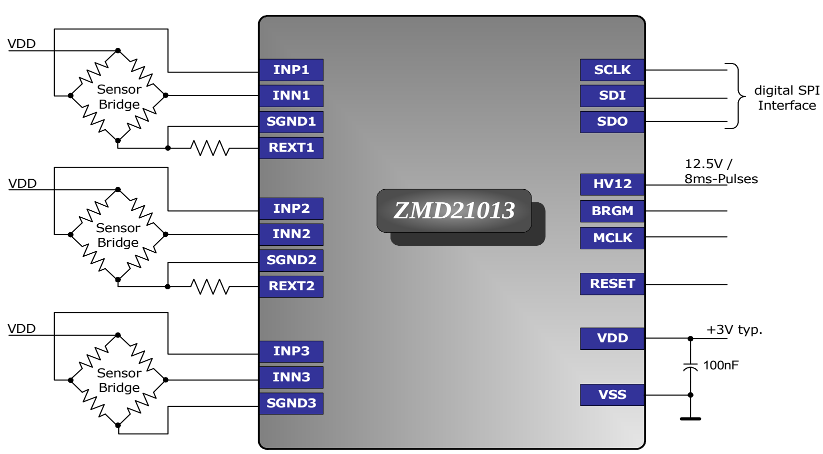
ZMD21013

MUSic Low Power Multi-Channel Sensor Interface IC

Data Sheet PRELIMINARY

Features

- Universal applicability to any resistive bridge sensor, e.g. piezo-resistive, ceramic-thickfilm, etc.
- Programmable amplification and A/D-conversion (resolution, conversion time) of sensor input signals
- Low power (e.g. 25µW in average for: V_{DD} = 3V, 16bit resolution, 1value/sec), high sensitivity (down to 0.9µV/V), multi-channel sensor interface IC
- Temperature measurement mode inherently supported
- Outdoor temperature robustness (-25°C…85°C)
- Completely ratiometric systems
- Wide supply voltage range (2.2V…5.5V)
- On-chip EEPROM for configuration and calibration data
- Internal clock-generator (RC oscillator)
- Input multiplexer for independent bridges
- Voltage-driven (switched or static) bridge mode
- Internal auto-zero-mode
- Low noise SC amplifier with offset compensation and adaptive operational amplifier's biasing
- Full duplex, high throughput and flexible digital communication interface (SPI)



Outline

The device is the first member of ZMD's MUlti-channel / MUlti-use Sensor Interface (MUSic^{TM}) IC family focusing on sensor-controlled, battery-powered, microcontroller based mobile electronics products.

The ZMD21013 is an integrated, multi-channel, high-precision, resistive sensor interface IC, especially suited for low power applications. In general, the ZMD21013 amplifies and digitizes the respective voltage signals of the connected sensors. The applied sensors will only be switched on for sampling. Hence the overall sensor-interface system will consume less power.

The IC can be flexibly adapted to almost any resistive sensor type. A temperature measurement can be realized in addition to any arbitrary resistive sensor application.

The ZMD21013 is optimized for bridge-typed sensors. The sensor bridges operate in a voltage-driven mode in standard case. Via the IC's multiplexer, one of the three input channels as well as the measurement mode are selected. The A/D-conversion's resolution and time, input range and sensitivity as well as measurement mode are programmable. The measurement values are provided at a digital output of the flexible digital serial interface.

Optional, in each measurement mode, the auto-zero-mode allows for monitoring and compensation of the circuitry's offsets and offset drifts, respectively. The ZMD21013 contains an RC-clock generator and an integrated 16x8bit EEPROM (permanent storage of configuration data).

Application Support

Configuration of the chip is handled through programming of the on-chip EEPROM.

An evaluation kit incl. board, samples and software is available.

Customization of the IC is possible for high-volume requests.

Table of Contents

Page

1 General Device Specification

1.1 Absolute Maximum Ratings (Non Operating)

The maximum rating parameters and limits, respectively, define the outer range of electrical or thermal resistibility of the IC. In this section, the parameters' limits do not reflect limits of operation.

Table 1: Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Unit	Note
V_{DD}	Supply voltage	-0.3	6.0	V	
V_{A-ESD}	ESD capability at analog pins (incl. HV12)	-2	2	kV	1
V_{D-ESD}	ESD capability at digital pins	-4	4	kV	1
θ_{STG}	Storage temperature	-55	150	°C	
R_{thjS}	Thermal resistance of TSSOP20 package (single-layer PCB)	88	114	K/W	2,3
R_{thjM}	Thermal resistance of TSSOP20 package (multi-layer PCB)	63	73	K/W	3,4
I_{in}	Input current into any pin (latch-up protection)	-100	+100	mA	5

[1] Electrostatic discharge (ESD) - Model: *Human Body Model* (HBM)
[2] Single-layer printed circuit board (PCB) considered
[3] Range obtained by variation of air flow velocity between 0lfm ($0ms^{-1}$) and 500lfm ($2.54ms^{-1}$)
[4] Multi-layer printed circuit board (PCB) considered
[5] @ θ_{amb} = 100°C

1.2 Operating Conditions

This section provides detailed parameter insights into the possible settings and specified limits of the ZMD21013. The IC is available in two qualification options:

- consumer (0…70)°C and
- industrial (-25…85)°C.

Table 2: General Operating Conditions

No.	Symbol	Parameter	Min	Max.	Unit	Note
P1.1	V_{DD}	Positive supply voltage for IC operation	2.2	5.5	V	1
P1.2	N_{LT}	Long-term noise - ADC-stability	~0.5		LSB	2
P1.3	t_{up}	Initial startup time	0.3		ms	
P1.4	$\theta_{amb,C}$	Ambient temperature range, operating range	0	70	°C	3
P1.5	$\theta_{amb,I}$	Ambient temperature range, operating range	-25	85	°C	4
P1.6	$I_{DD,\ idle}$	Idle current consumption	<0.5		µA/s	5
P1.7	f_{DEV}	Annual measurement deviation	~0.01		%FS/a	6
P1.8	C_{VDD}	Buffer capacitance (between V_{DD} and V_{SS})	100		nF	

1 Voltage referred to reference supply voltage V_{SS}, i.e. normalization: $V_{applied} = V_{specified} – V_{SS}$, typical value V_{DD} = 3.0V @ V_{SS} = 0V
2 specified for 16bit ADC with applied moving average filter of order 64 (i.e. mean of 64 values)
3 beyond the specification limits, the IC is expected to operate properly within the extended temperature span: Consumer-qualified: 0°C to 70°C … **BUT:** *ZMD does not guarantee for this! Any damage or subsequent damage originating from mentioned extended temperature range operation is explicitly no subject of warranty.*
4 beyond the specification limits, the IC is expected to operate properly within the extended temperature span: Industrial qualified: -25°C to 85°C … **BUT:** *ZMD does not guarantee for this! Any damage or subsequent damage originating from mentioned extended temperature range operation is explicitly no subject of warranty.*
5 setup: V_{DD} = 3V, MCLK = 32kHz, without external load, θ_{amb} = +25°C, incl. 1mA bridge current
6 If auto-zero mode is used and an external measurement resistor is applied.

