ZMD31050 RB^{IC}series

Advanced Differential Sensor Signal Conditioner

Datasheet PRELIMINARY

Features

- Digital compensation of sensor offset, sensitivity, temperature drift and non-linearity
- Accommodates nearly all bridge sensors by PGA and programmable ADC
- Capable with sensor signals from 1 up to 275mV/V span
- Sensor connections check and aging detection
- Selectable temperature compensation reference: bridge, thermistor, internal diode or external diode
- Output options: voltage (0...5V), current (4...20mA), PWM, I^{2}C, SPI, ZACwire^{TM} (one-wire-interface), alarm
- Adjustable output resolution (up to 15 bits) versus sampling rate (up to 3.9kHz)
- Selectable bridge excitation: ratiometric voltage, constant voltage or constant current
- Input channel for separate temperature sensor
- Operation temperature -40...+125°C (-50...+150°C derated)
- Supply voltage +2.7V...+5.5V
- Available in SSOP16 or as die

Benefits

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

Brief Description

The ZMD31050 is a CMOS integrated circuit that belongs to ZMD's RB^{IC}series. It performs highly-accurate amplification/scaling and sensor-specific correction of bridge sensor signals.
Digital compensation of sensor offset, sensitivity, temperature drift and non-linearity is accomplished via a 16-bit RISC micro-controller running a correction algorithm with calibration coefficients stored in non-volatile EEPROM.

The ZMD31050 accommodates virtually any bridge sensor (e.g. piezo-resistive, ceramic-thickfilm or steel membrane based). In addition, the IC can interface a separate temperature sensor.

The bi-directional digital interfaces (I^{2}C, SPI, ZACwire^{TM}) can be used for a simple PC-controlled calibration, in order to program a set of calibration coefficients into an on-chip EEPROM. Thus a specific sensor and a ZMD31050 are mated digitally: fast, precise and without the cost overhead associated with laser trimming, or mechanical potentiometer methods.

- **Application kit available (SSOP16 samples, calibration PCB, calibration software, technical documentation)**
- **Support for industrial mass calibration available**
- **Quick circuit customization possible for large production volumes**

Application Circuit (Examples)

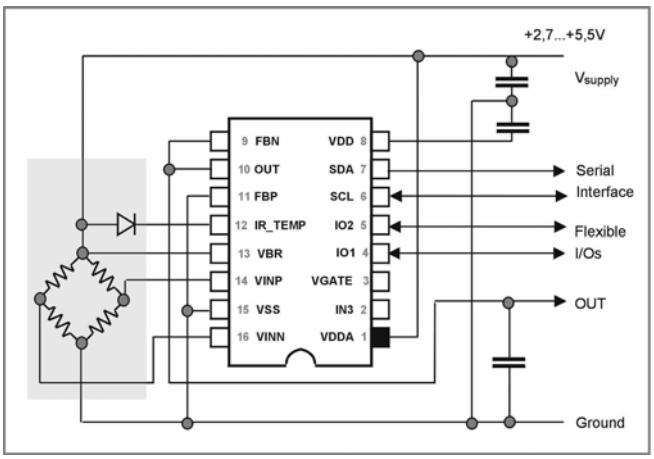


Fig.1: Ratiometric measurement with voltage output, temperature compensation via external diode

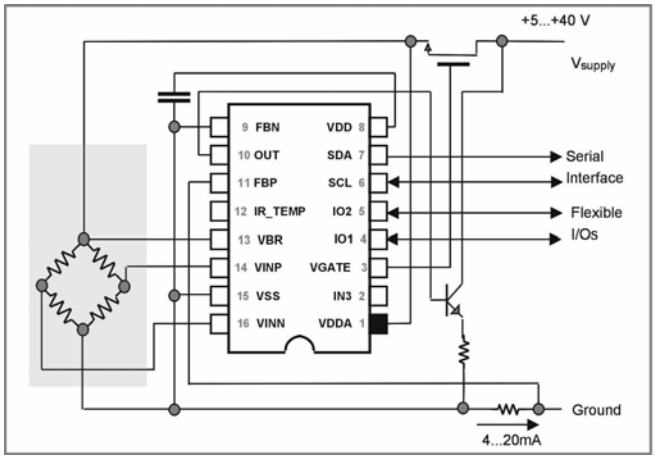


Fig.2: Two wire 4...20mA (5...40V) configuration. Temperature compensation via internal diode

