



# Application Note

# AN2403

## Signal-to-Noise Ratio Requirement for CapSense Applications

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**Associated Project:** No

**Associated Part Family:** CY8C20x34, CY8C21x34, CY8C24x94

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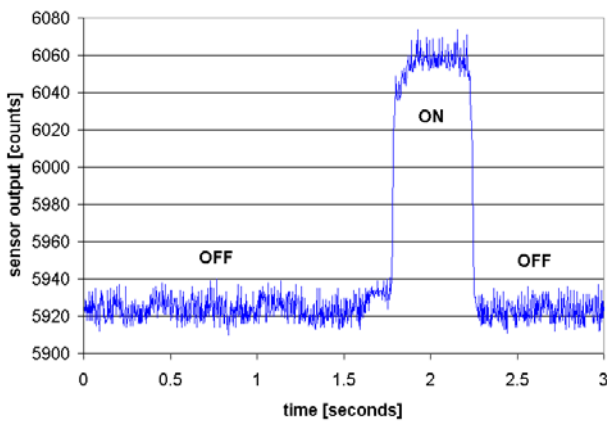
### Abstract

A minimum Signal-to-Noise Ratio (SNR) requirement of 5:1 is derived for CapSense applications. This is a system level requirement for all implementations of CapSense.

### Introduction

A typical output of a PSoC® CapSense system is shown in Figure 1. Sensor capacitance is converted into a count value (see Reference [1]). The unprocessed count value is referred to as the raw count. Processing of the raw count results in ON/OFF states for the sensor.

**Figure 1. Typical CapSense Signal**  
User Module Firmware Converts Raw Count into ON/OFF States



In order for the user module to discriminate between ON and OFF states for the sensor, the signal needs to be significantly larger than the noise. The purpose of this Application Note is to establish a “best practices” minimum requirement for how much larger the signal needs to be compared to the noise.

### 1. Definitions

A number of terms need to be defined.

#### 1.1 CapSense Counts

The PSoC user module library includes more than one method for performing CapSense, including CSA and CSD (see Reference [2]). Regardless of the method, the function of the CapSense system is to convert sensor capacitance into a digital count value.

#### 1.2 Baseline Counts and Thresholds

The high level API of the CapSense user module determines the ON/OFF state of a sensor by setting a baseline and comparing counts to threshold levels.

**Figure 2. Illustration of Baseline and Thresholds**

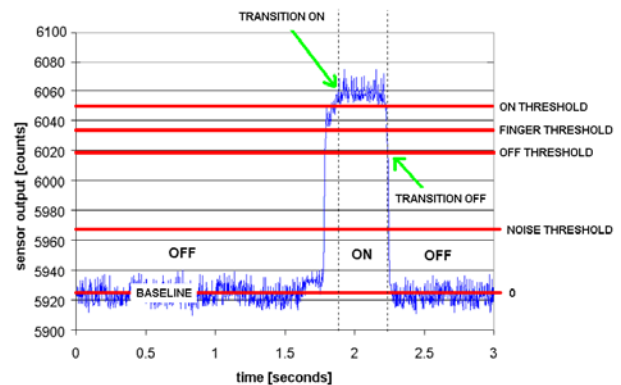


Figure 2 illustrates baseline and thresholds using the example data of Figure 1. The baseline is an estimate of the average sensor count level when the sensor is in the OFF state. The baseline provides a reference level for the ON/OFF comparison. Subtracting the baseline level from the raw count produces the difference count that is used in the ON/OFF decision process.

$$\text{DifferenceCount} = \text{RawCount} - \text{Baseline} \quad (1)$$

The straight line version of the baseline shown in Figure 2 is a simplification. The actual baseline is dynamically adjusted by the user module to compensate for environmental changes through a process called baseline update.

The thresholds are offset by a constant amount from the baseline level as shown in Figure 2. The thresholds have the following functions:

**Noise Threshold:** If the difference count is below the noise threshold, then the baseline is updated.

**ON Threshold (Finger Threshold + Hysteresis):** If the difference count is increasing and exceeds the level of (Finger Threshold + Hysteresis), then the sensor state changes from OFF to ON. Note the "Transition ON" indicator in Figure 2.

**OFF Threshold (Finger Threshold - Hysteresis):** If the difference count is decreasing and drops below the level of (Finger Threshold - Hysteresis), then the sensor state changes from ON to OFF. Note the "Transition OFF" indicator in Figure 2.

### 1.3 Signal and Noise

Signal is a generic engineering term that can have many meanings. For the capacitive sensor application under consideration in this Application Note, signal is defined as the change in the average sensor output between the OFF and ON states when the rising edge of the difference count starts below the noise threshold.

Noise is another term that has many meanings. The following discussion presents a definition of CapSense noise that uses a simple mathematical model of the sensor output over time.

