MS1088

Fully Calibrated Temperature Sensor IC

1 General Description

The integrated circuit MS1088 is a fully integrated tested and calibrated digital low power temperature sensor with a typical temperature measurement accuracy of ±0.3°C. It offers digital SPI or I²C interface and battery end-of-life (EOL) detection. The MS1088 is available in quad flat no leads package (QFN) or chip scale package.

2 Applications

- Wireless sensor tags
- Human body temperature measurement
- Wearables
- Power-Supply temperature monitoring
- Environmental temperature monitoring and HVAC
- Computer peripheral thermal protection
- Notebook computers
- Cell phones
- Battery management
- Thermostat controls

3 Typical application

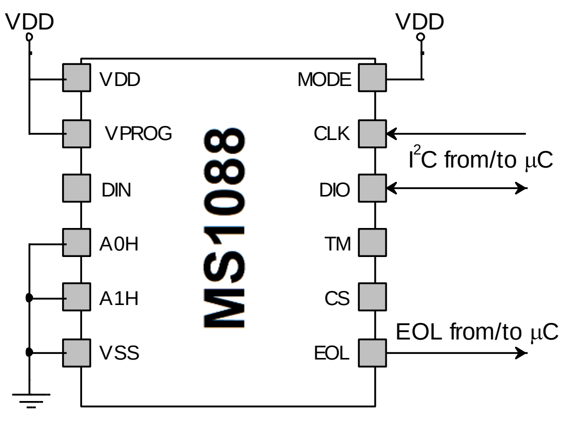

Figure 1: Application diagram (I²C mode)

4 Features

- Digital output: I²C serial 2-wire or SPI serial 4-wire
- Up to 4 sensors can be addressed over the same serial bus (4 sub-addresses)
- Hardware-Handshake to wake up your Microcontroller when measurement is finished.
- Temperature measuring range : -40°C to +120°C
- Accuracy: typically ±0.3°C from 10°C to +40°C
- Resolution: 0.05°C
- Ultra low current in sleep mode: 20nA
- Fast measurement time: 50 ms
- Current in active state : 75 µA
- Avg. current at 1 measurement per minute: 80 nA
- Supply range: 2.2V to 3.5V
- Battery EOL detection: threshold level programmable between 2.20V to 2.95V
- Digital output pin for EOL detection
- Available in QFN or CSP package

5 Ordering Information

Table 1: Ordering information

Type	Package	Shipping	Article No.
MS1088D	QFN16 3x3mm	Tape&Reel	9160372
	CSP 1.39x0.93mm	Tape&Reel	9160379

6 Pinout

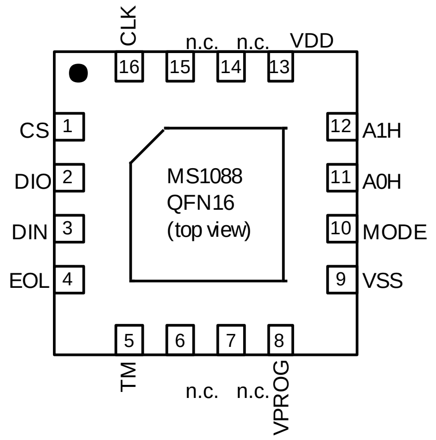

Figure 2 Pinout QFN

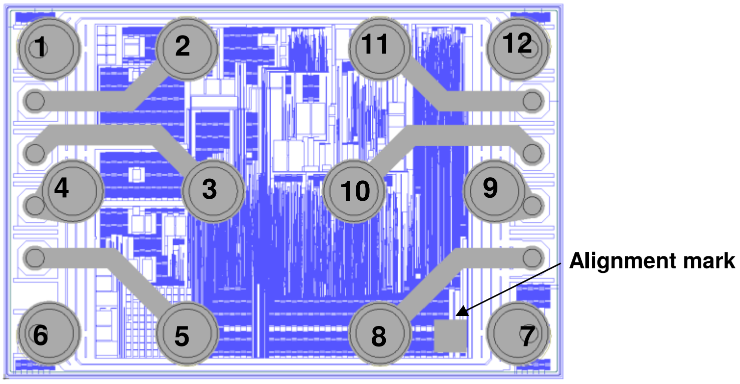

Figure 3 Pinout CSP

7 Pin description

Table 2: Pin description

Pin	Symbol	I/O[1]	Description
1	CS	I	Chip select (SPI)
2	DIO	I/O	Data input/output
3	DIN	I	Data input (SPI)
4	EOL	O	Battery EOL output
5	TM	I/O	Hardware Handshake
6			n.c.
7			n.c.
8	VPROG	S	Positive supply voltage
9	VSS	S	Ground
10	MODE	I	Serial interface mode
11	A0H	I	Sub-address A0H
12	A1H	I	Sub-address A1H
13	VDD	S	Positive supply voltage
14			n.c.
15			n.c.
16	CLK	I	Serial clock

8 Reset

After power up the MS1088 must be initialized dependent on the selected interface.

[1] I: Input, O: Output, S: Supply

8.1 Initialize in I2C Mode

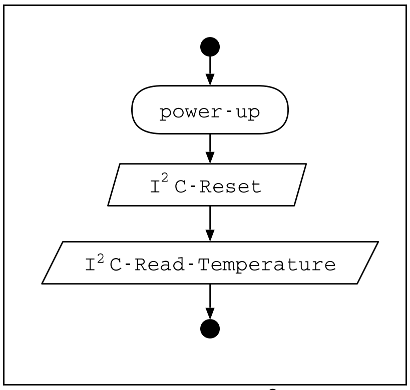

Figure 4 Initialize I²C Mode

8.2 Initialize in SPI Mode

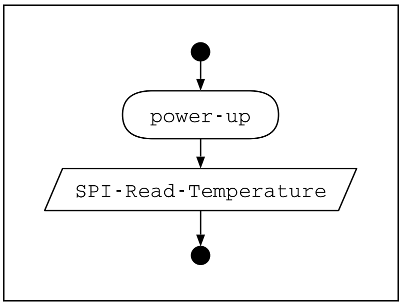

Figure 5 Initialize SPI-Mode

9 Serial interface selection

The MS1088 supports two serial interfaces: I²C or SPI. Both are implemented as slave interfaces. The selection between the two interfaces is made by the input pin MODE.

