



# AN66308 - CY8CMBR2044

## CapSense® Design Guide

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# 1. Introduction



## Abstract

This document describes how to implement capacitive sensing functionality using Cypress's CapSense® Express CY8CMBR2044 device. The following topics are covered in this guide:

- [Features of the CY8CMBR2044](#)
- [CapSense principles of operation](#)
- [Configuration options of the CY8CMBR2044 device](#)
- [Using the Design Toolbox with the CY8CMBR2044](#)
- [System electrical and mechanical design considerations for the CY8CMBR2044](#)
- [Low-power design considerations for the CY8CMBR2044](#)
- [Additional resources and support for designing CapSense into your system](#)

## Cypress's CapSense Documentation Ecosystem

[Figure 1-1](#) and [Table 1-1](#) summarize the CapSense® documentation ecosystem. These resources allow the implementers to quickly access the information they need to complete a CapSense product design. [Figure 1-1](#) shows a typical product design cycle with capacitive sensing; this document covers the topics highlighted in green. [Table 1-1](#) offers links to supporting documents for each of the numbered tasks in [Figure 1-1](#).

Figure 1-1. Typical CapSense Product Design Flow

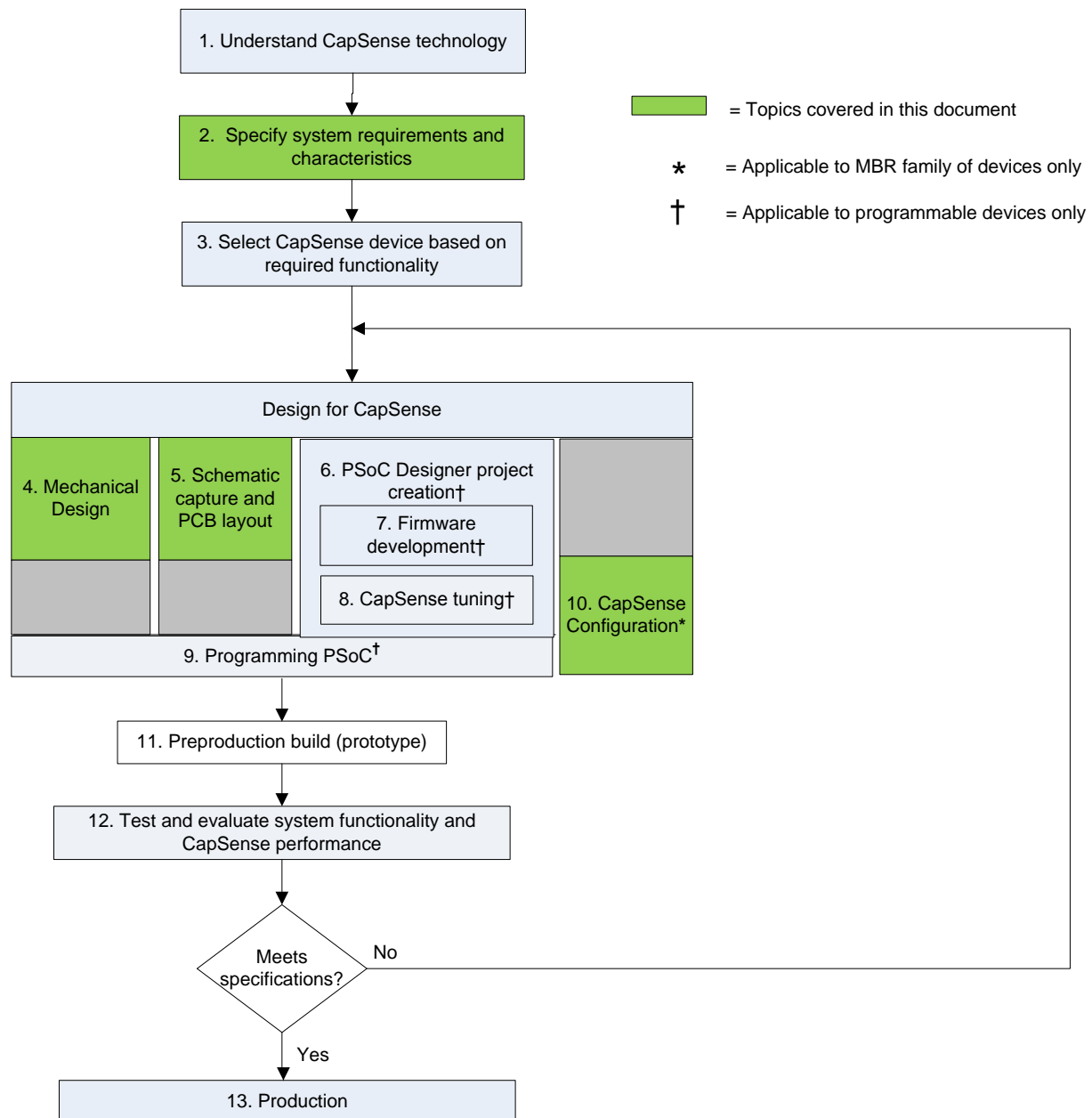


Table 1-1. Cypress Documents That Support Numbered Design Tasks of Figure 1-1

Numbered Design Task of Figure 1-1	Supporting Cypress CapSense® Documentation
1	<a href="#">Getting Started with CapSense</a>
2	<a href="#">CY8CMBR2044 Device Datasheet</a>
3	<a href="#">Getting Started with CapSense</a>
4	This document
5	This document
6	Not applicable for CY8CMBR2044
7	Not applicable for CY8CMBR2044
8	Not applicable for CY8CMBR2044
9	Not applicable for CY8CMBR2044
10	This document
11	This document

## CY8CMBR2044 CapSense Express™ Device Features

Cypress's CY8CMBR2044 is an ultra-low power device that can quickly and easily add CapSense capacitive touch sensing to your user interface. This device uses hardware to perform system configuration, eliminating the need for software tools, firmware development and device programming. The features of the device are listed as follows. For more details, see [CY8CMBR2044 Configuration Options](#).

- Easy-to-use capacitive button controller
  - ☐ Four-button solution configurable through Hardware straps
  - ☐ No software tools or programming required
  - ☐ Four general-purpose outputs (GPOs)
  - ☐ GPOs are linked to CapSense buttons
  - ☐ GPOs support direct LED drive
- Robust noise performance
  - ☐ Specifically designed for superior noise immunity to external radiated and conducted noise
  - ☐ Low radiated noise emission
- SmartSense™ Auto-Tuning
  - ☐ Saves time and effort in device tuning
  - ☐ CapSense parameters dynamically set in runtime
  - ☐ Maintains optimal button performance even in noisy environment

- ☐ Wide parasitic capacitance  $C_P$  range ( 5 pF – 40 pF)
- System Diagnostics of CapSense buttons – reports any faults at device power-up
  - ☐ Button shorted to Ground
  - ☐ Button shorted to  $V_{DD}$
  - ☐ Button to button short
  - ☐ Improper value of modulator capacitor ( $C_{MOD}$ )
  - ☐ Parasitic capacitance ( $C_P$ ) out of range
- Advanced features
  - ☐ Toggle ON/OFF feature on GPOs
  - ☐ Flanking Sensor Suppression (FSS) provides robust sensing even with closely spaced buttons
  - ☐ Configurable LED ON Time after button release
  - ☐ Button output reset if touched for excessive time
  - ☐ User-controlled Button Scan Rate
  - ☐ Serial Debug Data output
    - Simplifies production line testing and system debug
- Wider operating voltage range
  - ☐ 1.71 V to 5.5 V – ideal for both regulated and unregulated battery applications
- Low power consumption
  - ☐ Supply current in run mode as low as 15  $\mu A^a$  per button
  - ☐ Deep Sleep current: 100 nA
- Industrial temperature range:  $-40\text{ }^{\circ}C$  to  $+85\text{ }^{\circ}C$ 
  - ☐ 16-pad Quad Flat No leads (QFN) package (3 mm x 3 mm x 0.6 mm)

---

<sup>a</sup> Power consumption calculated with 1.7% touch time, 500 ms Button Scan Rate,  $C_P$  of each button < 19 pF



## Document Conventions

Convention	Usage
Courier New	Displays file locations, user entered text, and source code: C:\ ...cd\icc\
Italics	Displays file names and reference documentation: Read about the <i>sourcefile.hex</i> file in the <i>PSoC Designer User Guide</i> .
[Bracketed, Bold]	Displays keyboard commands in procedures: [Enter] or [Ctrl] [C]
File > Open	Represents menu paths: File > Open > New Project
Bold	Displays commands, menu paths, and icon names in procedures: Click the <b>File</b> icon and then click <b>Open</b> .
Times New Roman	Displays an equation: $2 + 2 = 4$
Text in gray boxes	Describes Cautions or unique functionality of the product.

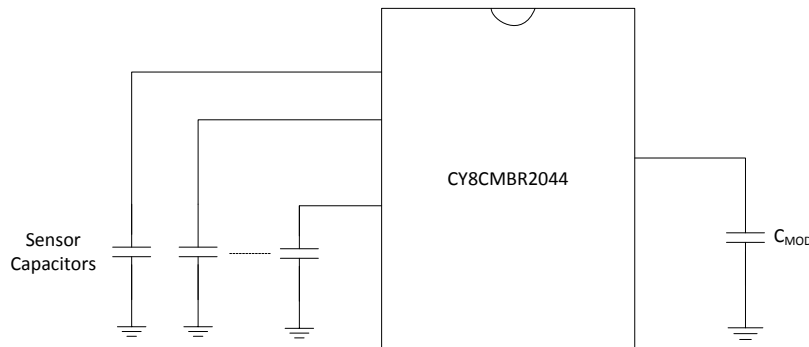
## 2. CapSense Technology



### CapSense Fundamentals

CapSense is a touch sensing technology that works by measuring the capacitance of each input pin on the CapSense controller that has been designated as a sensor. As shown in [Figure 2-1](#), the total capacitance on each of the sensor pins can be modeled as equivalent lumped capacitors with values of  $C_{X,1}$  through  $C_{X,n}$  for a design with  $n$  sensors. Circuitry internal to the CY8CMBR2044 device converts the magnitude of each  $C_X$  into a digital code that is stored for post-processing. A modulating capacitor,  $C_{MOD}$ , is used by the CapSense controller's internal circuitry.  $C_{MOD}$  will be discussed in more detail in [Capacitive Sensing Method](#).

