

# ZMD31020

## Sensor Signal Conditioner

Datasheet

### Features

- Digital compensation of sensor offset, sensitivity, temperature drift and non-linearity
- Adjustable to nearly all piezo-resistive bridge sensor types
- Digital one-shot calibration: quick and precise
- Selectable temperature compensation reference: internal or external diode
- Output options: 0...5V analog ratiometric voltage or 12 bit digital I<sup>2</sup>C interface
- Product traceability by user-defined EEPROM entries
- Operation temperature range, depending on product version, up to -40...+125 °C
- Supply voltage +4.5...+5.5V
- Sampling rate ≥100Hz
- Available in SSOP14 or as die

### Benefits

- No external trimming components required
- PC-controlled configuration and calibration via digital bus interface - simple, low cost
- High accuracy ( $\pm 0.1\%$  FSO @ -25 to 85 °C;  $\pm 0.25\%$  FSO @ -40 to 125 °C)

### Brief Description

ZMD31020 is a CMOS integrated circuit for highly-accurate amplification and sensor-specific correction of bridge sensor signals. The device provides digital compensation of sensor offset, sensitivity, temperature drift and non-linearity by a 16-bit RISC micro controller running a correction algorithm. ZMD31020 accommodates nearly all piezo-resistive bridge sensor types.

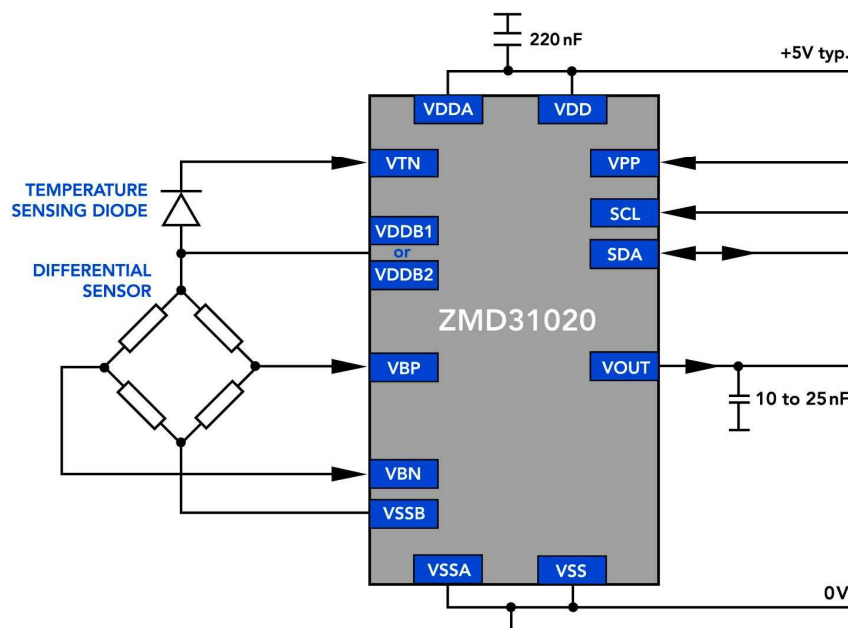
The bi-directional digital I<sup>2</sup>C interface can be used for a simple PC-controlled one-shot calibration procedure, in order to program a set of calibration coefficients into an on-chip EEPROM. Thus a specific sensor and a ZMD31020 are mated digitally: fast, precise and without the cost overhead associated with trimming by external devices or laser.

ZMD31020 has been designed for industrial and consumer applications and is specifically suited for most pressure sensors.

§ Demo kit available (incl. calibration PCB, SSOP14 samples, software, technical documentation)

§ Support for industrial calibration available

§ Quick circuit customization possible for large production volumes



Application Circuit Example

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### 1. PIN DESCRIPTION

PIN Number	Name	Description
1	VOUT	analog conditioned sensor signal output
2	VDDA (*)	analog device functions positive supply
3	VDD	digital device functions positive supply
4	VSS	digital device functions negative supply
5	SCL	I <sup>2</sup> C clock input, on-chip pull-up resistor
6	SDA	I <sup>2</sup> C data input / output, on-chip pull-up resistor
7	VPP	positive EEPROM programming voltage
8	VBN	differential sensor signal negative input
9	VDDDB2 (*)	positive supply for sensor and temperature sensing diode
10	VTN	input for temperature sensing diode
11	VDDDB1 (*)	positive supply for sensor and temperature sensing diode
12	VBP	differential sensor signal positive input
13	VSSB (**)	sensor negative supply
14	VSSA (**)	analog device functions negative supply

(\*) VDDA, VDDDB1 and VDDDB2 tied to common on-chip positive supply rail

(\*\*) VSSA and VSSB tied to common on-chip negative supply rail

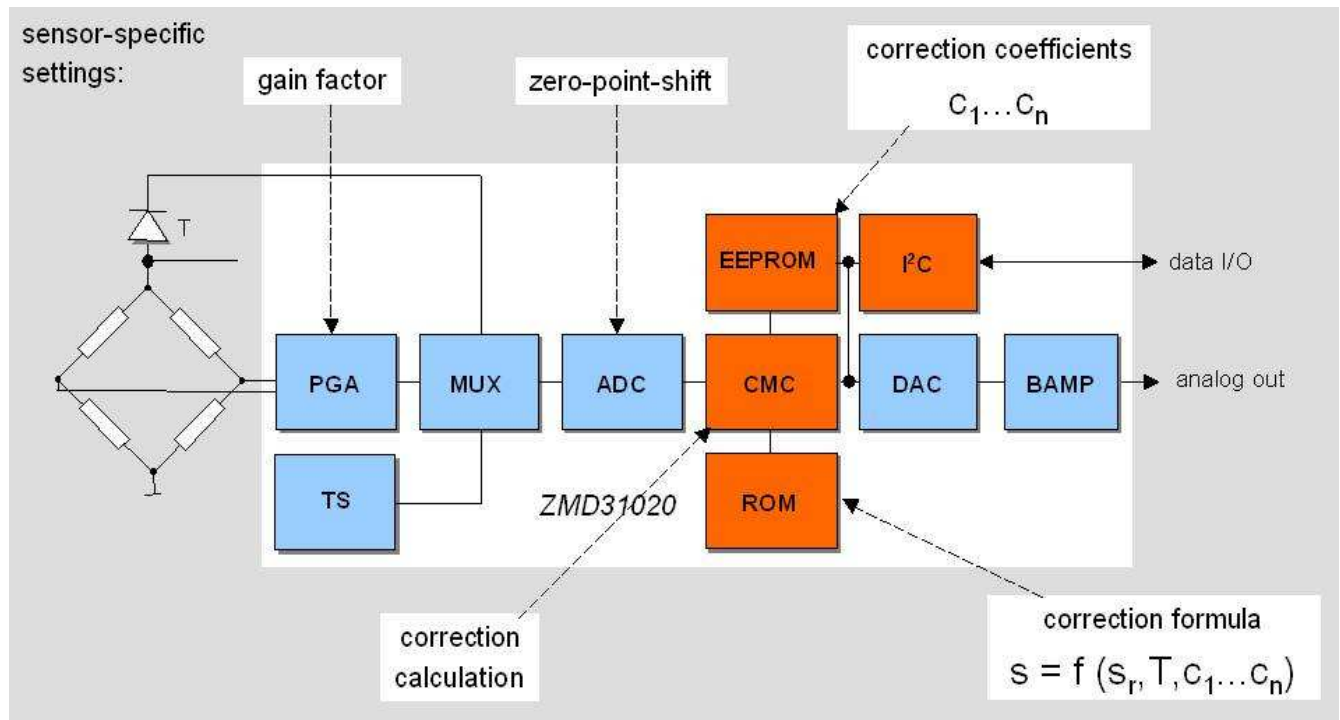
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## 2. CIRCUIT DESCRIPTION