ZMD31050 RB^{IC}series

Advanced Differential Sensor Signal Conditioner

Datasheet PRELIMINARY

Contents

1. Circuit Description

1.1 Signal Flow

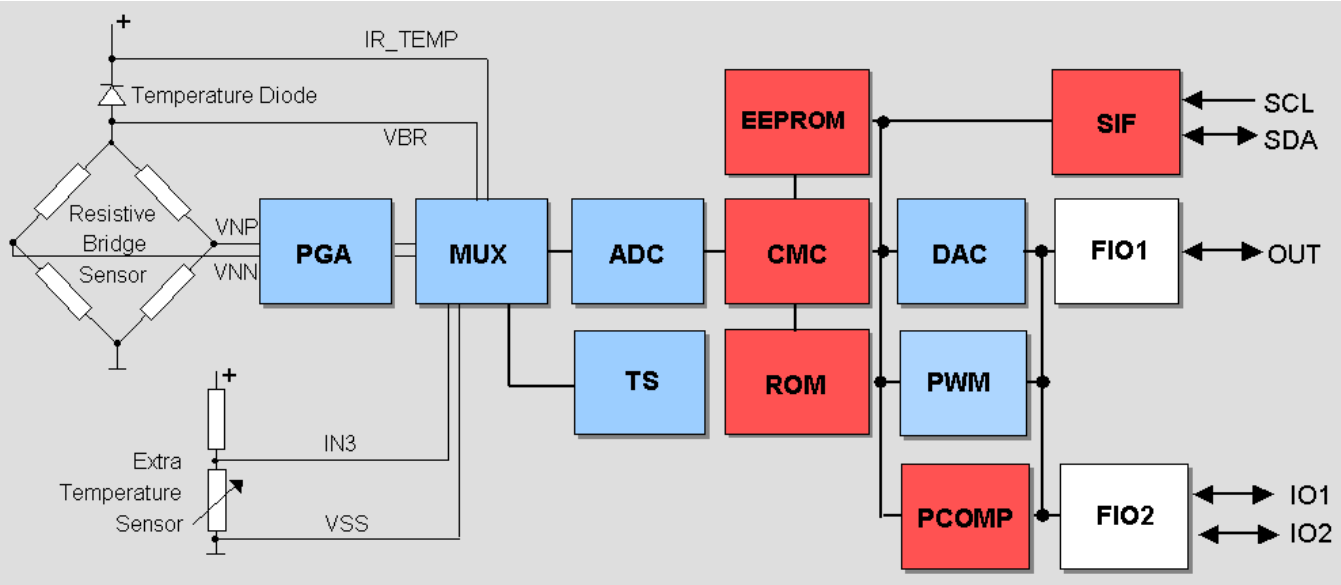


Fig.3: Block diagram of ZMD31050

PGA	programmable gain amplifier
MUX	multiplexer
ADC	analog-to-digital converter
CMC	calibration microcontroller
DAC	digital-to-analog converter
FIO1	flexible I/O 1: analog out (voltage/current), PWM2, ZACwire™ (one-wire-interface)
FIO2	flexible I/O 2: PWM1, SPI data out, SPI slave select, Alarm1, Alarm2
SIF	serial interface: I2C data I/O, SPI data in, clock
PCOMP	programmable comparator
EEPROM	for calibration parameters and configuration
TS	on-chip temperature sensor (pn-junction)
ROM	for correction formula and –algorithm
PWM	PWM module

The ZMD31050's signal path is partly analog (blue) and partly digital (red).
The differential signal from the bridge sensor is pre-amplified by the programmable gain amplifier (PGA). The Multiplexer (MUX) transmits the signals from bridge sensor, external diode or separate temperature sensor to the ADC in a certain sequence (instead of the temp. diode the internal pn-junction (TS) can be used optionally). Afterwards the ADC converts these signals into digital values. 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 sensor-specific coefficients (stored into the EEPROM during calibration).

Dependent on the programmed output configuration the corrected sensor signal is output as analog value, as PWM signal or in digital format (SPI, I^2C, ZACwire™). The output signal is provided at 2 flexible I/O modules (FIO) and at the serial interface (SIF). The configuration data and the correction parameters can be programmed into the EEPROM via the digital interfaces.
The modular circuit concept enables fast custom designs varying these blocks and, as a result, functionality and die size.

1.2 Application Modes

For each application a configuration set has to be established (generally prior to calibration) by programming the on-chip EEPROM regarding to the following modes:

- Sensor channel
  - Sensor mode: ratiometric voltage or current supply mode.
  - Input range: The gain of the analog front end has to be chosen with respect to the maximum sensor signal span and the zero point of the ADC has to be set with respect to the possible input voltage range
  - Additional offset compensation: The extended analog offset compensation has to be enabled if required, e.g. if the sensor offset voltage is near to or larger than the sensor span.
  - Resolution/response time: The A/D converter has to be configured for resolution and converting scheme (first or second order). These settings influence the sampling rate, signal integration time and this way the noise immunity
  - Sample order: The order and interval of multiplexed measurements (pressure, temperature, auto zero) has to be set
- Analog output
  - Choice of output method (voltage value, current loop, PWM) for output register 1.
  - Optional choice of additional output register 2: PWM module via IO1 or alarm out module via IO1/2.
- Digital communication: The preferred protocol and its parameter have to be set.
- Temperature
  - The temperature measure channel for the temperature correction has to be chosen.
  - Optional: the temperature measure channel as the second output has to be chosen.
- Supply voltage : For non-ratiometric output the voltage regulation has to be configured.

Note: *Not all possible combinations of settings are allowed (see section 1.5).*

The calibration procedure must include
  - the set of coefficients of calibration calculation

and depending on configuration,
  - the adjustment of the extended offset compensation,
  - the zero compensation of temperature measurement,
  - the adjustment of the bridge current

and if necessary
  - the set of thresholds and delays for the alarms,
  - the reference voltage.

1.3 Analog Front End (AFE)

The analog front end consists of the programmable gain amplifier (PGA), the multiplexer (MUX) and the analog-to-digital converter (ADC).

1.3.1. Programmable Gain Amplifier

The following table shows the adjustable gains and the processable sensor signal spans.

No.	PGA Gain	Max. span in mV/V
1	420	2
2	300	2.8
3	210	4
4	150	5.6
5	105	8
6	75	11.2
7	52.5	16
8	37.5	22.4
9	21.75	32
10	14	45
11	10	64
12	7	90
13	3	275

Table 1: Adjustable gains and processable sensor signal spans

1.3.2. Measurement Cycle Realized by Multiplexer

The Multiplexer selects, depending on EEPROM settings, the following inputs in a certain sequence.

- Pre-amplified bridge sensor signal
- Bridge temperature signal measured by external diode
- Bridge temperature signal measured by internal pn-junction
- Bridge temperature signal measured by bridge resistors
- Separate temperature signal measured by external thermistor
- Internal offset of the input channel measured by input short circuiting

The complete measurement cycle is controlled by the CMC. The cycle diagram at the right shows its principle structure.

The EEPROM adjustable parameters are:

- Pressure measurement count, n=<1,2,4,8,16,32,64,128>
- Enable temperature measurement 2, e2=<0,1>

After Power ON the start routine is called. It contains the pressure and auto zero measurement. When enabled it measures the temperature and its auto zeros.