Figure 2-1. CapSense Implementation in a CY8CMBR2044 Device



Each sensor input pin is connected to a sensor pad by traces, vias, or both, as necessary. A nonconductive overlay is required to cover the sensor pad and constitutes the product's touch interface. When a finger comes into contact with the overlay, the conductivity and mass of the body effectively introduces a grounded conductive plane parallel to the sensor pad. This action is represented in [Figure 2-2](#). This arrangement constitutes a parallel plate capacitor, whose capacitance is given by the following equation:

$$C_F = \frac{\epsilon_0 \epsilon_r A}{D} \quad \text{Equation 1}$$

Where:

$C_F$  = The capacitance affected by a finger in contact with the overlay over a sensor

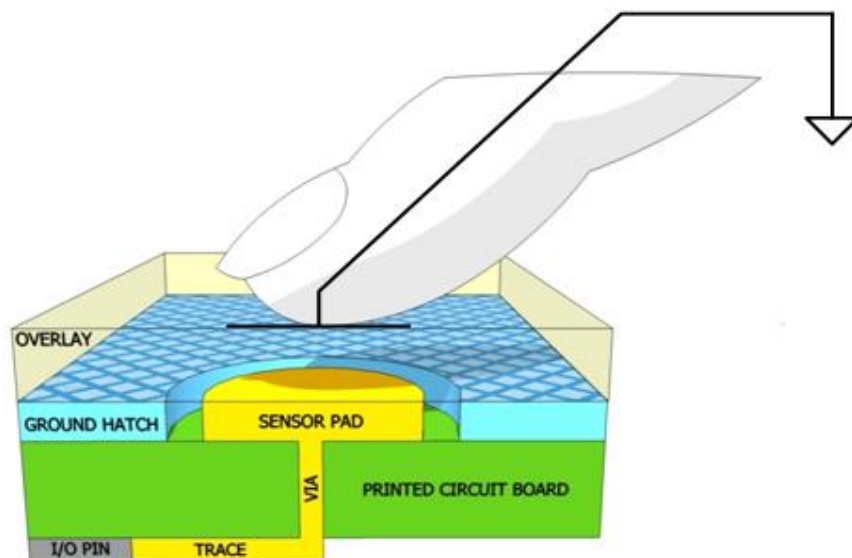
$\epsilon_0$  = Free space permittivity

$\epsilon_r$  = Dielectric constant (relative permittivity) of overlay

$A$  = Area of finger and sensor pad overlap

$D$  = Overlay thickness

Figure 2-2. Section of typical CapSense PCB with the Sensor being activated by a Finger



In addition to the parallel plate capacitance, a finger in contact with the overlay causes electric field fringing between itself and other conductors in the immediate vicinity. Typically, the effect of these fringing fields is minor, and it can usually be ignored.

Even without a finger touching the overlay, the sensor input pin has some parasitic capacitance ( $C_P$ ).  $C_P$  results from the combination of the CapSense controller internal parasitic and electric field coupling among the sensor pad, traces, and vias, and other conductors in the system, such as ground plane, other traces, any metal in the product's chassis or enclosure, and so on. The CapSense controller measures the total capacitance ( $C_X$ ) connected to a sensor pin.

When a finger is not touching a sensor, use this equation:

$$C_X = C_P \quad \text{Equation 2}$$

With a finger on the sensor,  $C_X$  equals the sum of  $C_P$  and  $C_F$ :

$$C_X = C_P + C_F \quad \text{Equation 3}$$

In general,  $C_P$  is an order of magnitude greater than  $C_F$ .  $C_P$  usually ranges from 10 pF to 20 pF, but in extreme cases it can be as high as 40 pF.  $C_F$  usually ranges from 0.1 pF to 0.4 pF.

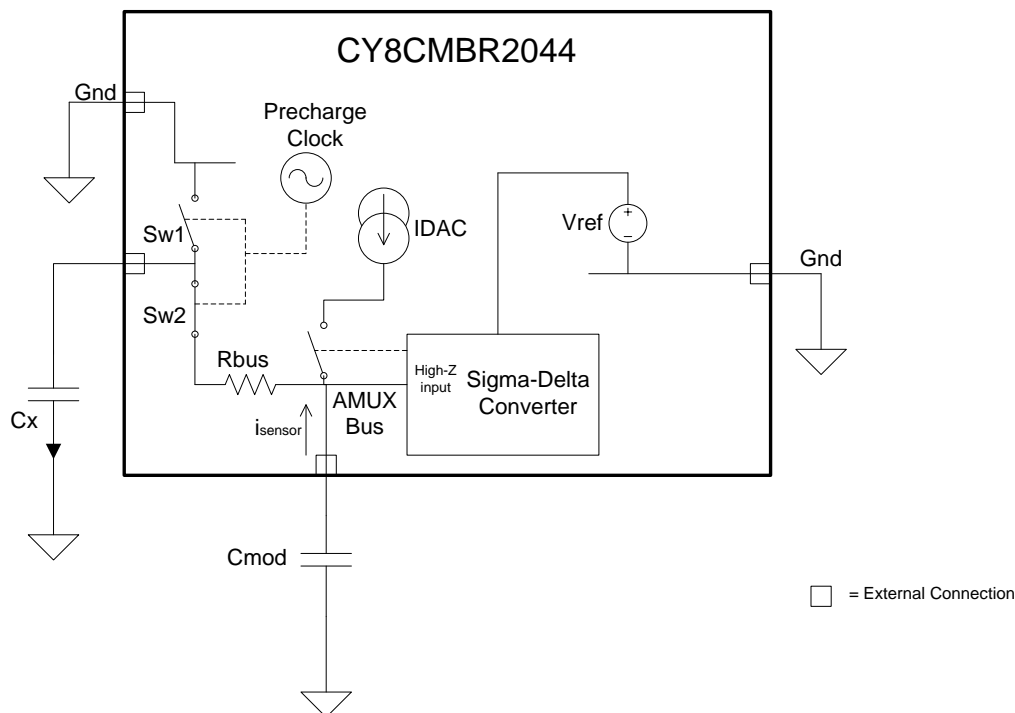
## Capacitive Sensing Method

CY8CMBR2044 device supports the CapSense Sigma Delta (CSD) with SmartSense™ Auto-Tuning for converting sensor capacitance ( $C_X$ ) into digital counts. The CSD method is described in the following sections.

### CapSense Sigma-Delta (CSD)

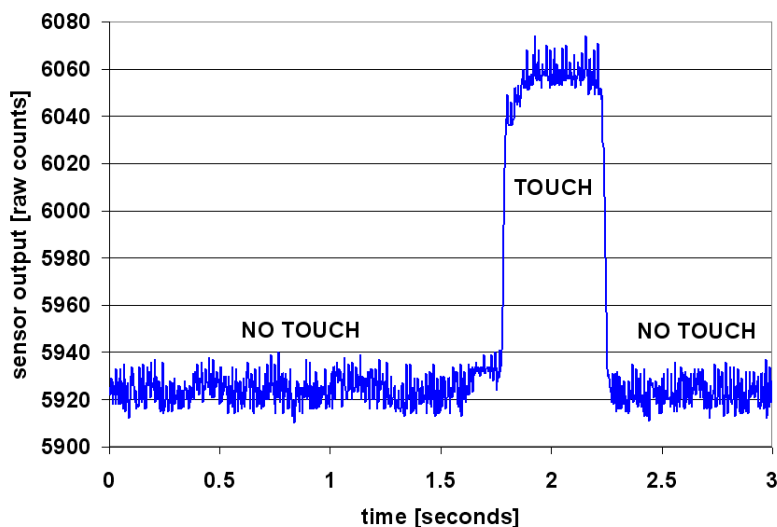
The CSD method in the CY8CMBR2044 device incorporates  $C_X$  into a switched capacitor circuit, as shown in Figure 2-3. The sensor ( $C_X$ ) is alternatively connected to GND and the Analog MUX (AMUX) bus by the non-overlapping switches Sw1 and Sw2, respectively. Sw1 and Sw2 are driven by a precharge clock to bleed a current ( $I_{\text{SENSOR}}$ ) from the AMUX bus. The magnitude of  $I_{\text{SENSOR}}$  is directly proportional to the magnitude of  $C_X$ . The sigma-delta converter samples AMUX bus voltage and generates a modulating bit stream that controls the constant current source ( $I_{\text{DAC}}$ ), which charges AMUX such that the average AMUX bus voltage is maintained at  $V_{\text{REF}}$ . The sensor bleeds off the charge  $I_{\text{SENSOR}}$  from the modulating capacitor ( $C_{\text{MOD}}$ ).  $C_{\text{MOD}}$ , in combination with  $R_{\text{bus}}$ , forms a low-pass filter that attenuates precharge switching transients at the sigma-delta converter input.

Figure 2-3. CSD Block Diagram



In maintaining the average AMUX voltage at a steady state value ( $V_{REF}$ ), the sigma-delta converter matches the average charge current ( $I_{DAC}$ ) to  $I_{SENSOR}$  by controlling the bit stream duty cycle. The sigma-delta converter stores the bit stream over the duration of a sensor scan, and the accumulated result is a digital output value, known as raw count, which is directly proportional to  $C_x$ . This raw count is interpreted by high-level algorithms to resolve the sensor state. Figure 2-4 plots the CSD raw counts from a number of consecutive scans during which the sensor is touched and then released by a finger. As explained in [CapSense Fundamentals](#), the finger touch causes  $C_x$  to increase by  $C_F$ , which in turn causes raw counts to increase proportionally. By comparing the shift in steady state raw count level to a predetermined threshold, the high-level algorithms can determine whether the sensor is in an ON (Touch) or OFF (No Touch) state.

Figure 2-4. CSD Raw Counts During a Finger Touch



## SmartSense Auto-Tuning

Tuning the touch-sensing user interface is a critical step in ensuring proper system operation and a pleasant user experience. In the typical design flow, the button interface is tuned in the initial design phase, during system integration, and before the production ramp. Because it's an iterative process, tuning can be time-consuming. SmartSense Auto-Tuning was developed to simplify the user interface development cycle. It is easy to use and reduces the design cycle time by eliminating the hassles of further manual tuning in prototype and manufacturing stages. SmartSense Auto-Tuning tunes each CapSense button automatically at power up and then monitors and maintains optimum button performance during runtime. This technology adapts for manufacturing variation in PCBs and overlays and automatically tunes out noise from sources such as LCD inverters, AC lines, and switch-mode power supplies.

### Process Variation

SmartSense Auto-Tuning for the CY8CMBR2044 is designed to work with button parasitic capacitance in the range of 5 pF to 40 pF, (typical button  $C_P$  values range from 10 pF to 20 pF). The sensitivity parameter for each button is set automatically, based on the characteristics of that particular button. The parameter improves the yield in mass production because every button maintains a consistent response regardless of the  $C_P$  variation (from 5 pF to 40 pF) between the buttons. Parasitic capacitance of the individual buttons can vary due to PCB layout and trace length, PCB manufacturing process variation, or vendor-to-vendor PCB variation within a multi-sourced supply chain. The sensitivity of a button depends on its parasitic capacitance; higher  $C_P$  values decrease sensitivity, resulting in decreased finger touch signal amplitude. In some cases, a change in  $C_P$  detunes the system, resulting in unfavorable button performance (either too sensitive or insensitive) or even a nonoperational button. In either situation, you must retune the system and, in some cases, you need to requalify the user interface subsystem. SmartSense Auto-Tuning resolves these issues.