Table 3: Measurement Modes' Characteristics

No.	Symbol	Parameter	Min.	Max.	Unit	Note
P2.1	V_{SPAN60}	Input range, measurement mode: 60	-16	49	mV/V	1, 2
P2.2	$V_{SPAN120}$	Input range, measurement mode: 120	-16	115	mV/V	1, 2
P2.3	V_{SPANTC}	Input range, (temp.) measurement mode: TC	-165	165	mV/V	2
P2.4	V_{LSB60}	Input sensitivity, measurement mode: 60	3		µV/LSB	3
P2.5	V_{LSB120}	Input sensitivity, measurement mode: 120	6		µV/LSB	3
P2.6	V_{LSBTC}	Input sensitivity, (temp.) measurement mode: TC	15		µV/LSB	3
P2.7	ΔS	Sensitivity variation	-20	20	ppm/grd	3, 4

1 differential input voltage
2 referred to supply voltage, (V_{DD} – V_{SS})
3 setup: auto-zero function active, bridge resistance: R_{BRG} = 3.4kOhm, 16bit ADC resolution, V_{DD} = 3V
4 within specified temperature range (P1.4)

Table 4: Interference Relevant Transfer Properties

No.	Symbol	Parameter	Min.	Typ.	Max.	Unit	Note
P3.1	INL	Integral nonlinearity	-4	0	4	LSB	1
P3.2	DNL	Differential nonlinearity	-2	0	2	LSB	1
P3.3	NOISE	Overall noise performance	-3	-	3	LSB	1, 2
P3.4	PSRR	Power supply rejection ratio	-4	0	4	LSB_{pp}	1, 3

1 setup: auto-zero function active, bridge resistance: R_{BRG} = 3.4kOhm, 16bit ADC resolution, V_{DD} = 3V
2 obtained at: θ_{amb} = 25°C, sample rate 1/6
3 change of digital output vs. fluctuations of supply voltage ±0.3V @MCLK=35kHz, V_{DD} = {2.2V, 3.3V, 5.5V}

Table 5: Operative Current Consumption

No.	Symbol	Parameter	Max.	Unit	Note
P4.1	I_{DD}	Active 16bit resolution (bridge supply on)	7.5	µA/s	1
P4.2	I_{DD}	Active 14bit resolution (bridge supply on)	4.0	µA/s	1
P4.3	I_{DD}	Active 12bit resolution (bridge supply on)	2.5	µA/s	1
P4.4	I_{DD}	Active 10bit resolution (bridge supply on)	1.5	µA/s	1
P4.5	I_{DD}	A/D-conversion active (bridge supply off)	285	µA	

1 setup: 1 conversion per second, V_{DD} = 3V, no external load, MCLK = 32kHz, θ_{amb} = 25°C, incl. 1mA bridge current … average current consumption

Table 6: Bridge-Operation Properties (supply time & realized samples)[1]

No.	ADC-Resolution[2]	Parameter					Unit
P5.0		**BSMR[3]**	**1/32**	**1/16**	**1/8**	**1/4**	
P5.1	10bit (MSB: 6, LSB:5)	Bridge supply time	125	250	500	1000	µs
		Number of samples	2	4	8	16	Samples[4]
P5.2	12bit (MSB: 7, LSB:6)	Bridge supply time	250	500	1000	2000	µs
		Number of samples	4	8	16	32	Samples[4]
P5.3	14bit (MSB: 8, LSB:7)	Bridge supply time	500	1000	2000	4000	µs
		Number of samples	8	16	32	64	Samples[4]
P5.4	16bit (MSB: 9, LSB:8)	Bridge supply time	1000	2000	4000	8000	µs
		Number of samples	16	32	64	128	Samples[4]

1 @ MCLK = 32kHz
2 ADC is divided into two stages: "MSB" and "LSB"; the bridge is powered only for A/D conversion of the MSB-signal-part – the LSB A/D-conversion is based on the remaining signal portion (el. charge / voltage) after the MSB A/D-conversion (no V_{DD} supply for the bridge during LSB A/D-conversion)
3 NOT a direct measurement parameter! BSMR (bridge supply time to main measurement conversion time ratio) is an input configuration parameter. BSMR = 1/16 is the default setting (after HW-reset).
4 realized samples at the bridge (duration of each sample: 2 clocks, i.e. ~62µs)

Explanation example for internal bridge operation (BSMR = ¼, Resolution = 10bit … MSB width: 6bit, LSB width: 5bit):

By definition a bridge sample's duration corresponds to the bridge being powered for two clocks (2 · 1/32kHz = 62.5µs). The BSMR = ¼ defines four A/D-conversions of the respective bridge sample. To obtain an MSB-conversion of 6bit (derived from 10bit separated ADC resolution due to divided MSB-LSB-ADC-stages), the bridge must be powered $2^6 / 4 = 16$ times, i.e. 16 realized samples at the bridge (sample availability for A/D conversion is ensured via the Sample-and-Hold functionality of the Amplifier stages). Thus, the bridge's supply time is given by 16 · 62.5µs = 1000µs.

In general, it holds: the lower the BSMR and the higher the ADC-resolution, the more precise measurement results are obtained with a longer bridge supply time, i.e. higher power consumption. Thus, precision and power consumption have to be well balanced to identify the most appropriate setting for your application

Table 7: Digital Parameters' Characteristics

No.	Symbol	Parameter	Min.	Typ.	Max.	Unit	Note
P6.1	MCLK	External clock signal	28000	32770	36000	Hz	
P6.2	D_{MCLK}	Duty cycle of MCLK	45	50	55	%	
P6.3	SCLK	Serial data clock (SPI)	-	-	2	MHz	
P6.4	V_{IH}	Input: high level voltage	$0.8 \cdot V_{DD}$	-	V_{DD}	V	1
P6.5	V_{IL}	Input: low level voltage	V_{SS}	-	$0.2 \cdot V_{DD}$	V	1
P6.6	t_{IR}	Input: Rising edge duration	-	-	1	µs	
P6.7	t_{IF}	Input: Falling edge duration	-	-	1	µs	
P6.8	V_{OH}	Output: high level voltage	$0.8 \cdot V_{DD}$	-	V_{DD}	V	2
P6.9	V_{OL}	Output: low level voltage	V_{SS}	-	$0.2 \cdot V_{DD}$	V	3
P6.10	t_{OR}	Output: Rising edge duration	-	-	1	µs	
P6.11	t_{OF}	Output: Falling edge duration	-	-	1	µs	
P6.12	RCO	Internal oscillator (clock) signal	25000	34300	45000	Hz	

[1] holds for V_{DD}-limits: V_{DD} = (2.2 … 5)V
[2] @ I_{source} = 4mA
[3] @ I_{sink} = 4mA