Table 3: Serial interface selection

MODE	Serial Interface	Pin	Description
0	SPI	CLK	Serial clock (SCLK)
		DIO	MISO (master in / slave out)
		DIN	MOSI (master out / slave in)
		CS	Chip select: CS = ‘0’: SPI interface is enabled CS = ‘1’: SPI interface is disabled and output DIO is in high impedance state
1	I²C	CLK	Serial clock (SCL; chip internal pull-up resistor connected to VDD)
		DIO	Serial data (SDA; chip internal pull-up resistor connected to VDD)
		DIN	Not used; **do not connect**
		CS	Not used; **do not connect**

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10 Serial peripheral interface (SPI)

SPI is a synchronous serial 4-wire protocol. The signals are MOSI (master out / slave in), MISO (master in / slave out), SCLK (serial clock) and CS (chip select).

Three signals are shared between all devices on the same SPI bus: SCLK, MOSI and MISO. SCLK is generated by the master device and is used for synchronization. MOSI and MISO are the two data lines. The direction is indicated by the names. The data flows simultaneously in both directions.

Each slave has its own CS line. The master pulls the CS line to '0' to communicate with a slave. The MS1088 is always in slave mode.

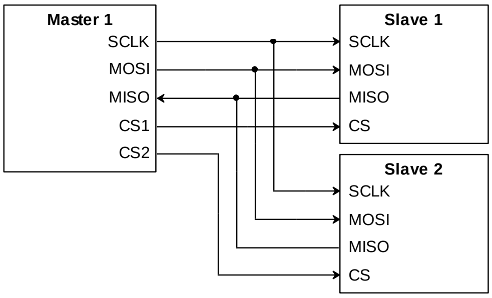
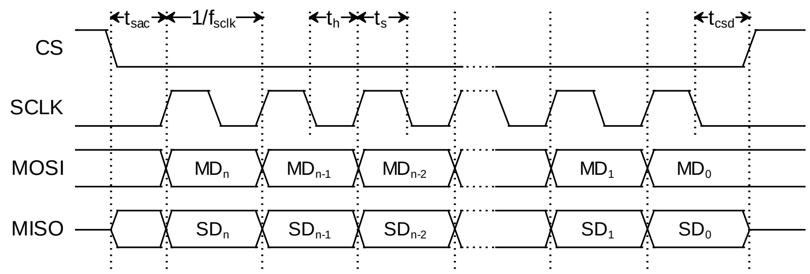


Figure 6: General SPI implementation of one master and two slaves

10.1 SPI protocol

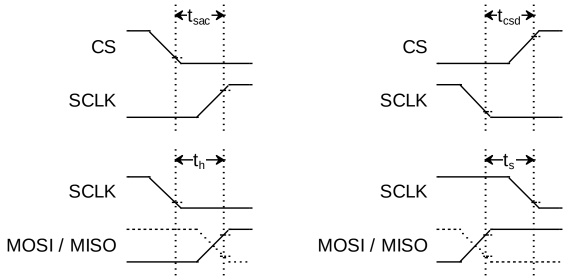
The data flow of the SPI serial interface is defined by the parameters Clock Polarity (CPOL) and Clock Phase (CPHA). MS1088 expects CPOL = ‘0’ and CPHA ‘1 which means that the data is clocked by the falling edge of the clock signal.

The CS signal of the addressed slave must be pulled to ‘0’ before a data transmission can be started and must stay at ‘0’ during the data transmission. The serial interface of the MS1088 immediately enters a reset state if the CS signal is pulled to ‘1’. During the reset state the output MISO is in high impedance state and the clock signal SCLK is ignored.



Remark:
MD: Data from master (MSB first, LSB last)
SD: Data from slave (MSB first, LSB last)

Figure 7: SPI timing



Remark:
All timings are measured at **10%** or **90%** of the signal level

Figure 8: SPI timing details

10.2 Addressing the MS1088 in SPI mode

The two address pins A0H and A1H are used to define the hardware address of the MS1088. This allows connection of up to four MS1088 on the same 4-wire SPI bus. A MS1088 is addressed if the value of the hardware address bits A0H and A1H is equal to the value of the address bits A0S and A1S in the SPI data protocol.

Table 4: Addressing the MS1088 in SPI Mode[1]

A0H	A1H	A0S	A1S	Description
‘a’	‘b’	‘a’	‘b’	MS1088 addressed
‘a’	‘b’	‘a’	‘a’	MS1088 not addressed
‘a’	‘b’	‘b’	‘a’	MS1088 not addressed
‘a’	‘b’	‘b’	‘b’	MS1088 not addressed

[1] The logical values of ‘a’ and ‘b’ can either be ‘0’ or ‘1’

10.3 SPI data shift register

The SPI data shift register of MS1088 has a size of 16 bits. The first two bits are the address bits A0S and A1S, the next two bits are control and state bits followed by the data bits.

Input data shift register (MOSI)

Bit 15 … Bit 0

A1S	A0S	C1	C0	DI4	DI3	DI2	DI1	DI0	X	X	X	X	X	X	X

DI4–DI0: data bits; X: not used

Remark:
Bits 15 and 14 (A1S, A0S) are address bits
Bits 13 and 12 (C1, C0) are command bits
Bits 11 to 7 (DI4...DI0) are data bits
Bits 6 to 0 are not used and can have either state

Output data shift register (MISO)

Bit 15 … Bit 0

0	0	0	R1	DO11	DO10	DO9	DO8	DO7	DO6	DO5	DO4	DO3	DO2	DO1	DO0

DO11–DO0: data bits

Remark:
Bits 15 and 14 are always '0'
Chip addressed:
Bit 13 is always '0'
Bit 12 is the state bit R1: it is '1' if the chip is ready to start a temperature measurement
It is '0' if a temperature measurement is active
Bits 11 to 0 contain the temperature measurement value
Chip not addressed:
Bits 13 to 0 are in high impedance state

Figure 9: SPI data shift register[1]

[1] The chip is ready to start a temperature measurement if the state bit R1 is '1'. The chip is not ready to start a temperature measurement or a temperature measurement is already active if R1 is '0'. The command S2 is ignored in this case.