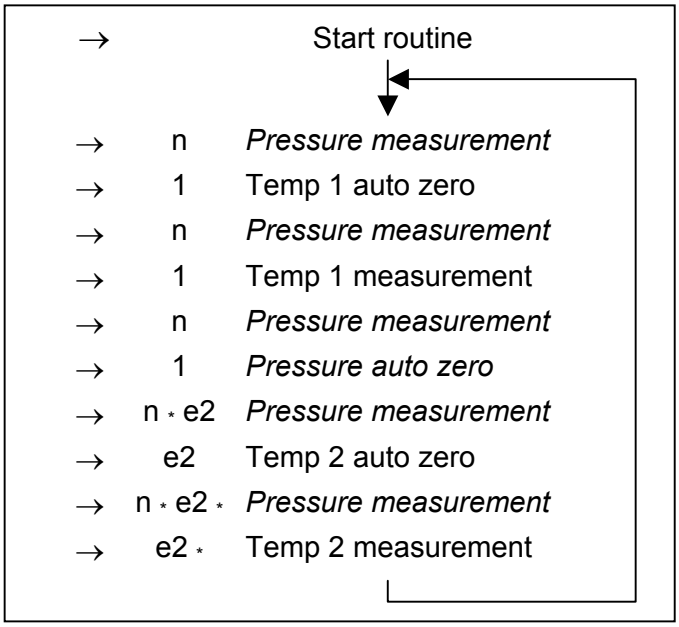


Fig. 4: Measurement cycle ZMD31050

1.3.3. Analog Offset Compensation

The bridge sensor offset is cancelled by the analog offset compensation in the AFE (coarse offset removal) and by the digital correction in the CMC (offset fine tuning).
The analog offset compensation in the AFE can be adjusted by 6 EEPROM bits. It allows a zero point shift up to 300% of the processable signal span.
The zero point shift of the temperature measurements can also be adjusted by 6 EEPROM bits.

1.3.4. Analog-to-Digital Converter

The ADC is a charge balancing converter in full differential switched capacitor technique. It can be used as first or second order converter:

In the **first order** mode it is inherently monotone and insensitive against short and long term instability of the clock frequency. The conversion time depends on the desired resolution and can be roughly calculated by:

$$t_c = 2^R\ \mu s$$

The available resolutions are R=<9,10,11,12,13,14,15>.

The result of the AD conversion is a relative counter result corresponding to the following equation:

$$VIN /VREF = ZOUT/N - ZS$$

ZOUT: number of counts (result of the conversion)
N: total number of counts (=2^R)
VIN: differential input voltage of ADC
VREF: differential reference voltage
ZS: zero point shift (ZS=$^1/_{16}$, $^1/_8$, $^1/_4$, $^1/_2$, controlled by the EEPROM content)

With the ZS value a sensor input signal can be shifted in the optimal input range of the ADC.

In the **second order** mode two conversions are stacked with the advantage of much shorter conversion time and the drawback of a lower noise immunity caused by the shorter signal integration period. The conversion time at this mode is roughly calculated by:

$$t_c = 2^{(R+3)/2}\ \mu s$$

The available resolutions are R=<10,11,12,13,14,15>. The result of the AD conversion is a relative counter result corresponding to the following equations:

$$VIN /VREF = ZOUT/N – ZS$$

$$ZOUT = Z1 * (N2/2) + Z2$$

$$N = N1 * N2$$

Z1: number of counts (result of the 1st conversion)
Z2: number of counts (result of the 2nd conversion)
N1: total number of counts 1st conversion (=$2^{(R+1)/2}$)
N2 total number of counts 2nd conversion (=$2^{(R+1)/2}$)
VIN: differential input voltage of ADC
VREF: differential reference voltage
ZS: zero point shift (RS=$^1/_{16}$, $^1/_8$, $^1/_4$, $^1/_2$, controlled by the CMC)

Note: The AD conversion time is only a part of a whole sample cycle. Thus the sample rate is lower then the AD conversion rate.

ADC		Max. Output Resolution			Sample Rate
Order	Resolution*	Digital	Analog	PWM	
	Bit	Bit	Bit	Bit	Hz
1	9	9	9	9	1302
	10	10	10	10	781
	11	11	11	11	434
	12	12	11	12	230
	13	13	11	12	115
	14	14	11	12	59
	15	15	11	12	30
2	10	10	10	10	3906
	11	11	11	11	3906
	12	12	11	12	3906
	13	13	11	12	1953
	14	14	11	12	1953
	15	15	11	12	977

Table 2: Output resolution versus sample rate

*ADC Resolution should be 1 or 2 Bits higher then applied Output Resolution

1.4 System Control

The system control has the following features:

- Control of the I/O relations and of the measurement cycle regarding to the EEPROM-stored configuration data
- 16 bit correction calculation for each measurement signal using the EEPROM stored calibration coefficients and ROM-based algorithms
- Started by internal POC, internal clock - generator or external clock
- For safety improvement the EEPROM data are proved with a signature within initialization procedure, the registers of the CMC are steadily observed with a parity check. Once an error is detected, the error flag of the CMC is set and the outputs are driven to a diagnostic value

Note: *The conditioning includes up to third order sensor input correction. The available adjustment ranges depend on the specific calibration parameters, a detailed description will be issued later. To give a rough idea: Offset compensation and linear correction are only limited by the loose of resolution it will cause, the second order correction is possible up to about 30% full scale difference to straight line, third order up to about 20%. The temperature calibration includes first and second order correction and should be fairly sufficient in all relevant cases.*

1.5 Output Stage

	Used serial IF		Used I/O pins			
No.	I²C	SPI	OUT	IO1	IO2	SDA
1	X					Data I/O
2	X			ALARM1		Data I/O
3	X				ALARM2	Data I/O
4	X			ALARM1	ALARM2	Data I/O
5	X			PWM1		Data I/O
6	X			PWM1	ALARM2	Data I/O
7	X		Analog			Data I/O
8	X		Analog	ALARM1		Data I/O
9	X		Analog		ALARM2	Data I/O
10	X		Analog	ALARM1	ALARM2	Data I/O
11	X		Analog	PWM1		Data I/O
12	X		Analog	PWM1	ALARM2	Data I/O
13	X		PWM2			Data I/O
14	X		PWM2	ALARM1		Data I/O
15	X		PWM2		ALARM2	Data I/O
16	X		PWM2	ALARM1	ALARM2	Data I/O
17	X		PWM2	PWM1		Data I/O
18	X		PWM2	PWM1	ALARM2	Data I/O
19		X		Data out	Slave select	Data in
20		X		Data out ALARM1	Slave select -	Data in -
21		X		Data out PWM1	Slave select -	Data in -
22		X	Analog	Data out	Slave select	Data in
23		X	Analog	Data out ALARM1	Slave select -	Data in -
24		X	Analog	Data out PWM1	Slave select -	Data in -
25		X	PWM2	Data out	Slave select	Data in
26		X	PWM2	Data out ALARM1	Slave select -	Data in -
27		X	PWM2	Data out PWM1	Slave select -	Data in -

Table 3: Output configurations overview

The ZMD31050 provides the following I/O pins: OUT, IO1, IO2 and SDA.