1.3 Package Pin Assignment

Table 8: *ZMD21013* Pin List

Package pin No.	Name	Direc-tion	Type	Description
1	VSS		SUPPLY	Negative / reference supply voltage / power connect
2	BRGM	IN	Pull-up	Bridge mode (current continuously into bridge, Pull-up)
3	REXT1	IN	Analog / CMOS	Channel1: (optionally) connect external resistor for temperature measurement
4	INN1	IN	Analog / CMOS	Channel1: differential sensor signal (negative input)
5	SGND1	IN	Analog / CMOS	Channel1: sensor bridge ground
6	INP1	IN	Analog / CMOS	Channel1: differential sensor signal (positive input)
7	RESET	IN	Digital	System reset (H-active)
8	SCLK	IN	Digital	SCLK: serial clock
9	SDO	OUT	Digital	SDI: serial data output / tristate
10	SDI	IN	Digital	SDI: serial data input
11	HV12	IN	HV-pulses; power	Pulsed input voltage (12.5V) for EEPROM programming[1]
12	MCLK	IN	Digital	Master clock
13	INP3	IN	Analog / CMOS	Channel3: differential sensor signal (positive input)
14	SGND3	IN	Analog / CMOS	Channel3: sensor bridge ground
15	INN3	IN	Analog / CMOS	Channel3: differential sensor signal (negative input)
16	REXT2	IN	Analog / CMOS	Channel2: (optionally) connect external resistor for temperature measurement
17	INP2	IN	Analog / CMOS	Channel2: differential sensor signal (positive input)
18	SGND2	IN	Analog / CMOS	Channel2: sensor bridge ground
19	INN2	IN	Analog / CMOS	Channel2: differential sensor signal (negative input)
20	VDD		SUPPLY	Positive supply voltage / power connect

[1] An external 12.5V, 8ms-pulsed voltage has to be applied in order to program the IC’s EEPROM. There is no internal charge pump for this purpose.

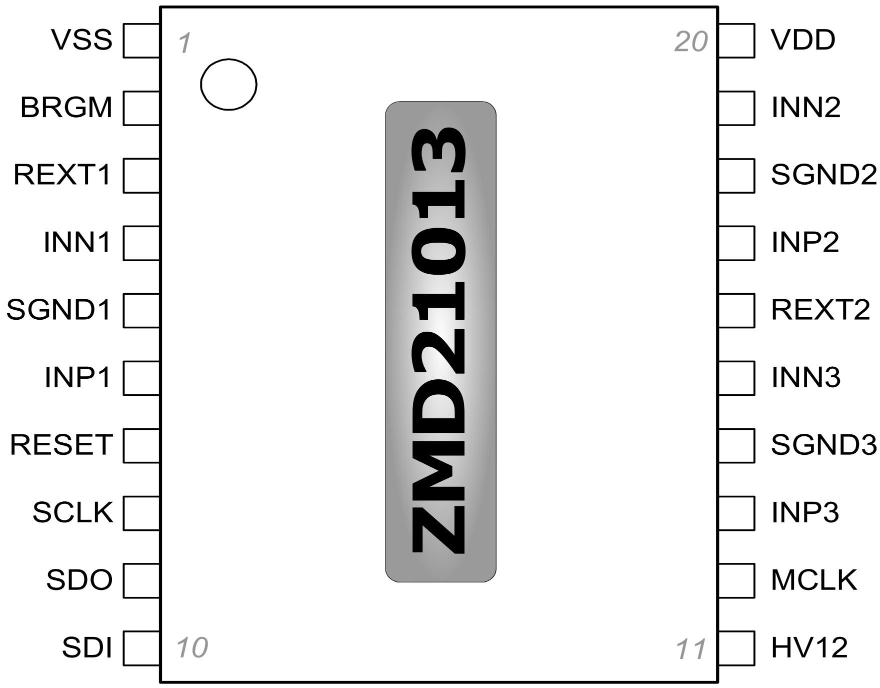


Figure 1: *ZMD21013* Package Pin Assignment

2 Functional Description

The *ZMD21013* is high-precision resistive sensor interface circuit. As cornerstone of ZMD's MUSic™ family, it is optimized for multi-channel, low-power, microcontroller based mobile applications. The *ZMD21013* can support a large variety of consumer and industrial applications (e.g. altimeter, barometer, pressure monitoring, compass functionalities, flow, velocity and density measurements and many others), each in combination with a temperature measurement. The latter is supported by especially (strain-)robust integrated measurement resistors: (500, 3.4k, 14k)Ohm – not separately listed as main IC's components. Moreover the IC contains a 16x8bit EEPROM to store non-volatile configuration data, calibration coefficients, and an optional user programmable ID.

Engaged, the *ZMD21013* is in one of the following operation modes:

Idle mode: Neither analog-to-digital-conversion nor SPI communication is running or active (SCLK must not be utilized, MCLK can be inactive). The IC consumes almost no power.

Active mode: The analog-to-digital-conversion is running. The respectively selected input signal (sensor bridge, TC resistor, auto-zero) is digitized. A clock signal (either MCLK or internal RC-oscillator clock) is required. SPI-communication ought to be inactive.

Communication mode: The analog stages (grounded *blue* in Figure 2) are inactive. No input signal A/D-conversion is running. The communication (of the external microcontroller) with the SPI takes place. The interface clock signal SCLK is required.

For sensor signal readout (during active mode), the respective sensor bridge operates voltage-driven.

