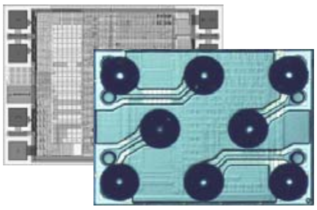
Application note for the capacitive switch



Contents

Introduction

The MS8883 IC is a capacitive switch that uses a patented digital technique (Patent from Edisen) to evaluate a change of capacitance on the device input. In order to use this switch, you must first define the following; the form and materials to be used, the desired switching distance from the sensing plate and the desired switching characteristic. The following text explains the relationship between your product design and the electrical switching to be expected.

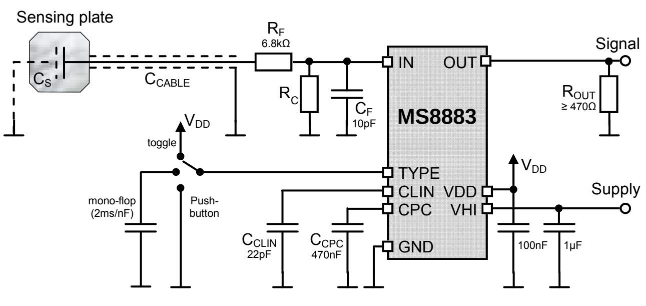


Figure 1: Typical circuit

It is essential to have the datasheet handy. This can be downloaded from http://www.microdul.com/ .

Dimensioning of R_C, C_{CPC} and C_{CLIN}.

Next we will explain how switching can be influenced by the choice of C_{CPC}, R_C and C_{CLIN}. The adaption of the switch to a particular application usually requires several components to be adjusted because certain parameters can be influenced by one or more factors. We start by considering the sensor area, sensor environment and triggering because these aspects are decisive for the behaviour of the switch.

The circuit has three parameters that influence the switching behaviour. These are listed below in order of their influence:

- Switch sensitivity (C_{CPC} capacitance between CPC and VSS)
- Calibration of the total capacitance on the sensor input (R_C between IN and V_{SS})
- Switching speed (C_{CLIN}, between CLIN and V_{SS})

Once the sensing area is defined (geometry, material, distance from sensing plate to input) you can start with the typical values given in the data sheet for C_{CPC} and C_{CLIN}.

R_C

Although this resistance is not listed first in the list above, it is important since no switching can take place without it. This resistor must be used when the cable connecting the sensing plate to the input is longer than about 0.5m or when the sensing plate area is larger than approximately the area of an adult hand.

According to the data sheet, the total capacitance on the input should be between 10pF and 60pF in order for the control loop to work correctly and reliably. In practice it is normally impossible to measure this capacitance so the voltage on C_{CPC} must be measured instead. Ideally the operating point voltage on C_{CPC} should lie at $V_{DD}/2$ (not $V_{HI}/2$).

This measurement must be done with a high impedance probe (R_{in} >5GΩ) since this point has a high resistance [1)]. The lower limit for R_C is approximately 20kΩ. You should note that the IC has an internal 50kΩ resistor connected in parallel to R_C (Pin IN to V_{SS}). Higher internal currents flow and the precision is less when R_C is less than 20kΩ.

Switching should be checked by touching the sensor plate whether or not the final application will use

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

touch or proximity switching. Capacitance C_{CPC} should be changed if no switching occurs. Increasing the value of C_{CPC} should be tried first. If the sensor still does not switch, simplifying the switch construction should be tried. In most cases changing C_{CPC} will result in the sensor switching.

C_{CPC}
The sensitivity can be set once the sensor switches reliably (see previous step). Touching the sensor plate is the least critical case and usually works with the value of C_{CPC} given in the datasheet (C_{CPC} = 470nF typical). Adjustments are usually necessary when:

1. The sensor area is small and the triggering area is comparable or smaller. For example, if the sensor is used in a keyboard, the keys may have a small area. The area of a finger is comparable to the sensor area. The switch must be fine tuned such that neighbouring switches do not react.
2. The distance between the sensor plate and triggering object is larger than the sensor plate area (switching at a distance).
3. Switching through materials having different ε_r is desired.