SmartSense Auto-Tuning makes platform designs possible. For example, consider the capacitive touch sensing multimedia keys on a laptop computer; the spacing between the buttons depends on the size of the laptop and the keyboard layout. In this example, the wide-screen machine has larger spaces between the buttons than a standard-screen model would. The additional space means increased trace length between the button and the CapSense controller. The bigger trace length, in turn, leads to a higher parasitic capacitance of the button. As a result, the parasitic capacitance of the CapSense buttons can vary in different models of the same platform design. Though the buttons' functionality is identical for all of the laptop models, the buttons must be tuned for each model. SmartSense Auto-Tuning lets you do platform designs using the recommended practices shown in the PCB Layout in [Getting Started with CapSense](#).

Figure 2-5. Design of Laptop Multi-Media Keys for 21-inch Model



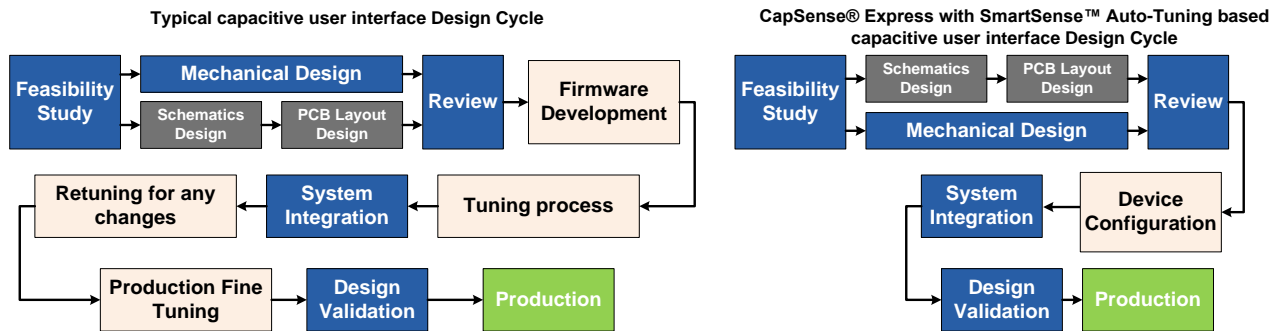
Figure 2-6. Design of Laptop Multi-Media Keys for 15-inch Model with Same Functionality and Button Size



### Reduced Design Cycle Time

When you design a capacitive button interface, the most time-consuming tasks are firmware development, layout, and button tuning. With a typical touch-sensing controller, the button must be retuned when the same design is ported to different models or when the mechanical dimensions change in the PCB or the button PCB layout. A design with SmartSense™ Auto-Tuning meets these challenges because it needs no firmware development, no manual tuning, and no retuning. In addition, SmartSense™ Auto-Tuning speeds up a typical design cycle. [Figure 2-7](#) compares the design cycles of a typical touch-sensing controller and a SmartSense™ Auto-Tuning-based design.

Figure 2-7. Typical Capacitive Interface Design Cycle Comparison



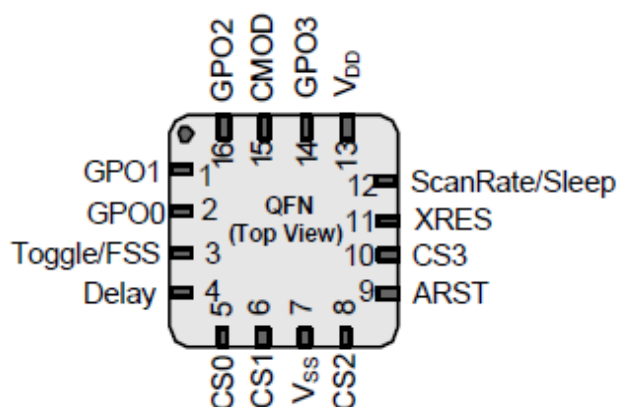
## 3. CapSense Schematic Design



### CY8CMBR2044 Configuration Options

Cypress's CY8CMBR2044 enables you to implement capacitive touch sensing using only hardware. This section provides an overview of the CapSense controller pins and how to configure them.

Figure 3-1. CY8CMBR2044 Pin Diagram



#### CapSense Buttons (CSx)

The CY8CMBR2044 controller has four capacitive sense inputs, CS0–CS3. Each capacitive button requires a connection to one of the capacitive sense inputs. You must ground all unused CapSense (CSx) inputs pins.

#### General-Purpose Outputs (GPOx)

There are four active LOW outputs on the CY8CMBR2044 controller, GPO0–GPO3. Each output, GPOx, is driven by its corresponding capacitive sensing input, CSx. You can use GPOs to directly drive LEDs or to replace mechanical switches. GPOs are in strong drive<sup>a</sup> mode. You must leave all unused GPOs floating.

#### Modulation Capacitor (C<sub>MOD</sub>)

Connect a 2.2-nF (±10%) capacitor to the C<sub>MOD</sub> pin.

<sup>a</sup> When a pin is in strong drive mode, it is pulled up to V<sub>DD</sub> when the output is HIGH and pulled down to Ground when the output is LOW. The output cannot be floating.

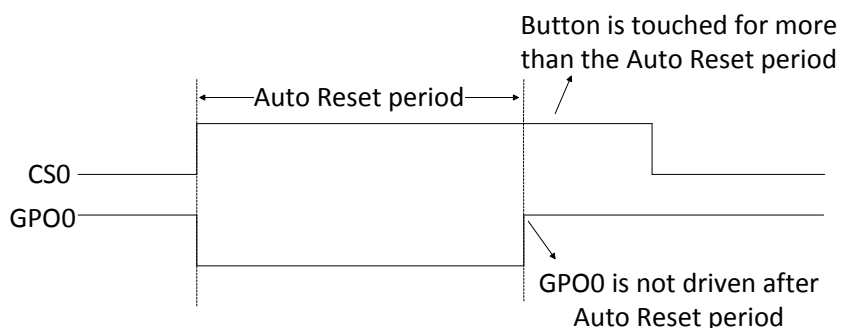
## Button Auto Reset (ARST)

Button Auto Reset determines the maximum time a GPOx is driven when CSx is continuously touched. This feature prevents a button from getting stuck if a metal object is placed too close to it. The ARST period can be configured to be 5 seconds or 20 seconds. The Button Auto Reset is defined in [Table 3-1](#) and shown in [Figure 3-2](#).

Table 3-1. ARST Pin Configuration

ARST Pin Connection	Button Auto Reset Period (seconds)
Ground	5
5 k $\Omega$ (10%) resistor to ground	20
VDD or floating	No Limit

Figure 3-2. Button Auto Reset



After the GPOx is turned off because of Button Auto Reset feature and after the button is released, do not touch the button for a specific amount of time (T) given, as follows:

- T equals 220 ms, if the CSx input is released within 2 seconds after Button Auto Reset period is elapsed.
- T equals 220 ms plus the Button Scan Rate, if the CSx input is released after 2 seconds, after Button Auto Reset period is elapsed.

## Toggle ON/OFF

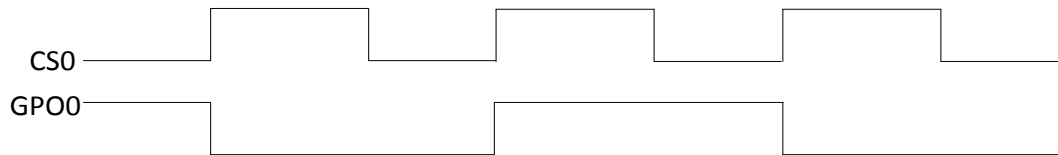
When Toggle ON/OFF is enabled, the state of GPOx changes on every rising edge of CSx. Toggle ON/OFF configuration is defined in [Table 3-2](#) and shown in [Figure 3-3](#).

Table 3-2. Toggle/FSS Pin Configuration

Toggle/FSS Pin Connection	Toggle ON/OFF	FSS
Ground	Disabled	Disabled
1.5 k $\Omega$ (5%) resistor to ground	Enabled	Disabled
5.1 k $\Omega$ (5%) resistor to ground	Disabled	Enabled
V <sub>DD</sub>	Enabled	Enabled



Figure 3-3. Example of Toggle ON/OFF Feature



## Flanking Sensor Suppression (FSS)

FSS helps to distinguish closely spaced buttons by allowing only one CSx to be in the TOUCH state at a time. If a finger contacts multiple CSx buttons, only the first one to sense a TOUCH state will turn ON.

FSS also is useful when a button can produce opposite effects – for example, an interface with two buttons for brightness control (UP or DOWN).

FSS configuration is defined in [Table 3-2](#) and shown in [Figure 3-4](#) and [Figure 3-5](#).