2.1 Measurement Modes

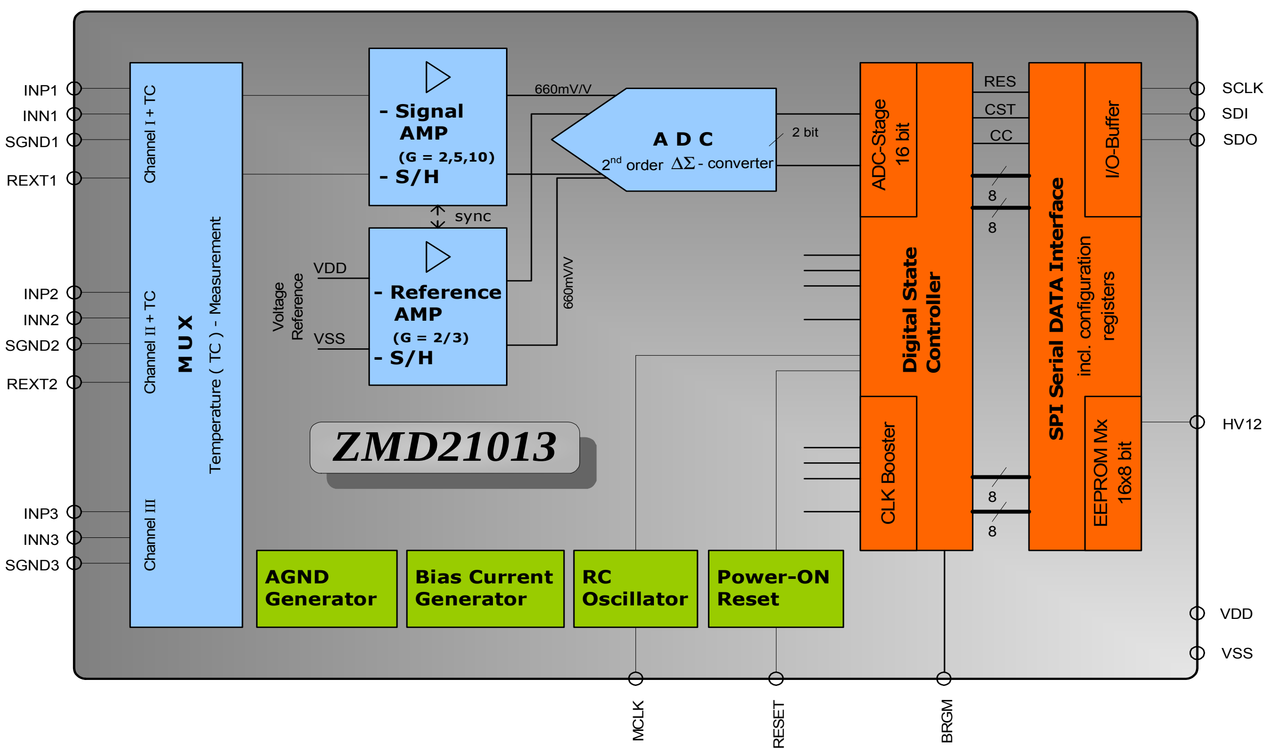


Figure 2: Functional Block Diagram

The *ZMD21013* provides four measurement modes for: connected sensor's signal readout, determination of temperature and generation of compensation value. The definition of the selected channel as well as the respective measurement mode is realized by programming the configuration registers via the SPI-standard interface (cp. next section). Generally, the bridges (and hence the sensors) will only be switched on when sampling is realized (during any measurement). This culminates in a reduction of power consumption of the overall sensor-*ZMD21013*-system. The bridge foot point and V_{SS} are connected via a very low resistance switch in the normal sensor signal measurement modes (P60, P120). Switched on, the switch resistance must be much less than the bridge resistance to circumvent potential influences (like drifts or TC-changes) on the sensor supply voltage. The possible measurement modes are as follows:

Table 9: Possible modes of realized measurement

Selected Measurement Mode	Description	In brief
P60	This is the usual sensor measurement mode for any application with the requirement of maximum precision (3µV/LSB). The differential output voltage of the respective sensor bridge (according to the MUX-selection: channel I, II or III) is processed by the IC. A signal amplification of 20dB (factor 10) is realized. The full-scale input voltage range is 60mV. The effective sensitivity (ca. 3µV/LSB) is twice as high as in P120 mode.	• Usual sensor signal measurement • Small FS: 60mV • Ultra-high sensitivity • 20dB amplification
P120	This is the sensor measurement mode for any application with relaxed precision requirements (6µV/LSB) but wider measurement range. The differential output voltage of the respective sensor bridge (according to the MUX-selection: channel I, II or III) is processed by the IC. A signal amplification of 14dB (factor 5) is realized. The full-scale input voltage range is 120mV. In exchange for a wider full-scale range, the sensitivity (ca. 6µV/LSB) is less than in P60 mode. Nonetheless, this sensitivity is sufficient for high-precision applications.	• Usual sensor signal measurement • Wider FS: 120mV • Very-high sensitivity • 14dB amplification
TC	For the temperature coefficient (TC) measurement mode, the sensor bridge's low end must be connected to the IC via a series resistor. For that purpose, one can select between three internal resistors (500, 3.4k, 14k)Ohm or an additional external resistor. The respective resistance must be equivalent of the overall bridge resistance. The obtained signal is related to the reference voltage $V_{DD}/2$. Thereupon a temperature equivalent signal is obtained and provided at the IC's digital output. A signal amplification of 6dB (factor 2) is realized. This mode can only be applied for channel I or II.	• Temperature (coefficient) measurement • Select 1 of 3 internal or connect external resistor • 6dB amplification

… continued table

Auto-Zero	This mode is always realized in combination with one of the above modes in order to obtain/generate correction values for systematic interface errors. The sensor bridge's differential input of the respective sensor bridge (according to the MUX-selection: channel I, II or III) is short connected. A measurement value is generated which characterizes the IC's (analog part) systematic offset within each measurement. This auto-zeroing value should be utilized in the connected external microcontroller to realize the offset correction of subsequent sensor measurements. During the auto-zeroing, the IC's setup should be the same as for the operational mode, i.e. P60, P120 or TC.	• Utilizable in combination with any other mode • Short connect bridge input • Generate correction/compensation values of the IC

2.2 SPI Interface

The byte-wise organized Serial Peripheral Interface (SPI) is used for communication between the *ZMD21013* IC and an external microcontroller. The SPI is realized as three-wired version with serial clock (SCLK), serial data in (SDI) and serial data out (SDO) pins. It contains a 16x8bit EEPROM (see also section 2.4), two configuration registers and an address decoder for internal communication purposes and two 8bit registers acting as A/D-conversion result memory. The EEPROM is directly accessible (for writing data) via the high-voltage pin (HV12, pulsed input voltage: 12.5V, cp. Table 8).

