# Ultra-low power, two channel capacitive sensor and touch switch for human body detection

## 1 General Description

The integrated circuit MS8890B is an ultra-low power, two channel capacitive sensor specially designed for human body detection. It offers two operating modes: meter mode or switch mode. In switch mode the sensor capacitance is compared with the internal reference capacitance. The sensor output changes polarity if the sensor capacitance falls below or rises above a threshold capacitance. The threshold capacitance can be individually set for both channels. The MS8890B can also be operated in meter mode where the absolute capacitance values of the sensor channels are measured. The MS8890B is configured via an $I^2C$ serial interface. The comparator outputs are available at circuit pins in switch mode or can be read via the $I^2C$ serial interface. The configuration of the various options and the operation of the meter mode are done via the $I^2C$ serial interface. After programming the configuration to the one-time-programmable (OTP) memory the MS8890B can be operated in switch mode as a single chip solution.

## 2 Applications

- Human body detection (e.g. in-ear phone, finger detection)
- Wrist detection (e.g. wearables)
- Fluid detection (e.g. coffee machine)
- Close proximity sensing
- Touch switch

## 3 Typical application

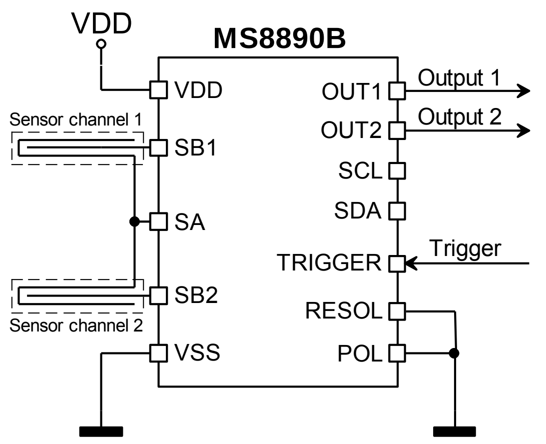


Figure 1: Application diagram for switch mode with external trigger source

## 4 Features

- Two capacitive sensor channels
- One or two channel operation
- Meter mode or switch mode
- Capacitance meter with 4 measuring ranges covering 0 to 400fF with a resolution of 8 or 9-bit
- 8 or 9-bit resolution selectable with pin RESOL
- Individually programmable threshold capacitance for both sensor channels in switch mode
- Programmable measuring interval in switch mode (single trigger, 2 measurements/s, 32 measurements/s, permanent)
- Programmable noise filter in switch mode
- Comparator outputs available at pins OUT1 (sensor CS1) and OUT2 (sensor CS2) in switch mode
- Polarity of comparator outputs selectable by pin POL
- $I^2C$ serial interface available at pins SDA and SCL
- No external components needed
- Sensors capacitance can be realized with conductive tracks on PCB or casing
- Idle current typ. 50nA
- Active current during measurement typ. 11µA
- Average current for 2 measurements/s in switch mode typ. 725nA (1 channel, no noise filter)
- Voltage operating range 1.8 to 4.5V
- Temperature operating range -40 to 85°C
- Available in QFN16 3x3mm or CSP

## 5 Ordering Information

| Type | Package | Shipping | Article No. |
|---|---|---|---|
| MS8890B | QFN16 3x3mm | tape&reel | 9160384 |
| | CSP 1.03x1.52mm | tape&reel | 9160385 |

Table 1: Ordering information

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## 6 Pinout

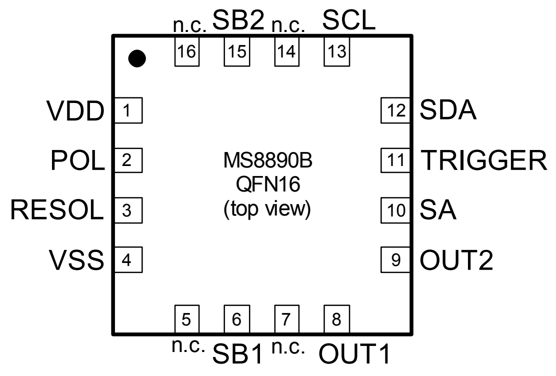


Figure 2: Pinout QFN16

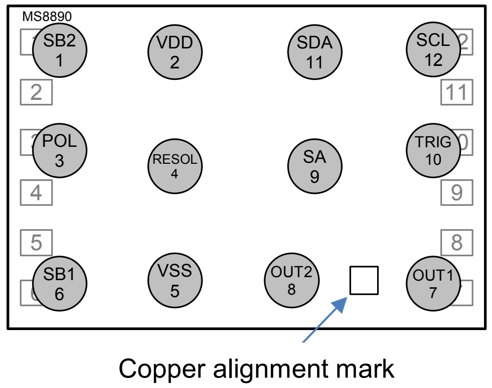


Figure 3: Pinout CSP
bottom view ('dead-bug' view)

## 7 Pin description

| Pin QFN | Pin CSP | Symbol | Type | Description |
|---|---|---|---|---|
| 1 | 2 | VDD | supply | Positive supply voltage |
| 2 | 3 | POL | digital input | Sets polarity of OUT1 and OUT2<br>POL = '0': OUTx is high if $C_{sensor} < C_{TH}$<br>POL = '1': OUTx is high if $C_{sensor} > C_{TH}$ |
| 3 | 4 | RESOL | digital input, programing supply | ADC resolution<br>RESOL = '0': 8-bit<br>RESOL = '1': 9-bit (supported measuring range is only 50 to 100% of selected range)<br>RESOL is also used for applying the programming voltage during programming of the OTP memory |
| 4 | 5 | VSS | supply | Negative supply voltage |
| 5 | | n.c. | | not connected; pin can be left open |
| 6 | 6 | SB1 | analog input | Input sensor CS1 |
| 7 | | n.c. | | not connected; pin can be left open |
| 8 | 7 | OUT1 | digital output/ | Switch mode output of sensor CS1 (CMOS stage) |
| 9 | 8 | OUT2 | digital output | Switch mode output of sensor CS2 (CMOS stage) |
| 10 | 9 | SA | digital output | Sensor output |
| 11 | 10 | TRIGGER | digital input | External trigger to start measurement in switch mode |
| 12 | 11 | SDA | digital I/O | SDA ($I^2C$ interface) |
| 13 | 12 | SCL | digital input | SCL ($I^2C$ interface) |
| 14 | | n.c. | | not connected; pin can be left open |
| 15 | 1 | SB2 | analog input | Input sensor CS2 |
| 16 | | n.c. | | not connected; pin can be left open |

Table 2: Pin description

Notes:
1. SB1 and SB2 are internally switched to VSS over 8kΩ resistors when the measurement is inactive.
2. All digital inputs must be connected to either VSS or to VDD in the application except pins SDA and SCL.



