

## Application Note

### 1 General product description

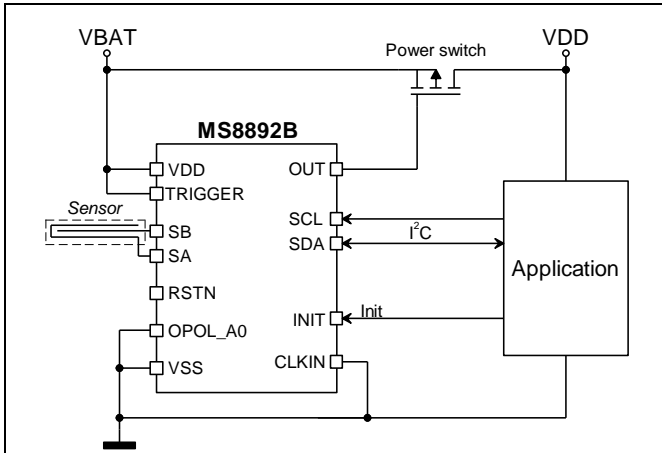


Figure 1 Example application of the MS8892B as system wake-up controller

The integrated circuit MS8892B is an ultra-low power capacitive sensor specially designed for human body detection and as a wake-up source for ultra-low power systems. It offers two operating modes: meter mode or switch mode. In switch mode the sensor capacitance is compared with the internal reference capacitance. The capacitance threshold can be set absolutely or relative to a baseline value, which is automatically determined and therefore includes fabrication and material tolerances. The MS8892B can optionally be operated with a latching output. In this configuration it can be used as a wake-up device and directly control a power management IC (PMIC) or a PMOS type power switch for achieving the lowest possible consumption in ultra-low power systems. The output stage and latching mode of the MS8892B allow a direct connection to another wake-up source with open-drain output mode, like an RTC, with the output state controlled by the MS8892B. In meter mode the absolute sensor capacitance is measured. The measuring range of the MS8892B covers 200 to 1000fF with a resolution of 8 bits. The configuration of the various options and the operation of the meter mode are controlled via the I<sup>2</sup>C serial interface. If the configuration is programmed into the non-volatile memory of the MS8892B, it can be operated fully autonomously.

The MS8892B is available in a Quad Flat No leads (QFN) package with a 3 x 3mm foot print, 0.85mm height and 16 pins or in a Chip Scale Package (CSP) with a 1.52 x 1.03mm foot print, 0.64mm height and 12 pins. Both packages can be soldered using a reflow process.

### 2 Introduction to capacitive sensing

In the MS8892B the capacitive sensor is formed between a driving line (SA) and a receiving line (SB). During the measurement, a rectangular signal is applied to SA and charge is transferred from SA to SB over the attached sensor capacitance CS. The sensor capacitance depends on the print layout, the print material and any material surrounding the SA and SB lines (for instance a device cover). Figure 2 shows the electrical field lines between the driving line SA and the receiving line SB without interference from an object and Figure 3 shows the electrical field lines of the same arrangement when a finger touches the sensor area. The sensor capacitance is lower in Figure 3 because part of the electrical field between the driving line SA and the receiving line SB is shunted over the body / ground capacitance C<sub>bg</sub> and back to the device via the device / ground capacitance C<sub>dg</sub>.

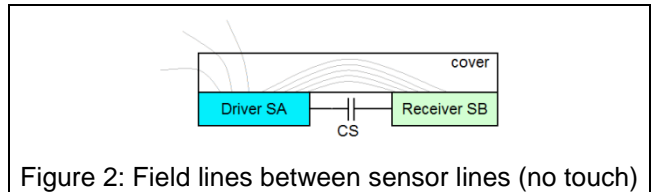


Figure 2: Field lines between sensor lines (no touch)

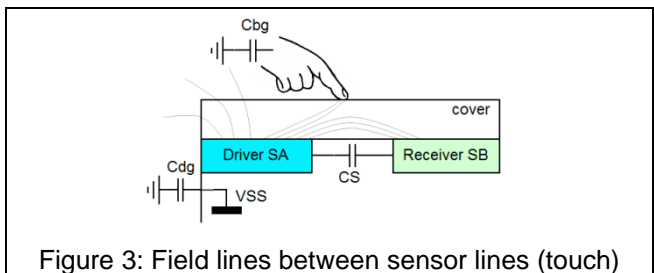


Figure 3: Field lines between sensor lines (touch)