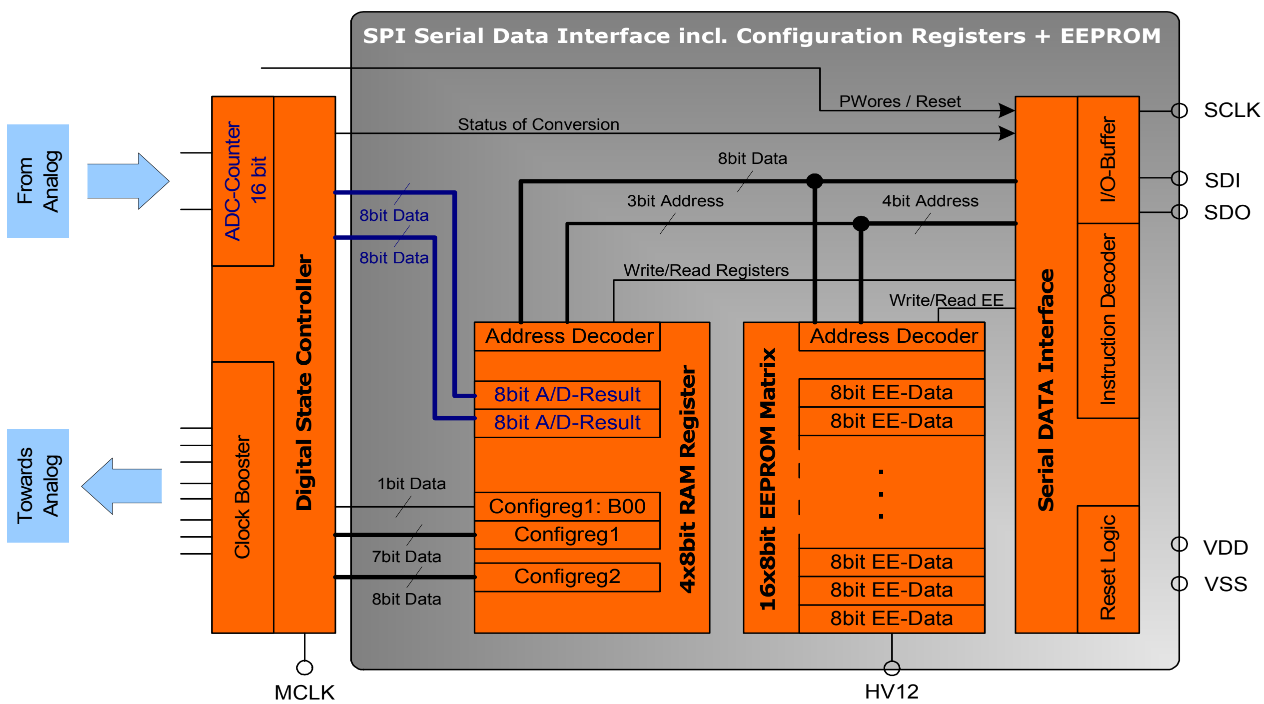


Figure 3: SPI Block Diagram

The serial clock signal (SCLK) initiates and synchronizes the IC's data transfer with each bit:

- at every rising edge of SCLK for transmission from the *ZMD21013* to the microcontroller and
- at every falling edge of SCLK for reception by the *ZMD21013* of data from the microcontroller.

With writing B00 = 1 in Configreg1, the signal conversion of the respective measurement (cp. measurement modes, Table 9) is initiated. Then, SDO passes into H. The H to L transition of SDO will indicate the end of the conversion and the availability of the respective measurement result in the 2x8bit A/D-result registers.

2.2.1 Programming Commands

The *ZMD21013* contains two 8bit configuration registers (Configreg1 and Configreg2). These registers can be programmed individually (8-Bit) and read together (16-Bit Data). Both registers will be reset with the Power-ON Reset and via the hardware reset by pin RESET, respectively. There are four options to reset the IC:

- Direct reset utilizing RESET-pin: resets: Configreg1, -2 and SPI; SDO in tristate,
- Reset by (AAABH) sequence via SPI: resets SPI,
- Automatic reset after conversion completion: resets: B00H in register Configreg1 and
- Automatic reset due to power up: resets: Configreg1, -2 and SPI; SDO in tristate.

Configreg1 contains the configuration data for every single conversion, i.e. the selection of:

- measurement mode,
- input channel and
- (TC) resistor.

If the very first bit B00 of Configreg1 is set to 1, the conversion will start. In Configreg2, global configuration data is preserved. Usually, Configreg2 will be written only during the initialization (in most applications).

Each data transfer from or to the IC is triggered by sending an 8bit Address Code (cp. Table 10) via SDI. This code determines the register or EEPROM address of interest which shall be accessed. Furthermore, each Address Code is bounded to either a read or a write access. The Address Codes are organized as follows:

- bit 7 specifies write (logic 1) or read (logic 0)
- bit 6 defines SPI data type: EEPROM data (logic 1) or configuration register data (logic 0)
- bit 5-4 must be logic 0 – no dedicated functionality
- bit 3-0 specify the respective register or EEPROM address

Any Address Code (first byte of a programming command, cp. Table 10) or data byte (sent or received) is ordered (temporally) with the MSB (bit 7) being transmitted first.

Table 10: SPI - Programming Commands

SDI	SDO	HV12	Write/Read	Description	POR
$C0XX_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX_H to EEPROM0	N/A
$C1XX_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX_H to EEPROM1	N/A
$C2XX_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX_H to EEPROM2	N/A

… continued table

C3XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM3	N/A
C4XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM4	N/A
C5XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM5	N/A
C6XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM6	N/A
C7XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM7	N/A
C8XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM8	N/A
C9XX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM9	N/A
CAXX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM10	N/A
CBXX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM11	N/A
CCXX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM12	N/A
CDXX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM13	N/A
CEXX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM14	N/A
CFXX$_H$	N/A	8ms-50µs-8ms	write only	write data (byte) XX$_H$ to EEPROM15	N/A
40$_H$	16xXX$_H$	N/A	read only	read EEPROM0…15	N/A
81XX$_H$	N/A	N/A	write only	Configreg1 (setup: XX$_H$, cp. Table 12)	0$_H$
82XX$_H$	N/A	N/A	write only	Configreg2 (setup: XX$_H$, cp. Table 13)	0$_H$
01$_H$	XXXX$_H$	N/A	read only	Get Configreg1/Configreg2 content	0$_H$
03$_H$	XXXX$_H$	N/A	read only	Get Adresults2/Adresults1 content (result of A/D-conversion)	0$_H$

2.2.2 Measurement Communication and Programming

The communication between the *ZMD21013* and the connected microcontroller via the SPI (send/receive instructions and data) can be summarized as follows:

1. The Address Code (cp. Table 10) is send via **SDI**, ordered: bit7-bit6-…-bit0.
2. Dependent on the Address Code, one of the following write or read operation will be performed.
   - An EEPROM-byte (CX_H) shall be programmed with arbitrary data. For that purpose, the respective 8bit data has to be transmitted (by the connected microcontroller) to the *ZMD21013* via **SDI**, ordered: bit7-bit6-…-bit0. This has to be started with the next clock after sending the Address Code (see Figure 4). Subsequent, after an additional break of at least 50µs, the **HV12** will be activated. Then, an 8ms "ERASE"-pulse followed by a 50µs break and then an 8ms "WRITE"-pulse must be sent via **HV12**.

     For example, sending "$C30A_H$" via **SDI** will prepare the SPI interface to write 00001100_2 to EEPROM3. Afterwards the L (>50µs) – H (8ms) – L (50µs) – H (8ms) pulse sequence has to be applied at **HV12**.

     *Note: If the ERASE-WRITE pulses are not realized and a new 8bit address code will be sent via **SDI** instead, the former EEPROM-write settings will get lost and **HV12** will be deactivated.*

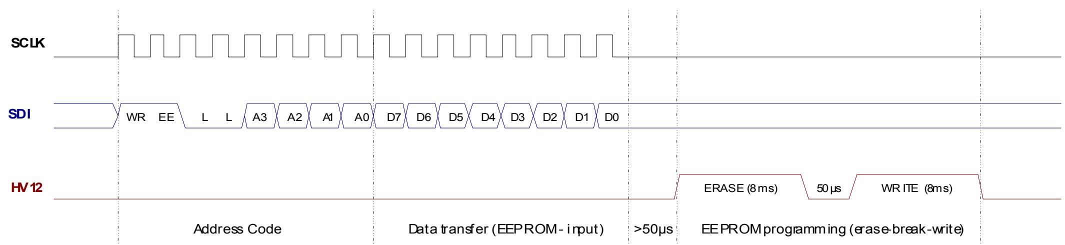


Figure 4: Write EEPROM Sequence.