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# 8 Description

## 8.1 Basic functionality

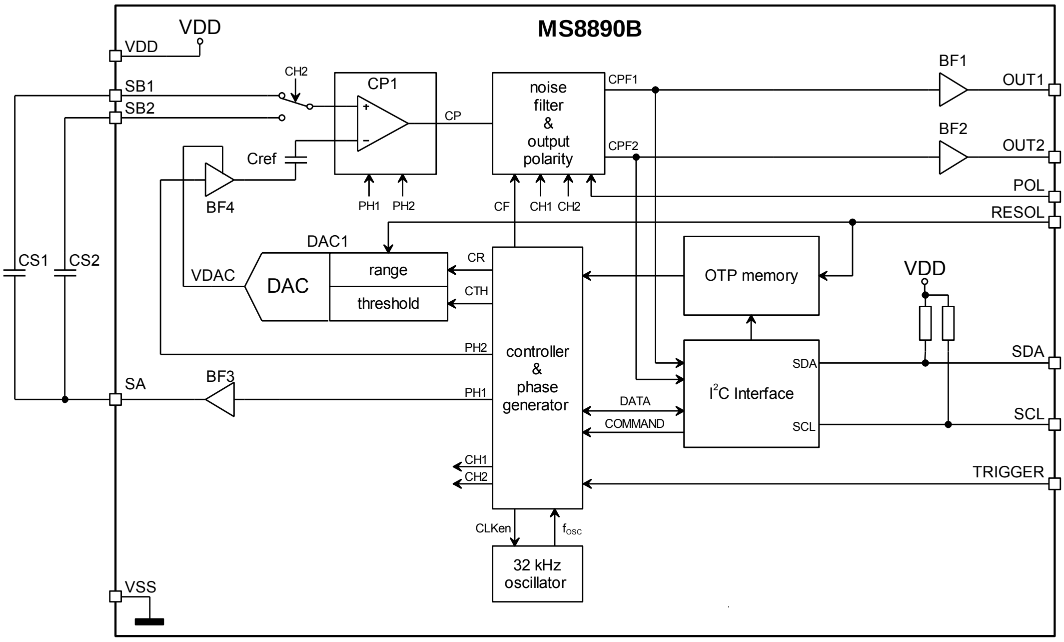


Figure 4: MS8890B block diagram

Figure 4 shows the block diagram of the circuit MS8890B. The circuit has two capacitive sensor channels CS1 and CS2. The sensor channels have one common sensor output SA and two individual sensor inputs SB1 (sensor CS1) and SB2 (sensor CS2). The sensor capacitance is measured by comparing the charge transferred at the sensor input with a reference charge defined by Cref and the voltage VDAC. VDAC is the output of the digital-to-analog converter DAC1. The equilibrium, where both charges are equal is found with a binary search. The equilibrium is defined by the following equation.

$$V_{DD} \cdot CS = VDAC \cdot Cref$$

The MS8890B can be operated in meter mode or switch mode. In meter mode the sensor capacitances CS1 and CS2 are measured and converted to 8 or 9-bit digital values which represent the absolute sensor capacitances. The applied resolution depends on the logical state of pin RESOL. The measured values are read via the $I^2C$ serial interface. In switch mode the charge transferred at the sensor input, which linearly depends on the sensor capacitance, is compared with a reference charge defined by Cref and VDAC. If the sensor capacitance drops below or rises above the threshold capacitance value (CTH1 for CS1, CTH2 for CS2) is detected by the comparator CP1 and indicated by a change of the signal CP from logical 0 to logical 1. Noise suppression is done with a programmable noise filter. The noise filter has three levels (no, low and high filter). The signals CPF1 (sensor channel 1) and CPF2 (sensor channel 2) are the switch mode outputs after the noise filter and available at the outputs OUT1 and OUT2. The polarity of the switch mode outputs can be defined by the input POL (POL = ‘0’: OUTx is logical ‘1’ if CSx is smaller than CTHx; POL = ‘1’: OUTx is logical ‘1’ if CSx is larger than CTHx). The input POL is evaluated during the measuring sequence and has to be stable during this time. The states of the switch mode output signals CPF1 and CPF2 can be read via the $I^2C$ serial interface. Several options can be programmed to adapt the capacitive sensor function to the application. The options are detailed in sections 8.1.7 to 8.1.10.

### 8.1.1 Measuring sequence in switch mode

In switch mode the capacitance at the sensor channel is compared with a threshold capacitance. This is done by comparing charges. The results of the comparison are available at the outputs OUT1 and OUT2 or over the $I^2C$ serial interface. A measuring sequence in switch mode is either started with a single trigger (over input pin TRIGGER or by the $I^2C$ serial command COMP) or executed

periodically. The measuring method/interval is defined by option MI in the options register OPT1 and by the logical value of pin TRIGGER.
The measuring sequence always has the same format. It starts with the evaluation of sensor CS1 followed by the evaluation of sensor CS2. Each measuring cycle has 1 (M1), 4 (M1 to M4) or 16 (M1 to M16) measuring phases. The number of measuring phases is defined by the level of the noise filter. The level of the noise filter is set according to option CF in the options register OPT1. The noise filter is switched off completely if option NoF (options register OPT2) is set to logical ‘1’. The evaluation result is available after the last measuring phase of CS1 or CS2. Figure 5, Figure 6 and Figure 7 show the measuring sequences for different filter levels and for two sensor channels (CS1 and CS2). Only sensor channel CS1 is evaluated if bit SNG in the register OPT1 is set to logical ‘1’.

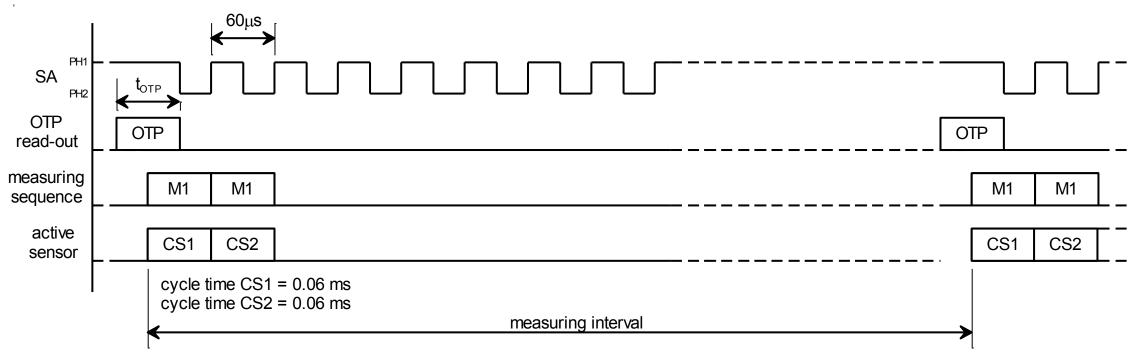


Figure 5: Measuring sequence if no noise Filter is applied (NoF = ‘1’, TRIGGER = ‘1’)

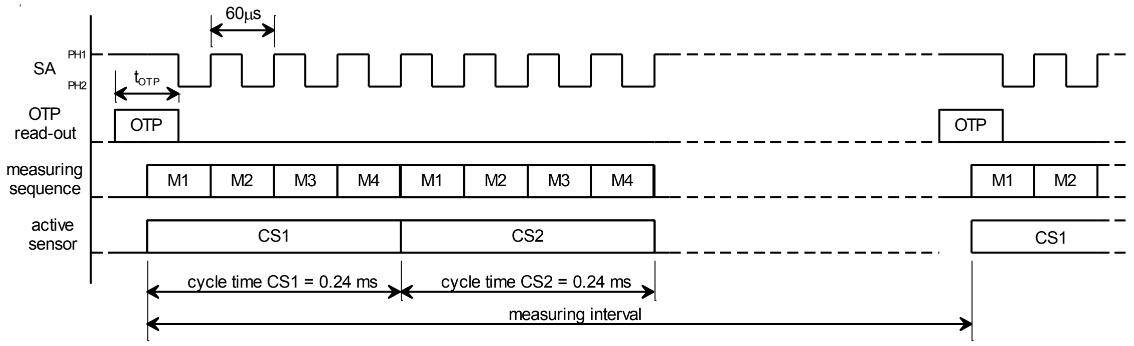


Figure 6: Measuring sequence if noise filter is low (NoF = ‘0’, CF = ‘0’)