Figure 3-4. FSS Implementation, Single Button Touched

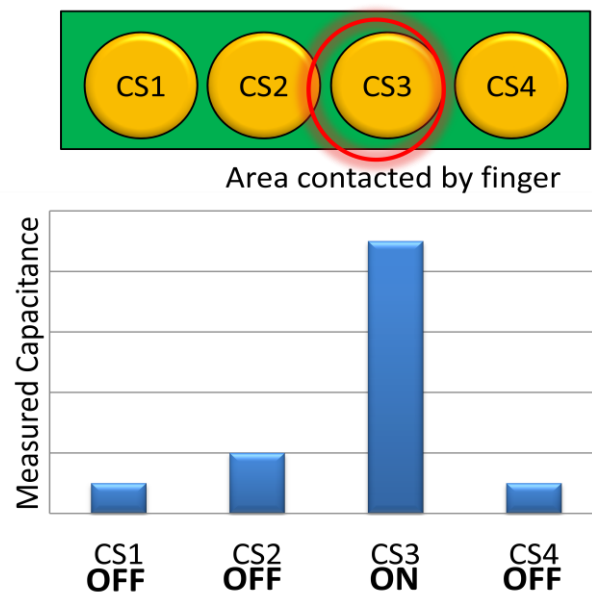
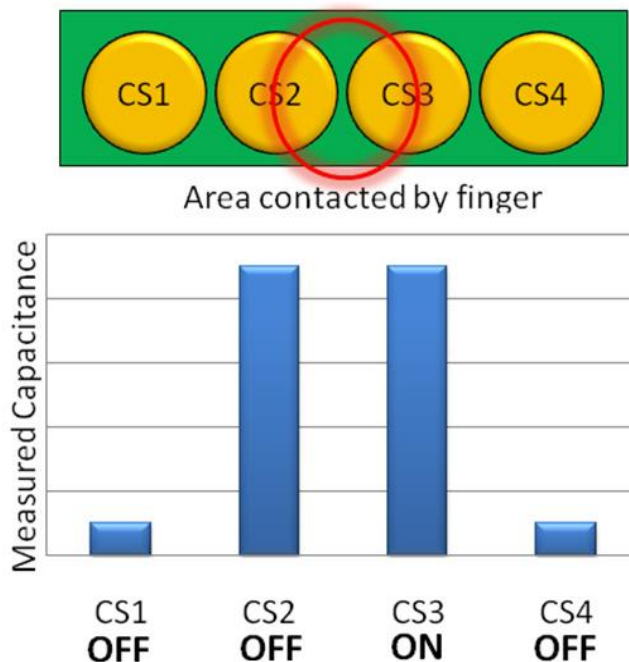


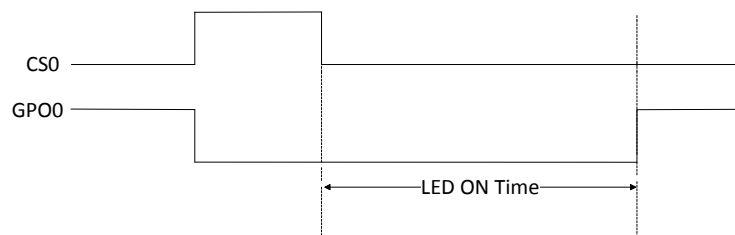
Figure 3-5. FSS Implementation, Multiple Buttons Touched



## LED ON Time

LED ON Time specifies the duration for which GPOx is driven low after CSx is released. LED ON Time can range from 0 ms to 2000 ms.

Figure 3-6. LED ON Timing



The LED ON Time duration, D, is configurable from the Delay pin. For different values of resistors connected to the Delay pin, the time can be varied. The resistor,  $R_{DELAY}$ , is defined by Equation 4.

$$R_{DELAY} = (D \times 4) + 40 \Omega$$

Equation 4

Where:

D is a multiple of 20 ms

Table 3-3 provides some example values for the Delay pin configuration and the resulting LED ON Time.  $R_{DELAY}$  resistor tolerance should be less than 1 percent.

Table 3-3.  $R_{\text{DELAY}}$  Value for LED ON Time

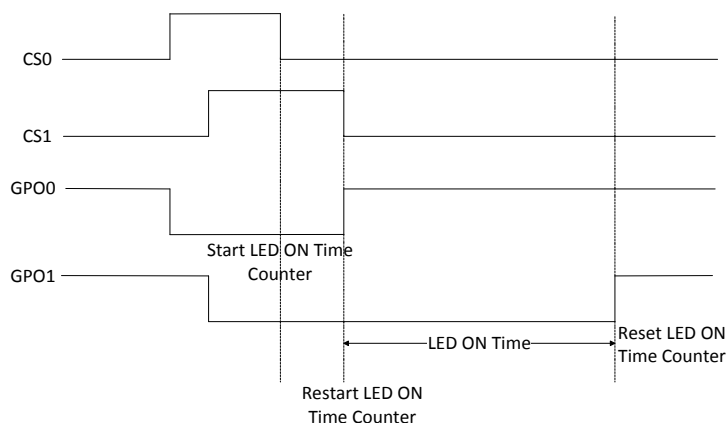
$R_{\text{DELAY}}$ ( $\Omega$ )	Approx. LED ON Time (ms)
Grounded	0
120	20
200	40
280	60
...	...
7960	1980
8040	2000
> 8040	2000
Pulled to $V_{\text{DD}}$	2000
Floating	2000

Place  $R_{\text{DELAY}}$  between the Delay pin and ground. LED ON Time varies from device to device. It is  $\pm 12\%$  accurate at room temperature and  $\pm 18\%$  accurate at a temperature range of  $-40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$ .

If a [Button Auto Reset](#) is triggered for CSx, LED ON Time is not applied on GPOx. LED ON Time is disabled if [Toggle ON/OFF](#) is enabled.

LED ON Time applies only to one GPOx at a time, meaning the LED ON Time counter resets every time a CSx transitions to a NO TOUCH state. [Figure 3-7](#) illustrates how LED ON Time operates: CS1 resets the LED ON Time counter, causing GPO0 to turn OFF prematurely.

Figure 3-7. LED ON Timing Diagram for Multiple Buttons



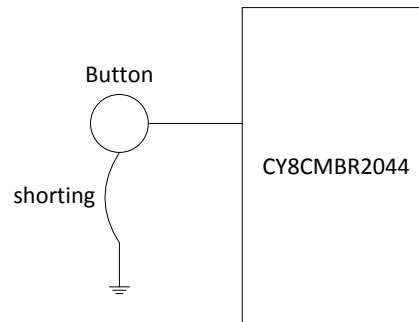
## System Diagnostics

A built-in Power-on Self Test (POST) mechanism performs some tests at power-on reset (POR), which can be useful in production testing. If any button fails these tests, a 5 ms pulse is sent out on the corresponding GPO within 175 ms after POR. The following tests are performed on all of the buttons:

### *Button Shorted to Ground*

If any button is found to be shorted to ground, it is disabled.

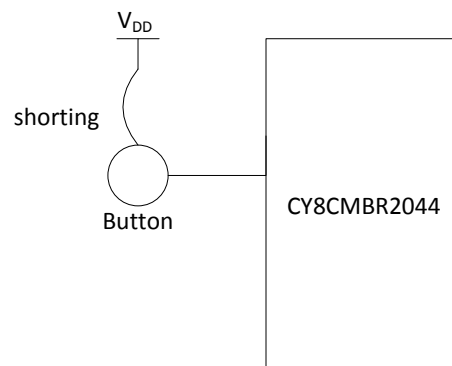
Figure 3-8. Button Shorted to Ground



### *Button Shorted to $V_{DD}$*

If any button is found to be shorted to  $V_{DD}$ , it is disabled.

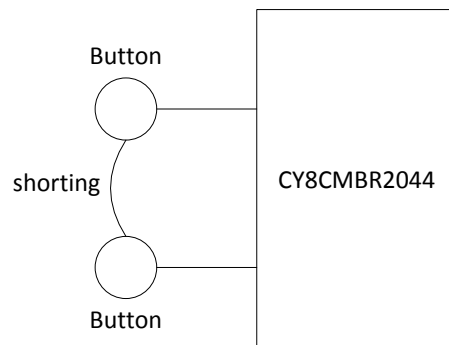
Figure 3-9. Button Shorted to  $V_{DD}$



### *Button to Button Short*

If two or more buttons are found to be shorted to each other, all of these buttons are disabled.

Figure 3-10. Button to Button Short



### *Improper Value of $C_{MOD}$*

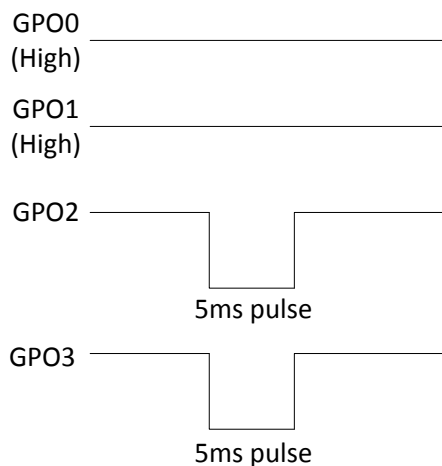
Recommended value of  $C_{MOD}$  is  $2.2 \text{ nF} \pm 10\%$ .

If the value of  $C_{MOD}$  is found to be less than 1 nF or greater than 4 nF, all the buttons are disabled.

### *Button $C_P > 40$ pF*

If the parasitic capacitance ( $C_P$ ) of any button is found to be more than 40 pF, that button is disabled.

Figure 3-11. Example Showing CS), CS1 Passing the POST and CS2, CS3 Failing



## Scan Rate/Sleep

Use this pin to set the button scan rate and sleep mode operation of the CY8CMBR2044. Do not leave this pin floating.

### *Button Scan Rate*

The button scan rate specifies the time between successive button scans by the device. An external resistor determines the button scan rate for the CY8CMBR2044. You can use the [Cp, Power Consumption and Response Time Calculator](#) to determine the scan rate resistor value or [Table 3-4](#). The button scan rate is configurable from 20 ms to 531 ms.

Table 3-4. Resistor Value Selection for Button Scan Rate

Resistor R (1%) in ohms	Approximate ScanRate (in ms)	Resistor R (1%) in ohms	Approximate ScanRate (in ms)
60	20	4060	209
165	22	4185	217
310	24	4310	226
435	27	4435	235
560	30	4560	244
685	34	4685	253
810	38	4810	263
935	42	4935	272
1060	46	5060	282
1185	51	5185	291
1310	55	5310	301
1435	61	5435	311
1560	66	5560	321
1685	71	5685	331
1810	77	5810	341
1935	83	5935	352
2060	89	6060	362
2185	96	6185	373
2310	102	6310	383
2435	107	6435	394
2560	115	6560	405
2685	122	6685	416
2810	129	6810	427
2935	137	6935	438
3060	144	7060	449
3185	152	7185	461
3310	159	7310	472
3435	167	7435	484
3560	175	7560	495
3685	183	7685	507
3810	192	7810	519
3935	200	7935	531

Button Scan Rate varies from device to device. It is  $\pm 12$  percent accurate at room temperature and  $\pm 18$  percent accurate at a temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

### Sleep Mode

There are two possible configurations:

1. Connect the Button Scan Rate resistor to ground. This enables low power sleep mode
2. Connect the Button Scan Rate resistor to an external Master (host processor) and configure the host pin to be HIGH ( $V_{DD}$ ). This enables deep sleep mode.

Further details are in the [Sleep Modes](#) section.

### Serial Debug Data Out

Serial Debug Data reports firmware revision, CapSense status, GPO status, raw count, baseline, difference count, and parasitic capacitance for all buttons. When Serial Debug Data is enabled this information is output on a single CSx pin. To enable Serial Data Out, pull down the CSx pin where you want the serial data to appear with a 5.6-k $\Omega$  resistor with a 5-percent tolerance. If more than one CSx pin is pulled down, debug data is sent out only on one CSx pin. The priority is:

CS0 > CS1 > CS2 > CS3

The Cypress [Multi-Chart Tool](#) can be used to view the data. The Serial Debug Data is sent by the device in the order according to Table 3-5. The MultiChart tool arranges the data in the format as shown in [Table 3-6](#).