Via these pins the following signal formats can be output: Analog (voltage/current), PWM, Data (SPI/I²C), Alarm.

The following values can be provided at the O/I pins: bridge sensor signal, temperature signal 1, temperature signal 2, alarm.

Note:
The Alarm signal only refers to the bridge sensor signal, but never to a temperature signal.

Due to the necessary pin sharing there are restrictions to the possible combinations of outputs and interface connections.
The table beside gives an overview about possible combinations.

Note:
In the SPI mode the pin IO2 is used as Slave select. Thus no Alarm 2 can be output in this mode.

1.5.1. Serial Digital Interface

The ZMD31050 includes a serial digital interface which is able to communicate in three different communication protocols – I^{2}C^{TM}, SPI^{TM} and ZACwire^{TM} (one wire communication).
In the SPI mode the pin IO2 operates as slave select input, the pin IO1 as data output.

Initializing Communication

After power-on the interface is for about 20ms (start window) in the state ZACwire. During the start window it is possible to communicate via the one wire interface (pin OUT).
Detecting a proper request inside the start window the interface stays in the state ZACwire. This state can be left by certain commands or a new power-on.
If no request happens during the start window then the serial interface switches to I^{2}C or SPI mode (depending on EEPROM settings) and the OUT pin is used as analog output or as PWM output (also depending on EEPROM settings.
The start window can generally be disabled (or enabled) by a special EEPROM setting.

1.5.2. ZACwire^{TM} Single Wire Digital Interface

The ZMD31050 employs ZMD's ZACwire^{TM} single wire digital interface concept. It combines a simple and easy protocol adaptation with a cost saving pin sharing.
Both the analog voltage output and digital interface (calibration and/or digital output value) occur over the same pin. An advantage of ZMD's ZACwire^{TM} output signal capability is, that it enables "end of manufacture" calibration – no additional pins are required to digitally calibrate a finished assembly. This reduces cost and complexity.
The ZACWIRE interface is intended for calibration use only although the calibrated output signal is also available via this interface. The master slave configuration is shown below.

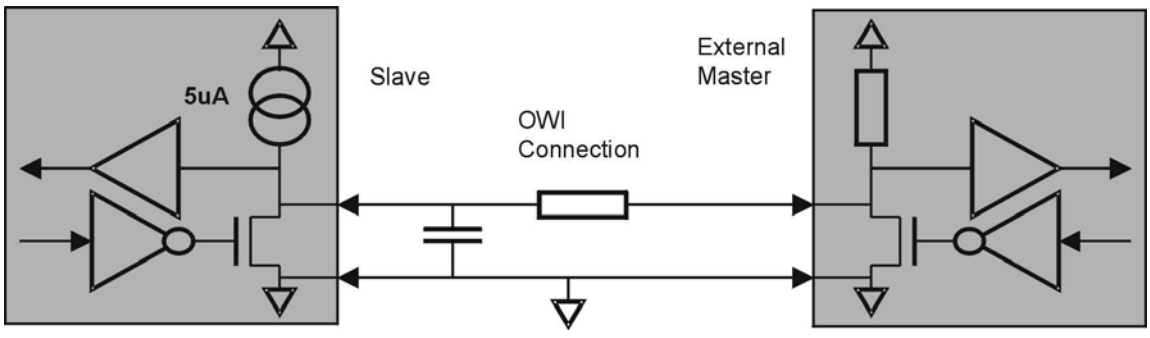


Fig. 6 Block scheme of ZACWIRE - connection

Protocol Description

Both devices are peers, however only the external device starts communication and requests data, in this sense it is referred to as master and the ZMD31050 as slave.
Though ZACwire™ is designed as bilateral protocol, it is necessary for reasons of compatibility to use an address in the communication. After the start condition the master has to send an address-byte, consisting of a 7 bit slave address and a read/write–bit (0 – write, 1 – read). The slave–address of the ZMD31050 is 78hex, additionally 127 free programmable addresses (00hex to 7Fhex) are available.

General properties & Timing

BUS not busy: ZACWIRE line is pulled to HIGH in idle period.

Start - condition (START): A START will be recognized if a LOW-impulse on ZACWIRE follows a power on.

Stop- condition (STOP): A STOP will be recognized when no transition on ZACWIRE happens for at least about 250µs or twice the BIT – time of the last valid data bit, i.e. the time distance between the last two LOW-HIGH transitions. The master finishes every transmission by going back to HIGH (pull up). It can interrupt slave in read mode by holding down the ZACWIRE potential for the stop time.

Valid data: Data will be recognized whenever two LOW-HIGH transitions follow a start condition, when the length of the pulse is longer than 1/8 and shorter than 7/8 of the distance inbetween these LOW-HIGH transitions (t_{Bit}). Pulses of 1/8 to 3/8 t_{Bit} are defined as LOW, pulses of 5/8 to 7/8 t_{Bit} as HIGH.

