Application Note

1 General product description

The integrated circuit MS8891A 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. In meter mode the absolute sensor capacitance is measured. The MS8891A has four measuring ranges covering 0 to 1600fF with a resolution of 8 bits. The configuration of the various options and the operation of the meter mode are done via the I^{2}C serial interface. The MS8891A can be autonomously operated in switch mode. The MS8891A 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 MS8891A the capacitive sensor is formed between a driving line (SA) and a receiving line (SB). Sensor channel 1 is formed between SA1 and SB1 and sensor channel 2 between SA2 and SB2. 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 1 shows the electrical field lines between the driving line SA and the receiving line SB without interference from an object and Figure 2 shows the electrical field lines of the same arrangement when a finger touches the sensor area. The sensor capacitance is lower in Figure 2 because part of the electrical field between the driving line SA and the receiving line SB is shunted over the body / ground capacitance Cbg and back to the device via the device / ground capacitance Cdg.

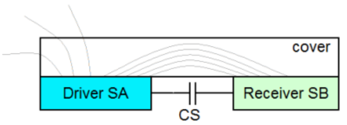

Figure 1: Field lines between sensor lines (no touch)

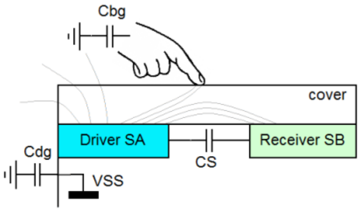

Figure 2: Field lines between sensor lines (touch)

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) ε_r. The larger the value ε_r is, the higher the capacitance is. Typical values for commonly used materials are listed in Table 1.

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

Material	ε_r
Air	1
Paper	1 to 4
Glass	5 to 10
PMMA	3.4
FR2, FR4	4.3 to 5.4
Skin	42
Water	80

The sensor capacitance depends on the sensor architecture 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 capacitcance is typically related to shunting the field lines to ground (Figure 2).
The influence of the cover thickness on the capacitance value is shown in the example in Figure 3. The sensor capacitance («no touch») is increasing nonlinearly as a function of the cover thickness (blue curve). The capacitance value is saturated 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 ε_r of a finger is higher than ε_r of air). With increased 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.

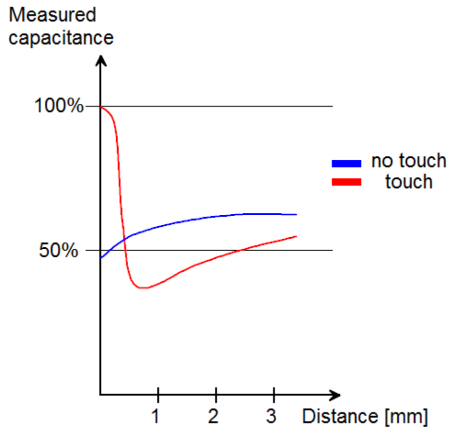

Figure 3: Example of measured capacitance as a function of cover thickness

3 Sensor design

Figure 4 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 should be shielded from any other dynamic signal. Ground planes or any other static signals can be used to shield the SB trace between the MS8891A 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 ds between the driving and the receiving line should be in the order of 0.5 to 3mm.
- The length ls of the receiving line SB should be in the order of 0.5 to 10mm.

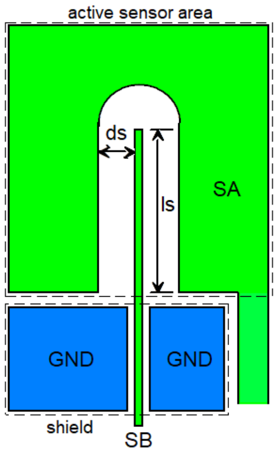

Figure 4: Basic sensor layout

The sensor layout presented in Figure 4 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 4 are listed in Table 2.

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

Distance ds [mm]	Length ls [mm]	Approx. sensor capacitance [fF]
2.5	4	160
1.6	4	220
0.6	4	320

Note: Sensor is routed on a FR4 print (1.6mm thickness) and covered by solder resist.

4 Switch mode

4.1 Autonomous operation in switch mode

The MS8891A 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 1 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 2 measurements per second
11	permanent

Also the threshold capacitance values CTH1, CTH2 and the other options in register OPT1 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.

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5 Meter mode

5.1 Avoiding I²C communication problems in meter mode

A measurement in meter mode is started by sending the command MCS to the MS8891A via the I²C interface. The measurement runs through the sequence as shown in Figure 5. 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 end is reached after the 8th rising edge of signal SA1, if one sensor is active (SNG = '1'), or after the 8th rising edge of signal SA2, if two sensors are active (SNG = '0'). The MS8891A does not respond with an I²C acknowledge if signal Busy is active. To avoid I²C communication problems, it is recommended to wait until the end of the measuring sequence before addressing the MS8891A via I²C again. A measuring sequence is finished latest 1ms (SNG = '1') or 2ms (SNG = '0') after the reception of command MCS.