Serial data is sent out with ~115,200 baud rate.

For designs using less than four CapSense buttons, the unused CS pin should be selected for Serial Debug Data.

For designs using all four CapSense buttons, use two CSx pins for Serial Debug Data. For example, pull down CS0 with a 5.6-k $\Omega$  resistor and read the data for CS1, CS2, and CS3. Next, pull down CS1 with a 5.6-k $\Omega$  resistor and read the data for CS0, CS2, and CS3.

Table 3-5. Serial Data Output Sent by CY8CMBR2044

Byte	Data	Notes
0	0x0D	Dummy data for multi chart
1	0x0A	
2	0x00	–
3	FW_Revision	Firmware Revision
4	0x00	–
5	CS0_Cp	CS0 parasitic capacitance (pF) in Hex
6	CS0_RawCount_MSB	Unsigned 16-bit integer
7	CS0_RawCount_LSB	
8	CS1_RawCount_MSB	Unsigned 16-bit integer
9	CS1_RawCount_LSB	
10	CS2_RawCount_MSB	Unsigned 16-bit integer
11	CS2_RawCount_LSB	
12	CS3_RawCount_MSB	Unsigned 16-bit integer
13	CS3_RawCount_LSB	
14	CS_Status	Gives CapSense button status, least significant bit (LSB) contains CS0 status
15	GPO_Status	Gives GPO status, LSB contains GPO0 status
16	0x00	–
17	CS1_Cp	CS1 parasitic capacitance (pF) in Hex
18	CS0_Baseline_MSB	Unsigned 16-bit integer
19	CS0_Baseline_LSB	
20	CS1_Baseline_MSB	Unsigned 16-bit integer
21	CS1_Baseline_LSB	
22	CS2_Baseline_MSB	Unsigned 16-bit integer
23	CS2_Baseline_LSB	
24	CS3_Baseline_MSB	Unsigned 16-bit integer
25	CS3_Baseline_LSB	
26	0x00	–
27	CS2_Cp	CS2 parasitic capacitance (pF) in Hex
28	0x00	–
29	CS3_cp	CS3 parasitic capacitance (pF) in Hex
30	CS0_DiffCount_MSB	Unsigned 16-bit integer
31	CS0_DiffCount_LSB	
32	CS1_DiffCount_MSB	Unsigned 16-bit integer
33	CS1_DiffCount_LSB	
34	CS2_DiffCount_MSB	Unsigned 16-bit integer
35	CS2_DiffCount_LSB	
36	CS3_DiffCount_MSB	Unsigned 16-bit integer

Byte	Data	Notes
37	CS3_DiffCount_LSB	
38	0x00	Dummy data for MultiChart
39	0xFF	
40	0xFF	

Table 3-6. Serial Debug Data Arranged in Multichart

#	Raw Count Array		Baseline Array		Signal array	
	MSB	LSB	MSB	LSB	MSB	LSB
0	0x00	FW_Revision	CS_Status	GPO_Status	0x00	CS2_Cp
1	0x00	CS0_Cp	0x00	CS1_Cp	0x00	CS3_Cp
2	CS0_RawCount		CS0_Baseline		CS0_DiffCount	
3	CS1_RawCount		CS1_Baseline		CS1_DiffCount	
4	CS2_RawCount		CS2_Baseline		CS2_DiffCount	
5	CS3_RawCount		CS3_Baseline		CS3_DiffCount	



## Design Toolbox

The [Design Toolbox](#) helps you to design a CY8CMBR2044 CapSense solution. It offers basic information about the board layout and feature settings and recommends whether the design is fit for mass production.

### General Layout Guidelines

The table below summarizes the layout guidelines for the CY8CMBR2044. These guidelines are discussed in Electrical and Mechanical Electrical and Mechanical Design Considerations of this guide. For a thorough treatment of this material, see [Getting Started with CapSense](#), Section 3.7.

Figure 3-12. Design Layout Recommendations

Sl. No.	Category	Min	Max	Recommendations/Remarks
1.	Button Shape			Solid round pattern, Round with LED hole, rectangle with round corners
2.	Button Size	5mm	15mm	Given in Layout Estimator sheet
3.	Button-Button spacing	equal to button ground clearance		8 mm
4.	Button Ground Clearance	0.5mm	2mm	Given in Layout Estimator sheet
5.	Ground Flood - Top layer			Hatched ground 7 mil trace and 45 mil grid (15% filling)
6.	Ground Flood - Bottom layer			Hatched ground 7 mil trace and 70 mil grid (10% filling)
7.	Trace Length from Sensor pad to device pin		450	Given in Layout Estimator sheet
8.	Trace Width	0.17 mm	0.20 mm	0.17 mm (7 mil)
9.	Trace Routing			Traces should be routed on the non sensor side. If any non CapSense trace crosses CapSense trace, ensure that intersection is orthogonal.
10.	Via Position for the sensors			Via should be placed near the edge of the button to reduce trace length thereby increasing sensitivity.
11.	Via Hole Size for sensor traces			10 mil
12.	No. of via on sensor trace	1	2	1
13.	CapSense series resistor placement		10mm	Place CapSense series resistors close to the device for noise suppression .CapSense resistors have highest priority compared to LED resistors place them first.
14.	Distance between any CapSense trace to Ground Flood	10 mil	20 mil	20 mil
15.	Device placement			Mount the Device on the layer opposite to sensor. The CapSense trace length between the Device and sensors should be minimum (see trace length above)
16.	Placement of Components in two layer PCB			Top layer-Sensors and bottom layer-device, other components and traces.
17.	Placement of Components in four layer PCB			Top layer-Sensors, 2 <sup>nd</sup> Layer – CapSense traces & Vdd and avoid the Vdd traces below the sensors, 3 <sup>rd</sup> Layer-hatched ground, Bottom layer- device other components and non CapSense traces
18.	Overlay Thickness	0 mm	5mm	Use layout Estimator sheet to decide on overlay, given maximum limit is for plastic overlay.
19.	Overlay material			Should be non-conductive material. Glass, ABS Plastic, Formica, wood etc. No air gap should be there between PCB and overlay. Use adhesive to stick the PCB and overlay.
20.	Overlay Adhesives			Adhesive should be non conductive and dielectrically homogenous. 467MP and 468MP adhesives made by 3M are recommended.
21.	LED Back Lighting			Cut a hole in the sensor pad and use rear mountable LEDs.
22.	Board Thickness			Standard board thickness for CapSense FR4 based designs is 1.6 mm.

## Layout Estimator

The Layout Estimator provides the minimum button size and maximum trace length recommendation based on the intended end-system requirements and industrial design. The inputs include the overlay material, overlay thickness, and trace capacitance of circuit board material. Refer to [Figure 3-13](#), Table B, to learn the dielectric constants for different overlay materials and the trace capacitance per unit length for different PCBs. Table A calculates the minimum button diameter and maximum trace length for the design, based on three relative ranges of system noise. Low, medium, and high noise is a relative figure of merit to help you with button development. Noise conditions can vary button to button based on the end-system environment. If the noise conditions are unknown, use medium noise conditions as the starting point. The actual noise seen at each button will be determined in the design validation step described in [Design Validation](#).

Use the outputs of this sheet to guide the sensor board layout process and then check the design prior to prototyping with the  $C_P$ , Power Consumption and Response Time Calculator sheet as detailed [Cp, Power Consumption and Response Time Calculator](#).

Figure 3-13. Layout Estimator

TableA- Estimator			
Input Parameters	Value	Units	Comments
Overlay Thickness	5	mm	
Overlay - Dielectric constant	8	farad/m	
Capacitance of trace per inch	2	pF	
<b>Minimum Recommended Button Diameter</b> (based on minimum 0.25pF Finger response)			
Noise Conditions - Low (0.05 pF Noise)	7	mm	
Noise Conditions - Medium (0.075 pF Noise)	8	mm	
Noise Conditions - High (0.1 pF Noise)	10	mm	
<b>Maximum Trace length</b>			
Noise Conditions - Low (0.05 pF Noise)	400	mm	
Noise Conditions - Medium (0.075 pF Noise)	393	mm	
Noise Conditions - High (0.1 pF Noise)	381	mm	
Button to Ground clearance	2	mm	
<div> <div></div>input cells, edit with actuals           <div></div>output cells, based on inputs         </div>			
Note: Button diameter of all the buttons CS0 to CS3 will be same with respect to overlay thickness, but can differ with respect to noisy conditions			

TableB - Reference values	
Overlay Material	Dielectric constant
Plastic	2.8
Plexi glass	8
Formica	4.6-4.9
Glass (Standard)	7.6-8.0
Glass (Ceramic)	6
Mylar	3.2
ABS Plastic	3.8-4.5
Wood	1.2-2.5
Trace and board type	Capacitance per inch in pF
Copper trace , PCB, 2 layer, 64mil, FR4	2
Copper trace, flex PCB, 2 layer	8

### Inputs:

- Overlay thickness
- Overlay dielectric constant
- Capacitance of trace per inch of board

### Outputs:

- Recommended minimum button diameter and maximum trace length for different noise conditions
- Button to ground clearance

**Note** The button diameter of each button can be different in the design based on whether the noise varies button to button.

## C<sub>P</sub>, Power Consumption and Response Time Calculator

After the board layout has been completed, use this calculator to check the design before building the button board prototype. To verify the C<sub>P</sub> value of each button, insert the button diameters and trace lengths into Table A. After you enter the information, the toolbox confirms whether each button is within the specified C<sub>P</sub> range of 5 pF to 40 pF. The power calculator in Table B is used to optimize power consumption. Power consumption is a function of the button scan rate, which is set by the resistor value on the ScanRate/Sleep pin. Refer to [Section 3.4 Scan Rate](#) and [Table 3-4](#). Table C outputs the button response time based on the inputs in Tables A and B.