The change in capacitance between «no touch» and «touch» depends on many parameters. For example:

- Sensor layout and architecture
- Cover material and/or print material properties
- Cover and/or print thickness
- Object size (e.g. finger)
- Capacitance of object to ground (e.g. human body)
- Capacitance of device to ground

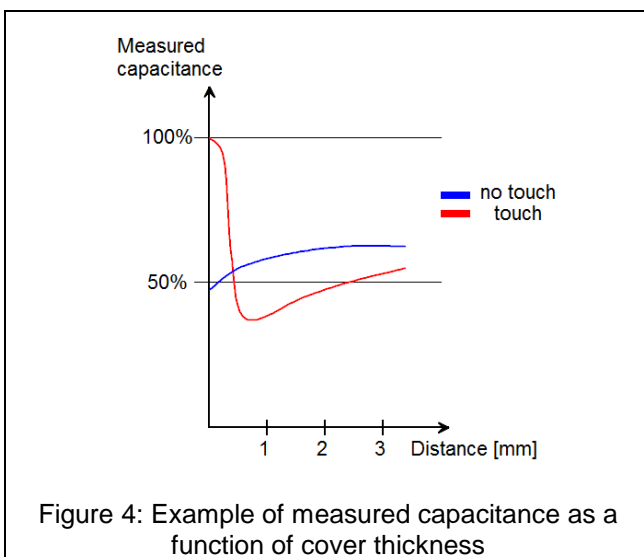
The influence of the material covering the driving line and the receiving line is expressed by the dielectric constant (or relative permittivity)  $\epsilon_r$ . Larger  $\epsilon_r$  values result in higher capacitance values. Typical values for commonly used materials are listed in Table 1.

Table 1: Relative permittivity of commonly used materials at room temperature

Material	$\epsilon_r$
Air	1
Paper	1 to 4
Glass	5 to 10
PMMA (acrylic glass)	3.4
FR2, FR4 (PCB epoxy laminate)	4.3 to 5.4
Skin	42
Water	80

The sensor capacitance depends on the sensor construction and especially on the thickness of the cover. An approaching object can reduce or increase the capacitance between the driving line SA and the receiving line SB depending on the change of the electrical field lines between SA and SB. Increasing the sensor capacitance is typically related to increasing of the relative permittivity and decreasing the sensor capacitance is typically related to shunting the field lines to ground (Figure 3).

The influence of the cover thickness on the capacitance value is shown in the example in Figure 4. The sensor capacitance («no touch») is increasing nonlinearly as a function of the cover thickness (blue curve). The capacitance value is saturating after approximately 3 to 4 mm. When the cover above the sensor area is touched by an object the capacitance is largest for small thicknesses (e.g. if  $\epsilon_r$  of a finger is higher than  $\epsilon_r$  of air). With increasing distance shunting the electrical field lines to ground becomes dominant (for 1mm and higher). There is a certain thickness where both effects are equivalent and no change in capacitance is resulting between «no touch» and «touch». Such a sensor construction has to be avoided for switch mode operation.



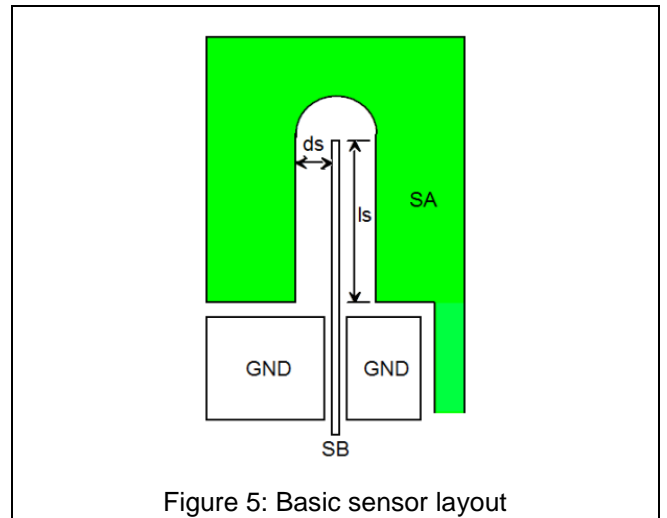
### 3 Sensor design

Figure 5 shows a basic sensor layout placed on a PCB (e.g. FR4). The following points should be carefully considered in the sensor layout:

1. The receiver line SB has to be shielded from any other dynamic signal. Grounded traces or planes or any other static signal can be used to shield the SB trace between the MS8892B and the active sensor area. The total shielding capacitance must not exceed 5pF.
2. The driving line SA should surround the receiving line SB on the active sensor area.

The sensor capacitance depends on the dimensions of the sensor layout. The following values are meant as a starting point for a new sensor layout (other values are possible):

- The distance  $d_s$  between the driving and the receiving line should be in the order of 0.5 to 3mm.
- The length  $l_s$  of the receiving line SB should be in the order of 0.5 to 10mm.



The sensor layout presented in Figure 5 is an example. Other sensor shapes can be realized. Examples of sensor dimensions and corresponding sensor capacitances based on the sensor layout presented in Figure 5 are listed in Table 2.

Table 2: Examples of sensor dimensions and corresponding sensor capacitance values

Distance $d_s$ [mm]	Length $l_s$ [mm]	Approx. sensor capacitance [fF]
2.5	4	160
1.6	4	220
0.6	4	320

Note: These are values for a sensor which is made on an FR4 PCB with 1.6mm thickness, and covered by solder resist.

Often the sensor is placed below a cover (plastic housing, acrylic glass) in the real application. A cover should be attached avoiding air gaps using a glue or sticky foil, or a mechanically rigid construction. Air gaps are not well controlled variable under touch force. This can lead to unwanted capacitance variations.

## 4 Autonomous operation in switch mode

The MS8892B can be operated autonomously without control of a microcontroller or other trigger sources in switch mode. For this purpose the measuring interval MI needs to be set in the options register OPT1 to «periodic» or «permanent» measurement followed by programming the setting to the non-volatile memory.

Table 3: Measuring interval options

MI[1:0]	Function
00	single trigger
01	periodic 32 measurements per second
10	periodic 8 measurements per second
11	periodic 2 measurements per second

Also the threshold capacitance value CTH and the other options in registers OPT1 and OPT2 must be defined and programmed to the non-volatile memory for autonomous operation in switch mode. In addition pin TRIGGER must be connected to VSS.

## 5 Avoiding I2C communication problems in meter mode

A measurement in meter mode is started by sending the command MCS to the MS8892B via the I2C interface. The measurement runs through the sequence as shown in Figure 6. The internal signal Busy indicates the active measuring sequence. Busy is set after the reception of the command MCS and cleared after the end of the measuring sequence. The MS8892B **does not respond with an I2C acknowledge** while signal Busy is active. To avoid I2C communication problems, it is recommended to wait until the end of the measuring sequence before addressing the MS8892B via I2C again. A measuring sequence is finished latest 1ms after the reception of command MCS.

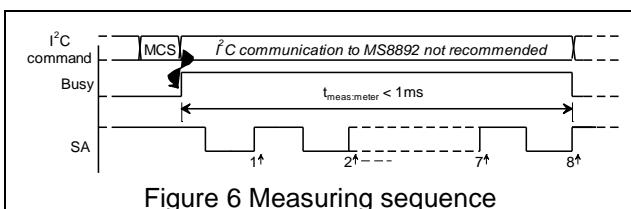


Figure 6 Measuring sequence

## 6 Effects of electro-magnetic interference

The sensor input line SB behaves like an antenna with a high input resistance in active mode. A surrounding electromagnetic field (EMF) can be collected at the antenna and interfere with the capacitance measurement. Interference by an EMF can be measured in meter mode. For reliable operation in switch mode, the threshold level needs to be set with sufficient margin to the interference.

The source of interference by EMF can be internal (e.g. microcontroller) or external (e.g. fluorescent lamp). Proper shielding of the receiver line SB will minimize internal interference. Proper shielding can be achieved with a ground plane surrounding the receiver line SB. The total shielding capacitance should not exceed 5pF. External shielding is difficult since the sensor area has to be exposed. A small sensor area will help to minimize interference from an external EMF.