10.4 SPI commands

Table 5: SPI command table

Command	C1	C0	Data DI/DO D11=MSB, D0=LSB	Description
S1	0	0	TD = DO[11..0]	Read temperature value TD[1]
S2	0	1	-	Start temperature measurement once[2]
S3	1	0	DI[4..0] = ‘0xxxx’ DI[4..0] = ‘10000’ DI[4..0] = ‘10001’ DI[4..0] = ‘10010’ DI[4..0] = ‘10011’ DI[4..0] = ‘10100’ DI[4..0] = ‘10101’ ⋮ DI[4..0] = ‘11111’	Deactivate EOL measurement. Set EOL threshold level $V_{th0:EOL}$ = 2.20V Set EOL threshold level $V_{th1:EOL}$ = 2.25V Set EOL threshold level $V_{th2:EOL}$ = 2.30V Set EOL threshold level $V_{th3:EOL}$ = 2.35V Set EOL threshold level $V_{th4:EOL}$ = 2.40V Set EOL threshold level $V_{th5:EOL}$ = 2.45V (default) ⋮ Set EOL threshold level $V_{th15:EOL}$ = 2.95V

10.5 Temperature conversion

The temperature T is calculated by inserting the digital temperature value TD received by command S1 into the following formula:

$$T\ (°C) = \frac{TD}{20} - 80$$

$$T\ (°F) = \left(\frac{TD}{20} - 80\right) \times 1.8 + 32$$

11 I²C interface

The MS1088 has a slave receiver/transmitter I²C interface. Pin CLK (SCL) is clock and pin DIO (SDA) is data input/output. DIO has an open-drain drive. Pull-up resistors are connected internally to CLK and DIO. Additional pull-up resistors need to be connected to CLK and DIO if the external load on pins CLK and DIO is too high.

11.1 Addressing the MS1088 in I²C mode

The 7 bit I²C slave address consists of five base address bits A4 to A0 and two sub-address bits A1S and A0S. The MS1088 is addressed correctly if the slave address matches with the base address and the sub-address bits match with the hardware address bits A1H and A0H. With the two sub-address bits it is possible to operate four MS1088 independently on the same I²C bus.

Table 6:I²C slave address

Bit	A4	A3	A2	A1	A0	A1S	A0S
	1	0	0	1	0	A1S	A0S

[1] The TD value is 0 if no temperature measurement had been performed or a temperature measurement is currently active.

[2] The command S2 is ignored if a temperature measurement is active.

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11.2 I²C protocol

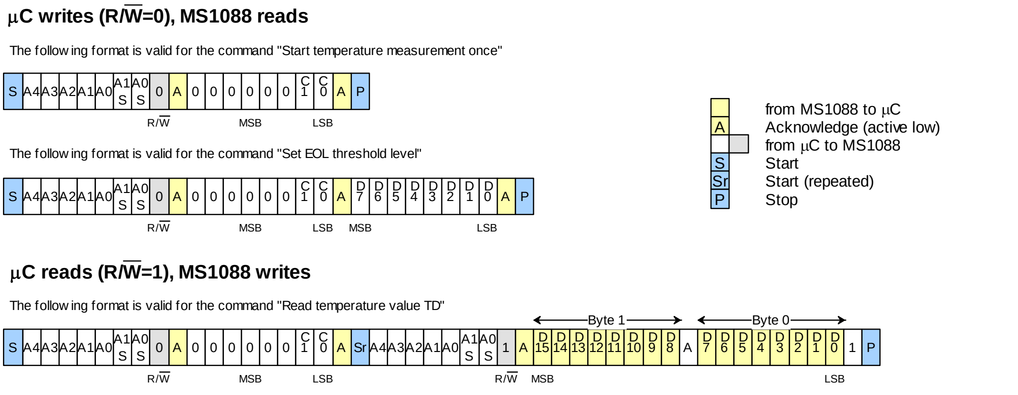

Figure 10: I²C protocol

11.3 I²C bus timing

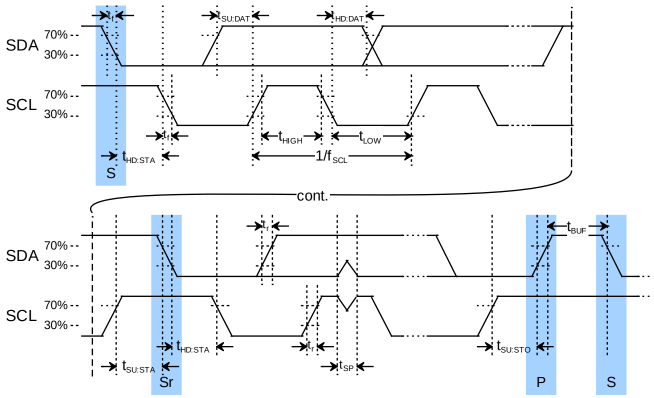

Figure 11: Bus timing

Noise suppression is implemented on both inputs DIO (SDA) and CLK (SCL). For further information about the I²C bus refer to the NXP “I²C-bus specification and user manual”, Rev. 03, June 2007.

11.4 I²C commands

Table 7: I²C command table

Command	C1	C0	R/W	Data D15=MSB, D0=LSB	Description
I1	0	0	1	TD = D[15..0]	Read temperature value TD[1]
I2	0	1	0	-	Start temperature measurement once[2]
I3	1	0	0	DI[4..0] = '0xxxx' DI[4..0] = '10000' DI[4..0] = '10001' DI[4..0] = '10010' DI[4..0] = '10011' DI[4..0] = '10100' DI[4..0] = '10101' ⋮ DI[4..0] = '11111'	Deactivate EOL measurement. Set EOL threshold level $V_{th0:EOL}$ = 2.20V Set EOL threshold level $V_{th1:EOL}$ = 2.25V Set EOL threshold level $V_{th2:EOL}$ = 2.30V Set EOL threshold level $V_{th3:EOL}$ = 2.35V Set EOL threshold level $V_{th4:EOL}$ = 2.40V Set EOL threshold level $V_{th5:EOL}$ = 2.45V (default) ⋮ Set EOL threshold level $V_{th15:EOL}$ = 2.95V
I4	1	1	0	-	Chip reset

11.5 Temperature conversion

The digital temperature value TD is stored in the first 12 bits D[15]…D[4] of the data received by command I1. The Temperature can be calculated by the following formula:

$$\mathrm{T}\ (°\mathrm{C}) = \frac{\mathrm{TD}}{20} - 80$$

$$\mathrm{T}\ (°\mathrm{F}) = \left(\frac{\mathrm{TD}}{20} - 80\right) \times 1.8 + 32$$

The other 4 bits are generated according to a simple error correcting code (ECC), which will correct a transmission error of 1 bit (and detect an error of 2 bits).