### 2.1 Signal Flow



Block diagram of ZMD31050

PGA	programmable gain amplifier
MUX	multiplexer
ADC	analog-to-digital converter
CMC	calibration microcontroller
DAC	digital-to-analog converter
BAMP	buffer amplifier
TS	on-chip temperature sensor (pn-junction)
EEPROM	for calibration parameters and configuration
ROM	for correction formula and –algorithm
I <sup>2</sup> C	serial interface: I <sup>2</sup> C data I/O, clock

The ZMD31020's signal path is partly analog (blue) and partly digital (red). The differential signal from the resistive bridge sensor is pre-amplified by the programmable gain amplifier (PGA). There are 3 different adjustable gains.

The Multiplexer (MUX) transmits the differential signal or the temperature signal to the ADC in a certain sequence. (The external temperature sensing diode or the internal temperature sensor can be used optionally.) The ADC converts the differential signal with 12 bits resolution and the temperature signal with 10 bits resolution into digital values.

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The digital signal correction takes place in the calibration micro-controller (CMC). It is based on a special correction formula located in the ROM and on a set of sensor-specific calibration parameters stored in the EEPROM. The resulting corrected sensor signal is output via the I<sup>2</sup>C-interface (with 12 bits resolution) , or, after conversion by the DAC, as analog voltage (with 11 bits resolution) at the buffer amplifier (BAMP). The programming of the configuration data and of the calibration parameters into the EEPROM (during the calibration procedure) is also realized via the I<sup>2</sup>C interface.

## 2.2 Configuration Word

Many of the following sections, describing each block of ZMD31020 in detail, will refer to configuration bits, part of the configuration word stored under address &H09 of the parameter EEPROM. These bits are settings for a number of on-chip device functions and select specific functional or parametrical behaviour.

The contents of the parameter EEPROM are determined and calculated, written and stored under PC-control during the calibration procedure. Hence the configuration bits are coded and non-volatile stored once calibration of a ZMD31020 device / sensor pair has taken place, and will remain unchanged during regular sensing operation, unless re-calibration is performed

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	-	CH	TS	BP	G1	G0	O1	O0

*Configuration word, stored under address &H09 of the parameter EEPROM*

Only 7 bits of the configuration word are relevant settings as follows:

Bit 0, Bit 1	O0, O1: select ADC's offset compensation
Bit 2, Bit 3	G0, G1: select PGA's gain
Bit 4	BP: cross-switches differential sensor inputs VBP and VBN
Bit 5	TS: selects on-chip vs. off-chip temperature sensor
Bit 6	CH: enables PGA's chopper-stabilization

The possible options of these settings are shown in table form in the following paragraphs.

## 2.3 Differential Sensor

ZMD31020 has been specifically designed for ratiometric differential sensors, e.g. Wheatstone bridge type sensors. A ratiometric sensor typically generates a differential output signal proportional to the supply voltage applied to it. The sensor is supplied from VDDB1 or VDDB2 (whichever pin/pad is more favourable layoutwise) at the + side and tied to VSSB at the – side. The sensor's differential output signal is routed to VBP and VBN. Sensor and signal conditioner ZMD31020 have the same supply (see block schematic in section 2.1), hence the differential input voltage seen by ZMD31020 is ratiometric to it's supply voltage.

## 2.4 Temperature Sensing

The characteristic of a sensor element tends to change with temperature. To compensate for this, ZMD31020 is equipped to measure temperature by an external diode or by an on-chip pn-junction. TS – configuration bit 5 – will select the desired sensor option as follows:

TS	Temperature sensing diode
0	off chip
1	on chip

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### 2.5 Analog Input Channel

ZMD31020's block schematic in section 2.1 shows the structure of the analog input channel. The signal path for the sensor signal as well as for temperature is fully differential up to the ADC. The analog multiplexer provides a cost-effective, sequential conversion by a common ADC. Each signal path can be separated from the source at its input and can be short-circuit there for offset-cancellation purposes; for more details see the ZMD31020 Functional Description.

#### 2.5.1 Bridge Polarity Setting

The sensor signal path features a cross-switch to reverse the polarity of the bridge sensor signal.

BP – configuration bit 4 – sets the bridge polarity as follows:

BP	Differential signal
0	$V_{BR\_P} - V_{BR\_N}$
1	$V_{BR\_N} - V_{BR\_P}$

#### 2.5.2 Programmable Gain Amplifier PGA

The PGA realizes a coarse sensitivity adaptation of the bridge sensor signal in several amplification steps (sensitivity fine-tuning takes place later in the CMC). Three different gains can be set by G0 and G1 - configuration bits 2 and 3 - as follows:

G1	G0	Gain $a_{IN}$
0	x	15.66
1	0	24
1	1	42

The chopper-stabilisation of the PGA reduces the signal noise and is enabled by CH - configuration bit 6:

CH	Chopper-stabilisation
0	Disabled
1	Enabled

#### 2.5.3 Analog-to-digital Converter ADC

The ADC is a first order charge balancing analog-to-digital converter in full differential switched capacitor technology. The amplified bridge sensor signal is converted by the ADC with full 12 bits resolution against a reference voltage of 0.96 ( $V_{DDA} - V_{SSA}$ ). As both the signal to be measured as well as the reference voltage, it is measured against, are ratiometric to supply voltage ( $V_{DDA} - V_{SSA}$ ), the ADC's conversion result is insensitive to supply-tolerances and -instabilities. In addition, the ADC realizes a coarse offset compensation (ADC-Range-Shift  $RS_{ADC}$ ) of the bridge sensor signal (offset fine-tuning takes place afterwards in the CMC).