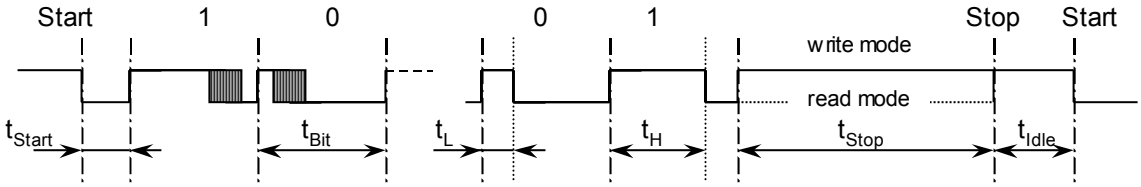


Fig. 7 Protocol Structure

Write operation: During transmission from master to slave (WRITE) the address byte follows a command byte. Depending on the transmitted command optional 2 data bytes are possible. The internal microprocessor evaluates the received command and processes the related routine.

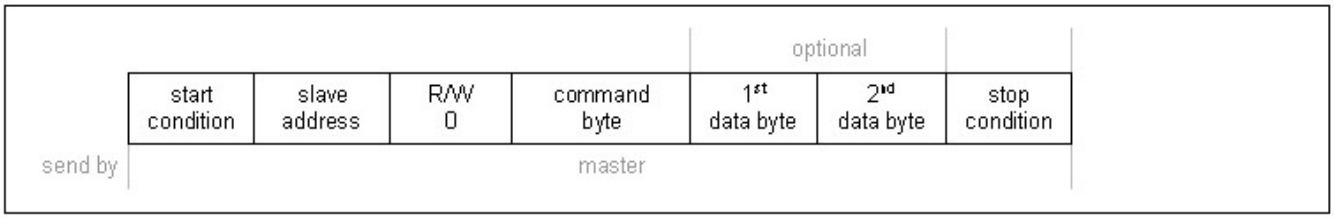


Fig. 8 Write operation

Read operation: After a data request from master to slave (by sending an address byte including a set data direction bit) the slave answers by sending data from the activated interface output registers. The slave generates the data bits with a bit period equal to the last received bit (R/W bit). The master has to generate a stop condition after receiving the requested data.
A data request is answered by the interface module itself and does consequently not interrupt the current process of the internal microprocessor.
The data in the activated registers is sent continuously until a stop condition is detected. After transmitting all available data the slave starts repeating the data.
During running measurement cycle data is incessantly updated with conditioning results. To get other data from slave (e.g. EEPROM content) usually a certain command has to be sent before the data request to initiate the transfer of this data to the interface output registers. This command does interrupt the current process of the internal microprocessor and consequently also a running measurement cycle.

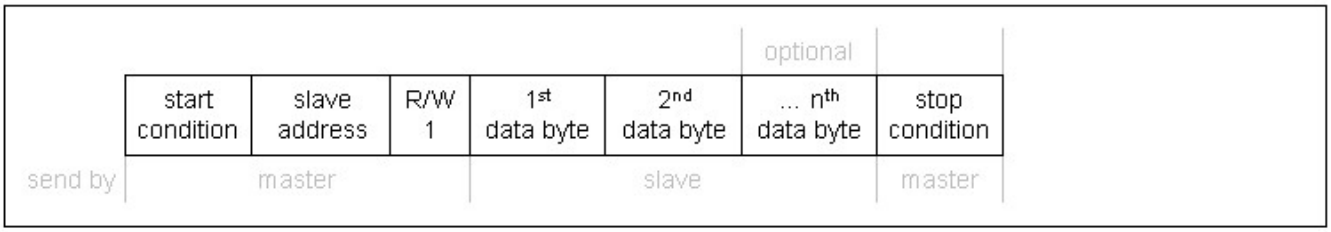


Fig. 9 Read operation - data request

1.5.3. Analog Output

For the analog output 3 registers of 12 bit depth are available, which can store the actual pressure and the results of temperature measurement 1 and 2. Each register can be independently switched to one of two output slots connected to the Pin OUT and IO1 respectively. In these output slots different output modules are available according to the following table:

Output slot:	OUT	IO1
Voltage	x	
PWM	x	x

Table 5:Analog output configuration

The Voltage module consists of an 11bit resistor string - DAC with buffered output and a subsequent inverting amplifier with class AB rail-to-rail OPAMP. The two feedback nets are connected to the Pins FBN and FBP. This structure offers wide flexibility for the output configuration, for example voltage output and 4 to 20 mA current loop output.

The PWM module provides pulse streams with signal dependent duty cycle. The PWM - frequency depends on resolution and clock divider. The maximum resolution is 12 bit, the maximum PWM - frequency is 4 kHz (9 bit). If both, second PWM and SPI protocol are activated, the output pin IO1 is shared between the PWM output and the SPI_SDO output of the serial interface (Interface communication interrupts the PWM output).

1.5.4. Comparator Module (ALARM Output)

The comparator module consists of two comparator channels connectable to IO1 and IO2 respectively. Each of them can be independently programmed referring to the parameters threshold, hysteresis, switching direction and on/off – delay, additional a window comparator mode is available.

1.6 Voltage Regulator

For ratiometric applications 3V to 5V (+/- 10%) the external supply voltage can be used for sensor element biasing. If an absolute analog output is desired then the internal voltage regulator with external power regulation element (FET) can be used. It is bandgap reference based and designed for an external supply range from Vdda + 2V to 40V. With the voltage regulator the internal supply and sensor bridge voltage can be varied between 3V and 5V.

1.7 Error Detection

A check of the sensor bridge for broken wires which is done permanently by two comparators watching the input voltage of each input (between 0.5V … VDDA-0.5V).
This error states as well as the digital errors (CRC, parity) are indicated by forcing the output voltage into the diagnostic region, which is above 97.5% and below 2.5% of the VDDA supply. The following table shows the system response for different faults.