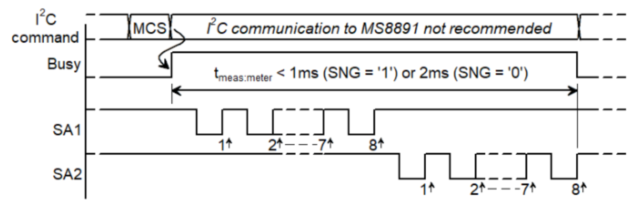

Figure 5: Measuring sequence

6 Measuring interference

6.1 Electromagnetic field (EMF)

The sensor input lines SB1 and SB2 behave like antennas 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 lines SB1 and SB2 will minimize internal interference. Proper shielding can be achieved with ground planes surrounding the receiver lines SB1 and SB2. 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 Calibration strategy for switch mode operation

Figure 6 shows a basic flow chart of the calibration strategy for switch mode operation for sensor channel CS1. The same strategy applies for sensor channel CS2. The sensor capacitance has to be measured when the sensor area is “not touched” and again when it is “touched” by the object. After measuring both situations the threshold capacitance can be calculated. As a good starting point the threshold value CTH1 should be set in the middle of the measured values of both situations («no touch» and «touch»).

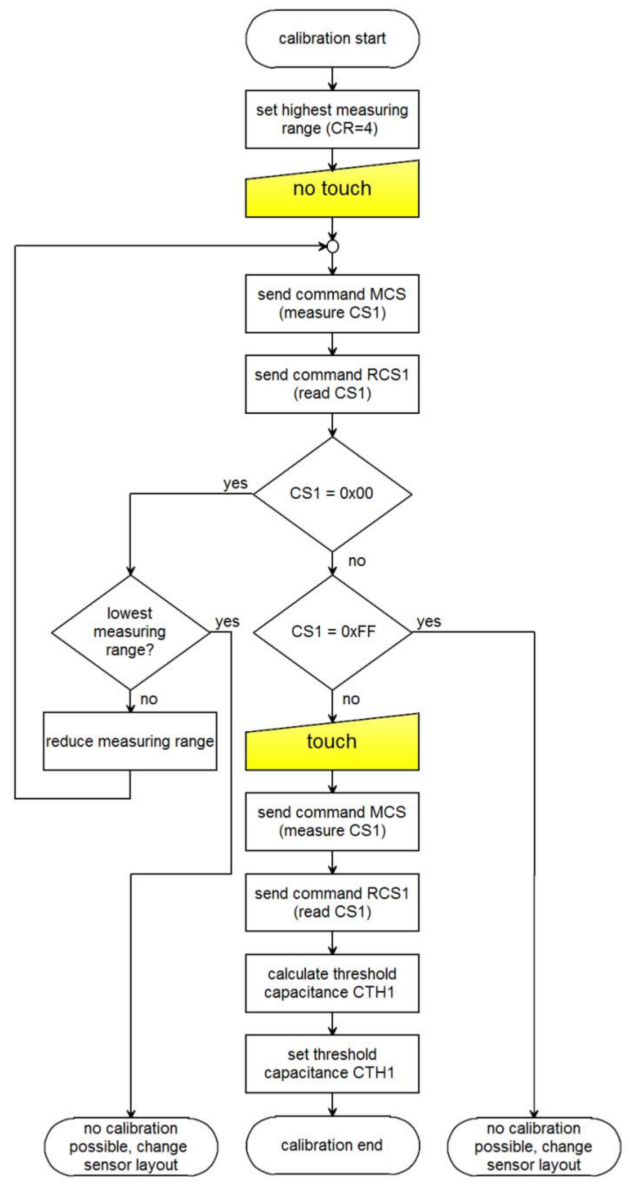

Figure 6: Basic flow chart of calibration strategy

The calibration may need some fine tuning since the sensor capacitance value (when touched) can be different in the calibration setup and in the final application. The reason for a difference of the sensor values between calibration and final application are a change of the electrical properties of the external network.

8 Evaluation board

The MS8891A evaluation board is available on request. The schematic of the evaluation board is shown in Figure 7. Most of the MS8891A signals are available on three connectors JP1, JP2 and JP3. The pinning of the three connectors is given in Table 4. The input POL is initially soldered to VSS on the back side of the evaluation board. This connection can be easily removed on the PCB and soldered to VDD for changed behavior. The pin TRIGGER is pulled to VDD level by R5. This allows to control TRIGGER from a microcontroller. TRIGGER can be soldered to VSS level permanently. The Outputs OUT1 and OUT2 are connected to light-emitting diodes (LED). They show the result of the compare measurement in switch mode.

The MS8891A soldered to the evaluation board is not configured. Configuration of the operation mode options and the threshold capacitances has to be done via the I^{2}C serial interface connected to connector JP1. Programming the configured values into the non-volatile memory of the MS8891A is possible. Details on how to program the non-volatile memory are given in section 10 “OTP Memory” of the datasheet.