$RS_{ADC}$  can be set as follows:

O1	O0	$RS_{ADC}$ (*)
0	0	15/16
0	1	7/8
1	0	3/4
1	1	1/2

(\*) ADC-Range-Shift, related to the maximum processable sensor signal span (former name was "CRROB")

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### 2.5.4 Temperature Measurement

The temperature sensing diode, selected by TS – configuration bit 5, is biased with a constant current of 40µA. It's forward drop changes with  $-2.1\text{mV}/^\circ\text{K}$  typically, and is passed as differential temperature signal. The 40µA current source is only on during temperature measurement, to prevent any interference with the bridge sensor signal's measurement. The differential temperature signal is resolved by the ADC with only 10 bits, against a differential reference voltage of 0.980V, derived from an on-chip bandgap. Whenever measuring temperature, the ADC is set to  $\text{RS}_{\text{ADC}} = 15/16$ .

### 2.6 Correction Microcontroller CMC

The CMC performs the sensor signal fine-tuning in the digital domain. It is a 16 bit RISC micro-controller, driven by an on-chip clock generator with a nominal clock frequency of 1.5 MHz. The overall clock frequency tolerance is smaller than  $\pm 25\%$ . The CMC includes a 16-bit width ALU and a (16 x 16)-bit RAM. Furthermore it has a 12-bit input counter into which the ADC will serially transmit conversion results; 4096 clock cycles are needed per result. The CMC is connected to a (1k x 16)-bit instruction ROM and a (12 x 16)-bit parameter EEPROM. At the output side the CMC is equipped with an I<sup>2</sup>C-interface as a digital series output for the corrected sensor signal. Initially, during calibration, the same interface is used bi-directionally: to write the configuration word into the EEPROM, to read non-corrected sensor value as well as temperature, and again and finally to write the valid calibration parameters into the EEPROM.

### 2.7 Parameter EEPROM

The parameter EEPROM is a non-volatile store for 12 parameter values, each with 16 bits of width.

Address	Parameter	Default content
0 <sub>HEX</sub>	calibration parameter a0 for sensor's non-linearity correction	5234 <sub>Hex</sub>
1 <sub>HEX</sub>	calibration parameter a1 for sensor's offset correction	0023 <sub>Hex</sub>
2 <sub>HEX</sub>	calibration parameter a2 for first order sensor offset drift correction	2044 <sub>Hex</sub>
3 <sub>HEX</sub>	calibration parameter a3 for second order sensor offset drift correction	3022 <sub>Hex</sub>
4 <sub>HEX</sub>	calibration parameter a4 for gain correction	6356 <sub>Hex</sub>
5 <sub>HEX</sub>	calibration parameter a5 for first order gain drift correction	1045 <sub>Hex</sub>
6 <sub>HEX</sub>	calibration parameter a6 for second order gain drift correction	2073 <sub>Hex</sub>
7 <sub>HEX</sub>	low-side scale limit value for corrected sensor signal	03E8 <sub>Hex</sub>
8 <sub>HEX</sub>	high-side scale limit value for corrected sensor signal	0FA0 <sub>Hex</sub>
9 <sub>HEX</sub>	configuration word	0040 <sub>Hex</sub>
A <sub>HEX</sub>	customer-specific identification word	1234 <sub>Hex</sub>
B <sub>HEX</sub>	customer-specific identification word	5678 <sub>Hex</sub>

#### *Contents of the parameter EEPROM*

The configuration word and it's contents under address &H09 have been described already in chapter 2.5.

The calibration parameters are stored under addresses &H00 through &H06. The calculation of these parameters is described in the ZMD31020 Functional Description.



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Address locations &H07 and &H08 contain a low-side resp. high-side scale limit value for the corrected sensor signal. Lower resp. -higher corrected signal values are clamped arithmetically to these limits by the CMC. Both the low and high-side scale limits can be adjusted with a resolution of 12 bits. The 12 bit limit value must be programmed into the least significant portion of either address. The 4 most significant bit locations of either address are don't care bits and may be programmed freely.

Address locations &H0A and &H0B are available for customer-specific identification words, e.g. for traceability purposes.

The contents of EEPROM addresses &H00 through &H09 are loaded into the RAM register block of the CMC upon power-on. The configuration bits are routed from the configuration register to the various device functions to be set up, see chapter 6.1.

Erasing and programming of the various EEPROM address locations during calibration requires programming pulses of about 12V amplitude and about 10ms pulse width (see section 3.3.5). Further programming details are to find in the ZMD31020 Functional Description.

Since a calibration is typically performed only once in a sensor's lifetime, no overhead chip-area for a charge-pump has been spent. Thus the programming pulse has to be generated off-chip, and applied at the VPP pin/pad. During normal operation mode the VPP pin/pad must be left open.

**Note:** An on-chip switch short-circuits VPP to VDD in normal operation mode; the switch is opened to release the VPP pin/pad for programming.)

## 2.8 Sensor Signal Correction Method and Sequence

In normal operation mode (regular sensing operation) the CMC runs a cyclic program which will output a corrected 12-bit sensor value about every 10ms.

Within this cycle the CMC stages measurement of the 'raw' sensor signal with 12 bits resolution, preceded by measurement of temperature in 10 bits, and calculates a corrected sensor output value. Calculation is based on a correction formula to which the 'raw' sensor signal and temperature as measured are applied in first and second order terms - along with the 7 calibration parameters.

The measurement procedure of the 'raw' sensor signal and of temperature as well as the correction formula are described in all details in the ZMD31020 Functional description

## 2.9 Digital I<sup>2</sup>C Interface

The 2-wire I<sup>2</sup>C interface encompasses a clock line input SCL and a bi-directional data line SDA.

### 2.9.1 Digital Corrected Sensor Signal Output and I/O for Calibration and Device Test

During normal operation mode (regular sensing operation) the I<sup>2</sup>C interface will output the corrected sensor signal (12 bits) digitally and serially. During calibration the interface is input for the configuration word, output for the 'raw' non-corrected sensor signal as well as for temperature, and finally again input for the calculated calibration parameters as well as the scale limit values and possibly customer-specific identifiers. As a third option, the interface is used to input digital vectors during device test, e.g. to exercise the output DAC, see section 2.10.