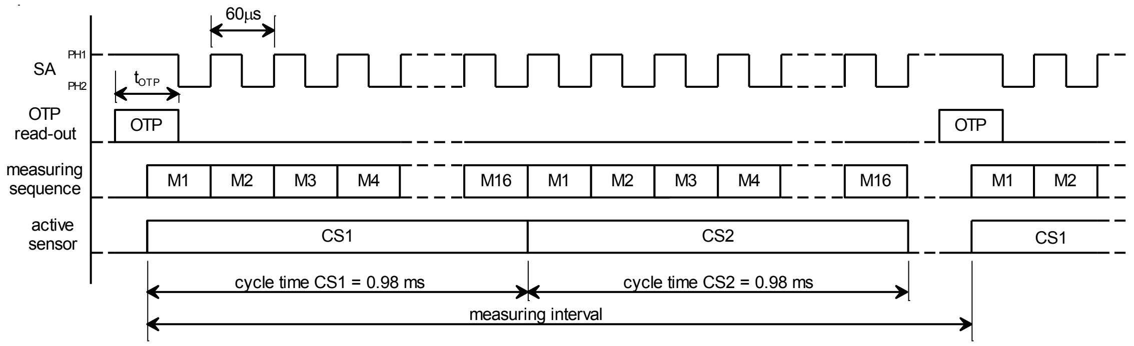


Figure 7: Measuring sequence if noise filter is high (NoF = ‘0’, CF = ‘1’)

The OTP memory read-out sequence is started ½ $t_{OTP}$ before the first measuring phase M1 and stopped at the first falling edge of SA. The duration of $t_{OTP}$ is equal to one measuring phase. The read-out of the OTP memory bits can be suppressed in RAM mode (register OPT2). This can be important for proper evaluation of the threshold capacitance. RAM mode is only possible if input TRIGGER is set to logical ‘1’.

### 8.1.2 Measuring sequence in meter mode

The meter mode is used to measure the absolute sensor capacitances of CS1 and CS2. The measured values of CS1 and CS2 can be used to configure the switch mode or used in a connected microcontroller for further evaluation. The meter mode is started by sending the command MCS to the MS8890B. Meter mode is only possible if input TRIGGER is set to logical ‘1’ and the measuring interval MI in the options register OPT1 is set to single trigger before applying the command MCS. The command MCS runs through the measuring sequence as shown in Figure 8. The sensor capacitance CS1 is measured first followed by CS2. The 8-bit digital capacitance value (B7 to B0) is evaluated with a successive approximation ADC via a binary search through all quantization levels. The measurement is finished after the measurement of the last bit (B0) of CS2. The MS8890B enters the idle mode (oscillator disabled) after the end of the measurement.
It is possible to increase the resolution of the measurement by 1 bit to 9 bits. This is done by setting pin RESOL to logical ‘1’. In this case the measuring range is limited to 50 to 100% of the selected range which means that the most significant bit (bit 9) is always ‘1’.
Only sensor channel CS1 is measured if bit SNG in the register OPT1 is set to logical ‘1’.

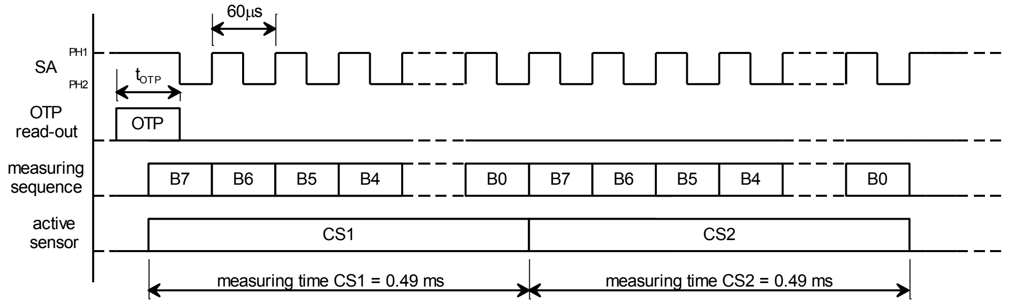


Figure 8: Measuring sequence in meter mode

### 8.1.3 Clock generation and current consumption

The MS8890B contains an integrated oscillator as main clock source. The oscillator runs nominally at $f_{OSC}$ = 32.8kHz. The oscillator is used to control the measuring interval and the measuring sequences and runs continously if the measuring interval MI is set to periodic or permanent. The current consumption is highest during the measurement sequence where blocks for measure are active.
The oscillator is not needed to control the measuring interval if the measuring interval MI is set to single trigger. In this case the oscillator is switched off at the end of the measuring sequence and the MS8890B enters the idle state.

### 8.1.4 Single hardware trigger (switch mode)

Pin TRIGGER can be used to trigger a single compare measurement. A negative pulse at pin TRIGGER of duration $t_{TRG}$ activates a single trigger. A single measuring sequence is started after the time $t_{TRG}$. A trigger of a single measurement is only possible if the measuring interval MI is set to single trigger.

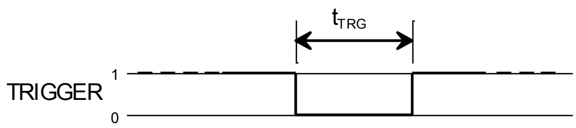


Figure 9: Single hardware trigger at pin TRIGGER

### 8.1.5 Single software trigger (switch mode)

Command COMP executes a single compare measurement. A trigger of a single measurement is only possible if the measuring interval MI is set to single trigger and pin TRIGGER is set to logical ‘1’.

### 8.1.6 Stand-alone operation in switch mode

After programming the non-volatile memory, the MS8890B can be used in switch mode without control of a microcontroller. Pin TRIGGER must be set to logical ‘0’ for periodic or permanent measuring interval or to logical ‘1’ for single trigger operation.
Pin TRIGGER set to logical ‘0’ automatically starts a compare measurement about 30ms after power-up. This first measurement reads-out the non-volatile memory and sets the programmed options. The following measurements are executed according to the programmed interval. The measuring interval is 32 measurements per seconds if the measuring interval MI is not programmed (MI[1:0] = ‘00’)
Registers CTH1, CTH2 and OPT1 are always overwritten by the non-volatile memory contents prior to a measurement if pin TRIGGER is set to logical ‘0’. Register OPT2 is in reset state if pin TRIGGER is set to logical ‘0’.



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### 8.1.7 Measuring range

Four measuring ranges can be selected according to the following table in the options register OPT1. The measuring ranges can be individually selected for CS1 (option CR1) and CS2 (option CR2). The resolution of the measurement can be increased by one bit if pin RESOL is set to logical ‘1’ but this reduces the supported measuring range to 50 to 100% of the selected range.

| Range *CR* | RESOL | ADC/DAC Resolution *CU* | CS range | | Unit |
|---|---|---|---|---|---|
| | | | Min. | Max. | |
| 1 | 0 | 0.2 | 0 | 50 | fF |
| 1 | 1 | 0.1 | 25 | 50 | fF |
| 2 | 0 | 0.4 | 0 | 100 | fF |
| 2 | 1 | 0.2 | 50 | 100 | fF |
| 3 | 0 | 0.8 | 0 | 200 | fF |
| 3 | 1 | 0.4 | 100 | 200 | fF |
| 4 | 0 | 1.6 | 0 | 400 | fF |
| 4 | 1 | 0.8 | 200 | 400 | fF |

Table 3: Measuring range

### 8.1.8 Noise filter

The output CP of the comparator is input to a digital noise filter. Three different levels of noise suppression can be selected:

- No noise filter
  The noise filter is switched-off if option NoF in the options register OPT2 is set. Option NoF overrules the settings made with option bit CF. The noise filter can only be disabled with option bit NoF if pin TRIGGER is set to logical ‘1’.
- Noise suppression CF = low
  4 measurements are performed per measurement cycle. The signal at the output of the noise filter (CPF1 or CPF2) changes the state if at least 3 measurements per measurement cycle are equal (= 3 detections). The signal at the output of the noise filter remains at its previous state otherwise.
- Noise suppression CF = high
  16 measurements are performed per measurement cycle. The signal at the output of the noise filter (CPF1 or CPF2) changes the state if at least 12 measurements per measurement cycle are equal (= 12 detections). The signal at the output of the noise filter remains at its previous state otherwise.

| Noise suppression | NoF | CF | Measurements per sensor | Minimum number of detections | Measuring sequence | |
|---|---|---|---|---|---|---|
| | | | | | 2 sensors | 1 sensor |
| No | 1 | x | 1 | 1 | 0.12 ms | 0.06 ms |
| Low | 0 | 0 | 4 | 3 | 0.49 ms | 0.24 ms |
| High | 0 | 1 | 16 | 12 | 1.95 ms | 0.98 ms |

Table 4: Noise suppression

Note: The measuring sequence time does not include the OTP read-out time (see section 8.1.1).

### 8.1.9 Hysteresis

The comparator has a built-in hysteresis as an additional noise filter. The amplitude of the hysteresis is equal to +/- CU. CU is the unit capacitance which is defined by the measuring range (see Table 3). The hysteresis is switched off in meter mode and is also switched off when the noise filter is switched off (option bit NoF set and pin TRIGGER set to logical ‘1’).



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### 8.1.10 Measuring interval

In switch mode the measuring sequence can be executed once (single trigger), periodically or permanently. Four options are available. The minimum measuring interval is given by twice the time of the measuring sequence plus ½ $t_{OTP}$.

| **Noise suppression *CF*** | **Measuring interval *MI*** | | | | |
|---|---|---|---|---|---|
| | **single trigger** | **periodic slow** | **periodic fast** | **Permanent (measuring frequency)** | |
| | | | | **2 sensors** | **1 sensor** |
| No | single measurement | 2 measurements per second | 32 measurements per second | 3.6 kHz | 6.6 kHz |
| Low | | | | 1.0 kHz | 1.9 kHz |
| High | | | | 0.25 kHz | 0.5 kHz |

Table 5: Measuring interval

# 9 I²C interface

The MS8890B has a slave receiver/transmitter I²C serial interface. SDA is data I/O and SCL is clock. SDA is used as an input or as an open-drain output. It is actively pulled low and is passively held high by the pull-up resistor on the I²C bus. 175kΩ Pull-up resistors are internally connected to SDA and SCL. The impedance on the I²C bus can be lowered by additional external resistors if needed.

## 9.1 Supported I²C protocol

The following symbol set is used in the subsequent figures showing the I²C protocol.

- **S** = START symbol
- **Sr** = START repeated
- **P** = STOP symbol
- **A** = Acknowledge bit
- = sent from I²C slave
- = sent from I²C master

### 9.1.1 Addressing

The I²C slave address has 7 bits. The fixed slave address of the MS8890B is shown in the following table.

| **Bit** | **A6** | **A5** | **A4** | **A3** | **A2** | **A1** | **A0** |
|---|---|---|---|---|---|---|---|
| Value | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

Table 6: Fixed I²C slave address of MS8890B

### 9.1.2 I²C master writes command

This protocol is used, if the I²C master only needs to send a single command to the MS8890B without additional data. The 8-bit command C7 to C0 is transmitted in the first data byte.

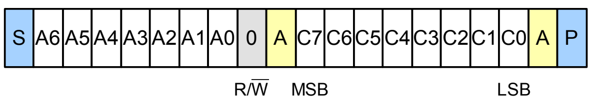


Figure 10: I²C command transmission

### 9.1.3 I²C master writes one byte

This protocol is used, when the I²C master needs to program a register. The command part (C7 to C0) specifies the write register command including the selection of the register. The data byte (D7 to D0) contains the register content to be written.

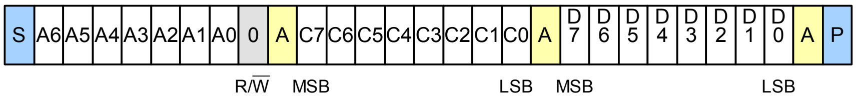


Figure 11: I²C write data transmission

### 9.1.4 I²C master reads one byte

In order to read a register, the I²C master first has to send the corresponding read command. Therefore the transmission starts with a command-write sequence. The transmission is not stopped after this. A repeated start is sent followed by a retransmission of the address. In this second part the R/W bit is set to logical high, indicating to the slave that it must transmit the data byte.

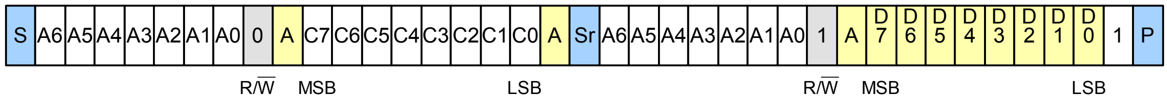


Figure 12: I²C read data transmission

## 9.2 I²C command table

Table 7 is a list of all allowed commands. Other commands are not allowed.

| Command byte (C7 to C0) | Symbol | Function | Transfer type |
|---|---|---|---|
| 00h | MCS | Measure CS1 and CS2 | Command |
| 01h | RCS1 | Read CS1 (register REG1) | Read 1 byte |
| 02h | RCS2 | Read CS2 (register REG2) | Read 1 byte |
| 03h | COMP | Compare (switch mode) | Command |
| 04h | RRES | Read comparison results (register RES) | Read 1 byte |
| 05h | WTH1 | Write register CTH1 | Write 1 byte |
| 06h | RTH1 | Read register CTH1 | Read 1 byte |
| 07h | WTH2 | Write register CTH2 | Write 1 byte |
| 08h | RTH2 | Read register CTH2 | Read 1 byte |
| 09h | WOPT1 | Write register OPT1 | Write 1 byte |
| 0Ah | ROPT1 | Read register OPT1 | Read 1 byte |
| 0Bh | WOPT2 | Write register OPT2 | Write 1 byte |
| 0Ch | ROPT2 | Read register OPT2 | Read 1 byte |
| 0Dh | PTH1 | Program register CTH1 to OTP memory | Command |
| 0Eh | PTH2 | Program register CTH2 to OTP memory | Command |
| 0Fh | POPT1 | Program register OPT1 to OTP memory | Command |

Table 7: I²C command table

## 9.3 Register description

### 9.3.1 Register

| Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | Reset value |
|---|---|---|---|---|---|---|---|---|---|
| REG1 | REG1[7:0] | | | | | | | | '0000 0000' |
| REG2 | REG2[7:0] | | | | | | | | '0000 0000' |
| CTH1 | CTH1[7:0] | | | | | | | | '0000 0000' |
| CTH2 | CTH2[7:0] | | | | | | | | '0000 0000' |
| OPT1 | SNG | MI[1:0] | | CF | CR2[1:0] | | CR1[1:0] | | '0000 0000' |
| OPT2 | n/a | | | | NoF | INT[1:0] | | RAM | 'xxxx 0000' |
| RES | n/a | | | | | | CPF2 | CPF1 | 'xxxx xx00' |

Table 8: Registers

### 9.3.2 REG1: Capacitance value of sensor CS1

| Bit(s) | Symbol | Function | Reset value |
|---|---|---|---|
| 7:0 | REG1[7:0] | Capacitance value of sensor CS1. The value is binary coded. The LSB value is defined by the unit capacitance CU (option CR1) | '0000 0000' |