## 7 Threshold calibration strategy for switch mode operation

### 7.1 Quick start

In most real application situations the capacitance variation between *no-touch* and *touch* state amounts to more than 10 counts and the capacitance value when touched is smaller. Therefore, a quick start setup can be achieved with the relative threshold mode using a fixed threshold step size of -10.

1. Acquire the baseline capacitance in *no-touch* state by sending command MCS (or by a short pulse on the INIT pin)
2. Select the relative threshold mode and RAM mode in register OPT2
3. Set the threshold register RTH to 0x0A (negative step, height 10)
4. Select one of the periodic switch mode measurement settings and keep the default filter setting in register OPT1

At this time the MS8892B is reacting on touch events which can be observed on the output OUT. The switching behavior can be optimized by adjusting the relative threshold value, the filter settings, and the measurement rate.

### 7.2 Optimised absolute threshold

To obtain an optimized threshold value, measurements of the capacitance in *no-touch* and *touch* state are required. The threshold value must be set between the two values, ideally halfway between the *touch* and *no-touch* values. If the difference between *no-touch* and *touch* capacitance is large, the switching behavior can be influenced by tuning the

threshold up/down. A safety margin of several counts must be kept between the threshold and the *no-touch* or *touch* capacitance value.

If the fabrication and material tolerances are small, the absolute threshold can have a fixed value for a single product. If the tolerances are larger, a threshold calibration per device may be necessary. In this situation the relative threshold mode can simplify the calibration, as described in the following section.

### 7.3 Optimised relative threshold

The capacitance difference obtained between the *no-touch* and *touch* states is usually fairly constant for a given application, even if the fabrication and material tolerances don't allow a fixed threshold setting. In this case, using the relative threshold mode allows setting a robust threshold without the need to determine an individual threshold per device.

The capacitance difference between *no-touch* and *touch* state has to be obtained just once for a given application. Based on this value, the threshold step height can be estimated, further optimized and then used throughout the production for all devices. In turn, the relative threshold mode requires one threshold baseline measurement after power-up of the MS8892B. In autonomous operation mode (TRIGGER = 0), the first measurement after (1) power-up, (2) an RSTN reset or (3) a short pulse on INIT will be baseline measurement. In I<sup>2</sup>C controlled mode, the baseline measurement can still be triggered with (1) an INIT pulse or (2) by an MCS measurement command.

## 8 Power saving using an external clock / trigger source

The MS8892B can be operated with an external clock source to trigger the periodic measurements. In this configuration, the internal oscillator of the MS8892B is shut down between measurements. This reduces the average power consumption from approximately 700 nA to 60 nA (with a clock frequency of 1024 Hz and 2 measurements per second). See also sections 8.4 (clocking system), 11.2 (DC characteristics, with power consumption figures) and 12.2 (application example) of the latest datasheet.

The best power consumption benefit is achieved using an ultra-low power oscillator (RTC, nano-power timer, etc.) as external clock source.

### 8.1 RTC as external clock source

Real time clocks (RTCs) have often very low power consumption figures, even below 100 nA (as an example the Microcrystal RV-3028-C7 consumes typically 45 nA at 3 V). A common feature of RTCs is a clock output delivering frequency in the few kHz range.

The MS8892B supports the nominal clock frequencies of 1024 Hz and 8192 Hz, which support the specified measurement rates of 2, 8 or 32 measurements per second, and the measurement rate in turn defines the reaction time of the sensor. These two nominal clock frequencies are typical output frequencies of most RTCs on the market.

The external clock input of the MS8892B is however not restricted to the nominal clock frequencies. Even if the exact clock frequencies of 1024 Hz or 8192 Hz are not available, the external clock input can be useful. The measurement rate simply scales with the applied clock frequency. For example a clock frequency of 2 kHz combined with the 1024 Hz mode of the MS8892B will result in measurement periods of 3.9, 15.6 or 62.5 measurements per second. Measurement rates faster than 50 per second are possible but not suggested, as a further reduction of the reaction time will not be noticeable and power consumption rises with the measurement rate.