### 2.9.2 Data Communication Specifics

An I<sup>2</sup>C bus is controlled by a master device, which generates the clock, controls the bus access, and generates START and STOP conditions. ZMD31020 is designed to work as a slave - thus it will only respond to requests from a master device. Obviously a typical master device during regular sensing operation is a connected electronic controller unit requesting sensor data. (During calibration a connected PC or computer will be the master. During device test the ATE system will be the master.)



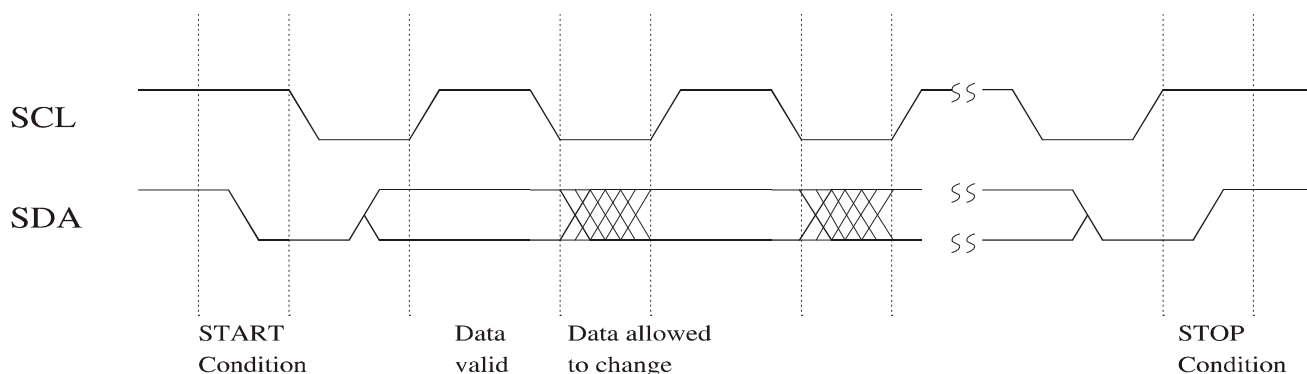
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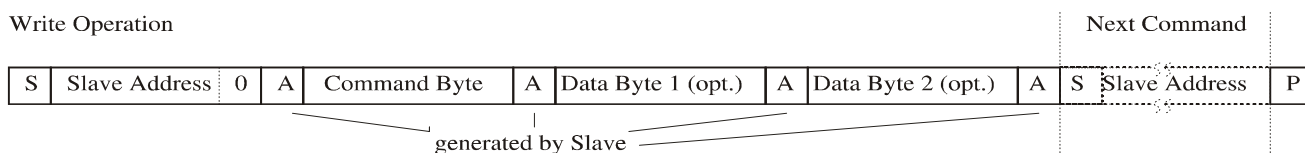
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ZMD31020 complies with the following protocol (for data communication timing details see parameter section):

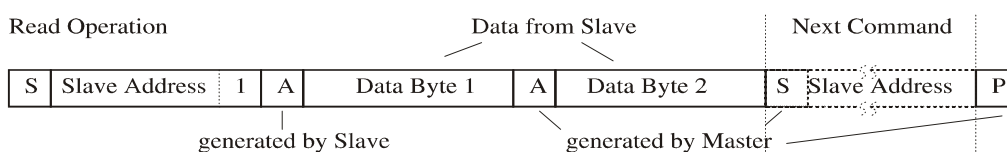
- **Bus not busy:** During idle periods both data line (SDA) and clock line (SCL) remain HIGH.
- **START condition (S):** HIGH to LOW transition of SDA line while clock (SCL) is HIGH is interpreted as START condition. All commands must be preceded by START condition. Master can generate START condition at any time. More than one command can be transmitted without generation of intermediate STOP condition.
- **STOP condition (P):** LOW to HIGH transition of SDA line while clock (SCL) is HIGH determines STOP condition. All command sequences must be ended with STOP condition.
- **Data valid (D):** State of data line represents valid data when, after START condition, data line is stable for duration of HIGH period of clock signal. Data on line must be changed during LOW period of clock signal. There is one clock pulse per bit of data.
- **Acknowledge (A):** Data is transferred in pieces of 8 bits (1 byte) on serial bus, MSB first. After each byte receiving device – whether master or slave – is obliged to pull data line LOW as acknowledge for reception of data. Master must generate an extra clock pulse for this purpose. When acknowledge is missed, slave transmitter becomes inactive. It is on master either to send last command again or to generate STOP condition in that case.
- **Slave address:** Each device connected to bus has unique slave address. After generating START condition, master transmits address consisting of 7-bit slave address and R/W - bit. Addressed slave responds with acknowledge while other slaves on bus become inactive and ignore following data bytes. R/W – bit determines direction of data transfer. If R/W is “0”, data is transmitted from master to slave (write operation). If R/W is “1”, (read operation) data is transmitted from slave to master. Slave address of the IC is hard coded to value 1111000xb.
- **Write operation:** When writing to IC, slave address + R/W - bit (F0h) is followed by command byte and – depending on command – optionally 2 data bytes. Calibration microcontroller reads command byte and executes specific program for each command. Commands available are described below.
- **Read operation:** When R/W – bit is set to “1” (F1h), IC sends 2 data bytes containing contents of output register of serial interface. To read specific data, master must send special commands before reading which instruct calibration microcontroller to place requested data in serial interface output register.



Write Operation



Read Operation



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### 2.10 The Analog Output Stage

ZMD31020's analog output stage consists of an 11-bit resistor-string linear DAC, which converts the MSB-portion of the corrected sensor signal, followed by an output buffer amplifier, designed for full supply voltage range output swing and generating the output voltage  $V_{OUT}$ .

$V_{OUT}$  presents the actual corrected sensor signal as an analog voltage on a linear voltage scale with 11 bits resolution. The output voltage is ratiometric to the supply voltage ( $V_{DDA} - V_{SSA}$ ).

Furthermore it exhibits low- and high-side scale limits; either limit is programmable and clamping to these limit values is performed digitally by the CMC (see section 2.7 and the ZMD31020 Functional Description).

$V_{OUT}$  will change as corrected sensor signal values become available, hence with a refresh rate of about 10ms.

$V_{OUT}$  can source/sink a maximum load current of 2mA.