Detected fault	Diagnostic level on analog out	Delay of detection
Signature error of EEPROM	lower	1ms
Parity error of RAM	lower	1ms
Lost of bridge positive supply	upper	1ms
Lost of bridge negative supply	upper	1ms
Open bridge connection	upper	1ms

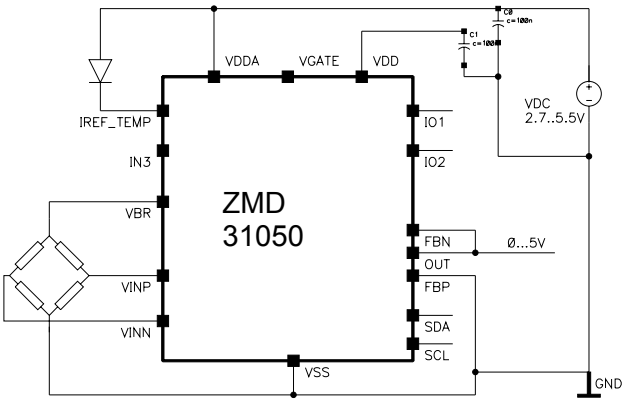
Table 6: System response for different diagnostic faults

The ZMD31050 detects various possible errors. A detected error is signalized by changing into a diagnostic mode. In this case the analog output is set to High or Low (maximum or minimum possible output value) and the output registers of the digital serial interface are set to a significant error code (see Table 7). Note that the error detection functionality (except the CRC-check regarding the EEPROM content) has to be enabled by configuration words.

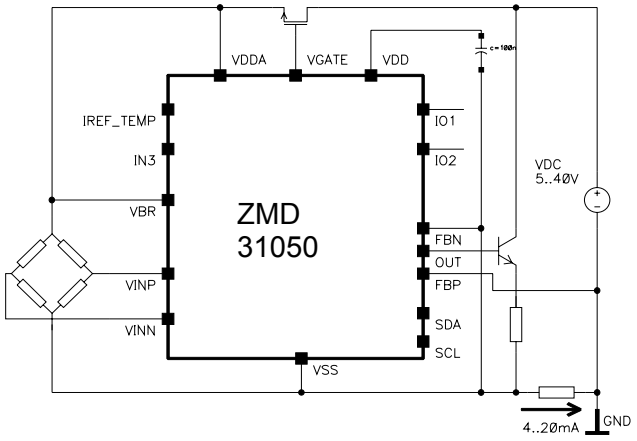
Detectable Error	Description	Sets SIF-Out to	Sets Analog Out to Diagnostic Mode
CRC-Error	CRC-Check during read out of EEPROM after Power On or after SIF-Command COPY_EEP2RAM	CAAA	Low
RAM Parity Error	Parity-Check at every RAM access (Enabled by CFGAPP:SCCD)	CF0F	Low
Register Parity Error	Permanent Parity-Check of Configuration Registers (Enabled by CFGAPP:SCCD)	CE38	Low
Sensor Connection	Connection-Check of Sensor Bridge (Enabled by CFGAPP:SCCD)	CFCF	High
Common Mode Voltage out of limits	Check if Bridge Common Mode Voltage is complies the programmed limits (Enabled by CFGCYC:ECMV)	E000 + $V_{CM,13bit}$ $V_{CM,13bit}$: Measured Common Mode Voltage (13 significant Bits)	High

Table 7:Error Codes

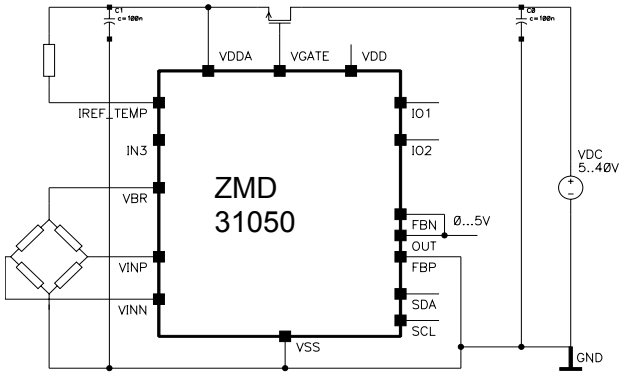
2. Application Circuit Examples



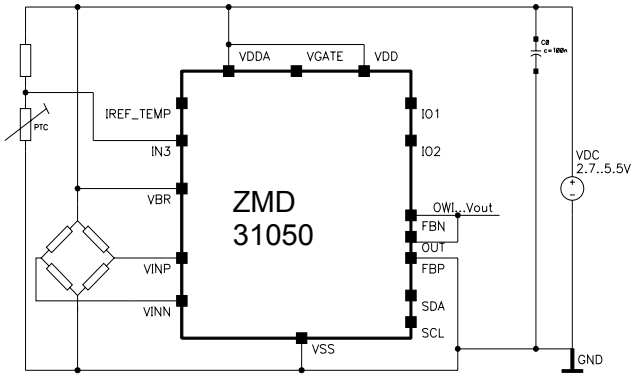
Example 1
Typical ratiometric measurement with voltage output, temperature compensation via external diode, internal vdd regulator and supply lost diagnosis (bridge must not be at Vdda) is used



Example 2
True two wire 4...20mA (5...40V) configuration, voltage regulation using external JFET, internal temperature measurement, internal Vdd regulator is used



Example 3
Absolute voltage output, constant current biasing of the sensor bridge, temperature compensation by bridge voltage drop measurement



Example 4
Ratiometric measurement, 3 – wire connection for end of line calibration of the sensor module, temperature measurement with external voltage divider incl. thermistor

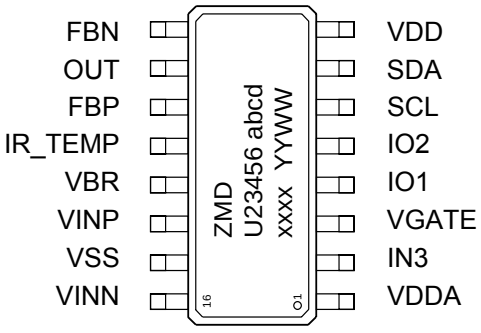
3. ESD/Latch-Up-Protection

All Pins have an ESD Protection of >2000V (except the Pins INN,INP,FBP with > 1200V) and a Latch-up protection of ±100mA or of +8V/ –4V (to VSS/VSSA).
ESD Protection referred to the human body model is tested with devices in SSOP16 packages during product qualification. The ESD test follows the human body model with 1.5kOhm/100pF based on MIL 883, Method 3015.7.