   - In this scenario, the content of the complete EEPROM (40_H) is readout. Here, the EEPROM entries are transmitted to the microcontroller via **SDO**. The ordering of the data is as follows: bit7-…-bit0 (EEPROM0) – bit7-…-bit0 (EEPROM1) - … - bit7-…-bit0 (EEPROM15), i.e. 128 bits (cp. Figure 5). The transmission of the EEPROM entries starts with the subsequent clock (**SCLK**) after the 40_H Address Code has been sent. The readout will take ca.: 128 · 1/32kHz = 4ms.

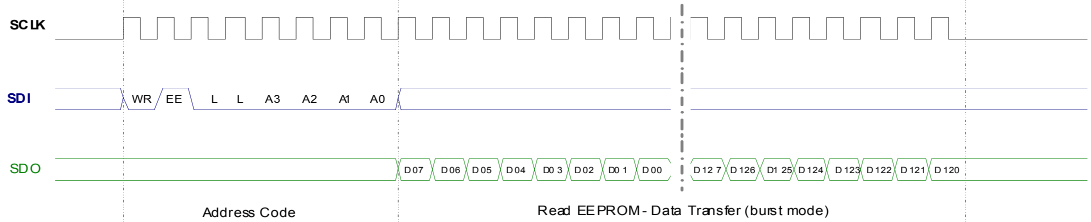


Figure 5: Read EEPROM Sequence (burst read of complete EEPROM).

- One of the most frequent commands will be: Configreg1-write (81_H). Writing data into the configuration register 1 corresponds usually to the start of a conversion and measurement with the respective setup (cp. Table 12). For the complete sequence, 81_H is sent to the IC via **SDI** being followed by the 8bit configuration setting (according to Table 12) for Configreg1. The order of the configuration data is: bit7-…-bit0. Figure 6 shows this sequence.

  Due to setting the first bit B00 of Configreg1 to logic 1 a conversion / measurement can be triggered. This is realized by either applying **MCLK** or by having selected (within the setup of Configreg2) to utilize the internal RC-oscillator. A running conversion is indicated by logic 1 at **SDO**. As soon as **SDO** turns from logic 1 to logic 0 (High-Low transition), the conversion / measurement is finished.

  Now, the A/D-result registers contain the new conversion data. All analog components including the RC-oscillator turn into idle mode. Additionally, the first bit B00 of Configreg1 is reset to logic 0. The result of the conversion / measurement can be readout by the microcontroller (*read A/D-result register*). It is recommended (but not required) to stop **MCLK** after a completed conversion measurement which will save further power of the overall sensor-*ZMD21013*-microcontroller system.

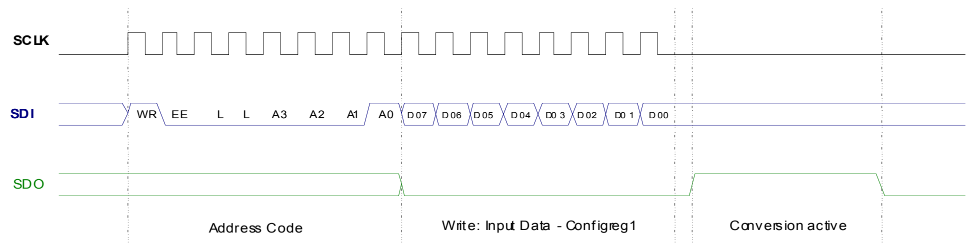


Figure 6: Write Configuration Register 1 (Configreg1) Sequence … Start Measurement and A/D-Conversion.

- Appropriate settings of the A/D-conversion are necessary for a conversion / measurement. These have to be provided to the IC within the Configreg2-write (82_H) sequence, realized via **SDI**. After the 82H Address Code, the required 8bit configuration register settings (cp. Table 13) must be transmitted to the *ZMD21013* via **SDI**. The data order is again: bit7-…-bit0. In Figure 7, the corresponding communication sequence is shown.

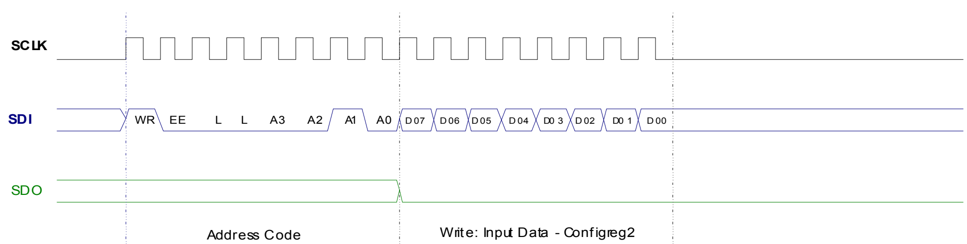


Figure 7: Write Configuration Register 2 (Configreg2) Sequence.

- Apart from setting up the configuration, it might be essential to obtain the current state or entries of the configuration registers. Such operation is supported by the Configreg1/2-read (01_H) command and Address Code, respectively. After the 01_H Address Code has been sent via **SDI**, the 8bit entries of configuration register 1 directly followed by the 8bit entries of configuration register 2 are transmitted to the external microcontroller via **SDO** (see Figure 8). At **SDO**, the transmitted 2x8bits are ordered: bit7-…-bit0 (Configreg1) – bit7-…-bit0 (Configreg2).

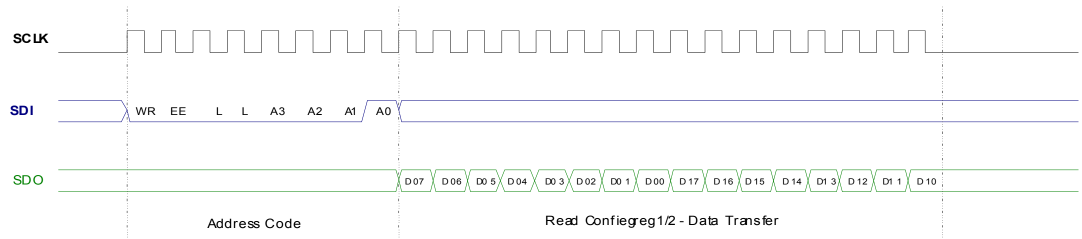


Figure 8: Read Configuration Registers 1 and 2 (Configreg1/2) Sequence.

- When a conversion / measurement has been conducted, the corresponding result is written into the A/D-result registers. The A/D-Results-read (03_H) command initiates the result transfer. After the transmission of the 03_H Address Code via **SDI**, 2x8bits of result data are sent from the IC to the external microcontroller via **SDO**. This data transfer begins with the next **SCLK**-clock after the 03H-Address-Code's end. The sequence of this communication is illustrated in Figure 9. The 2x8bits are ordered: bit15-…-bit0. They are a digital representation of the respective analog measurement value.