Section 12.2 'Ultra-low power wake-up controller' in the MS8892B datasheet describes a typical application with an RTC as clock source, and both the RTC and the capacitive touch sensor MS8892B function as system wake-up elements, while consuming less than 150 nA.

### 8.2 Non-standard trigger mode

Measurements of the MS8892B can also be triggered by negative pulses on the TRIGGER input (single hardware trigger mode). In this mode the internal oscillator is disabled and the average current consumption of the MS8892B is approximately 50 nA. The maximum TRIGGER low pulse duration is specified as 100  $\mu$ s in the datasheet ( $t_{TRG}$ ). Holding TRIGGER low for a duration longer than 2 ms will change the operating mode of the MS8892B from single hardware trigger mode to stand-alone mode, with periodic measurements every 32 ms and with an average current consumption of about 850 nA. Simulations and measurements have shown, that a TRIGGER low pulse longer than 2 ms is acceptable and that the MS8892B behaves well in these cases. This has also been demonstrated in a real application.

### Temperature patch application

The application is a temperature patch that measures human body temperature when contact is made with the human body skin. The patch has an MS8892B which detects whether there is contact with the skin and supplies power to the application load consisting of an IN100 (RF beacon) and the Microdul MS1088 (temperature measurement sensor) when contact is made.

The measurements of the MS8892B are triggered with the TI TPL5111, which is a 35nA timer that generates a 50 ms low pulse every 1 second in the configuration of Figure 7. This is a non-standard method of using the



TPL5111 (deviating from the main application description in the datasheet), which allows to reduce the bill-of-materials.

Figure 7 shows the block diagram of the temperature patch application with a simplified symbol for the load, while Figure 8 shows the load in more details.

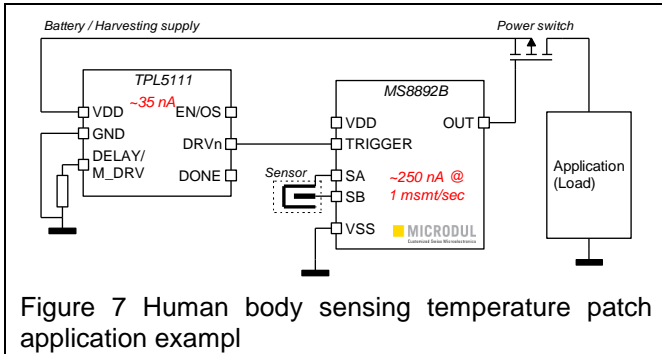


Figure 7 Human body sensing temperature patch application exampl

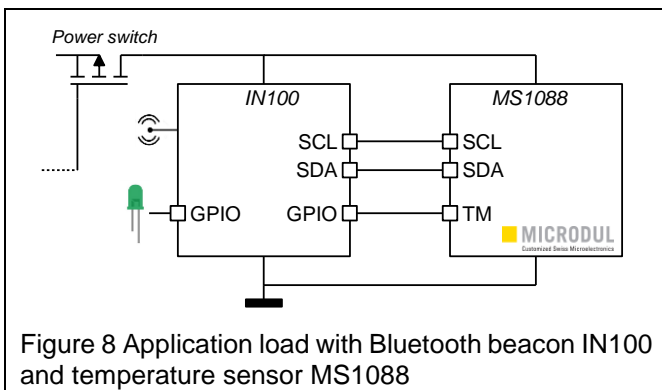


Figure 8 Application load with Bluetooth beacon IN100 and temperature sensor MS1088

The DRVn output signal is connected directly to the MS8892B so that a 50 ms low pulse is generated at the TRIGGER pin every 1 second. This triggering method allows to have a total current below 300 nA in the state where no touch is detected and the power switch is in off-state, thus disconnecting the load from the supply.

The TRIGGER signal period can be changed via an external resistor connected to DELAY/M\_DRV pin of the TPL5111 timer. A higher resistor means periods of seconds or minutes. In this way one can reduce the total current consumption to below 150nA in stand-by mode.