[1]The TD value is 0 if no temperature measurement had been performed or a temperature measurement is currently active.

[2] The command I2 is ignored if a temperature measurement is active. An active temperature measurement is indicated if the MS1088 suppresses the acknowledge signal.

11.6 Error Correcting Code (ECC)

In I²C mode, the MS1088 encodes the last 4 bits (D3, D2, D1, D0) with an ECC, which may be used to correct transmission errors. The bits are calculated by the following formulas:

$$D3 = D15 \oplus D14 \oplus D13 \oplus D9 \oplus D8 \oplus D7 \oplus D5$$

$$D2 = D15 \oplus D12 \oplus D11 \oplus D9 \oplus D8 \oplus D6 \oplus D5$$

$$D1 = D14 \oplus D11 \oplus D10 \oplus D9 \oplus D7 \oplus D6 \oplus D5$$

$$D0 = D13 \oplus D12 \oplus D10 \oplus D8 \oplus D7 \oplus D6 \oplus D5$$

The Symbol ⊕ represents an XOR operator. If implemented by a sequential code, the bits of each formula may also be added, if the result is an even number, the ECC-bit is logical 0, otherwise it's a logical 1. Since a 1-error-correcting Code with four parity-bits can have up to 2^{11} words (see "Hamming Code"), the last bit of TD (D[4]) is not protected by the ECC. But an error on the LSB will result in an overall temperature error of just 0.05 K.

The result "ECC failed" will occur, if there are two transmission errors.

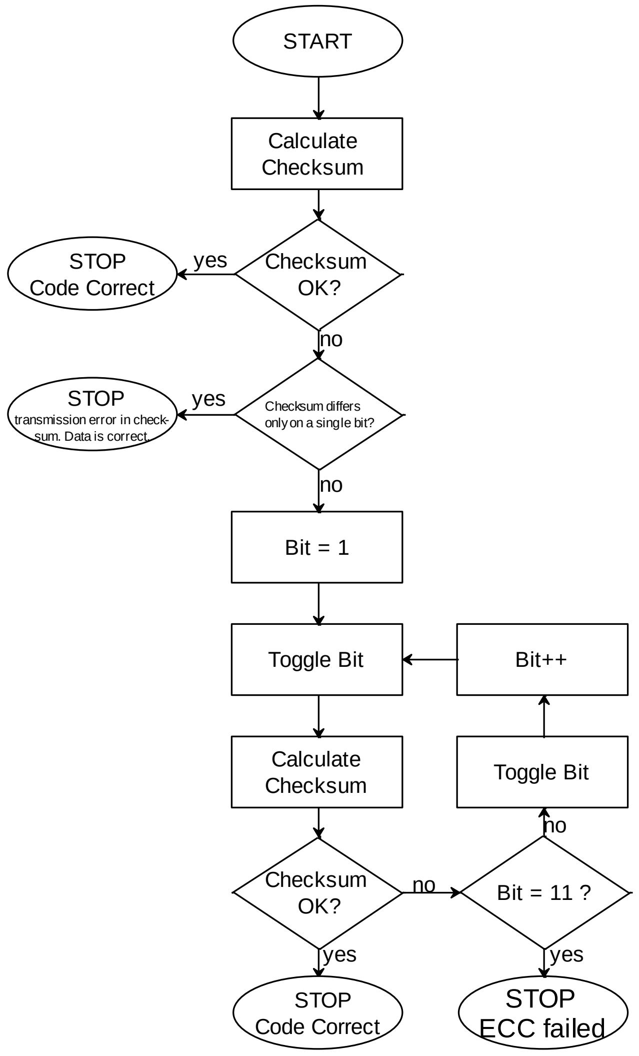

Figure 12: Possible ECC implementation (flowchart)

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11.7 I²C communication examples

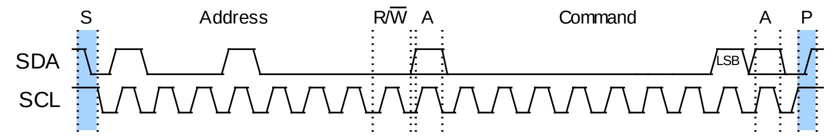

Figure 13: I²C example "Start temperature measurement once"

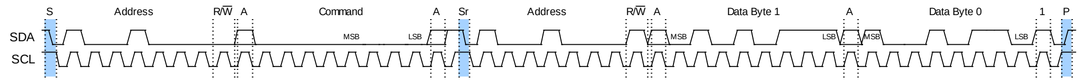

Figure 14: I²C example "Read temperature value TD"

The digital value D is '0101 0111 1001 0110' (MSB to LSB) in the example above. Since the last four Bits are used for the ECC, the temperature is stored in the first 12 Bits. Therefore, the digital temperature value TD is '0101 0111 1001' (binary). This corresponds to a decimal TD value of 1401, which corresponds to an analogue temperature value TA of -9.95°C.

12 Hardware Handshake

In addition to starting a measurement using an interface command (I2 or S2), the MS1088 offers a simple hardware handshake to start a measurement and receive a "measurement finished" signal, which may be used as a wake-up interrupt.

To start a measurement, the pin TM needs to be set to 0 by the micro controller for at least 50 microseconds. After the measurement is done, the Pin TM will change to 0 until the result is read out.

To receive a signal, the microcontroller has to be set to a high-impedance mode. If the function should not be used, do not connect the pin, since its state is always defined.