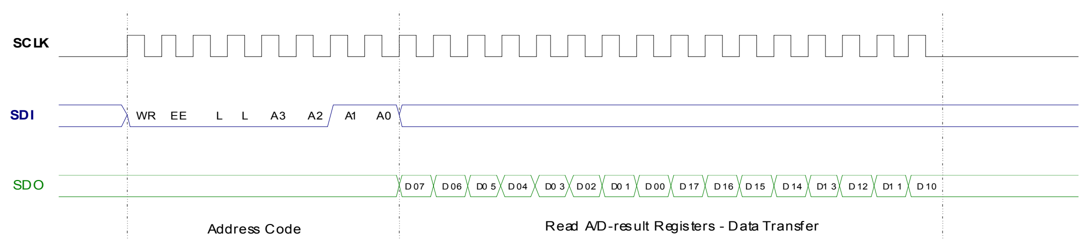


Figure 9: Read A/D-Conversion Result Registers 1 and 2 (A/D-Result1/2) Sequence.

3. Alternatively to the 8bit Address Codes, the 16bit Soft-Reset: $AAAB_H$ can be sent via **SDI**. The *ZMD21013* is especially designed such that this sequence (cp. Table 11 and Figure 10) can be detected even if the IC and the external microcontroller are not correctly synchronized.

Table 11: SDI-Sequence for "Soft-Reset".

RESET sequence	Remarks
10101010 10101011	SPI interface logic will be set back into the start-up state 16 clocks after the RESET sequence was transmitted

The "Soft-Reset" command has special properties. It requires a 16-Bit sequence for activation. To ensure the detection of the soft-reset (even when synchronization between microcontroller and *ZMD21013* is lost) a dedicated 16-Bit shift-register is integrated within the SPI. This register is monitoring the data stream on **SDI** continuously.

The content of this register is checked against the specific pattern (Table 11) after each SCLK. To avoid accidental activation of the soft-reset, the sequence is unique (in commands and data). The SPI interface logic will be set back into the start-up state with the appropriate soft-reset sequence ($AAAB_H$). All configuration registers keep their current data. If a measurement is running during soft-reset activation, the conversion will be carried out until being finished regularly before the soft-reset will be executed.

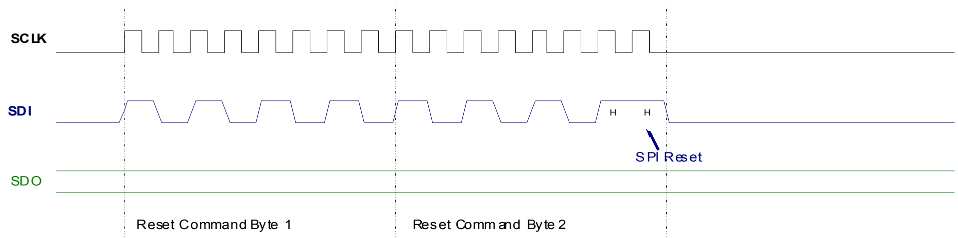


Figure 10: IC's Soft-Reset Sequence.

Moreover it shall be remarked that incomplete programming sequences might lead to unexpected behavior of the SPI. Therefore it is recommended to reset the SPI and the IC, respectively, in case the microcontroller has accidently caused any exceptional communication.

Programming Summary:

The communication between the *ZMD21013* and the connected microcontroller via the SPI (send/receive instructions and data) can be summarized as follows:

4. Send Address Code (1st byte of SDI-input, cp. Table 10) via **SDI**, ordered: bit7-bit6-…-bit0
5. Send/Receive Data:

- *EEPROM-write* *(CX_H):*
  - § send data via **SDI**, ordered: bit7-bit6-…-bit0
  - § wait at least 50µs after bit0 sent (via SDI); delete/write via **HV12**
    send 8ms "ERASE"-pulse; wait 50µs; send 8ms "WRITE"-pulse
  - § Example: "$C30A_H$" will prepare the SPI interface to write 0001100_2 to the EEPROM3
- *EEPROM-read* *(40_H)*: receive all EEPROM entries via **SDO**, ordered: bit7-…-bit0 (EEPROM0) – bit7-…-bit0 (EEPROM1) - … - bit7-…-bit0 (EEPROM15), i.e. 128 bits (overall duration ca.: 128 · 1/32kHz = 4ms)
- *Configreg1-write* *(81_H) … start conversion with respective setup (cp. Table 12)*:
  - § send configuration for conversion via **SDI**, ordered bit7-…-bit0
  - § apply **MCLK** (running conversion is indicated by logic 1 at SDO)
  - § wait until **SDO** turns from logic 1 to logic 0 (H to L)

- *Configreg2-write* *(82_H):* send detailed configuration (cp. Table 13) data via **SDI**, ordered: bit7-…-bit0
- *Configreg1/2-read* *(01_H)*: receive all entries of the configuration registers via **SDO**, ordered: bit7-…-bit0 (Configreg1) – bit7-…-bit0 (Configreg2), i.e. 16 bits
- *A/D-Results-read* *(03_H):* receive 16bit-measurement result via **SDO**, ordered: bit15-…-bit0, i.e. digital representation of the respective analog measurement value

6. Alternatively to the 8bit Address Codes, the 16bit Soft-Reset: $AAAB_H$ can be sent via **SDI**

2.2.3 Register Specification

In order to establish the required setup, the configuration registers have to be programmed. The following tables describe the possible settings.

Table 12: Settings for Configuration Register "Configreg1"

Bit No.	**Configuration Setting**								
B00	Start-Bit … initiate new conversion (will be set to H after each data transfer)								
B01	select bridge-channel	L	BRG1	H	BRG2	L	BRG3	H	No select.
B02	select bridge-channel	L		L		H		H	
B03	select bridge resistor	L	3.4k	H	14k	L	500	H	R_{EX}
B04	select bridge resistor	L		L		H		H	
B05	mode P60 / P120	L … mode P60				H … mode P120			
B06	temperature coefficient measurement	L … P60 / P120				H … TC-mode			
B07	auto-zero mode	L … P60 / P120 / TC				H … auto-zero mode			

Table 13: Settings for Configuration Register "Configreg2"

Bit No.	**Configuration**								
B08	ADC-resolution	L	16bit	H	14bit	L	12bit	H	10bit
B09	ADC-resolution	L		L		H		H	
B10	ADC-correction[1]	L	N+1	H	N+0	L	N+2	H	*unspecified*
B11	ADC-correction[1]	L		L		H		H	
B12	SCA/ADC sample-rate	L	1/16	H	1/32	L	1/4	H	1/8
B13	SCA/ADC sample-rate	L		L		H		H	
B14	RC-oscillator	L … MCLK				H … RCO			
B15	EEPROM-Test / RCO-Test	L … off				H … test			

[1] The ADC correction supports internal compensation of spurious effects within the MSB-part A/D-conversion. For example, with setting "N+1", the integration within the A/D-conversion of the LSB (which follows after MSB-conversion) will be conducted one clock longer than with the original setting "N".

3 Package Outline (TSSOP20)

The IC is packaged in a 20-pin TSSOP package which has the dimensions shown in Figure 12 in and Table 14.