The MS8892B is configured in compare mode. The option register OPT1 is programmed to 0x01 (single

trigger, noise filter on, noise suppression high) and the option register OPT2 to 0x08 (comparator's output polarity is inverted; CPH is high if CS > CTH). Refer to the MS8892 datasheet, sections 9.3.4 and 9.3.5 for further details.

The application load consists of an InPlay IN100 Bluetooth RF beacon and the low power MS1088 temperature sensor from Microdul. Whenever human body skin is detected, the application load is powered and the temperature is measured periodically and the temperature values are sent to a Bluetooth receiver.

## 9 Using the Interrupt-over-I<sup>2</sup>C-bus functionality

The interrupt-over-I<sup>2</sup>C-bus (Section 9.5 in the datasheet) allows to signal capacitive events in switch mode even if the IC is in latching mode and the output is latched. If this mode is enabled in register OPT2, each switch-on/off transition detected will trigger a short pulse on the SDA line of the I<sup>2</sup>C interface. The MCU can then read out the RES register to obtain the current switch state.

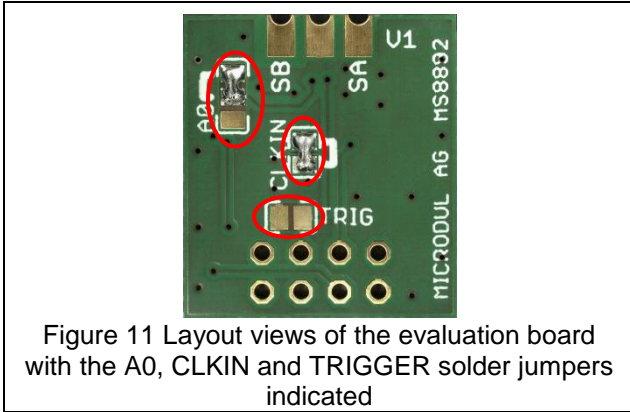
It has to be noted, that such interrupt pulse on the SDA line may coincide with an I<sup>2</sup>C communication attempt. This would compromise the ongoing communication. An immediately following repetition of the command would then be accepted, as the time slot after the interrupt is long enough before another interrupt may arrive.

The conflicting situation can reasonably only occur when in periodic switch mode, and the when the MCU tries to stop periodic mode. In periodic mode there should be no I<sup>2</sup>C interaction except reading the RES register right after such an SDA interrupt, which would fall into a safe slot just after the SDA pulse, or stopping the periodic mode by writing to the OPT1 register.

In order to properly exit periodic mode when I<sup>2</sup>C interrupt is enabled, it is best to send the stopping command 2x in sequence. Alternatively, the concerned register OPT1 could be read back after the stopping command, and the stopping command could be resent in case of failure. But that's more complex in terms of firmware than sending the command twice.



Figure 11 shows the bottom side of the evaluation board. The three highlighted areas show the solder options of the signals TRIGGER (TRIG), CLKIN and A0.

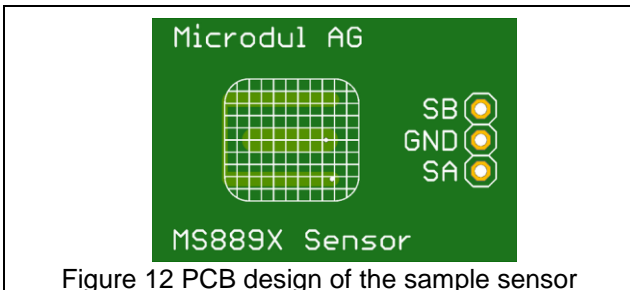


The evaluation board allows testing of the main features as a system power controller, including the

- Relative threshold mode, including the baseline measurement using an I<sup>2</sup>C command or the INIT pin
- The output latching mode, including the latch clearing using an I<sup>2</sup>C command or the INIT pin
- The control of a system power switch, modeled by the PMOS M1 and the LED OUT
- The connection to an external RTC for combined control of the power switch via the signal OUT and the extremely low power consumption when supplying the clock to CLKIN of the MS8892B

These possibilities are described with more detail in section 11.2 of the MS8892B datasheet.