4. Pin Configuration and Package

Pin-No.	Name	Description	Remarks
10	OUT	Analog output **&** PWM1/Frequ. Output **&**one wire interface i/o	Analog output & dig. out after power on
11	FBP	Positive feedback connection output stage	Analog input/output
9	FBN	Negative feedback connection output stage **&** crystal connection pin for Frequ. Output	Analog input/output
1	VDDA	Positive analog supply voltage	Supply
8	VDD	Positive digital supply voltage	Supply
15	VSS	Negative supply voltage	Ground
6	SCL	I²C clock **&** SPI clock	Digital input, pull-up
7	SDA	Data i/o for I²C **&** data in for SPI	Digital input, pull-up
14	VINP	Positive input sensor bridge	Analog input
16	VINN	Negative input sensor bridge	Analog input
13	VBR	Bridge top sensing in bridge current out	Analog input/output
2	IN3	Resistive temperature sensor input **&** external clock input	Analog input
12	IR_TEMP	Current source resistor i/o **&** temp. diode in	Analog in/out
3	VGATE	Gate voltage for external regulator FET	Analog output
4	IO1	SPI data out **&** ALARM1 **&** PWM2 Output	Digital IO
5	IO2	SPI chip select **&** ALARM2	Digital IO

The standard package of the ZMD31050 is a SSOP16 (5.3mm body width) with lead-pitch 0.65mm:



5. IC Characteristics

5.1 Absolute Maximum Ratings

No.	Parameter	Symbol	min	typ	max	Unit	Conditions
5.1.1	Digital Supply Voltage	V_{DDAMR}	-0.3		6.5	V	to VSS
5.1.2	Analog Supply Voltage	V_{DDAAMR}	-0.3		6.5	V	to VSS
5.1.3	Voltage at all analog and digital I/O - Pins	V_{INA}, V_{OUTA}	-0.3		V_{DDA} +0.3	V	Exception s. 5.1.4
5.1.4	Voltage at Pin FBP	$V_{FBP,AMR}$	-1.2		V_{DDA} +0.3	V	4 .. 20mA – Interface
5.1.5	Storage temperature	T_{STG}	-45		150	°C	

5.2 Operating Conditions (Voltages related to VSS)

No.	Parameter	Symbol	min	typ	max	Unit	Conditions
5.2.1	Ambient temperature	T_{AMB}	-40		125	°C	
5.2.2	Ambient temperature advanced performance	T_{ADV}	-25		85	°C	
5.2.3	Analog Supply Voltage	V_{DDA}	2.7		5.5	V	Ratiometric mode
5.2.4	Digital Supply Voltage	V_{DD}	.95		1.05	V_{DDA}	Uncontrolled Vdd mode
5.2.5	External Supply Voltage	Vsupp	V_{DDA} + 2V		40	V	In voltage regulator mode with external JFET
5.2.6	Common mode input range	V_{INCM}	0.25		0.65	V_{DDA}	absolute ratings in temperature range
5.2.7	Input Voltage Pin FBP	$V_{IN,FBP}$	-1		V_{DDA}	V	
5.2.8	Sensor Bridge Resistance	R_{BR}	3.0 *5.0*		25.0	kΩ	full temperature range *4 .. 20mA - Interface*
5.2.9	Reference Resistor for Bridge Current Source	R_{Ref}	0.07			R_{BR}	(leads to $I_{BR} = V_{DDA} / (16 \cdot R_{Ref})$)

5.2.10	Stabilization Capacitor	C_{VDDA}	50	100	470	nF	between VDDA and VSS, extern
5.2.11	Optional Stabilization Capacitor	C_{VDD}	0	100	470	nF	between VDD and VSS, extern
5.2.12	Maximum allowed load capacitance*	C_{Lout}			50	nF	Voltage mode
5.2.13	Minimum allowed load resistance	R_{Lout}	5			kΩ	Voltage mode
5.2.14	Minimum allowed load resistance	R_{Lout}	2			kΩ	0.5...4.5V mode, without supply voltage lost diagnosis

5.3 Build In Characteristics

No.	Parameter	Symbol	min	typ	max	Unit	Conditions
5.3.1.	Selectable Input Span, Pressure Measurement	V_{INSP}	1		275	mV/V	(4 Bit setting s. 3.3.1)
5.3.2	Selectable AnalogOffset Compensation Range		-300%		+300%	V InputSpan	(6 Bit Settling in 10% Steps)
5.3.3	A/D Resolution	RES_{AD}	9		15	Bit	(3 Bit setting)
5.3.4	D/A Resolution	RES_{DA}		11		Bit	Voltage or Current Output
5.3.5	PWM - Resolution	RES_{PWM}	9		12	Bit	
5.3.6	Reference current for external temperature diodes	I_{TSE}	12	16	25	µA	
5.3.7	Sensitivity internal temperature diode	$S_{T,TSI}$	2800	3200	3600	ppm f.s. /K	Raw values - without conditioning

* if used, consider special requirements of OWI single wire interface stated in Appendix A

5.3.8 Cycle Rate versus A/D-Resolution

(linear related to master clock frequency* - values calculated at exact 2 MHz)

ADC Order	Resolution	Conversion Cycle f_{con}
	Bit	Hz
1	9	1302
	10	781
	11	434
	12	230
	13	115
	14	59
	15	30
2	11	3906
	12	3906
	13	1953
	14	1953
	15	977

5.3.9 PWM Frequency

PWM	PWM Freq./Hz at 2 MHz Dig. Clock*			
Resolution	Clock Divider			
Bit	1	0,5	0,25	0,125
9	3906	1953	977	488
10	1953	977	488	244
11	977	488	244	122
12	488	244	122	61

- Internal RC – Oszillator programmable with 1,2,4 MHz +/- 25% , external clock is also possible