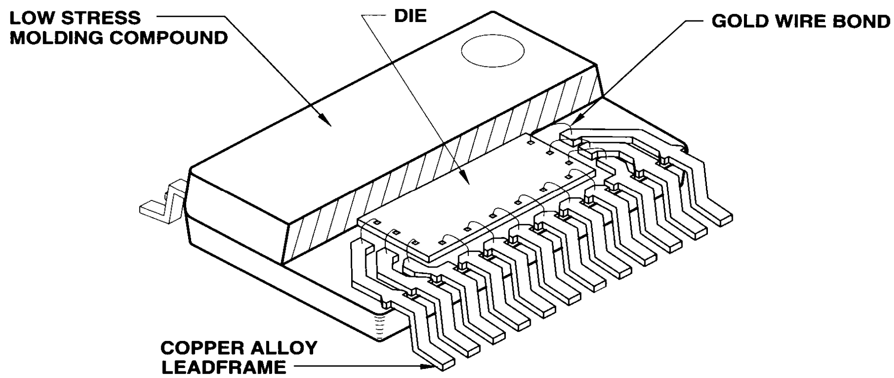


Figure 11: TSSOP Package

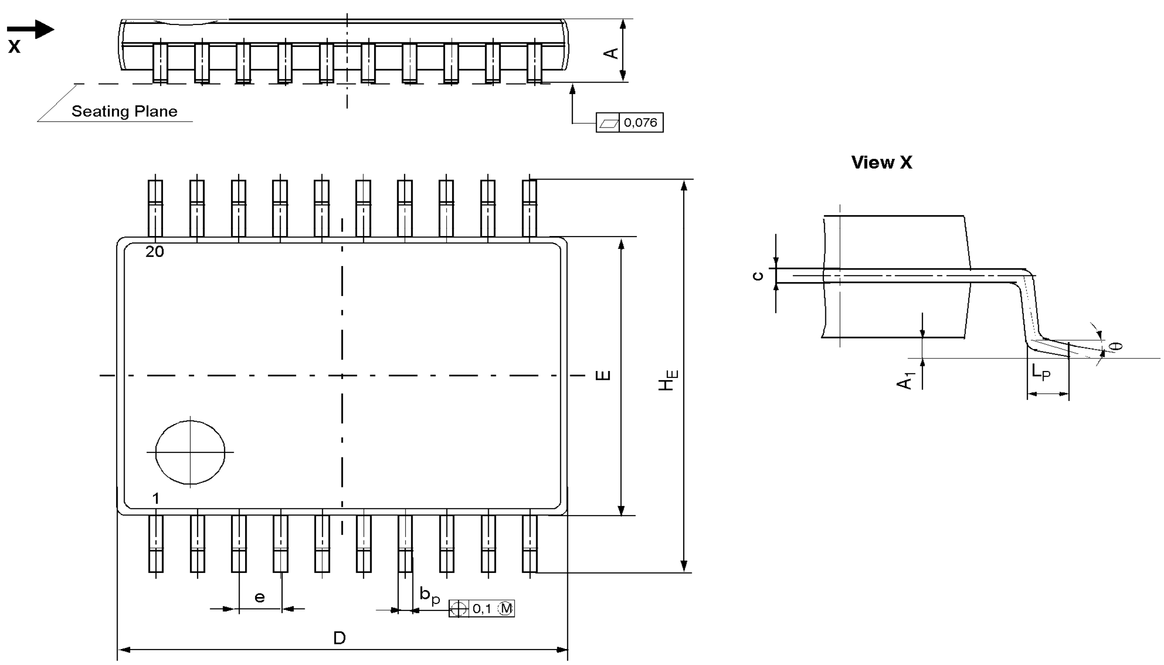


Figure 12: Package Outline Dimensions

Table 14: Package Dimensions* (mm) **refer to JEDEC : JEP95 MO-153*

Symbol	A	A1	D	E	H_E	L_P	b_P	e	c	θ
Nominal	1.00	0.10	6.50	4.40	6.40	-	-		-	3°
Maximum	1.10	0.15	6.60	4.50	6.50	-	0.30	0.65	0.20	8°
Minimum	0.9	0.05	6.40	4.30	6.30	0.50	0.19		0.09	0°

4 Package Marking

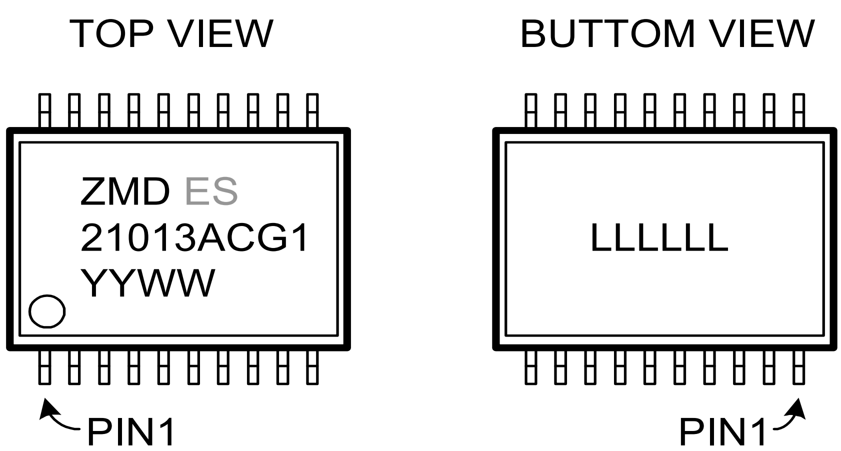


Figure 13: Package Marking

Top Marking:	**ZMD**	Manufacturer
	ES	Product is engineering sample (evaluation purpose only)
	21013	Product Name
	A	Revision code
	C, I	Temperature Range (0°C…70°C, -25°C…85°C)
	YYWW	Date code (year and workweek)
	G1	“green” RoHS-compliant package, lead free
	21013IGL G1	*pre-production engineering samples (no qualification, only functionally tested)*
Bottom Marking:	**LLLLLL**	ZMD Lot Number

5 Related Documents

- *ZMD21013* Product Flyer
- *ZMD21013* Specification

6 Contact Information

6.1 ZMD Sales

ZMD AG	**ZMD Stuttgart Office**	**ZMD America Inc.**	**ZMD Far East**
Grenzstrasse 28 01109 Dresden, Germany Phone: +49 (0)351.8822.306 Fax: +49 (0)351.8822.337 E-mail: sales@zmd.de	Nord-West-Ring 34 70974 Filderstadt - Bernhau-sen Phone: +49 (0)711.674.517-0 Fax: +49 (0)711.674.517-99 E-mail: sales@zmd.de	201 Old Country Road, Ste 204 Melville, NY 11747 Phone: +1 (631) 549-2666 Fax: +1 (631) 549-2882 E-mail: sales@zmda.com	1F, No 14, Lane 268, Sec.1 Guangfu Rd., Hsinchu City 300 Phone: +886-(0)3-563-1388 Fax: +886-(0)3-563-6385 E-mail: agraubner@zmdfareast.com

For the current revision of this document and for additional product information please look at www.zmd.biz.