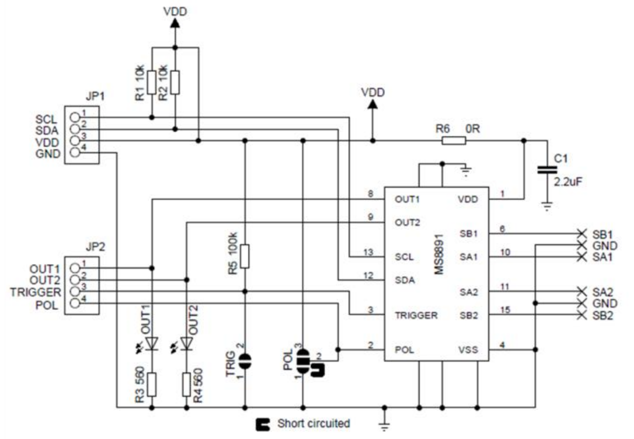

Figure 7: Schematic of MS8891A evaluation board

Table 4: Connectors on the evaluation board

Pin	JP1	JP2	JP3
1	SCL	OUT1	SB1
2	SDA	OUT2	GND (VSS)
3	VDD	TRIGGER	SA1
4	GND (VSS)	POL	SA2
5			GND(VSS)
6			SB2

Figure 8 shows the top view of the assembled evaluation board. The two connectors JP1 and JP2 are located on the lower side and connector JP3 is located on the upper side of the evaluation board. Pin 1 of connectors JP1, JP2 and JP3 is marked with a large white dot (●) located next to it.

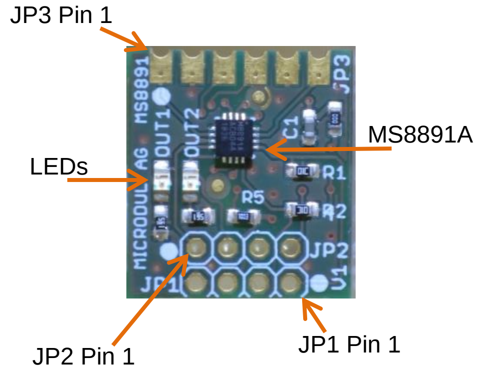

Figure 8: Assembled MS8891A evaluation board

Figure 9 shows the top and bottom views of the evaluation board’s layout. The two highlighted areas show the solder options of the two signals TRIGGER (TRIG) and POL. The existing connection for POL can be easily removed and connected to the opposite side with a solder iron.

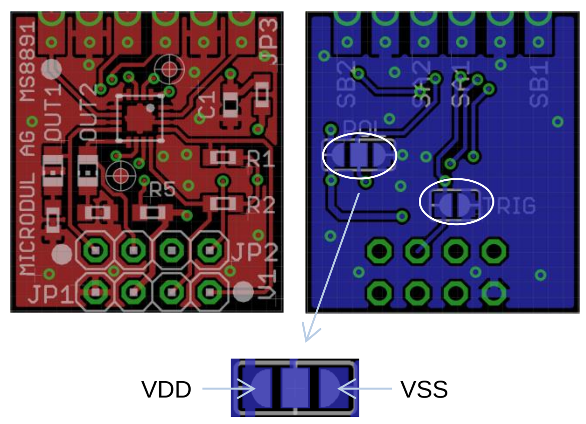

Figure 9: Layout views of the evaluation board

Arduino Code Example

The following code is an example which runs on the Arduino platform. It measures both sensor channels in a loop and prints out the measured values.

The example code can be downloaded from the Microdul web page:
https://www.microdul.com/en/standardprodukte/human-body-detector/

I2C address and register definitions.

```
#include <Wire.h>

#define MS8891 0x22

#define MCS    0x00
#define RCS1   0x01
#define RCS2   0x02
#define WOPT1  0x09
#define WOPT2  0x0B
```

Set RAM mode (WOPT2 = 0x01). Set both sensor channels to the lowest measuring range (WOPT1 = 0x00).

```
void setup()
{
  Wire.begin();
  Serial.begin(115500);

  write_data(MS8891, WOPT2, 0x01);   //Set RAM mode
  write_data(MS8891, WOPT1, 0x00);   //Set lowest measuring range
}
```

Measure CS1 and CS2 in the main loop (command MCS followed by commands RCS1 and RCS2) and print out the measured values.

```
void loop()
{
  int val_cs1, val_cs2;

  write_command(MS8891, MCS);        //Start measurement
  delay(2);                          //wait until measurement finished
  val_cs1 = read_data(MS8891, RCS1); //Read measurement result of channel1
  val_cs2 = read_data(MS8891, RCS2); //Read measurement result of channel2

  //use output with Arduino IDE Serial Plotter
  Serial.print(val_cs1);Serial.print(" ");Serial.println(val_cs2);

  delay(200);
}
```

Subroutine *write_data*: single byte I^{2}C write command

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

Subroutine *read_data*: single byte I^{2}C read command

```
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);
}
```

Subroutine *write_command*: I^{2}C command

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

9 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.

10 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.

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