The second point is actually a special case of the third point with the problem that the point where the switch should react is not solely defined by the sensing plate but also by the air (and its permittivity ε_r) between the plate and the triggering object. Since the nature of air can change slightly depending on conditions, the situation for proximity switching is not as well defined as when the plate has to be touched. This makes it difficult to give a precise range for switching at a distance. In addition, the sensor sampling influences switching at a distance (see section C_{CLIN}). The cases listed above can also occur in combination. A larger value of C_{CPC} increases the sensitivity which means:

- That the sensor area can be reduced
- The sensor reacts at a distance
- The range through materials with different permittivity is increased

C_{CLIN}
At first glance it may seem that this component has little to do with the switching characteristic but it does have an influence. C_{CLIN} defines the internal sampling frequency used to sample the signal on input pin IN. The sampling period is given by:

$$T(fk)\ [\mu s] = 300\mu s + C_{CLIN}[pF] \cdot 33\mu s/pF$$

The reaction of the sensor becomes faster as the frequency is increased since the necessary number of comparisons is reached in less time. On the other hand, this also means that the sensor self calibrates to new environments more quickly with the result that a slow moving hand will no longer cause the sensor to switch (since the sensor calibrates itself to the new environment with the hand more quickly than the change caused by the approaching hand). Another consequence of increasing the sampling frequency is that the sensor reacts to quick changes at a distance with higher sensitivity. This effect can be enhanced by increasing C_{CPC} or the sensing area.

To properly dimension C_{CLIN} it is important to know the normal “approach speed” of the triggering object. A machine often moves more quickly than a human and a single finger could move more quickly than an entire hand.

It is also important to note that the device power consumption increases when the sampling frequency increases.

Sensitivity and capacitance changes

This section deals with the physical aspects of switch triggering and describes what influence the environment, sensor area and sensor trigger object have on the switching. There are many factors that can increase and decrease the switch sensitivity.
The sensitivity is a function of:

- The approach speed of the triggering object
- The area of the sensor plate (or electrode) and the area of the triggering object
- The shape of the sensor plate and the triggering object
- The nature and thickness of the material between the electrodes
- The plate (or electrode) orientation
- The coupling between the sensor area, sensor triggering object and the ground (earth).

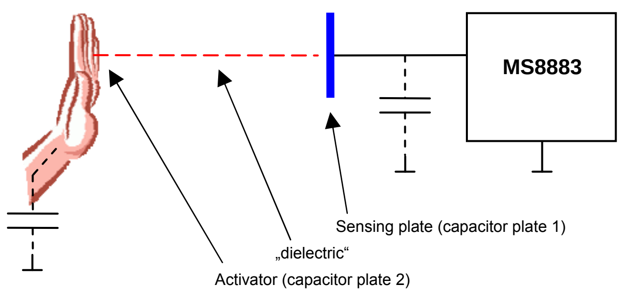


Figure 2: Typical example

The sensor area, triggering object and dielectric material between them constitute a capacitor. The capacitance seen on the sensor input (IN) consists of all the desired capacitance and parasitic capacitance to be compensated by the control loop. The capacitor connected to the hand (triggering object) in Figure 2 is used to show that a capacitance exists between the hand and ground (earth). The ground can be the negative supply or the earth depending upon the situation.

The capacitance of a plate capacitor is given by:

$$C = \frac{A}{d} \cdot \varepsilon 0 \cdot \varepsilon r$$

This expression is valid for our example but in practice the plates are seldom identical and the distance and dielectric can change.

Capacitance changes

The voltage on the sensor input is compared to an internal reference at discrete points in time defined by the sampling frequency. The control loop continuously tries to maintain voltage equilibrium on CPC by either subtracting or adding charge to the capacitor. An up-down counter counts how often charge flows consecutively in one direction. In equilibrium the counter is effectively continually reset since the charge flows first in one direction and then the other. The counter causes the output to switch when the counter has counted 63 times.The sensor reacts only to changes in capacitance. A finger that approaches the sensing plate continually changes capacitance of the plate.

According to the capacitance equation above, the capacitance can also be changed by changing the area and the permittivity. In practice the area and permittivity are more relevant for the sensitivity of the sensor.

Approach speed and dynamics

The sensor compensates changes in static or slowly changing capacitance. The sensor first switches when it can no longer compensate the change in capacitance.

Figure 3 shows how the capacitance changes with distance. You can see that an identical capacitance change ΔC is caused with a longer distance $\Delta d2$ further away from the sensing plate than $\Delta d1$ nearer to the sensing plate.