Figure 3-14. C<sub>P</sub>, Power Consumption and Response Time Calculator

**Table A: Cp Calculator**

Sensor	Button diameter		Trace length		Parasitic capacitance (Cp) of sensors (Approx)	Comments
CS0		mm		mm	0 pF	
CS1		mm		mm	0 pF	
CS2		mm		mm	0 pF	
CS3		mm		mm	0 pF	
Total No of buttons	0	Nos				

**Table B: Power calculator**

Select Button Scan Rate resistor value	60 ohms
Approximate Button Scan Rate value	20 ms
% of time finger is on the sensors	3 %
Max Sleep Current	0.0015 mA
Max Active Current	4 mA
Average Current without Finger	0 mA
Average Current with Finger	0 mA
Actual average current consumption	0 mA
Actual average current consumption per button	0 mA

**Table C: Response time calculator**

First button press	40 ms
consecutive button press	80 ms

	input cells, edit with actuals
	output cells, based on inputs

**Note:** The power values given here are worse case, the actual power values will be lower.

### Inputs:

- Button diameter and trace length of CS0–CS3 as designed in layout
- Button Scan rate resistor value
- The percentage of time a finger is on the buttons

### Outputs:

- Parasitic Capacitance (C<sub>P</sub>) for each sensor. Confirms whether the C<sub>P</sub> values are within the specified range of 5 pF to 40 pF
- Power consumption per button
- Button response time

After you have built and tested the prototype board, you can determine the actual parasitic capacitance (C<sub>P</sub>) and noise condition (noise count) of each button according to the [Section 3.1.10 Serial Debug Data Out](#). Use this information and the Design Validation Sheet to validate the design, as detailed in [Section 0Design Validation](#)

## Design Validation

After you have prototyped and tested the button board, use the Serial Debug Data Out test mode ([Section 3.1.10 Serial Debug Data Out](#)) to capture the raw count, baseline, difference count, and parasitic capacitance for all buttons. To enter this information into Table C of the sheet, follow these steps –

1. Enable the Serial Debug Data Out feature by connecting a 5.6 kΩ resistor to GND on any CSx pin.
2. Power on the device and connect the CSx pin to the computer through a COM/RS232 port.
3. Open MultiChart and configure it as following –
  - a. Select PORT - <Specify PORT number>
  - b. Port Speed – 115200
  - c. Visible points – 1000
  - d. Log file name – “C:\MultiChart log\CY8CMBR2044.csv”

To know more about MultiChart, see [AN2397 – CapSense Data Viewing Tools](#)

4. Click on “Enable/disable log-file”. This will automatically store the data to the log file. Log this data for at least 300 samples.
5. Click on “Enable/disable log-file”. This will stop logging the data.
6. Open the log file once. The toolbox will automatically be updated with the relevant data.

Table A shows the various design parameter values, taken up from the previous sheets, so that you need not enter any data in this sheet. This sheet provides a pass/fail grade for the prototype board. If your design fails, you can redesign your system by entering new values in Table A and further recommendations/results will be given. If your design passes, leave the “New value” column in Table A blank.

Figure 3-15 Design Validation

Table A: Actual Design Values

Input Parameters	Initial value	New value	Units
Overlay Thickness (in mm)	5		mm
Dielectric constant, overlay	8		farad/m
Capacitance of trace per inch in pF	2		pF
Button Scan Rate Resistor	60		ohms
Button Scan Rate Value	20		ms
No of buttons	0	0	Nos
% of time finger is on the sensors	3		%
CS0 Button diameter actual			mm
CS1 Button diameter actual			mm
CS2 Button diameter actual			mm
CS3 Button diameter actual			mm

Table B: Reference values

Overlay Material	Dielectric constant
Plastic	2.8
Plexi glass	8
Formica	4.6-4.9
Glass (Standard)	7.6-8.0
Glass (Ceramic)	6
Mylar	3.2
ABS Plastic	3.8-4.5
Wood	1.2-2.5
Trace and board type	Capacitance per inch in pF
copper trace , PCB, 2 layer, 64mil,FR4	2
copper trace , flex, 2 layer	8

TableC: Power, Button diameter actuals

Sensor	Values taken from Debug Data out			Average Current	Improvement Recommendations	
	Noise	Cp	Raw Count		Minimum Button diameter	Maximum Trace Length
CS0	0 counts	0 pF	0 counts	0 mA	0 mm	0 mm
CS1	0 counts	0 pF	0 counts	0 mA	0 mm	0 mm
CS2	0 counts	0 pF	0 counts	0 mA	0 mm	0 mm
CS2	0 counts	0 pF	0 counts	0 mA	0 mm	0 mm
Actual average current consumption				0 mA		

	input cells, edit with actuals
	output cells, based on inputs

For Table A: The Initial values of “Input Parameters” are the ones you have entered in the previous sheets. If your design passes, leave the “New value” column blank. If your design fails, enter the New values for the corresponding parameter to re-configure your design.

**Note**

While logging debug data for this sheet, make sure there is no finger present on the sensors for the log duration

### Inputs:

- If the design passes – None
- If the design fails –
  - New overlay thickness, overlay material permittivity, button diameter for each individual button, and trace capacitance

- Button Scan Rate resistor value used in design
- Percentage of time a finger is on the buttons

**Outputs:**

- Power consumption per button
- Design change recommendations. The Design Toolbox provides recommendations based on the actual values from the design if the button size or trace lengths are outside of best design practices.

If the button board does not pass, the [Design Toolbox](#) will provide recommendations. There are four areas that can be changed to remedy a failing design: button size, trace length, overlay material, and overlay thickness. Changing the button size or trace length requires a board spin, while changing the overlay material or thickness, or both, may be a shorter path to a passing design. The best solution depends on where the project stands in the development process and the end-system requirements. The Design Toolbox will guide you to a passing outcome.

## 4. Electrical and Mechanical Design Considerations



When designing a capacitive touch sense technology into your application it is crucial to keep in mind that the CapSense device exists within a larger framework. Careful attention to every detail, including PCB layout, user interface, and end-user operating environment, leads to robust and reliable system performance. For in-depth information, refer to [Getting Started with CapSense](#).

### Overlay Selection

In [CapSense](#) Equation 1 was presented for finger capacitance

$$C_F = \frac{\epsilon_0 \epsilon_r A}{D}$$

Where:

$\epsilon_0$  = Free space permittivity

$\epsilon_r$  = Dielectric constant of overlay

A = Area of finger and sensor pad overlap

D = Overlay thickness

To increase the CapSense signal strength, choose an overlay material with a higher dielectric constant, decrease the overlay thickness, and increase the button diameter. The [Design Toolbox](#) helps you to design a robust and reliable CY8CMBR2044 solution, as discussed in the chapter [CapSense Schematic Design](#).

Table 4-1. Overlay Material Dielectric Strength

Material	Breakdown Voltage (V/mm)	Min. Overlay Thickness at 12 kV (mm)
Air	1200–2800	10
Wood – dry	3900	3
Glass – common	7900	1.5
Glass – Borosilicate (Pyrex <sup>®</sup> )	13,000	0.9
PMMA Plastic (Plexiglas <sup>®</sup> )	13,000	0.9
ABS	16,000	0.8
Polycarbonate (Lexan <sup>®</sup> )	16,000	0.8
Formica	18,000	0.7
FR-4	28,000	0.4
PET Film – (Mylar <sup>®</sup> )	280,000	0.04
Polymide film – (Kapton <sup>®</sup> )	290,000	0.04

Conductive material cannot be used as an overlay because it interferes with the electric field pattern. Therefore, do not use paint containing metal particles.



## Bonding Overlay to PCB

Because the dielectric constant of air is very low, an air gap between the overlay and the button degrades the performance of the button. To eliminate the gap, use a nonconductive adhesive to bond the overlay to the CapSense PCB. A transparent acrylic adhesive film from 3M™ called 200MP is qualified for use in CapSense applications. This special adhesive is dispensed from paper-backed tape rolls (3M™ product numbers 467MP and 468MP).

## ESD Protection

Robust ESD tolerance is a natural byproduct of thoughtful system design. By considering how the contact discharge occurs in your end product, particularly in your user interface, you can withstand an 18-kV discharge event without incurring any damage to the CapSense controller.

CapSense controller pins can withstand a direct 12-kV event. In most cases, the overlay material provides sufficient ESD protection for the controller pins. [Table 4-1](#) lists the thickness of various overlay materials required to protect the CapSense sensors from a 12-kV discharge as specified in IEC 61000-4-2. If the overlay material does not provide sufficient ESD protection, apply countermeasures in the following order: Prevent, Redirect, Clamp.

### Prevent

Make sure all paths on the touch surface have a breakdown voltage greater than potential high-voltage contacts. In addition, design your system to maintain an appropriate distance between the CapSense controller and possible sources of ESD. If it is not possible to maintain adequate distance, place a protective layer of a high-breakdown-voltage material between the ESD source and CapSense controller. One layer of 5-mil-thick Kapton® tape will withstand 18 kV.

### Redirect

If your product is densely packed, it may not be possible to prevent the discharge event. In this case, you can protect the CapSense controller by controlling where the discharge occurs. Place a guard ring on the perimeter of the circuit board that is connected to chassis ground. As recommended in [PCB Layout Guidelines](#), using a hatched ground plane around the button can redirect the ESD event away from the button and CapSense controller.

### Clamp

Because CapSense sensors are purposely placed in close proximity to the touch surface, it may not be practical to redirect the discharge path. In this case, consider including series resistors or special-purpose ESD protection devices.

The recommended series resistance value is 560  $\Omega$ .

A more effective method is to provide special-purpose ESD protection devices on the vulnerable traces. Note that ESD protection devices for CapSense need to be low in capacitance. [Table 4-2](#) lists devices recommended for use with CapSense controllers.

Table 4-2. Low-Capacitance ESD Protection Devices Recommended for CapSense

ESD Protection device		Input Capacitance	Leakage Current	Contact Discharge maximum limit	Air Discharge maximum limit
Manufacturer	Part Number				
Littlefuse	SP723	5 pF	2 nA	8 kV	15 kV
Vishay	VBUS05L1-DD1	0.3 pF	0.1 $\mu$ A <	$\pm$ 15 kV	$\pm$ 16 kV
NXP	NUP1301	0.75 pF	30 nA	8 kV	15 kV

## Electromagnetic Compatibility (EMC) Considerations

### Radiated Interference

Radiated electrical energy can influence system measurements and potentially influence the operation of the processor core. The interference enters the CY8CMBR2044 chip at the PCB level, through CapSense button traces and any other digital or analog inputs. The Layout guidelines for minimizing the effects of RF interference follow:

- **Ground Plane:** provide a ground plane on the PCB
- **Series Resistor:** place series resistors within 10 mm of the CapSense controller pins
  - The recommended series resistance for CapSense input lines is 560  $\Omega$
- **Trace Length:** Minimize trace length whenever possible
- **Current Loop Area:** Minimize the return path for current. To reduce the impact of parasitic capacitance, hatched ground is given within 1 cm of the buttons and traces, instead of solid fill.
- **RF Source Location:** Partition systems with noise sources, such as LCD inverters and switched-mode power supplies (SMPS), to keep the interference separated from CapSense inputs. Shielding the power supply is another common technique to prevent interference.