## 3. ELECTRICAL SPECIFICATION

### 3.1 Absolute maximum ratings (all voltages referred to VSSA)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Analog supply voltage	VDDA		-0.3		6.5	V
Digital supply voltage	VDD	to VSS	-0.3		6.5	V
Voltage at all digital I/O	$V_{D\_I/O}$	to VSS	-0.3		$V_{DD}+0.3$	V
Voltage at all analog I/O	$V_{A\_I/O}$		-0.3		$V_{DDA}+0.3$	V
Guaranteed ESD-immunity		at all pins, HBM	-2		2	kV
Guaranteed latch-up immunity		at all pins	-100		100	mA
Storage temperature	$T_{STG}$		-40		150	°C
Average storage- and operation temperature for 15 years time of operation					100	°C

### 3.2 Operating Conditions

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Supply voltage	$V_{DDA} = V_{DD}$	to $V_{SSA} = V_{SS}$	4.5	5	5.5	V
Ambient temperature	$T_{AMB}$		-40		125	°C
Bridge resistance	$R_{BR}$		1		10	kΩ
Capacitance	$C_{VDD(A)}$	between $V_{DD} = V_{DDA}$ and $V_{SS} = V_{SSA}$	100	220	470	nF

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### 3.3 Electrical Parameters

(for  $T_{AMB} = -40\text{ }^{\circ}\text{C} \dots +125\text{ }^{\circ}\text{C}$ ; supply voltage: 4.5V ... 5.5V; all voltages referred to VSSA = VSS)

#### 3.3.1 Power Supply

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Supply current	$I_{DD} + I_{DDA}$	no sensor, no diode connected; $V_{OUT}$ open			7.7	mA

#### 3.3.2 PGA & 12-bit Input ADC

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Differential input voltage range options @ Input span $V_{IN\ SP} = 52\text{ mV/V}$ ; $a_{IN} = 15.66$						
Diff. inp. volt. range 1	$V_{IN\_DIFF\_1}$	$RS_{ADC} = 15/16$	-3		49	mV/V
Diff. inp. volt. range 2	$V_{IN\_DIFF\_2}$	$RS_{ADC} = 7/8$	-6		46	mV/V
Diff. inp. volt. range 3	$V_{IN\_DIFF\_3}$	$RS_{ADC} = 3/4$	-13		39	mV/V
Diff. inp. volt. range 4	$V_{IN\_DIFF\_4}$	$RS_{ADC} = 1/2$	-26		26	mV/V
Sensitivity	$S_{IN}$	$VDDA = 5V$		73		$\mu\text{V/LSB}$
Differential input voltage range options @ Input span $V_{IN\ SP} = 36\text{ mV/V}$ ; $a_{IN} = 24$						
Diff. inp. volt. range 1	$V_{IN\_DIFF\_1}$	$RS_{ADC} = 15/16$	-2		34	mV/V
Diff. inp. volt. range 2	$V_{IN\_DIFF\_2}$	$RS_{ADC} = 7/8$	-4		32	mV/V
Diff. inp. volt. range 3	$V_{IN\_DIFF\_3}$	$RS_{ADC} = 3/4$	-9		27	mV/V
Diff. inp. volt. range 4	$V_{IN\_DIFF\_4}$	$RS_{ADC} = 1/2$	-18		18	mV/V
Sensitivity	$S_{IN}$	$VDDA=5V$		50		$\mu\text{V/LSB}$
Differential input voltage range options @ Input span $V_{IN\ SP} = 20\text{ mV/V}$ ; $a_{IN} = 42$						
Diff. inp. volt. range 1	$V_{IN\_DIFF\_1}$	$RS_{ADC} = 15/16$	-1		19	mV/V
Diff. inp. volt. range 2	$V_{IN\_DIFF\_2}$	$RS_{ADC} = 7/8$	-2		18	mV/V
Diff. inp. volt. range 3	$V_{IN\_DIFF\_3}$	$RS_{ADC} = 3/4$	-5		15	mV/V
Diff. inp. volt. range 4	$V_{IN\_DIFF\_4}$	$RS_{ADC} = 1/2$	-10		10	mV/V
Sensitivity	$S_{IN}$	$VDDA=5V$		29		$\mu\text{V/LSB}$
Diff. input offset current	$I_{IN\_OFF}$		-10		10	nA

Note, that the parameter " $RS_{ADC}$ " is equal to the former "CRROB".

#### 3.3.3 Temperature Measurement: Current Sources, on-chip Diode & 12-bit ADC <sup>(4)</sup>

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Current source	$I_{TS}$	pin / pad VTN	20	40	55	$\mu\text{A}$
TC current source <sup>(1)</sup>	$TC_{I\_TS}$	pin / pad VTN	-2000		2000	ppm/K
Input voltage range	$V_{TN}$	rel. to $V_{DDB1} = V_{DDB2}$	-810		-200	mV
TC forward drop	$TC_{DROP}$	on-chip temp. sensor	-1.9	-2.1	-2.3	mV/K
Sensitivity	$S_T$	pin / pad VTN	0.84	0.97	1.1	mV/LSB

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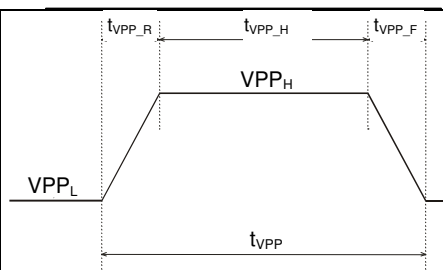
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### 3.3.4 12-bit ADC <sup>(1)</sup>

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
12-Bit sensor signal conversion						
ADC diff. non-lin.	$DNL_p$		-0.5		0.5	LSB
ADC integr. non-lin.	$INL_p$	to best-fit straight line	-0.5		0.5	LSB
10-Bit temperature signal conversion						
ADC diff. non-lin.	$DNL_T$		-0.5		0.5	LSB
ADC integr. non-lin.	$INL_T$	to best-fit straight line	-0.8		0.8	LSB

### 3.3.5 EEPROM programming

PARAMETER	SYM.	MIN.	TYP.	MAX.	
Prog. voltage HIGH level	$V_{PP_H}$	11.75	12.25	12.75	V
Prog. voltage LOW level (conn. to VDD on chip)	$V_{PP_L}$		VDD		V
Prog. cycle duration	$t_{VPP}$	9			ms
Rise time $V_{PP}$	$t_{VPP_R}$	0.5	1	2	ms
Fall time $V_{PP}$	$t_{VPP_F}$	0.5	1	2	ms
Prog. pulse duration	$t_{VPP_H}$	8			ms
Number of write/read cycles				100	
Programming temperature	$T_{PP}$	-40		+85	°C