Table 9: Description of REG1 – capacitance value of sensor CS1

### 9.3.3 REG2: Capacitance value of sensor CS2

| Bit(s) | Symbol | Function | Reset value |
|---|---|---|---|
| 7:0 | REG2[7:0] | Capacitance value of sensor CS2. The value is binary coded. The LSB value is defined by the unit capacitor CU (option CR2) | '0000 0000' |

Table 10: Description of REG2 – capacitance value of sensor CS2

### 9.3.4 CTH1: Threshold capacitance for sensor CS1

| Bit(s) | Symbol | Function | Reset value |
|---|---|---|---|
| 7:0 | CTH1[7:0] | Threshold capacitance value for sensor CS1 in switch mode. The value is binary coded. The LSB value is defined by the unit capacitor CU (option CR1) | '0000 0000' |

Table 11: Description of CTH1 – Threshold capacitance for sensor CS1

### 9.3.5 CTH2: Threshold capacitance for sensor CS2

| Bit(s) | Symbol | Function | Reset value |
|---|---|---|---|
| 7:0 | CTH2[7:0] | Threshold capacitance value for sensor CS2 in switch mode. The value is binary coded. The LSB value is defined by the unit capacitor CU (option CR2) | '0000 0000' |

Table 12: Description of CTH2 – Threshold capacitance for sensor CS2



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### 9.3.6 OPT1: Options register 1

| Bit(s) | Symbol | Value | Function | Reset value |
|---|---|---|---|---|
| 7 | SNG | <br>'0'<br>'1' | Active sensors<br>CS1 and CS2<br>CS1 | '0' |
| 6:5 | MI[1:0] | <br>'00'<br>'01'<br>'10'<br>'11' | Measuring interval<br>single trigger<br>periodic, 32 measurements per second<br>periodic, 2 measurements per second<br>permanent (see Table 4 for details) | '00' |
| 4 | CF | <br>'0'<br>'1' | Noise suppression<br>low (3/4 detections)<br>high (12/16 detections)<br>Note: Bit NoF overrules this setting | '0' |
| 3:2 | CR2[1:0] | <br><br>'00'<br>'01'<br>'10'<br>'11' | Measuring range CR and resolution CU for sensor CS2<br>CR = 1<br>CR = 2<br>CR = 3<br>CR = 4<br>See Table 3 for details | '00' |
| 1:0 | CR1[1:0] | <br><br>'00'<br>'01'<br>'10'<br>'11' | Measuring range CR and resolution CU for sensor CS1<br>CR = 1<br>CR = 2<br>CR = 3<br>CR = 4<br>See Table 3 for details | '00' |

Table 13: Description of OPT1 – options register 1

### 9.3.7 OPT2: Options register 2

| Bit(s) | Symbol | Value | Function | Reset value |
|---|---|---|---|---|
| 7:4 | n/a | | n/a | n/a |
| 3 | NoF | '0'<br>'1' | Noise filter switched on<br>Noise filter switched off | '0' |
| 2:1 | INT[1:0] | <br>'00'<br>'01'<br>'10'<br>'11' | Interrupt over $I^2C$ bus<br>Interrupt mode disabled<br>Interrupt if CPF1 state changes<br>Interrupt if CPF2 state changes<br>Interrupt if CPF1 or CPF2 state changes | '00' |
| 0 | RAM | <br>'0'<br><br><br>'1' | Source of configuration<br>ROM mode: CTH1, CTH2, OPT1 are overwritten by corresponding OTP memory registers prior to measurement<br>RAM mode: CTH1, CTH2, OPT1 are never overwritten prior to measurement | '0' |

Table 14: Description of OPT2 – options register 2

Note: The OPT2 register is in reset state if pin TRIGGER is set to logical '0'

### 9.3.8 RES: Comparison result register

| Bit(s) | Symbol | Value | Function | Reset value |
|---|---|---|---|---|
| 7:2 | n/a | | n/a | n/a |
| 1 | CPF2 | <br>'0'<br>'1' | Comparison result sensor CS2 (CPF2)<br>CS2 > CTH2 (POL = 0)<br>CS2 < CTH2 (POL = 0)<br>Note: The output value is inverted with POL = 1 | '0' |
| 0 | CPF1 | <br>'0'<br>'1' | Comparison result sensor CS1 (CPF1)<br>CS1 > CTH1 (POL = 0)<br>CS1 < CTH1 (POL = 0)<br>Note: The output value is inverted with POL = 1 | '0' |

Table 15: Description of RES – comparison result

## 9.4 Interface timing

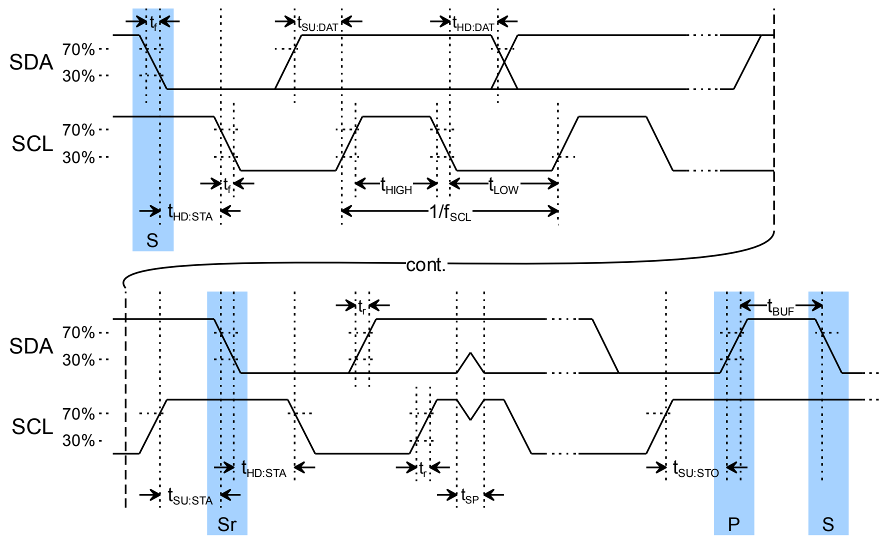


Figure 13: I$^2$C interface timing
The timing figures are specified in section 12

## 9.5 Interrupt over I$^2$C bus

In order to flag a change of the signals CPF1 or CPF2 over the I$^2$C bus, the MS8890B can behave like an I$^2$C master with restricted functionality. A change is signaled by sending a START condition, immediately followed by a STOP condition. This is illustrated in Figure 14. No further I$^2$C master capabilities are supported.

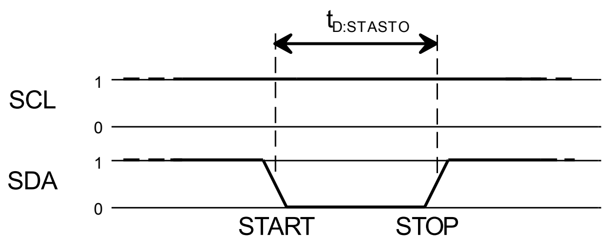


Figure 14: Interrupt over I$^2$C bus

The I$^2$C master has to detect the START-STOP condition and react accordingly. In order to enable this mode, the MS8890B has to be set into interrupt mode. The Interrupt mode and the interrupt conditions are specified in the register OPT2.

# 10 OTP memory

## 10.1 RAM or ROM operation

Option RAM in the register OPT2 defines if the configuration registers CTH1, CTH2 and OPT1 are overwritten by the corresponding OTP memory registers prior to each measurement. The default logical state of option RAM is ‘0’ after power-up. This means that the registers are overwritten from the OTP memory prior to measurement. Before changing any of the registers CTH1, CTH2 or OPT1 option RAM must be set to logical ‘1’. This guarantees that the volatile registers CTH1, CTH2 and OPT1 are not overwritten again by the OTP memory contents prior to any measurement. Option RAM can only be set if pin TRIGGER is set to logical ‘1’.