A triggering object travelling at a constant speed will cause a larger capacitance change nearer to the plate than further away from it.

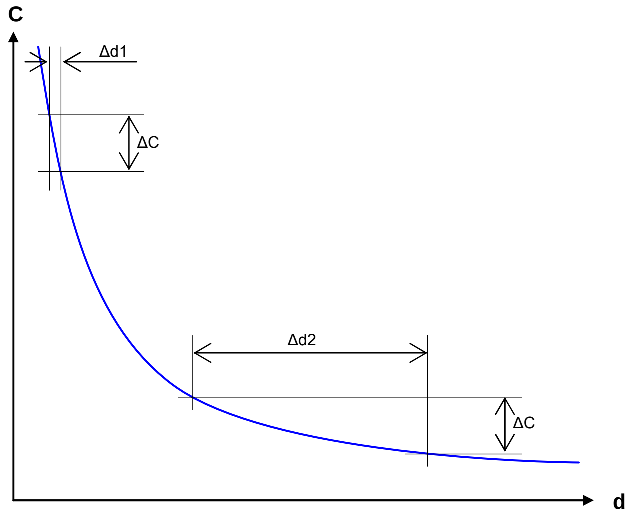


Figure 3: Capacitance change as function of the distance

Noting that the sensor requires more than 63 consecutive increases (or decreases) in capacitance over a fixed time period to cause a switch, it can be deduced that the switch distance increases with increasing approach speeds.

Influence of the size and form of the capacitor plates (electrodes)

An open input pin on the MS8883 represents the worst possible sensing area and is not recommended. The easiest method to increase the sensitivity is to increase the sensing area as illustrated in the capacitance equation (where we can see that “C” is proportional to “A”). In most cases simply increasing the sensing area will lead to the desired result. When the sensing area is limited by the application then you will have to increase the value of C_{CPC} to increase the sensitivity.

Increasing the size of the triggering object can also increase the sensitivity if this is allowed by the application. In some circumstances this may actually be desired in order to optimise the switching characteristic for a particular application. For example switching through a thick layer of material where the material itself influences the sensitivity (see Figure 4).

In Figure 4 we see that despite the large sensor area, a fingertip is unable to make the sensor switch but the whole hand can because it cuts all of the field lines. This simplified model can help you to understand how to optimise your application.

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

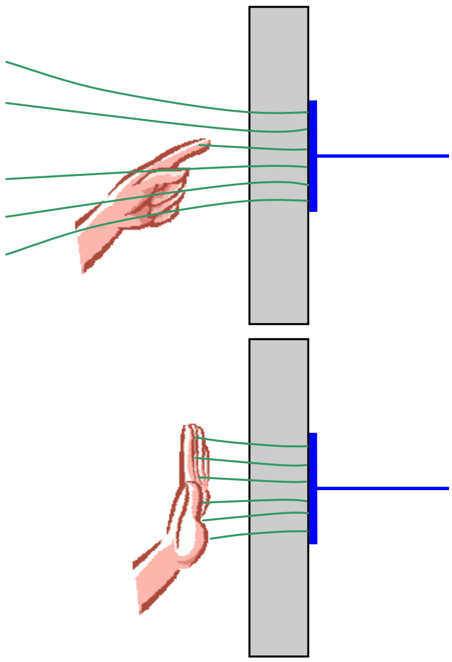


Figure 4: Influence of approaching objects

The minimal sensor area should not be smaller than the triggering object area. A larger sensing area is recommended. The sensor area or C_{CPC} must be increased in cases when switching takes place through different layers (e.g. over distance, with differing permittivity).

From the point of view of the MS8883 there is no limitation on the form or design of the sensing area. The sensing area can take any form as long as the required sensitivity can be obtained. Oval or round areas are recommended since they have the least edge effects.

Influence of the thickness and nature of the dielectric

The dielectric encompasses everything between the sensing area and the triggering object area.

The thickness and nature of each dielectric influences the electric field strength and flux passing through it. If different layers of material with differing permittivity are used then all layers will influence the field and flux. The field will be refracted, diffracted, reflected and attenuated dependent on the exact materials and construction used.