12.1 Hardware Handshake I2C-Mode

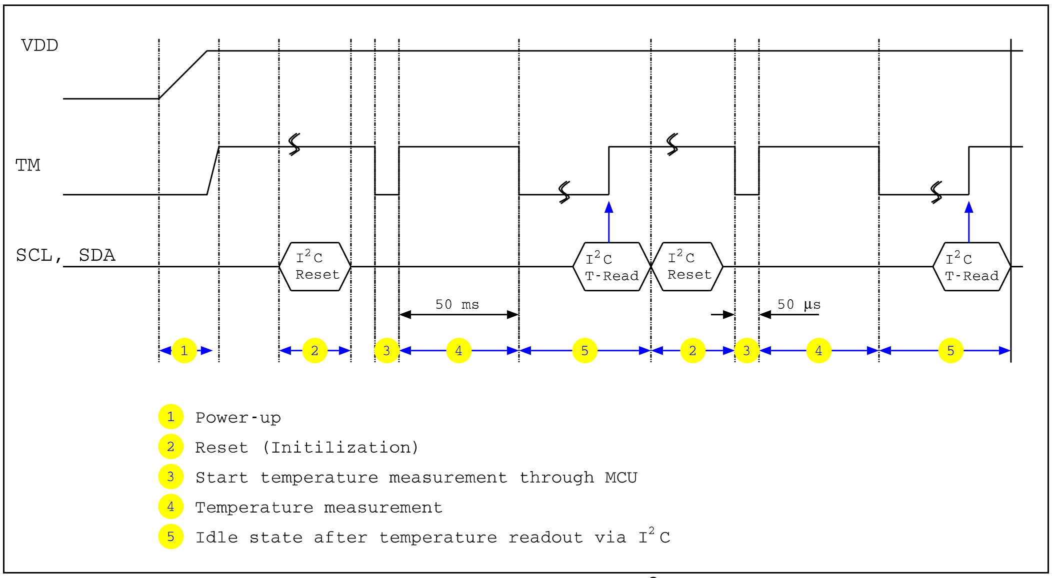

Figure 15 Signal waveform I²C-Mode

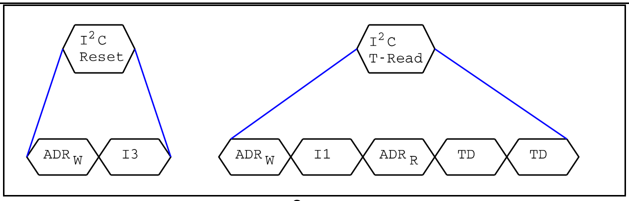

Figure 16 I²C commands

12.2 Hardware Handshake SPI-Mode

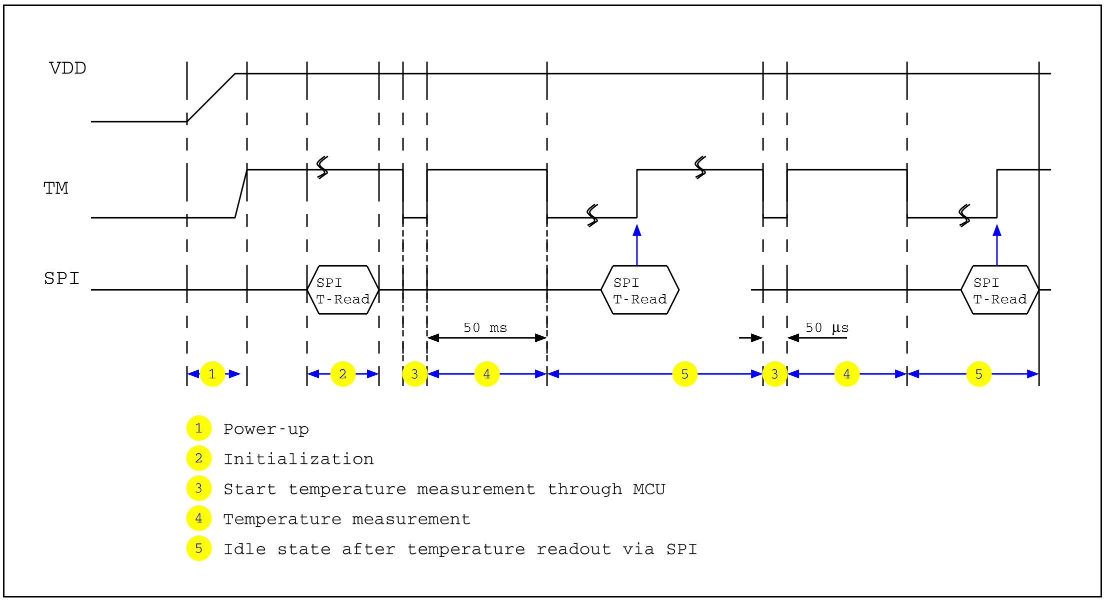

Figure 17 Signal waveform SPI-Mode

13 EOL battery detection

The supply voltage V_{DD} is compared before each temperature measurement with the EOL threshold level $V_{TH:EOL}$. The digital output EOL remains in the logic '0' state if V_{DD} is greater than $V_{TH:EOL}$. When V_{DD} falls below $V_{TH:EOL}$ the output is driven to a logic '1' state. The output EOL is driven in sleep and in active mode.

Sixteen different threshold levels from 2.20V to 2.95V in steps of 50mV can be set by serial bus commands. If the signal is not needed, EOL battery detection can be turned off. Refer to sections 10.4 and 11.4 for details. Deactivating the EOL measurement keeps the last result. It does not reset the EOL pin to logic '0' state.

The EOL result does not affect the temperature measurement.

14 Characteristics

14.1 Limiting values and ESD protection

Table 8: Limiting values[1] and ESD Protection[2]

Name	Parameter	Min	Max	Unit
V_{DD}	Positive supply voltage wrt to V_{SS}	-0.5	3.5	V
V_I	Input voltages wrt to V_{SS}	-0.5	V_{DD}+0.5	V
I_I, I_O	Input and output currents	-10	10	mA
I_{VSS}	Total current to V_{SS}	-25	25	mA
P_{TOT}	Power dissipation		300	mW
T_{stg}	Storage temperature	-60	+125	°C
T_J	Junction temperature		+125	°C
$V_{ESD\ (1)}$	Electrostatic discharge voltage CDM		+/- 1000	V

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14.2 Sensor performance

Table 9: Sensor performance
Conditions: V_{DD} = 3.0V DC[3], T = 25°C, if not stated otherwise

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{Error}	Temperature error (see Figure 13)	T = 10°C to +40°C	±0.5	±0.3	±0.5	°C
T_{RES}	Resolution (LSB)			0.05		°C
T_{PSVD}	Power supply voltage dependency			±0.1		°C/V
t_{TM}	Measuring time of single temperature conversion			50		ms

Important notes:

1. Assuming a Gaussian distribution the typical values represent 97% of the circuits.
2. Assuming a Gaussian distribution the max values represent about ±4 sigma (>99.99%) of the circuits.
3. The temperature sensor calibration data is stored in OTP (one time programmable) memory. The temperature sensor itself cannot be recalibrated. To improve the temperature sensor accuracy the whole temperature sensor application has to be calibrated at one or more temperatures. The correction curve (e.g. offset value for one point calibration) has to be stored externally (e.g. microcontroller).