## 10.2 OTP programming

After setting the registers CTH1, CTH2 and OPT1 the register contents can be programmed to the OTP memory. These registers must be programmed to the OTP memory if the MS8890B needs to function stand-alone. The OTP memory bits can be programmed once from logical ‘0’ to logical ‘1’. Once programmed, they cannot be reset to logical ‘0’ anymore.
The OTP programming sequence is started with one of the commands PTH1 (OTP programming of register CTH1), PTH2 (OTP programming of register CTH2) or POPT1 (OTP programming of register OPT1). These commands enable the programming mode. The non-volatile programming of the OTP memory bits is then done by applying a programming pulse at pin RESOL with voltage $V_{PROG}$ and duration $t_{PROG}$. The programming mode must be left latest after the OTP programming of the last register. This is done by sending any I²C command except PTH1, PTH2, POPT1 to the MS8890B.

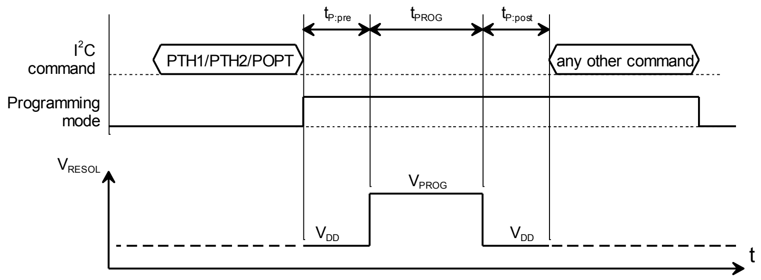


Figure 15: OTP memory programming

Note: Pin TRIGGER must be set to logical ‘1’ during OTP programming.

# 11 Application information

## 11.1 Basic sensor design

Many parameters define the sensor's capacitance value and its sensitivity. It is therefore not possible to give exhaustive design guidelines. The following design guidelines are meant as a starting point for the application specific sensor design. More details are given in the MS8890B application note (separate document).

Figure 16 shows a basic sensor layout. The sensor capacitor has two electrical conductors SA and SB (SB1 or SB2). SA is the transmitter and SB is the receiver. The transmitter SA surrounds the receiver as completely as possible. This gives the highest capacitance and also the highest immunity to noise. The sensor's capacitance is increased by increasing the sensor's antenna length. The sensor's capacitance is also increased by lowering the sensor's distance between the transmitter and the receiver.

It is important to shield (e.g. with VSS) the receiver antenna between the MS8890B package pins and the sensor area. The shielding capacity must not exceed 5pF. If properly shielded, the sensor is only sensitive at the sensor area and also the capacitance is only defined by the sensor area.

Figure 17 shows the typical sensor's relative capacitance value as a function of the distance to an object. The sensor capacitance is changed if an object (e.g. finger) is approaching the sensor area. The dependence between sensor capacitance and distance to the object depends on many parameters and must be evaluated in the application. A small distance between SA and SB reduces the relative sensitivity for large distances (curve A is almost flat for large distances). And a large distance between SA and SB increases the relative sensitivity for large distances (curve B is steeper than curve A for larger distances).

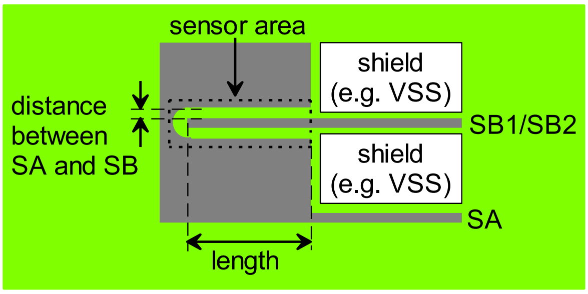


Figure 16: Basic sensor layout

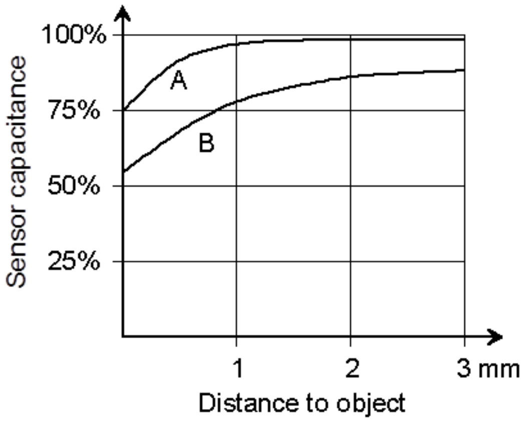


Figure 17: Sensor capacitance as a function of the distance to the object
Antenna distance is smaller for curve A than for curve B

# 12 Electrical Characteristics

## 12.1 Limiting values and ESD protection

| Name | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $V_{DD}$ | Positive supply voltage wrt to $V_{SS}$ | -0.5 | 9.0 | 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 | | 100 | mW |
| $T_{stg}$ | Storage temperature | -60 | +125 | °C |
| $T_J$ | Junction temperature | | +125 | °C |
| $V_{ESD}$ | Electrostatic discharge voltage (HBM JS-001-2017) | | +/- 2000 | V |

Table 16: Limiting values[1] and ESD protection[2]

## 12.2 DC characteristics

Conditions: $V_{DD}$ = 3V, Tamb = 25°C, if not stated otherwise

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Positive supply voltage | | 1.8 | | 4.5 | V |
| $I_{DD}$ | Operating current | Idle state, oscillator disabled | | 50 | | nA |
| | | Idle state, oscillator enabled, MI = periodic or permanent | | 720 | | nA |
| | | Active current during measurement<br>CR = 1, 2<br>CR = 3, 4 | | 7.5<br>11 | | µA<br>µA |
| | | Average current (switch mode), 2 measurements/s, NoF = ‘1’<br>2 sensors<br>1 sensor | | 730<br>725 | | nA<br>nA |
| | | Average current (switch mode), 2 measurements/s, CF = low<br>2 sensors<br>1 sensor | | 740<br>735 | | nA<br>nA |
| | | Average current (switch mode), 2 measurements/s, CF = high<br>2 sensors<br>1 sensor | | 770<br>750 | | nA<br>nA |
| | | Average current (switch mode), 32 measurements/s, NoF = ‘1’<br>2 sensors<br>1 sensor | | 820<br>800 | | nA<br>nA |
| | | Average current (switch mode), 32 measurements/s, CF = low<br>2 sensors<br>1 sensor | | 950<br>860 | | nA<br>nA |
| | | Average current (switch mode), 32 measurements/s, CF = high<br>2 sensors<br>1 sensor | | 1.5<br>1.1 | | µA<br>µA |

[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 in 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.