Figure 5 shows a real application. The sensor area is mounted behind 10mm thick glass, a 3mm air gap and 2mm thick plastic. The sensor area is limited due to the application. The range or permittivity for glass and plastic is:

- Glass: 6-8
- Plastic: 2-4

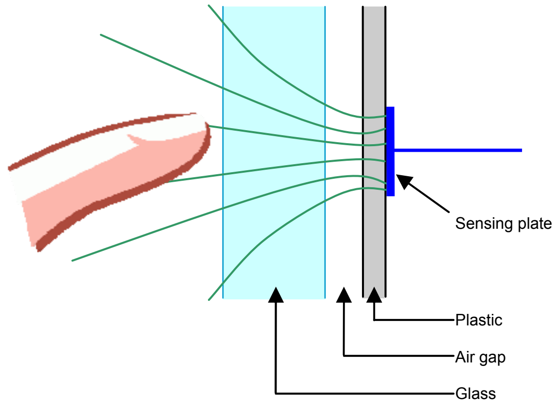


Figure 5: Different dielectrics

Materials having higher relative permittivity support higher sensitivity because the electrical field strength is proportional to the relative permittivity. The air gap above is a problem because the relative permittivity $\varepsilon_r = 1$ and is low compared to plastic or glass. The air gap will drastically reduce the sensitivity of the set-up. This is also the reasons why switches using an air gap require a larger sensor area or higher sensitivity. The only improvement possible in the application above was to increase the value of C_{CPC}. Another factor that had to be considered was the total thickness of the construction.

Plate (electrode) orientation

A large enough capacitance change will cause any application to switch. The following rule always applies:

The more field lines that the triggering object cuts, the larger the generated capacitance change will be.

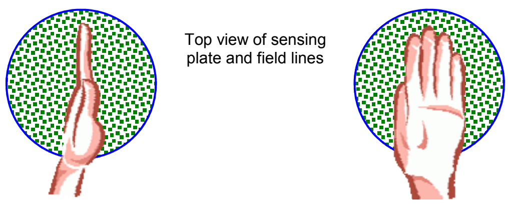


Figure 6: Trigger object area

Figure 6 illustrates this effect. The approaching palm area triggers a switch faster than the side of the hand.

Electrical environment

The presence of ground (earth) influences capacitive sensing. Figure 7 shows the expected field with and without neighbouring grounds.

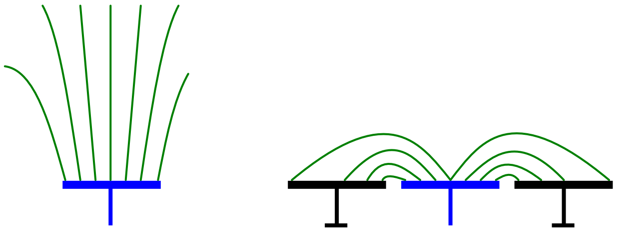


Figure 7: Influence of grounds

The electric field takes the shortest path to ground. As you can see, the presence of the ground in Figure 7 flattens the field and therefore shortens the switching distance and sensitivity in comparison to the example without a nearby ground. Alternatively you could take the view that the neighbouring grounds represent additional capacitance in the system that the device has to compensate.

The capacitive compromise

The capacitive switch is always a compromise. A non self-calibrated capacitive device must be initially calibrated and will only function with one set of materials and over a particular distance. Dirt, humidity and temperature changes can impair and prevent correct function in this case.

The self-calibrated switch MS8883 adjusts itself continuously to the environment. It will only switch when the capacitance changes more than 63 time consecutively in one direction.

Very slow changes will be neutralised by the calibration. Extremely quick changes will not be registered because the device never reaches the required count. In other words the disturbance is digitally filtered out.

Therefore the switch must be optimised for the typical application requirements. The big advantage is that this device is not affected by such things as dirt, humidity, ice or damage to the electrode.

Our experience is that the user intuitively and quickly adapts to the device behaviour without having to understand any of the technical details.

[1)] Measuring the voltage on the CPC capacitor is not usually possible since the impedance on pin CPC is too high for most oscilloscope probes. The problem can be solved by using a high impedance probe (a voltage follower for example).

Alternatively it is possible to use the following characteristic of the MS8883 to workaround the problem. On power-up the internal capacitors are charged using 50x the normal charging current in order to stabilise the control loop as quickly as possible. During this time it is possible to measure the voltage at CPC correctly using a standard oscilloscope probe.

More information: http://www.microdul.com/en/services_products/standard_products/ms8883.php

Disclaimer

Life support applications – The ASIC is not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Microdul AG customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Microdul AG for any damages resulting from such application.

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