[1] These are stress ratings only. Stress above one or more of the limiting values may cause permanent damage to the device. Operation of the device at these or at any other conditions above those given in the characteristics section of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

[2] Inputs and outputs are protected against electrostatic discharge during normal handling. However to be totally safe, it is advisable to undertake precautions appropriate to handling MOS devices.

[3]Calibration temperature

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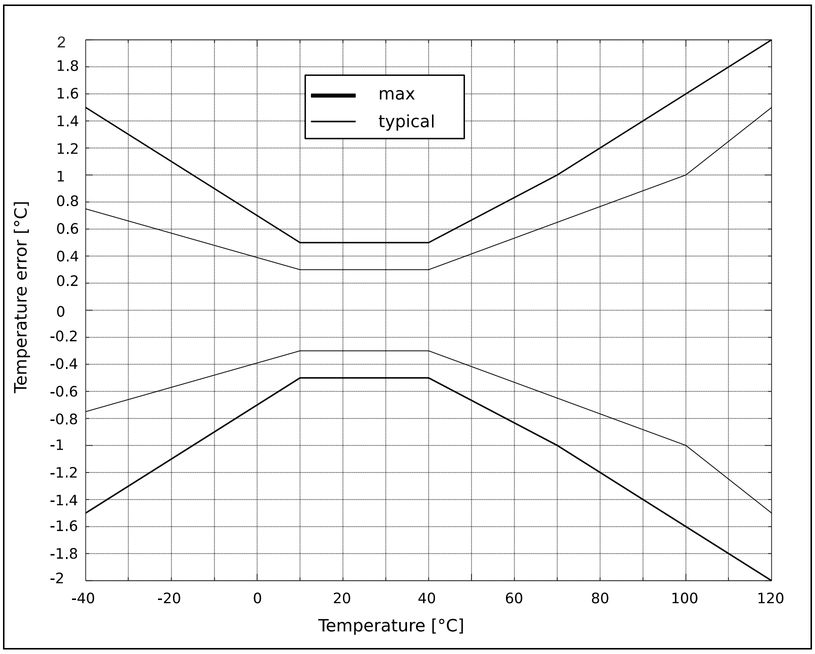

Figure 18: Temperature accuracy

14.3 DC Characteristics

Table 10: DC characteristics
Conditions: V_{DD} = 3.0V DC, T = 25°C, if not stated otherwise

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	Positive supply voltage	IC operation[1] Temperature measurements	2.2 2.4	3.0 3.0	3.6 3.6	V V
I_{DD}	Operating current	Stand-by		20		nA
		Measuring temperature		75		µA
		Average (one measurement every 60 seconds)		80		nA
$V_{th:EOL}$	EOL threshold level	$V_{th0:EOL}$ $V_{th1:EOL}$ $V_{th2:EOL}$ $V_{th3:EOL}$ $V_{th4:EOL}$ $V_{th5:EOL}$ (default value) $V_{th6:EOL}$ $V_{th7:EOL}$ $V_{th8:EOL}$ $V_{th9:EOL}$ $V_{th10:EOL}$ $V_{th11:EOL}$ $V_{th12:EOL}$ $V_{th13:EOL}$ $V_{th14:EOL}$ $V_{th15:EOL}$		2.20 2.25 2.30 2.35 2.40 2.45 2.50 2.55 2.60 2.65 2.70 2.75 2.80 2.85 2.90 2.95		V V V V V V V V V V V V V V V V
V_{EOL}	EOL output level	EOL = '1'; I_{EOL} = -1mA	0.8 V_{DD}			V
		EOL = '0'; I_{EOL} = 1mA			0.2 V_{DD}	V
$V_{DIO:SPI}$	DIO output level in SPI mode	MODE = '0', DIO = '1', I_{DIO} = -1mA	0.8 V_{DD}			V
		MODE = '0', DIO = '0',			0.2 V_{DD}	V

[1] All commands can be executed, but temperature accuracy may not be sufficient

		I_{DIO} = 1mA				
V_{IH}	Input high level for digital inputs		0.7 V_{DD}		V_{DD}	V
V_{IL}	Input low level for digital inputs		V_{SS}		0.3 V_{DD}	V
R_{SCL}	Internal pull-up resistor on SCL	MODE = '1'		145		kΩ
R_{SDA}	Internal pull-up resistor on SDA	MODE = '1'		145		kΩ
T_{amb}	Operating temperature range		-40	25	120	°C
C_{load}	Load capacitance at pin TM	No external pull-up resistor			10	pF

14.4 AC Characteristics

Table 11: AC characteristics[1]
Conditions: V_{DD} = 3.0V DC, T = 25°C, if not stated otherwise

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{sclk}	SPI clock frequency	SPI mode; MODE = '0' Load at DIO: C < 20pF, R > 1MΩ			1.0	MHz
t_{SAC}	Waiting time between falling edge of CS and first rising edge of clock	SPI mode; MODE = '0'	500			ns
t_{CSD}	Waiting time between last falling edge of clock and rising edge of CS	SPI mode; MODE = '0'	500			ns
t_h	Data hold time	SPI mode; MODE = '0'	100			ns
t_s	Data setup time	SPI mode; MODE = '0'	100			ns
f_{SCL}	I²C clock frequency	I²C mode; MODE = '1'			100	kHz
$t_{HD:STA}$	Hold time (repeated) START condition	I²C mode; MODE = '1'	4.0			µs
$t_{SU:STA}$	Set-up time (repeated) START condition	I²C mode; MODE = '1'	4.7			µs
t_{LOW}	LOW period of the SCL clock	I²C mode; MODE = '1'	4.7			µs
t_{HIGH}	HIGH period of the SCL clock	I²C mode; MODE = '1'	4.0			µs
$t_{HD:DAT}$	Data hold time	I²C mode; MODE = '1'	50			ns
$t_{SU:DAT}$	Data set-up time	I²C mode; MODE = '1'	250			ns
t_r	Rise time of the SDA and SCL signals	I²C mode; MODE = '1'			1	µs
t_f	Fall time of the SDA and SCL signals	I²C mode; MODE = '1'			0.3	µs
$t_{SU:STO}$	Set-up time for STOP condition	I²C mode; MODE = '1'	4.0			µs
t_{BUF}	Wating time between STOP and START condition	I²C mode; MODE = '1'	4.7			µs
t_{SP}	Spike suppression	I²C mode; MODE = '1'			100	ns
t_{Start}	Length of start pulse at pin TM		50			µs

[1] SPI timings are measured between 10% and 90% of the signal levels, I²C timings between 30% and 70% of the signal levels.