### 3.3.6 Serial I<sup>2</sup>C Interface

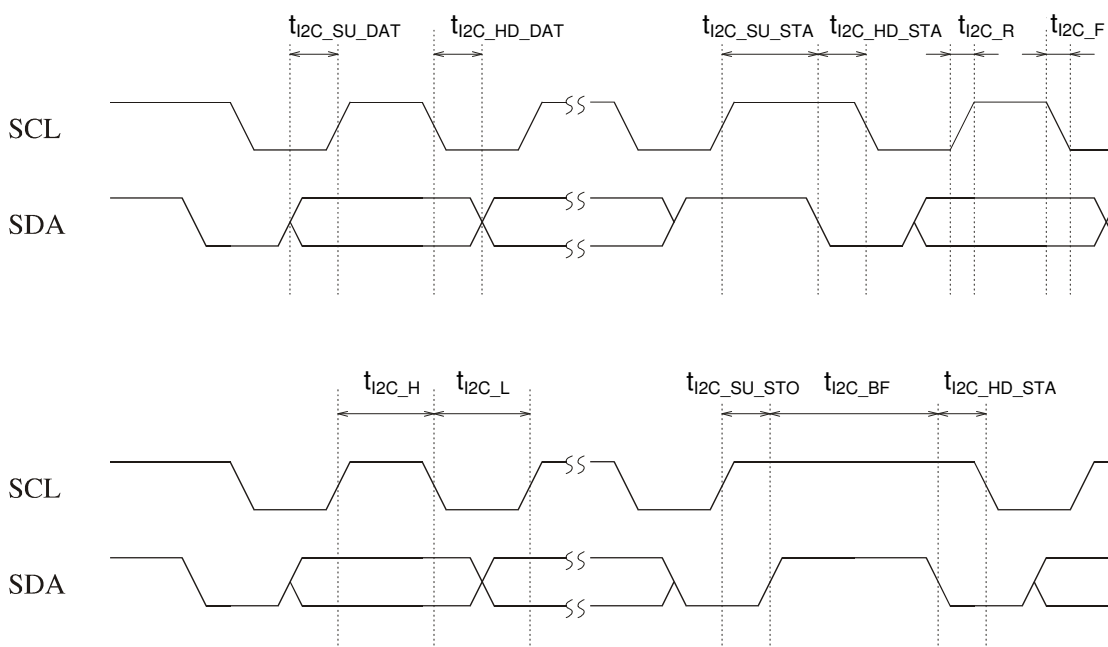
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Input high level	$V_{I2C\_IN\_H}$		0.9		1	$V_{DD}$
Input low level	$V_{I2C\_IN\_L}$		0		0.1	$V_{DD}$
Output low level	$V_{I2C\_OUT\_L}$				0.1	$V_{DD}$
Pull-up-resistance (at SCL and SDA)	$R_{I2C\_SCL/SDA}$		470			$\Omega$
Pull up current	$I_{I2C\_OUT\_H}$	pins SCL and SDA	5		20	$\mu A$
Load capacitance SDA	$C_{SDA}$				400	pF

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#### Timing Characteristics of the serial Interface



PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
SCL clock frequency	$f_{SCL}$		-		100	kHz
Bus free time betw. STOP and START condition	$t_{I2C\_BF}$		4.7			$\mu s$
Hold Time (repeated) START cond.	$t_{I2C\_HD\_STA}$	to first clock pulse	4.0			$\mu s$
LOW period of SCL	$t_{I2C\_L}$		4.7			$\mu s$
HIGH period of SCL	$t_{I2C\_H}$		4.0			$\mu s$
Setup time (repeated) START cond.	$t_{I2C\_SU\_STA}$		4.7			$\mu s$
Data hold time	$t_{I2C\_HD\_DAT}$		0			ns
Data setup time	$t_{I2C\_SU\_DAT}$		250			ns
Rise time of both SDA and SCL	$t_{I2C\_R}$		-		300	ns
Fall time of both SDA and SCL	$t_{I2C\_F}$		-		300	ns
Setup time for STOP condition	$t_{I2C\_SU\_STO}$		4			$\mu s$
Input filter spike suppression / noise interception	$t_{I2C\_NI}$	spikes on SDA or SCL of that length are suppressed			50	ns

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### 3.3.7 11-bit Output DAC & Output BUFFER <sup>(2)</sup>

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Output current	$I_{OUT}$	current source & sink	$\pm 2$			mA
Analog output offset voltage	$V_{OUT\_OFF}$		-10		10	mV
Temp.-coeff output offset voltage	$TC_{OUT\_OFF}$		-10		10	$\mu V/K$
DAC differential nonlinearity	$DNL_{OUT}$		-1		1	LSB
DAC integral nonlinearity	$INL_{OUT}$	to best-fit straight line	-4		4	LSB
Maximal output voltage	$V_{OUT\_MAX}$	$I_{OUTSOURCE} = 2mA$	0.975			$V_{DDA}$
Minimal output voltage	$V_{OUT\_MIN}$	$I_{OUTSINK} = -2mA$			0.025	$V_{DDA}$
$V_{OUT}$ low scale limit	$V_{OUT\_LSL}$	dig. ref.: $p_{min}$	0		0.25	$V_{DDA}$
$V_{OUT}$ high scale limit	$V_{OUT\_HSL}$	dig. ref.: $p_{max}$	0.75		1	$V_{DDA}$
Load resistance	$R_{L\_OUT}$		2.5			k $\Omega$
Load capacitance	$C_{L\_OUT}$		10		25	nF

### 3.3.8 Total System

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Startup time	$t_{STA}$	power up to 1st result			40	ms
Response time	$t_{RESP}$				11	ms
Conversion cycle time	$t_{CYC}$				10	ms
Non-linearity	NL	to best-fit straight line	-2500		+2500	ppm <sup>(3)</sup>
TC sensor signal	$TC_p$				20	ppm/K
TC temperature	$TC_T$				100	ppm/K