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| | | | | | | |
|---|---|---|---|---|---|---|
| | | Average current (switch mode), permanent, NoF = ‘1’<br>2 sensors<br>1 sensor | | 12<br>17 | | µA<br>µA |
| | | Average current (switch mode), permanent, CF = low<br>2 sensors<br>1 sensor | | 8<br>9.5 | | µA<br>µA |
| | | Average current (switch mode), permanent, CF = high<br>2 sensors<br>1 sensor | | 6.5<br>7 | | µA<br>µA |
| $I_{OTP}$ | OTP read-out current | | | 30 | | µA |
| Sensor capacitance | | | | | | |
| $CS_{max}$ | Maximum sensor capacitance | CR = 4 | | 400 | | fF |
| CU | ADC resolution (unit capacitor) | CR = 1<br>RESOL = ‘0’<br>RESOL = ‘1’ | | 0.2<br>0.1 | | fF<br>fF |
| | | CR = 2<br>RESOL = ‘0’<br>RESOL = ‘1’ | | 0.4<br>0.2 | | fF<br>fF |
| | | CR = 3<br>RESOL = ‘0’<br>RESOL = ‘1’ | | 0.8<br>0.4 | | fF<br>fF |
| | | CR = 4<br>RESOL = ‘0’<br>RESOL = ‘1’ | | 1.6<br>0.8 | | fF<br>fF |
| $d_{CU}$ | Relative accuracy of unit capacitor | | -5 | | +5 | % |
| OTP memory programming characteristics | | | | | | |
| $V_{PROG}$ | OTP programming voltage | Device in OTP programming mode | 9.9 | 10.0 | 10.1 | V |
| Digital inputs (MODE, SCL, SDA, SCL) | | | | | | |
| $V_{IL}$ | Input low level for digital inputs | | $V_{SS}$ | | $0.3V_{DD}$ | V |
| $V_{IH}$ | Input high level for digital inputs | | $0.7V_{DD}$ | | $V_{DD}$ | V |
| Digital outputs (OUT1, OUT2) | | | | | | |
| $V_{OL}$ | Output low level for digital outputs | $I_{OUT}$ = 2mA | $V_{SS}$ | | $0.2V_{DD}$ | V |
| $V_{OH}$ | Output high level for digital outputs | $I_{OUT}$ = -2mA | $0.8V_{DD}$ | | $V_{DD}$ | V |
| $I_{OUT}$ | Output current | | -5 | | 5 | mA |
| Analog inputs (SB1, SB2) | | | | | | |
| $V_{AI}$ | | | $V_{SS}$ | | $V_{DD}$ | V |
| $I^2C$ interface pins | | | | | | |
| $V_{O:SDA}$ | Output low level on SDA | $I_{SDA}$ = 2mA | $V_{SS}$ | | $0.2V_{DD}$ | V |
| $R_{SDA}$ | Pull-up resistor on SDA | | | 175 | | kΩ |
| $R_{SCL}$ | Pull-up resistor on SCL | | | 175 | | kΩ |
| Temperature range | | | | | | |
| $T_{amb}$ | Operating temperature range | | -40 | 25 | 85 | °C |

Table 17: DC characteristics

## 12.3 AC characteristics

Conditions: $V_{DD}$ = 3V, $T_{amb}$ = 25°C, if not stated otherwise

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $f_{OSC}$ | Oscillator frequency | MI[1:0] = '01' | 30.5 | 32.8 | 35 | kHz |
| $t_{meas:prox}$ | Measuring time for single measurement cycle in switch mode | No noise filter | | 0.06 | | ms |
| | | CF = low | | 0.24 | | ms |
| | | CF = high | | 0.98 | | ms |
| $t_{meas:meter}$ | Measuring time for single measurement sequence in meter mode | 2 sensors<br>1 sensor | | 0.98<br>0.49 | | ms<br>ms |
| $f_{MI}$ | Measuring frequency in switch mode | MI[1:0] = '10' | | 2 | | Hz |
| | | MI[1:0] = '01' | | 32 | | Hz |
| | | MI[1:0] = '11', NoF = '1'<br>2 sensors<br>1 sensor | | <br>3.6<br>6.6 | | <br>kHz<br>kHz |
| | | MI[1:0] = '11', CF = '0', NoF = '0'<br>2 sensors<br>1 sensor | | <br>1.0<br>1.9 | | <br>kHz<br>kHz |
| | | MI[1:0] = '11', CF = '1', NoF = '0'<br>2 sensors<br>1 sensor | | <br>0.25<br>0.5 | | <br>kHz<br>kHz |
| $t_{OTP}$ | OTP read-out time | | | 0.06 | | ms |
| $t_{TRG}$ | External single trigger | | 1 | 50 | 100 | µs |
| $t_{NOF}$ | Delay of polarity change | Polarity change of pin TRIGGER '0' to '1' or '1' to '0' | | | 2 | ms |
| OTP programming characteristics | | | | | | |
| $t_{PROG}$ | OTP programming pulse | | 95 | 100 | 105 | ms |
| $t_{P:pre}$ | Time between end of OTP programming command and start of OTP programming pulse | | 0.1 | | | ms |
| $t_{P:post}$ | Time between end of OTP programming pulse and start of next $I^2C$ command | | 0.1 | | | ms |
| $I^2C$ interface characteristics (SDA, SCL) | | | | | | |
| $t_{SP}$ | Pulse width of spikes that must be suppressed | | 0 | | 100 | ns |
| $f_{SCL}$ | SCL clock frequency | | 0 | | 100 | kHz |
| $t_{HD:STA}$ | Hold time (repeated) START condition | | 4.0 | | | µs |
| $t_{SU:STA}$ | Setup time (repeated) START condition | | 4.7 | | | µs |
| $t_{LOW}$ | LOW period of the SCL clock | | 4.7 | | | µs |
| $t_{HIGH}$ | HIGH period of the SCL clock | | 4.0 | | | µs |
| $t_{HD:DAT}$ | Data hold time | | 50 | | | ns |
| $t_{SU:DAT}$ | Data setup time | | 250 | | | ns |
| $t_r$ | Rise time SDA, SCL | | | | 1 | µs |
| $t_f$ | Fall time SDA, SCL | | | | 0.3 | µs |
| $t_{SU:STO}$ | Setup time for STOP condition | | 4.0 | | | µs |
| $t_{BUF}$ | Bus free time between START and STOP | | 4.7 | | | µs |



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| | | | | | | |
|---|---|---|---|---|---|---|
| $t_{D:STASTO}$ | Duration of interrupt over $I^2C$ bus pulse on SDA line | Interrupt mode enabled | | 3 | | µs |

Table 18: AC characteristics

# 13 Production note

## 13.1 QFN16 package information

### 13.1.1 Package outline

**QFN16** (JEDEC NO-220-VEED-4)
Package dimensions: 3.000 x 3.000 x 0.850mm
Tolerance ± 0.050mm on all dimensions
Weight: 0.022g ± 10%

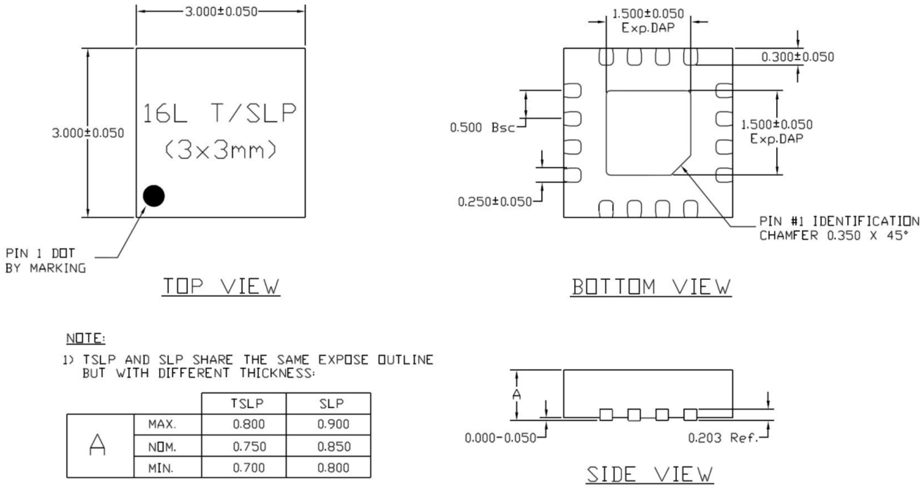


Figure 18: QFN16 package outline

### 13.1.2 PCB design

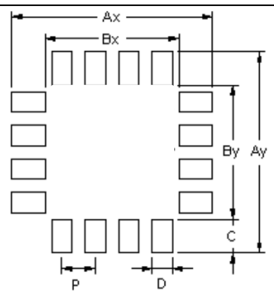


Figure 19: QFN16 footprint: Dimensions are given in Table 19.