5.4 Electrical Parameters (Voltages related to VSS)

No.	Parameter	Symbol	min	typ	max	Unit	Conditions
5.4.1 Supply / Regulation							
5.4.1.1	Supply current	I_{SUM}		2.2	2.5	mA	without bridge current and without load current, $f_{clk} \leq 2.2MHz$
5.4.1.2	Temperature Coeff. Voltage Reference 1	TC_{REF}	-200	+/- 50	200	ppm/K	
5.4.2 Analog Front End							
5.4.2.1	Parasitic differential input offset current1	I_{IN}	-2 -10		2 10	nA	temp. range 5.2.2., T_{ADV}
5.4.3 DAC & Analog Output (Pin OUT)							
5.4.3.1	Signal output range	V_{OUT}	0.025		0.975	V_{DDA}	Voltage mode
5.4.3.2	Slew rate [1]	SR_{OUT}	0.1			V/µs	Voltage mode, C_L < 20nF
5.4.3.3	Short circuit current limitation	$Imax_{OUT}$	5	10	20	mA	
No.	**Parameter**	**Symbol**	**min**	**typ**	**max**	**Unit**	**Conditions**
5.4.4 PWM Output (Pin OUT, IO1)							
5.4.4.1	PWM high voltage	PWM_{VH}	0.9			V_{DDA}	R_L > 10 kΩ
5.4.4.2	PWM low voltage	PWM_{VL}			0.1	V_{DDA}	R_L > 10 kΩ
5.4.4.3	PWM output slope[1]	PWM_{SL}	15			V/µs	C_L < 1nF
5.4.5 Temperature Sensors (Output IRT)							
5.4.5.1	Sensitivity external diode or resistor meas.	ST_{TSE}	1450	1520	1590	ppm f.s. / mV	Raw values - without conditioning
5.4.6 Digital Outputs (IO1, IO2,OUT in digital mode)							
5.4.6.1	Output-High-Level	$V_{OUTP,H}$	0.9			V_{DDA}	
5.4.6.2	Output-Low-Level	$V_{OUTP,L}$			0.1	V_{DDA}	
5.4.6.3	Output Current[1]	I_{OUTP}	4			mA	

1 no measurement in serial production, parameter is guarantied by design and/or quality observation

5.4.7 System Response							
5.4.7.1	Setup time*[1]	t_{IN}	2		5	ms	Power up to first measure result at output, without OWI – start window
5.4.7.2	Response time	t_{RES}	$2/f_{CON}$		$3/f_{con}$		
5.4.7.2	Overall accuracy	OA			0.1% 0.25%		Deviation from ideal line including INL, gain and offset errors -25...+85°C oper. temp. -40...+125°C op. temp.
5.4.7.3	Peak-to-Peak-Noise@output				5	mV	shorted inputs, bandwith ≤ 2kHz
5.4.7.4	Ratiometricity Error	RE			500	ppm	ratiometric input signals

* Depends on resolution and configuration - start routine begins approximately 0.8ms after power on

5.5 Interface Characteristics

5.5.1 Multiport Serial Interfaces (I^2C, SPI)							
5.5.1	Input-High-Level	V_{IH}	0.7		1	V_{DDA}	
5.5.2	Input-Low-Level	V_{IL}	0		0.3	V_{DDA}	
5.5.3	Output-Low-Level	V_{OL}			0.1	V_{DDA}	Open-Drain, I_{OL} = -3mA
5.5.4	LO SDA	$C_{L,SDA}$			400	pF	
5.5.5	Clock frequency SCL	f_{SCL}			400	kHz	
5.5.2 One Wire Serial Interface (ZACwire)							
5.5.1	Pull up resistance master	$R_{OWI,pu}$	330			Ω	
5.5.2	OWI line resistance	$R_{OWI,line}$			0.05	$R_{OWI,pu}$	
5.5.3	OWI load capacitance	$C_{OWI,load}$			0.08	t_{BIT} / $R_{OWI,pu}$	20µs < t_{BIT} < 100µs
5.5.4	Voltage level Low	$V_{OWI,low}$			0.2	V_{DD}	
5.5.5	Voltage level High	$V_{OWI,high}$	0.75			V_{DD}	

6. Test

Parameters given in this specification are design objectives. Final parameters which will be tested during series production will be specified by ZMD after investigations in the engineering samples. The resulting data sheet includes all parameters which will be tested by ZMD. The test program is based on this data sheet. The fulfillment of the test specification is obligatory to deliver and obligates to purchase.

Measurements at corner temperatures (-40°C, 125°C) cannot be taken. The ASIC will be tested at room temperature in mass production.

7. Reliability

A reliability investigation according to the in-house non-automotive standard will be performed.

8. Customization

For high-volume applications, which require an up- or downgraded functionality compared to the ZM31050, ZMD can customize the circuit design by adding or removing certain functional blocks. For it ZMD has a considerable library of sensor-dedicated circuitry blocks.
Thus ZMD can provide a custom solution quickly. Please contact ZMD for further information.

9. Related Documents

- ZMD31050 Feature Sheet
- ZMD31050 Functional Description

10. Ordering Information

Ordering Code	Description	Operating Temperature Range	Package Type	Device Marking	Shipping Form
ZMD31050AB	Dice on tested unsawn wafer	-40 ... +125°C**	die		6" wafer
ZMD31050AC	Dice on tested sawn wafer	-40 ... +125°C**	die		6" wafer on frame
ZMD31050AD	Dice in waffle tray	-40 ... +125°C**	die		Waffle tray * (100 dice / tray)
ZMD31050AF-T	Finished parts in tube	-40 ... +125°C	SSOP16 (5.3mm)	ZMD31050AF	Tube * (77 parts / tube)
ZMD31050AF-R	Finished parts in tape on reel	-40 ... +125°C	SSOP16 (5.3mm)	ZMD31050AF	Tape on reel * (2000 parts / reel)
ZMD31050AF-S	Finished parts in sample box	-40 ... +125°C	SSOP16 (5.3mm)	ZMD31050AF	Sample box * (5 parts / box)
ZMD31050AK	Application kit for sensor calibration and evaluation				Box, containing calibration board, CD-ROM, 5 samples (SSOP16)

* The quantity ordered should be a multiple of the quantity / packing unit as specified
** -50...+150°C derated

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