#### Notes for the electrical parameters:

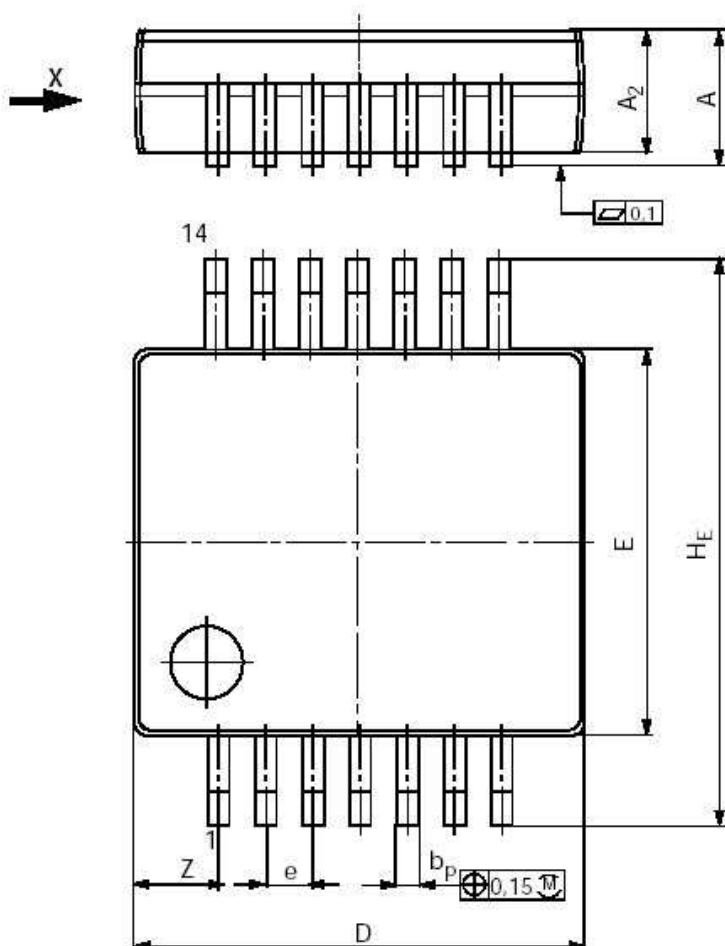
- 1) No measurement in mass production, parameter is guaranteed by design.
- 2) During normal operation mode using the analog output the I<sup>2</sup>C interface allows to read out the output digital value in parallel (= the digital input of the DAC).
- 3) Analog Signal Conditioning and Analog Digital Conversion for Measurement of the Pressure Sensor Bridge
- 4) The A/D conversion of the temperature signal is done with 10 bit resolution only.

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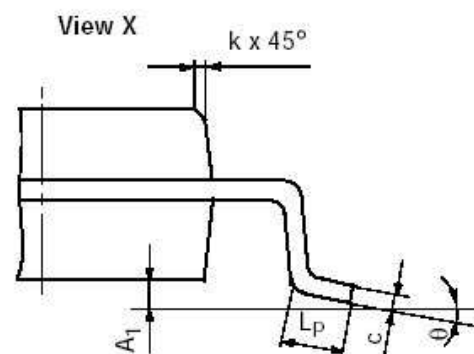
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### 4. PACKAGE DIMENSIONS



Dimensions of Sub-Group B1	
$A_{max}$	1.99
$B_{pmin}$	0.25
$b_{pmax}$	0.38
$e_{nom}$	0.65
$H_{Emin}$	7.65
$H_{Emax}$	7.90
$L_{pmin}$	0.63
$Z_{max}$	1.22



#### SSOP14 (209mil = 5.3mm)

weight:  $\leq 0.3g$   
package body material: low stress epoxy  
lead material: FeNi-Alloy or Cu-Alloy  
lead finish: solder plating  
lead form: Z-bends

Dimensions of Sub-Group C1	
$A_{min}$	1.73
$A_{1min}$	0.05
$A_{1max}$	0.21
$A_{2min}$	1.68
$A_{2max}$	1.78
$C_{min}$	0.09
$C_{max}$	0.20
$D_{min}^*$	6.07
$D_{max}^*$	6.33
$E_{min}^*$	5.20
$E_{max}^*$	5.38
$k_{min}$	0.25
$\theta_{min}$	0°
$\theta_{max}$	10°

All dimensions in mm, reference: DIN EN 190000

\* without mold-flesh



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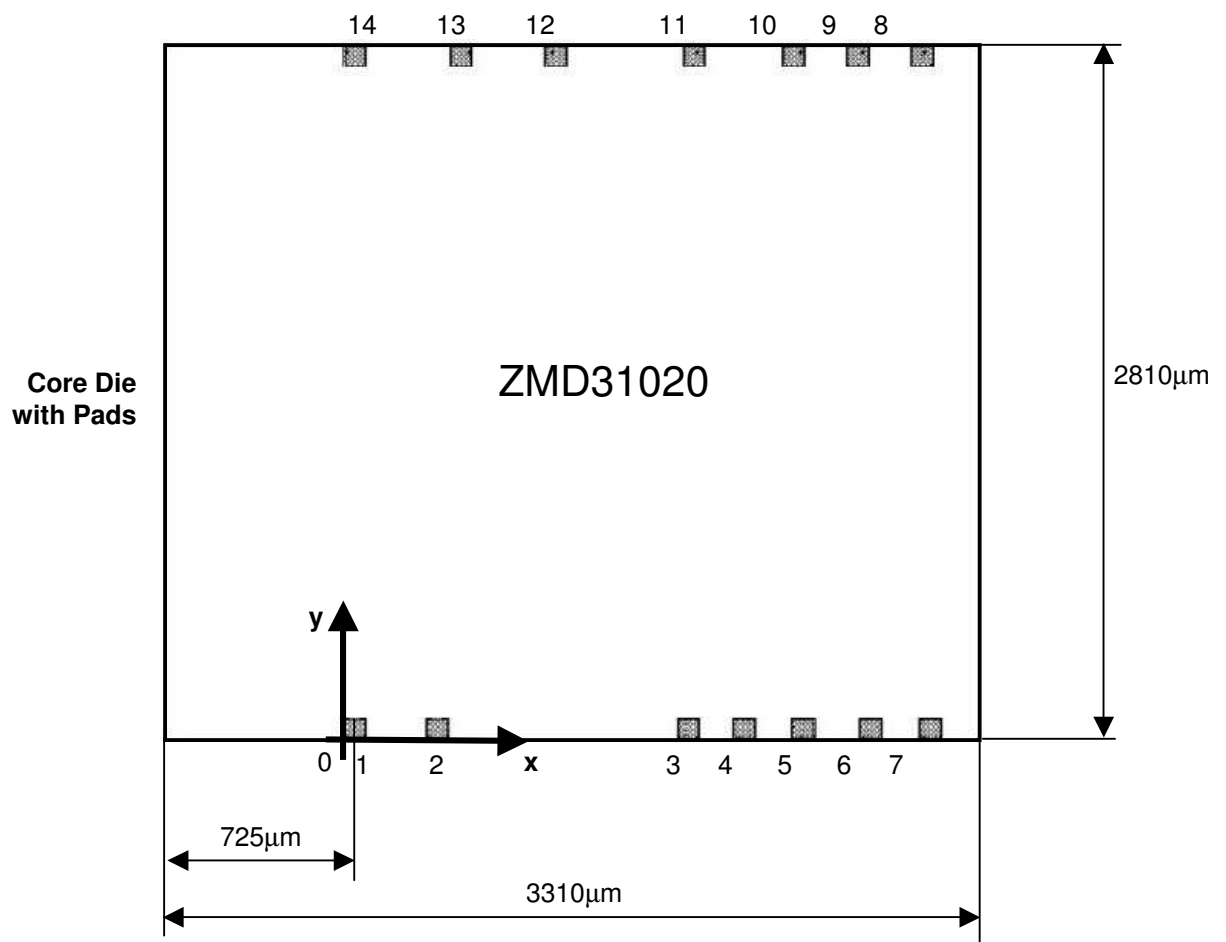
## Sensor Signal Conditioner