| 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 19: QFN16 footprint dimensions



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### 13.1.3 Solder mask opening for PCB area

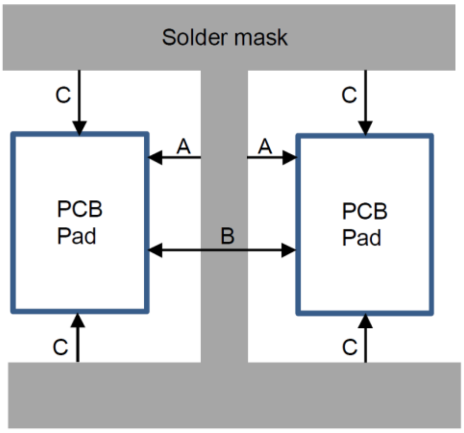


Figure 20: If necessary, the edge of the solder mask opening around the PCB pads can be set up to the edge of the pad (A). If the distance between the pads is insufficient for the solder mask (B) then the mask can be set to the bottom and the top edges of the pads (C).

### 13.1.4 Assembly instructions

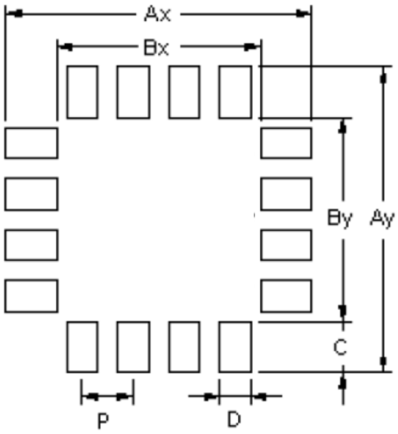


Figure 21: Stencil dimensions: The recommended stencil thickness is 0.10 to 0.13mm. Dimensions are given in Table 20.

| 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 20: 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 13.1.2. 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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## 13.2 CSP package information

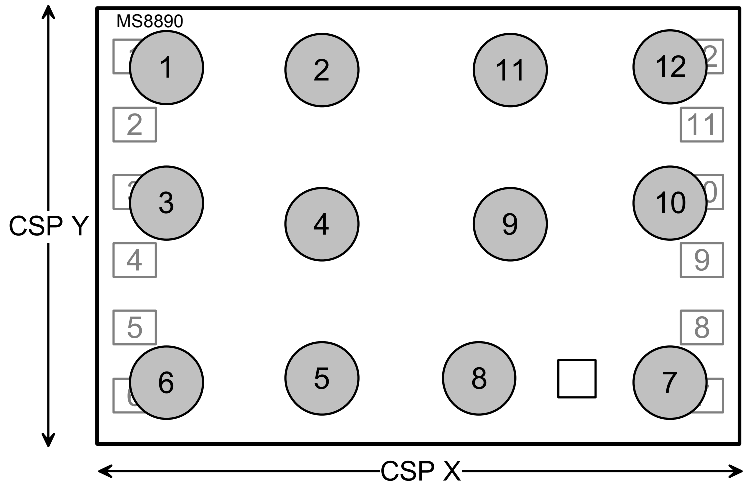


Figure 22: CSP Layout

| Parameter | Value | Accuracy wafer | die |
|---|---|---|---|
| CSP X | 1520µm | ±30µm | |
| CSP Y | 1030µm | ±30µm | |
| CSP Z | 637µm | ±50µm | |
| Nr. of I/Os | 12 | | |
| Min. Bump pitch | 355µm | | |
| Bump height | 100µm | ±20% | ±10% |
| Bump size | 172µm | ±20% | ±10% |
| Bump placement | | ±2µm | |
| Bump material | Sn/Ag | | |
| Structure | PI+RDL +PI+ Sn/Ag | | |
| Bump shear force | ≥2g/mil² | | |
| Bump to Bump resistance | >1 GΩ | | |

| Name | Pad | Pad Co-ordinate X µm | Pad Co-ordinate Y µm | Bump Co-ordinate X µm | Bump Co-ordinate Y µm |
|---|---|---|---|---|---|
| | 1 | 0 | 0 | 74.40 | -27.76 |
| | 2 | 0 | -164.16 | 444.40 | -32.76 |
| | 3 | 0 | -306.72 | 74.40 | -334.76 |
| | 4 | 0 | -470.88 | 444.40 | -387.76 |
| | 5 | 0 | -613.44 | 444.40 | -742.76 |
| | 6 | 0 | -777.60 | 74.40 | -749.76 |
| | 7 | 1337.04 | -777.60 | 1264.40 | -749.76 |
| | 8 | 1337.04 | -613.44 | 819.40 | -742.76 |
| | 9 | 1337.04 | -470.88 | 894.40 | -387.76 |
| | 10 | 1337.04 | -306.72 | 1264.40 | -334.76 |
| | 11 | 1337.04 | -164.16 | 894.40 | -32.76 |
| | 12 | 1337.04 | 0 | 1264.40 | -27.76 |

Notes:

1. Pad and solder bump co-ordinates are from the centre of the pad or bump respectively.
2. Values for CSP X and CSP Y are after saw.
3. CSP Z includes bump height.
4. Co-ordinates are given relative to pad 1 (pad 1 centre is ~90µm away on x direction and ~127µm away on y direction from edges after saw).

## 13.3 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.



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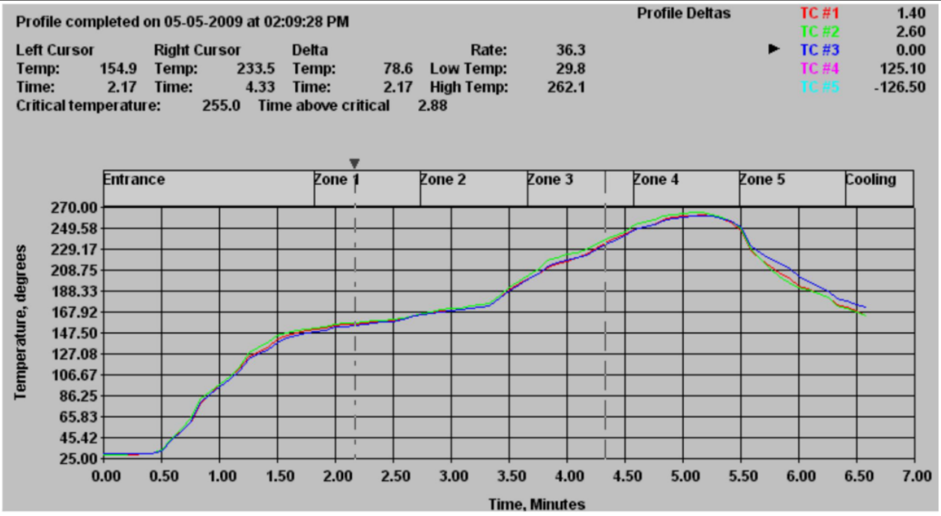


Figure 23: Recommended reflow profile. The maximum reflow temperature is 260°C for 40 seconds. The moisture sensitivity level is 1 (MSL1).

## 14 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. Customers using or selling this product for use in such appliances do so at their 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.

## 15 Contents





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