Tel. +41 44 455 35 11, Fax +41 44 455 35 95
http://www.microdul.com/
semiconductors@microdul.com

15 Application information

The MS1088 is a digital temperature sensor that is optimal for thermal management and thermal protection applications. The MS1088 is two-wire I^2C and four-wire SPI interface compatible and is specified over a temperature range of -40°C to +120°C.

Pull-up resistors are internally connected to CLK (SCL) and DIO (SDA) in I^2C mode. Additional pull-up resistors can be externally connected to CLK and DIO for high external capacitive loads. The interface's inputs and outputs are CMOS compatible in SPI mode.

15.1 Heat sources

The temperature sensor in the MS1088 is the chip itself. To maintain accuracy in applications requiring air or surface temperature measurement, care should be taken to isolate the package from ambient air temperature or parasitic heat sources. Figure 19 and Figure 20 show some basic rules how unwanted heat conduction and heat convection / heat radiation between a parasitic heat source and the MS1088 can be avoided.

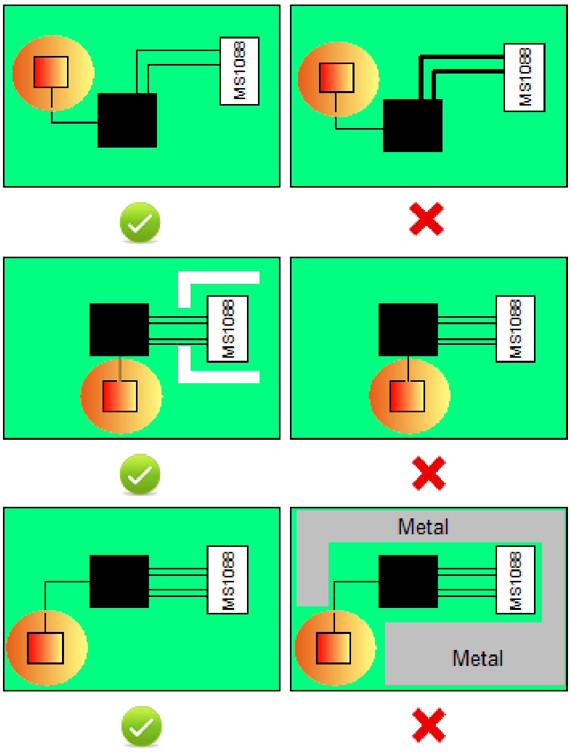

Figure 19: Thin metal lines, sufficient distance to parasitic heat sources, slits (white lines) around the temperature sensor and removal of unnecessary metal on the PCB help avoid heat conduction.

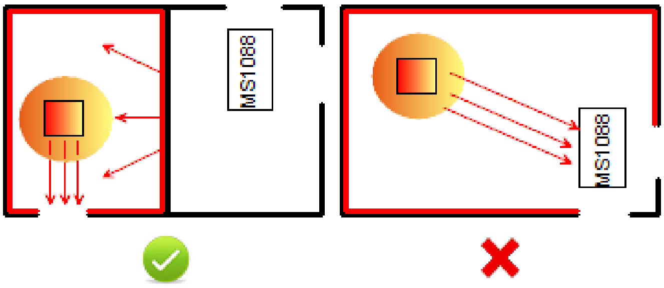

Figure 20: Physical separation of parasitic heat sources and the MS1088 avoids unwanted heating of the MS1088 by heat convection or heat radiation. Heating of the complete housing is avoided by sufficient heat transfer out of the housing (opening in the housing). Separation of the openings for the MS1088 and the heat transfer out of the housing avoids indirect heating.

15.2 Thermal coupling

To achieve a good thermal coupling between the MS1088 and the “environment under test” the MS1088 should be placed as close to the “environment under test” as possible. Heat conductive paste can improve the heat conduction transfer to the MS1088 and increase the accuracy of surface temperature measurements. For measuring the ambient temperature the MS1088 should be placed in an ambient airstream.

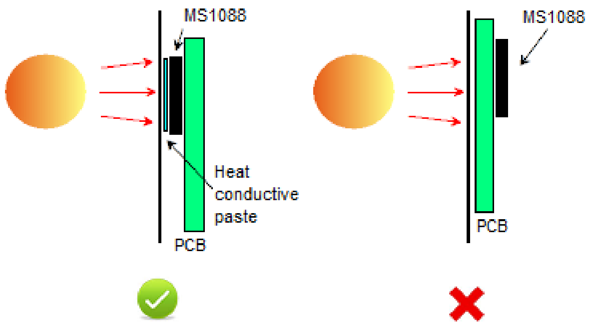

Figure 21: Place the MS1088 as close as possible to the “environment under test”. Heat conductive paste can improve heat transfer.

16 QFN Package Outline

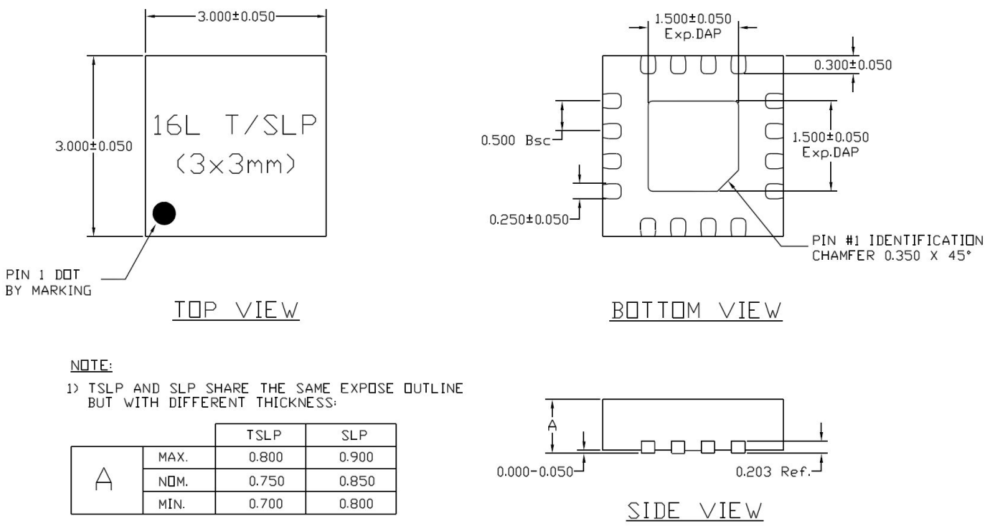

Figure 22: QFN package dimensions: 3.000 x 3.000 x 0.850mm, tolerance ± 0.050mmm on all dimensions. Weight 0.022g ± 10%

