_{start-up_temp}$ | - | 10 | - | ms | For temperature channel | 3.6 |

Table 17 Physical layer characteristics

| Parameter | Symbol | Values | | | Unit | Note | Number |
|--|-------------------|--------|------|------|---------|---|--------|
| | | Min. | Typ. | Max. | | | |
| Low state voltage level on $SENT_{OUT}$ | V_{OL} | - | - | 0.5 | V | 0.52 mA DC load current | 4.1 |
| High state voltage level on $SENT_{OUT}$ | V_{OH} | 4.1 | - | 5.5 | V | 0.10 mA DC load current | 4.2 |
| Length of one tick | t_{tick} | - | 3.0 | - | μ s | - | 4.3 |
| Clock tick time variation | $tick_{var}$ | -20 | - | 18 | % | - | 4.4 |
| Nibble fall time | t_{fall} | - | - | 6.5 | μ s | From 3.8 V to 1.1 V | 4.5 |
| Nibble rise time | t_{rise} | - | - | 18.0 | μ s | From 1.1 V to 3.8 V | 4.6 |
| Jitter | Δt_{fall} | - | - | 0.1 | μ s | Edge to edge with static environment for any pulse period | 4.7 |
| Signal stabilization time | t_{stable} | 6 | - | - | μ s | Signal stabilization time below 1.39 V or above 3.8 V | 4.8 |

⁴ Supply current depends on NTC resistor: additional current of approximately 2 mA has to be considered with min R_{NTC} (40 Ω) connected

⁵ For more details see, [Definition of Pressure signal path latency](#)

⁶ Time from power-up until SENT transmission start

Specification

Table 18 **Transfer function characteristics**

| Parameter | Symbol | Values | | | Unit | Note | Number |
|-------------------------|-----------|----------------------|-------|-------------------|---------|---|--------|
| | | Min. | Typ. | Max. | | | |
| Sensitivity pressure | S_p | - | 12.77 | - | LSB/kPa | - | 5.1 |
| Offset pressure | $offs_p$ | - | 65.31 | - | LSB | - | 5.2 |
| Sensitivity temperature | S_T | - | 8.0 | - | LSB/°C | - | 5.3 |
| Offset temperature | $offs_T$ | - | 585.2 | - | LSB | - | 5.4 |
| Accuracy pressure | acc_p | -3.0 -4.6 -5.0 | - | 3.0 4.6 5.0 | kPa | $T_a = 0^\circ\text{C} - 85^\circ\text{C}$ $T_a = -40^\circ\text{C} - 0^\circ\text{C}$ $T_a = 85^\circ\text{C} - 150^\circ\text{C}$ | 5.5 |
| Resistance value of NTC | R_{NTC} | 0.040 | - | 127 ⁷⁾ | kΩ | - | 5.6 |

⁷ Exceeding this value will not cause damage but the NTC accuracy (see [Figure 15](#)) is not specified. Turning back into the specified R_{NTC} range the sensor will be within specification again.

Package information

3.2 Identification code

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

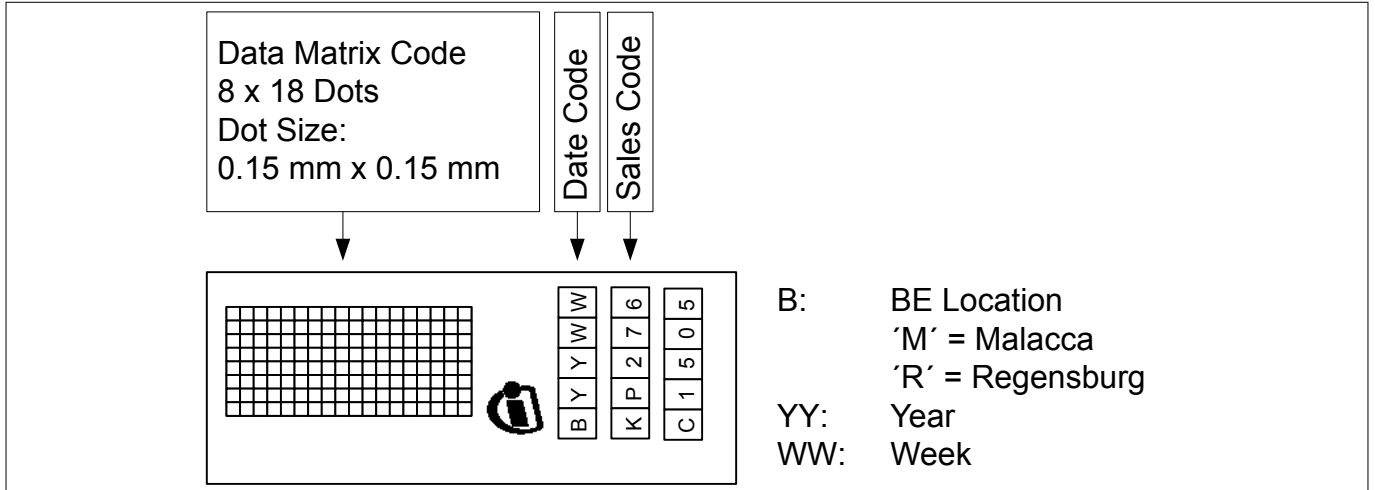


Figure 19 Identification code

The identification code for the KP276C1505 is on the same side of the package as pin 8 (GND).

Revision history

Revision history

| Document version | Date of release | Description of changes |
|------------------|-----------------|---|
| Revision 1.0 | 2019-01-25 | - |
| Revision 1.1 | 2019-11-11 | <ul style="list-style-type: none">• Change document class from "Confidential" to "Public"• CRC calculation information added in Figure 7 |

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