When the sensor is in the OFF state, the counts,  $X(t)$ , can be modeled by an average count and a noise component.

$$X(t) = X_0 + N_0(t) \quad (2)$$

- $X_0$  is the average of  $X(t)$
- $N_0(t)$  is the noise component for  $t$  during the OFF state

The same model applies when the sensor is in the ON state.

$$X(t) = X_1 + N_1(t) \quad (3)$$

- $X_1$  is the average of  $X(t)$
- $N_1(t)$  is the noise component for  $t$  during the ON state

$X_0$  is called the baseline level of the raw counts. The difference between  $X_0$  and  $X_1$  is called the signal,  $S$ .

$$S = (X_1 - X_0) \quad (4)$$

The noise components  $N_0(t)$  and  $N_1(t)$  are similar but not identical. For example,  $N_1(t)$  usually contains a higher level of AC line noise in finger sensing applications compared to  $N_0(t)$ . This occurs because the human body acts as an antenna to 50 Hz and 60 Hz line noise, and the finger contact with the sensor overlay couples the noise into the CapSense system.

## 2. Minimum SNR for CapSense

A "best practice" for CapSense includes the following threshold levels.

- NoiseThreshold = 40%\*S
- OFF Threshold = 60%\*S
- ON Threshold = 90%\*S

This will create a 20% window of the signal of which the counts will stay out, except during transition between OFF and ON.

In the worst-case situation, there will be noise sources that add to the background level of noise that drive the level of the counts,  $(X(t)-X_0)$ , up to the noise threshold during the OFF state. These sources include RF transmissions, AC line noise, fluorescent lamp ballasts, EL backlighting, and switching power supplies. Define the noise level  $N$  as the worst case measured peak noise in the OFF state.

$$N = \max(N_0(t)) = \max(X(t)) - X_0 \quad (5)$$

A "best practice" is to set a design margin between the worst-case noise limit,  $N$ , to 50% of the noise threshold.

$$N = 50\% * \text{NoiseThreshold} \quad (6)$$

The CapSense Signal-to-Noise Ratio, SNR, is defined as the ratio of signal  $S$  to noise  $N$ .

$$\text{SNR} = S:N \quad (7)$$

The relation between  $S$  and  $N$  will now be solved for:

$$S = N/40\%/50\% = 5*N \quad (8)$$

Therefore, the minimum requirement for CapSense SNR is:

$$\text{SNR} = 5:1 \quad (9)$$

### 3. Example: Measuring SNR

SNR should be measured in the noise environment where CapSense is intended to be used. In other words, measure the system SNR under worst-case noise conditions.

The first step in measuring SNR is to monitor the raw count for each sensor. This can be done using data logging to a text file and plotting in a spreadsheet, or through the use of the Cypress FastChart GUI tool and I2C-USB bridge. Whatever the method, the raw count should be observed for SNR measurement. The difference count should not be used in the measurement of SNR since it is a function of the baseline update process, which involves filtering (filling the "bucket") and nonlinear threshold events.

Another factor to consider is how the signal is produced. The worst-case ON and OFF scenario should be used when measuring SNR. If the system is designed to sense the presence of a finger, then measure SNR with a light touch of the sensor area, and position the contact point slightly off-center. For automated testing, a worst-case finger touch can often be simulated by an equivalent metal disc that is the size and shape of a small coin.

As an example of measuring SNR, consider the raw count waveform in Figure 1.

X0 = 5925 counts  
X1 = 6055 counts

S = 130 counts  
N = 5940 - 5925 = 15 counts

**SNR = 130:15 = 8.6:1**

NoiseThreshold = 40%\*130 = 52 counts  
OFF Threshold = 60%\*130 = 78 counts  
ON Threshold = 90%\*130 = 117 counts

Hysteresis = (117-78)/2 = 19 counts  
Finger Threshold = (117+78)/2 = 97 counts

If the measured SNR is found to be below 5:1, consult the CapSense Best Practices Application Note for the latest advice on improving SNR (see Reference [2]). A good layout is essential for a high SNR. For example, the selected overlay thickness or material type may limit SNR (see Reference [3]). After addressing layout issues of lower SNR, then filtering should be used to minimize the noise component of SNR. A simple IIR filter or averaging of multiple samples may be all that is required to boost the SNR above 5:1.

### Conclusion

A minimum requirement of 5:1 for CapSense has been derived. To ensure good performance, make sure your project meets this minimum requirement.

### References

- [1] Application Note AN2233, "Capacitive Switch Scan," Cypress Semiconductor
- [2] Application Note AN2394, "CapSense Best Practices," Cypress Semiconductor
- [3] Application Note AN2292, "Layout Guideline for PSoC CapSense," Cypress Semiconductor

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