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### 5. DIE DIMENSIONS AND PAD COORDINATES

#### 5.1 Die Dimensions

- Die size (incl. scribeline):  $3500\mu\text{m} \times 3000\mu\text{m} = 10.5\text{sqmm}$
- Core die size (without scribeline):  $3310\mu\text{m} \times 2810\mu\text{m} \approx 9.3\text{sqmm}$
- Die thickness:  $390\mu\text{m}$
- Scribeline (distance between two core dice on wafer):  $190\mu\text{m}$
- Pads size:  $90\mu\text{m} \times 90\mu\text{m}$



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### 5.2 Pad Coordinates

All pad coordinates refer to the pad centers and related to the left bottom corner of pad 1.

PIN-No.	PIN Name	Pad coordinates $\mu\text{m}$	
		X	Y
1	VOUT	45	45.00
2	VDDA	380.2	45.00
3	VDD	1403.30	45.00
4	VSS	1627.40	45.00
5	SCL	1868.8	45.00
6	SDA	2143.8	45.00
7	VPP	2385.3	45.00
8	VBN	2353.4	2763.00
9	VDDB2	2091.6	2763.00
10	VTN	1829.5	2763.00
11	VDDB1	1426.7	2763.00
12	VBP	864.1	2763.00
13	VSSB	478	2763.00
14	VSSA	48.1	2763.00

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### 6. EVALUATION KIT “ZMD31020KIT”

An evaluation kit is offered, see the illustration below. The Kit provides easy evaluation and experimental calibration of a sensor element / ZMD31020 combination. It contains a modular calibration board, a CD-ROM (calibration program, USB port driver, technical documentation), an USB cable and some finished samples in SSOP14 package. The evaluation kit is described in detail in its technical documentation.

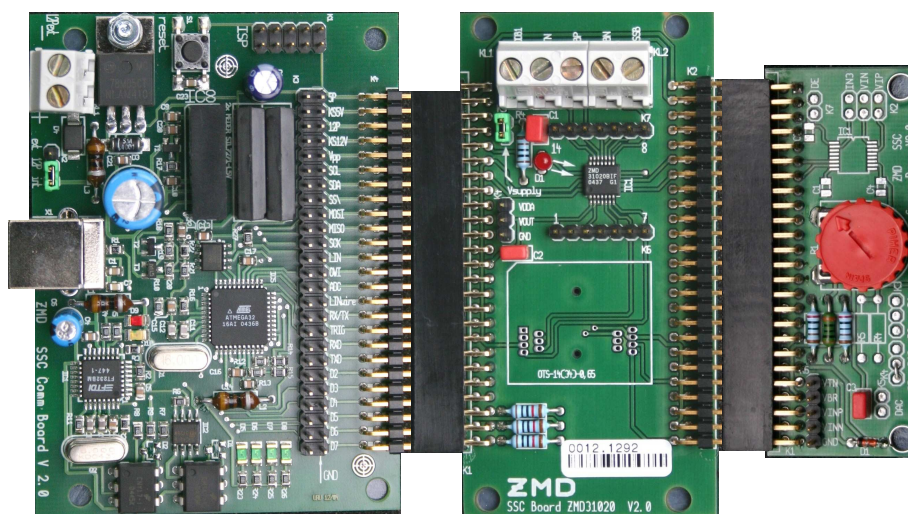


Fig. 3: Evaluation Kit „ZMD31020KIT“ (Hardware)

#### Important Note:

The Evaluation Kit is not intended to be used for industrial sensor calibration in serial production. If components of the Evaluation Kit are used for this purpose then an EEPROM programming pulse like specified in section 3.3.5 has to be assured. Otherwise the EEPROM data preservation may be affected.

For industrial sensor calibration ZMD and its partners offer a comprehensive support for the development of the required hard- and software. Please contact the ZMD sales offices for detailed information.

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### 7. ORDERING INFORMATION

Ordering Code	Description	Operation Temp.	Package	Marking	Shipping Form *
ZMD31020BCB	dice on tested unsawn wafer	0...+70 °C	die		6" wafer
ZMD31020BCC	dice on tested sawn wafer	0...+70 °C	die		plastic frame
ZMD31020BCD	dice in waffle tray	0...+70 °C	die		waffle tray (100 dice / tray)
ZMD31020BCF-T	finished parts in tube	0...+70 °C	SSOP14 (5.3mm)	ZMD 31020BCF	tube (77 parts / tube)
ZMD31020BCF-R	finished parts in tape on reel	0...+70 °C	SSOP14 (5.3mm)	ZMD 31020BCF	tape on reel (2000 parts / reel)
ZMD31020BIB	dice on tested unsawn wafer	-40...+125 °C*	die		6" wafer
ZMD31020BIC	dice on tested sawn wafer	-40...+125 °C*	die		plastic frame
ZMD31020BID	dice in waffle tray	-40...+125 °C*	die		waffle tray (100 dice / tray)
ZMD31020BIF-T	finished parts in tube	-40...+125 °C*	SSOP14 (5.3mm)	ZMD 31020BIF	tube (77 parts / tube)
ZMD31020BIF-R	finished parts in tape on reel	-40...+125 °C*	SSOP14 (5.3mm)	ZMD 31020BIF	tape on reel (2000 parts / reel)
ZMD31020KIT	evaluation kit				box, containing PCB, CD, USB cable and SSOP14 samples

Deviant from the regular industrial operation temperature range of -25 to +85 °C the ZMD31020 industrial version is specified for -40 to +125 °C.

\* The quantity ordered should be a multiple of the quantity / packing unit as specified

### 8. RELATED DOCUMENTS

- ZMD31020 Software description
- ZMD31020 Functional description
- ZMD31020 Response time (application note)

The information furnished here by ZMD is believed to be correct and accurate. However, ZMD shall not be liable to any licensee or third party for any damages, including, but not limited to, personal injury, property damage, loss of profits, loss of use, interruption of business or indirect, special, incidental, or consequential damages of any kind in connection with or arising out of the furnishing, performance, or use of this technical data. No obligation or liability to any licensee or third party shall result from ZMD's rendering of technical or other services.

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