### Conducted Immunity and Emissions

Noise entering a system through interconnections with other systems is referred to as conducted noise. Examples include power and communication lines. Because the CapSense controllers are low-power devices, you must avoid conducted emissions. The following guidelines will help to reduce conducted emission and immunity:

- Use decoupling capacitors.
- Add a bidirectional filter on the input to the system power supply. This is effective for both conducted emissions and immunity. A pi-filter can prevent power supply noise from effecting sensitive parts and also prevent the switching noise of the part itself from coupling back onto the power planes.
- If the CapSense controller PCB is connected to the power supply by a cable, minimize the cable length and consider using a shielded cable.
- To filter out high-frequency noise, place a ferrite bead around power supply or communication lines.

## PCB Layout Guidelines

The [Design Toolbox](#) will help you design a robust and reliable CY8CMBR2044 CapSense PCB layout, as discussed in [Section 0](#)

If your design uses the GPOs to sink current to the CapSense controller, and there is a lot of noise in the CapSense system, use series resistors on all of the GPOs to limit sink current. Sink current limit is determined by the maximum button  $C_P$  in your design at 5 V, as show in [Table 4-3](#).

Table 4-3. GPO Sink Current Limit for Low Output Voltage

Button $C_P$ Range	Sink Current Limit per GPO	Sink Current Limit for Device
$5 \text{ pF} \leq C_P \leq 12 \text{ pF}$	25 mA	120 mA
$12 \text{ pF} \leq C_P \leq 21 \text{ pF}$	20 mA	20 mA
$21 \text{ pF} \leq C_P \leq 40 \text{ pF}$	6 mA	6 mA

Detailed PCB layout guidelines are available in [Getting Started with CapSense](#), Section 3.7.



## 5. Low-Power Design Considerations



### System Design Recommendations

Cypress's CY8CMBR2044 is designed to meet the low-power requirements of battery powered applications.

To minimize power consumption, take these steps:

- Ground all unused CapSense inputs
- Minimize  $C_P$  using the design guidelines in [Getting Started with CapSense](#), Section 3.7.1.
- Reduce supply voltage
- Use a higher Button Scan Rate or Deep Sleep operating mode, refer to Button Scan Rate.

### Calculating Average Power

The [Design Toolbox](#), which is the tool of choice, automates the power consumption calculations described in the following sections. The average power consumed by the CY8CMBR2044 is determined by calculating the parameters below:

1. Button Scan rate,  $T_R$
2. Scan time,  $T_S$
3. Average current in a NO TOUCH state,  $I_{AVE\_NT}$
4. Average current in a TOUCH state,  $I_{AVE\_T}$
5. Average standalone current,  $I_{AVE\_SA}$
6. Average current,  $I_{AVE}$
7. Average power,  $P_{AVE}$

#### Button Scan Rate ( $T_R$ )

Control the Button Scan rate through the external resistor connected to the ScanRate/Sleep pin of CY8CMBR2044. The following equation provides the approximate scan rate:

$$T_R = 20 \text{ ms} + \sqrt[3]{\frac{R+60}{125}} \quad \text{Equation 5}$$

Where:

R = value of external resistor (in ohms).

Refer to [Table 3-4](#) to find the appropriate resistor value.

#### Response Time ( $T_{RES}$ )

Selecting the Scan Rate means balancing the response time and power consumption requirements of your application.

Response time,  $T_{RES}$ , is the amount of time the CY8CMBR2044 takes to produce a valid signal on GPOx after CSx senses a TOUCH state. The CY8CMBR2044 device has two different response times. The first is the time it takes to respond when the device wakes up from low power mode:

$$T_{RES} = T_R + 20 \text{ ms} \quad \text{Equation 6}$$

Where:

$T_R$  = Scan Rate

And the second is the time it takes to respond to any subsequent TOUCH after it wakes up, 80 ms.

## Scan Time ( $T_S$ )

Approximate scan time can be calculated using:

$$T_S = [0.375 \text{ ms} \times (K_{CS0} + K_{CS1} + K_{CS2} + K_{CS3})] + T_{FW} \quad \text{Equation 7}$$

Where:

$K_{CSX}$  = button sensitivity constant for CSx.

$T_{FW}$  = Firmware execution time, from [Table 5-2](#).

Table 5-1. Button Sensitivity Constant

$C_P$ (pF)	Button Sensitivity Constant (K)
Button connected to Ground	0
$5 \text{ pF} \leq C_P \leq 10 \text{ pF}$	1
$10 \text{ pF} < C_P \leq 22 \text{ pF}$	2
$23 \text{ pF} < C_P \leq 40 \text{ pF}$	4

Table 5-2. Average Current Parameters

Parameter	Typ	Max
$T_{FW}$	1.50 ms	1.57 ms
$I_{SLEEP}$	1.07 $\mu\text{A}$	1.5 $\mu\text{A}$
$T_S$	From Equation 7	+5% from TYP value
$T_R$	<a href="#">Table 3-4</a>	$\pm 10$ from Value
$I_{ACTIVE}$	2.67 mA	3.8 mA

### Average Current in NO TOUCH State ( $I_{AVE\_NT}$ )

$$I_{AVE\_NT} = \left( \frac{T_R - T_S}{T_R} \times I_{SLEEP} \right) + \left( \frac{T_S}{T_R} \times I_{ACTIVE} \right)$$

Equation 8

Where:

$T_R$  = Button Scan Rate

$T_S$  = Scan time

$I_{SLEEP}$  = current consumed by CY8CMBR2044 during low power sleep mode, from Table 5-2

$I_{ACTIVE}$  = current consumed by CY8CMBR2044 during active operation, from Table 5-2

### Average Current in TOUCH State ( $I_{AVE\_T}$ )

$$I_{AVE\_T} = \left( \frac{20\text{ mS} - T_S}{20\text{ mS}} \times I_{SLEEP} \right) + \left( \frac{T_S}{20\text{ mS}} \times I_{ACTIVE} \right)$$

Equation 9

Where:

$T_S$  = Scan time

$I_{SLEEP}$  = current consumed by CY8CMBR2044 during low power sleep mode, from [Table 5-2](#)

$I_{ACTIVE}$  = current consumed by CY8CMBR2044 during active operation, from [Table 5-2](#)

### Average Standalone Current ( $I_{AVE\_SA}$ )

$$I_{AVE\_SA} = \left( \frac{100 - P}{100} \times I_{AVE\_NT} \right) + \left( \frac{P}{100} \times I_{AVE\_T} \right)$$

Equation 10

Where

P = percentage of time CS is in the TOUCH state compared to total time CY8CMBR2044 is on

$I_{AVE\_NT}$  = average current for in the NO TOUCH state

$I_{AVE\_T}$  = average current in the TOUCH state

### Average Current ( $I_{AVE}$ )

$$I_{AVE} = \left[ I_{AVE\_SA} \times \left( \frac{T_{SA}}{T_{DS} + T_{SA}} \right) \right] + 0.1\text{ }\mu\text{A}$$

Equation 11

Where:

$T_{SA}$  = time device is in standalone mode

$T_{DS}$  = time device is in deep sleep mode

## Average Power ( $P_{AVE}$ )

$$P_{AVE} = V_{DD} \times I_{AVE}$$

Equation 12

Where:

$I_{AVE}$  = average current

## Example Calculation

As an example of how to calculate average power, consider a CapSense user interface on a bluetooth headset with three well-designed buttons. The  $C_P$  for all three buttons is between 10 pF and 22 pF. The buttons are scanned at a rate of 507 ms.

The scan time can be calculated using a sensor constant of 2 for all three buttons and Equation 13:

$$T_S = [0.375 \times (2 + 2 + 2)] + 1.57 = 3.82 \text{ ms}$$

Equation 13

The average current in NO TOUCH state is calculated as follows using Equation 14 and the maximum values for  $I_{SLEEP}$  and  $I_{ACTIVE}$ :

$$I_{AVE\_NT} = \left( \frac{507-3.82}{507} \times 1.57 \mu A \right) + \left( \frac{3.82}{507} \times 3.8 \text{ mA} \right) = 30.19 \mu A$$

Equation 14

The average current in TOUCH state is calculated as follows using Equation 15:

$$I_{AVE\_T} = \left( \frac{20-3.82}{20} \times 1.57 \mu A \right) + \left( \frac{3.82}{20} \times 3.8 \text{ mA} \right) = 727 \mu A$$

Equation 15

To calculate the average current, assume your headset receives 50 calls in an 8-hour business day and the user touches a CapSense button every 20 seconds during each call. This means your design operates in a TOUCH state about 1.8 percent of the 8 hours during which the headset is turned on. The average current consumption of the design is calculated as follows using Equation 16:

$$I_{AVE\_SA} = (0.982 \times 30.19 \mu A) + (0.018 \times 727 \mu A) = 42.73 \mu A$$

Equation 16

Assuming this design does not utilize deep sleep mode and that it operates at 1.71 V the average power is calculated as follows using Equation 17:

$$P_{AVE} = 1.71 \times 42.73 \mu A = 73.07 \mu W$$

Equation 17

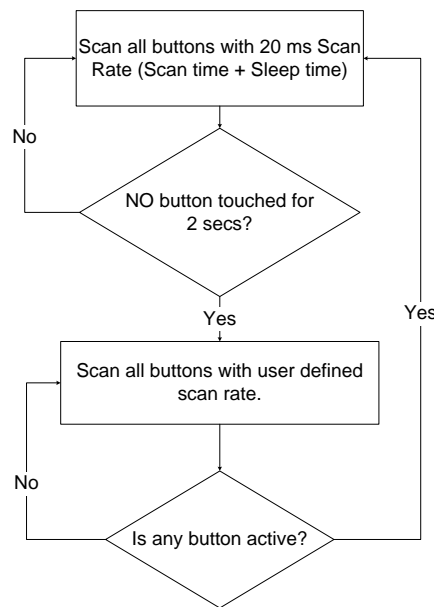
## Sleep Modes

Cypress's CY8CMBR2044 can be configured to operate in either low-power sleep mode or deep sleep mode.

### Low-Power Sleep Mode

When the CY8CMBR2044 device operates in low power sleep mode, the device draws 1  $\mu\text{A}$  when not scanning the CS inputs. The scan rate determines the amount of time. The behavior of CY8CMBR2044 controller in low-power sleep mode is described in [Figure 5-1](#).

Figure 5-1. Low-Power Sleep Mode



Because low-power sleep mode does not require a host processor to operate, it is also referred to as standalone mode.

### Deep Sleep Mode

If the CY8CMBR2044 is used in a system with a host processor, the ScanRate/Sleep control pin can be used to operate in deep sleep mode. When the host processor provides logic high to this input pin, the CY8CMBR2044 is put into deep sleep mode. This mode consumes 0.1  $\mu\text{A}$  (typ) of current. When the host drives a GND signal to the same input pin, the CY8CMBR2044 wakes up from sleep and operates in low-power sleep mode.