17 Application information

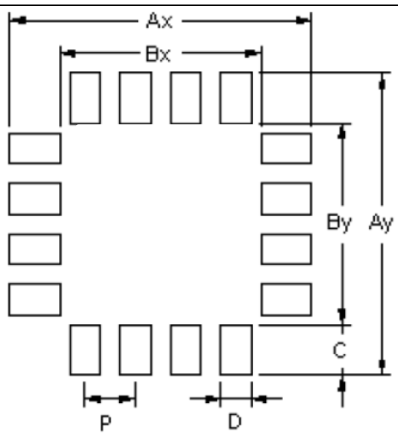

Figure 23: QFN16 footprint: Please refer to the Table 12 for the dimensions. For best temperature accuracy it is not recommended to solder the thermal pad of the QFN package to the printed circuit board

Symbol	Value	Tolerance	Unit
P	0.5	±0.03	mm
Ax	3.8	±0.03	mm
Ay	3.8	±0.03	mm
Bx	2.1	±0.03	mm
By	2.1	±0.03	mm
C	0.85	±0.03	mm
D	0.3	±0.03	mm

Table 12: QFN16 footprint dimensions

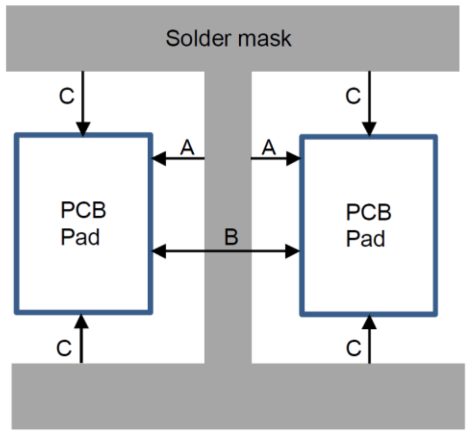

Figure 24: If necessary, the edge of the solder mask opening around the PCB pads can be set up to the edge of the pad (A). If the distance between the pads is insufficient for the solder mask (B) then the mask can be set to the bottom and the top edges of the pads (C).

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18 Assembly instructions

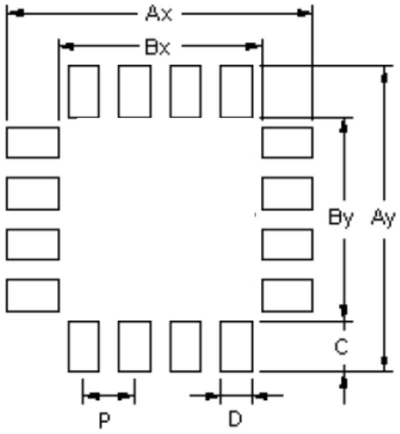

Figure 25: Stencil dimensions: The recommended stencil thickness is 0.10 to 0.13mm. Please refer to the tables below for the dimensions.

Symbol	Value	Tolerance	Unit
P	0.5	±0.03	mm
Ax	3.64	±0.03	mm
Ay	3.64	±0.03	mm
Bx	2.28	±0.03	mm
By	2.28	±0.03	mm
C	0.68	±0.03	mm
D	0.24	±0.03	mm

Table 13: Stencil dimensions

The recommendations in the table above are based on a stencil thickness of 0.10 to 0.13mm and the PCB footprint size given in section 16. The stencil dimensions are 80% of the footprint size. Both the stencil thickness and dimensions are recommendations. The stencil thickness and dimensions may have to be adjusted to take into account other components on the board. For example, components with leads may typically require a little more solder to compensate for co-planarity problems. Generally speaking increasing the stencil thickness and/or dimensions result in more solder being deposited and increases the risk of bridging. Decreasing the stencil thickness and/or dimensions results in less solder being deposited and increases the risk of insufficient solder for a good solder joint.

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19 Recommended reflow parameters

The reflow profile is dependent on many different parameters. The profile here is given as a guide. It may be necessary to adjust the profile slightly depending on the solder flux and equipment used.

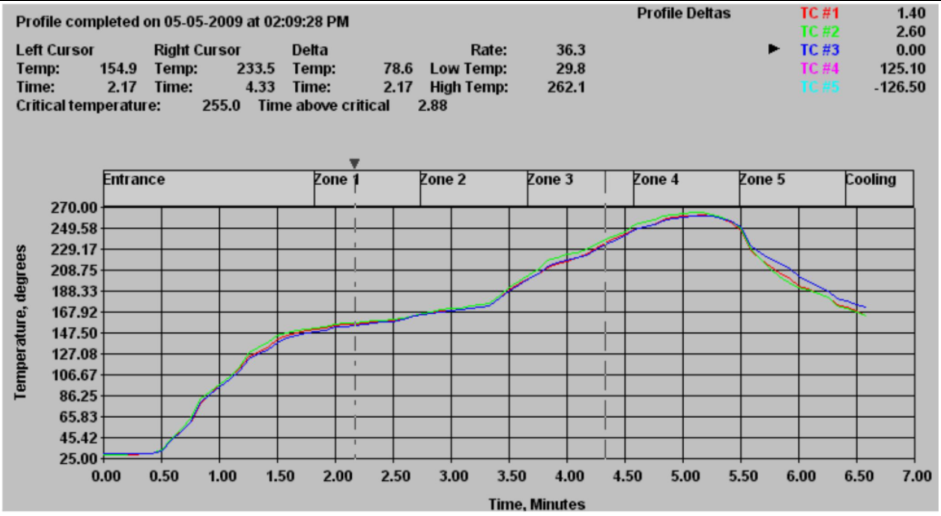

Figure 26: Recommended reflow profile. The maximum reflow temperature is 260°C for 40 seconds. The moisture sensitivity level is 1 (MSL1).

20 Legal disclaimer

This product is not designed for use in life support appliances or systems where malfunction of these parts can reasonably be expected to result in personal injury. Customer using or selling this product for use in such appliances does so at his own risk and agrees to defend, indemnify and hold harmless Microdul AG from all claims, expenses, liabilities, and/or damages resulting from such use of the product.