In order to get started quickly with the evaluation of the MS8892B on the evaluation board, a sample sensor board is included in the kit which can be directly soldered to the evaluation board or connected with standard 100mil headers. Adding a plex-glass overlay of 1-2 mm thickness on top of the sensor area is suggested. Without it, directly touching the sensor may show some unwanted on/off switching (due to excessive capacitive loading on SB).



As an alternative to the sensor PCB, simply attach two wires of 20-50 mm length to SA and SB to get started. The wires can be formed as desired, as long as the allowed capacitance of 1000 fF between SA and SB is not exceeded.

## 11 Coding requirements & examples

### 11.1 Coding requirements

*Waiting time after COMP or MCS commands*

The COMP or MCS commands trigger measurements with a duration of up to 1 ms. In order not to interfere with the measurement, a waiting time of  $\geq 2$  ms is suggested before sending the next command to the MS8892B.

*Measurements during periodic mode*

Measurements using I<sup>2</sup>C commands (MCS, COMP) are **not executed** when the MS8892B is in periodic measurement mode (MI  $\neq$  '00' or TRIGGER = 0). The CVAL register will not be updated, and reading CVAL (RCS command) will return the previous value. Other I<sup>2</sup>C commands will function normally.

### 11.2 Arduino code example

The following code is an example which runs on the Arduino platform. It configures the MS8892B in periodic switching mode using a relative threshold configuration to automatically adapt to the actual baseline capacitance of the attached sensor.

The example source code can be downloaded from the Microdul web page:

<https://www.microdul.com/en/ultra-low-power-sensors/human-body-detector/>

I<sup>2</sup>C address and command definitions:

```
#define MS8892_ADDR 0x24

#define MCS 0x00
#define RCS 0x01
#define COMP 0x02
#define RRES 0x03
#define LCLR 0x04
#define WTH 0x05
#define RTH 0x06
#define WOPT1 0x07
#define WOPT2 0x09
```

Configuration of the MS8892B for periodic comparison operation in relative threshold mode, including a capacitance measurement to determine the threshold baseline. It is important to add a small delay  $\geq 2$  ms after the measurement command MCS to let the measurement complete before changing the MS8892B configuration or reading the measurement value:

```
void setup() {
  Wire.begin();
  Serial.begin(115200);

  // set RAM Mode, invert polarity, rel. threshold
  write_data(MS8892_ADDR, WOPT2, 0b01001001);
  // set relative threshold step -10
  write_data(MS8892_ADDR, WTH, 10);
  // measure capacitance as threshold baseline
  write_command(MS8892_ADDR, MCS); delay(2);
  // set periodic comparison mode with 8 measurements/s
  write_data(MS8892_ADDR, WOPT1, 0b00001000);
}
```

The main loop simply lets the Arduino board LED flash every 2 seconds (heartbeat):

```
void loop() {
  // 2s heartbeat flashes on Arduino LED
  digitalWrite(LED_BUILTIN, HIGH);
  delay(100);
  digitalWrite(LED_BUILTIN, LOW);
  delay(1900);
}
```

The following subroutines simplify the I<sup>2</sup>C access to the MS8892B:

```
/* I2C access routines
*****/

void write_data(int address, int command, int databyte)
{
  Wire.beginTransmission(address);
  Wire.write(command);
  Wire.write(databyte);
  Wire.endTransmission();
}

int read_data(int address, int command)
{
  int value = 0;

  Wire.beginTransmission(address);
  Wire.write(command);
  Wire.endTransmission(false);
  Wire.requestFrom(address, 1);
  value = Wire.read();
  return (value);
}

void write_command(int address, int command)
{
  Wire.beginTransmission(address);
  Wire.write(command);
  Wire.endTransmission(true);
}
```

## 12 ESD

Inputs and outputs are protected against electrostatic discharge during normal operation. However to be totally safe, it is advisable to undertake precautions appropriate to handling MOS devices in all process steps.

## 13 Disclaimer

Whilst every effort is taken to make sure that the information contained in this document is correct, Microdul AG accepts no liability whatsoever for the accuracy or completeness of the information given. Microdul AG reserves the right to change or correct information without prior notice as necessary.

## 14 Ordering information

For ordering MS8892B samples and the MS8892 evaluation board, please contact:

[semiconductors@microdul.com](mailto:semiconductors@microdul.com)