## 6. Resources



### Website

Visit [Cypress's CapSense Controllers website](#) to access all of the reference material discussed in this section. Find a variety of technical resources at the CY8CMBR2044 web page.

### Datasheet

The datasheet for the CapSense CY8CMBR2044 device is available at [www.cypress.com](http://www.cypress.com).

- [CY8CMBR2044](#)

### Design Toolbox

The interactive [Design Toolbox](#) will enable you to design a robust and reliable CY8CMBR2044 CapSense solution. Watch the Design Tool Box example video on web.

### Multi-Chart

[Multi-Chart](#) is a simple PC tool for real-time CapSense data viewing and logging. The application allows you to view data from up to 48 sensors, save and print charts, and save data for later analysis in a spreadsheet.

## Design Support

To ensure the success of your CapSense solutions, Cypress has a variety of design support channels.

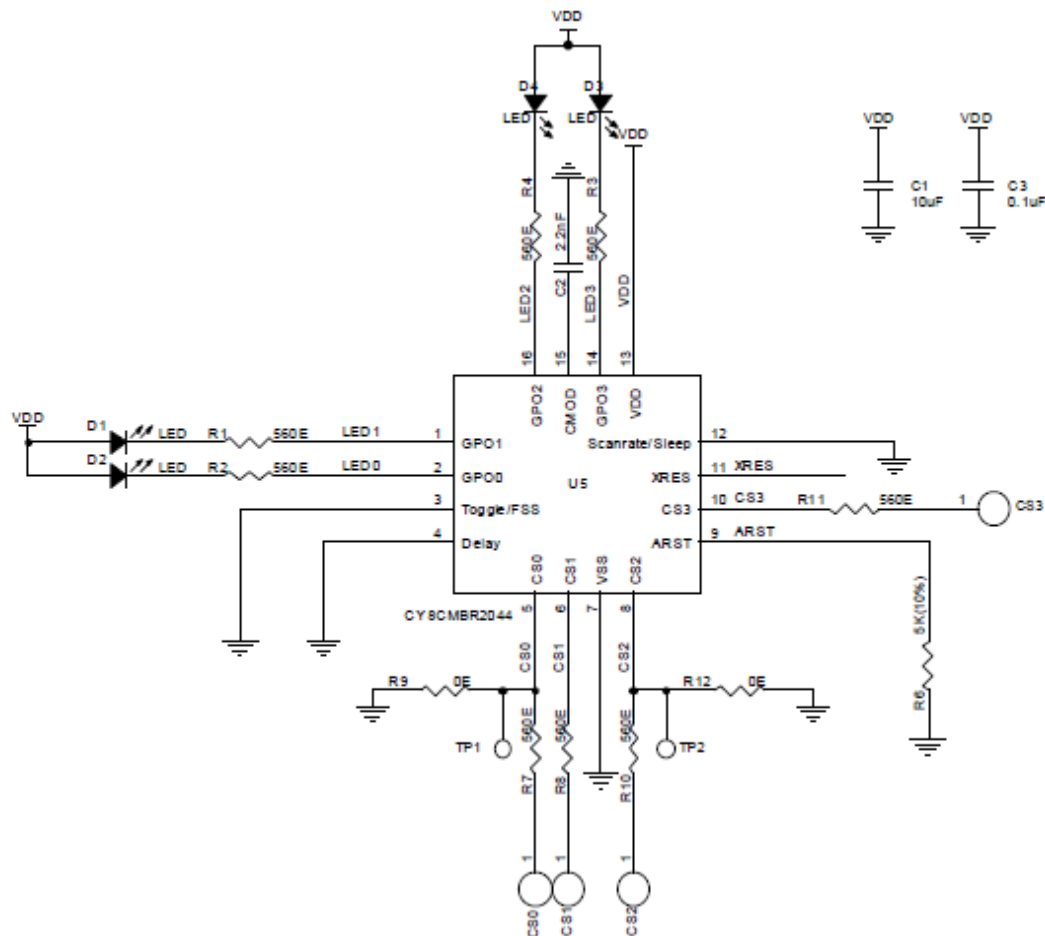
- [Knowledge Based Articles](#) – Browse technical articles by product family or perform a search on various CapSense topics.
- [CapSense Application Notes](#) – a wide variety of application notes built on information presented in this document.
- [White Papers](#) – Learn about advanced capacitive touch interface topics.
- [Cypress Developer Community](#) – Connect with the Cypress technical community and exchange information.
- [CapSense Product Selector Guide](#) – See the complete product offering of Cypress CapSense product line.
- [Video Library](#) – Quickly get up to speed with tutorial videos
- [CY8CMBR2044 Videos](#) – Get up to speed quickly with an overview of the [product features](#) and [design toolbox](#).
- [Quality & Reliability](#) – Cypress is committed to complete customer satisfaction. At our Quality website you can find reliability and product qualification reports.
- [Technical Support](#) – World class technical support is available on-line.

## 7. Appendix



### Schematic Example

Schematic 1: Four Buttons with Four GPOs



In the above schematic, the device is configured as:

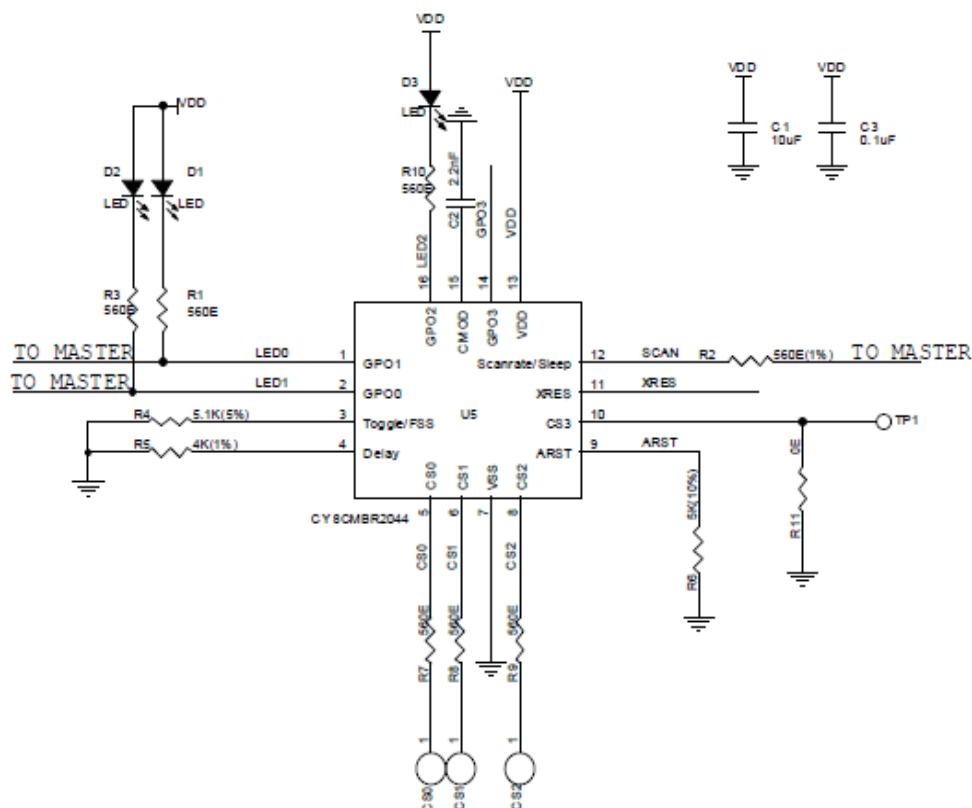
- **CS0 – CS3 pins: 560  $\Omega$  to CapSense buttons**
  - Four CapSense buttons (CS0 – CS3)



- **GPO0 – GPO3 pins: LED and 560  $\Omega$  to VDD**
  - CapSense buttons driving four LEDs (GPO0 – GPO3)
- **CMOD pin: 2.2 nF to Ground**
  - Modulator capacitor
- **XRES pin: Floating**
  - For external reset
- **Toggle/FSS pin: Ground**
  - Toggle ON/OFF disabled
  - FSS disabled
- **ARST pin: 5 k $\Omega$  to Ground**
  - Button Auto Reset enabled, Auto Reset Period = 20 seconds
- **Delay pin: Ground**
  - LED ON Time disabled
- **ScanRate/Sleep pin: Ground**
  - User configured scan rate = 20 ms

To enable Serial Debug Data output, connect a 5.6 kohm resistor on R9 or R12.

Schematic 2: Three Buttons with Advanced Features enabled



In the above schematic, the device is configured as:

- **CS0 – CS2 pins: 560 Ω to CapSense buttons; CS3 pin: Ground**
  - Three CapSense buttons (CS0 – CS2)
  - CS3 not used in design
- **GPO0 – GPO2 pins: LED and 560 Ω to VDD; GPO3 floating; GPO0-GPO1 pins interfaced to Master**
  - CapSense buttons driving three LEDs (GPO0 – GPO2)
  - GPO0, GPO1 interfaced to master for direct status read
- **CMOD pin: 2.2 nF to Ground**
  - Modulator capacitor
- **XRES pin: Floating**
  - For external reset
- **Toggle/FSS pin: 5.1 kΩ to Ground**
  - Toggle ON/OFF disabled
  - FSS enabled
- **ARST pin: 5 kΩ to Ground**
  - Button Auto Reset enabled, Auto Reset period = 20 seconds

- **Delay pin: 4 k $\Omega$  to Ground**
  - LED ON Time of 1000 ms
- **ScanRate/Sleep pin: 560  $\Omega$  to Master**
  - User configured scan rate = 30 ms
  - Master to control device operating mode

To enable Serial Debug Data output, connect a 5.6 kohm resistor on R11.

## Acronyms

Acronym	Description
AC	Alternating current
ARST	Auto Reset
C <sub>F</sub>	Finger capacitance
C <sub>P</sub>	Parasitic capacitance
CS	CapSense
CSD	CapSense Sigma Delta
EMC	Electromagnetic Compatibility
ESD	Electrostatic Discharge
FSS	Flanking Sensor Suppression
GPO	General-Purpose Output
MSB	Most significant bit
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
LSB	Least significant bit
PCB	Printed Circuit Board
POR	Power on Reset
POST	Power on Self-Test
RF	Radio Frequency
SMPS	Switched Mode Power Supply

# Glossary



## **AMUXBUS**

Analog multiplexer bus available inside PSoC that helps to connect I/O pins with multiple internal analog signals.

## **SmartSense™ Auto-Tuning**

A CapSense algorithm that automatically sets sensing parameters for optimal performance after the design phase and continuously compensates for system, manufacturing, and environmental changes.

## **Baseline**

A value resulting from a firmware algorithm that estimates a trend in the Raw Count when there is no human finger present on the sensor. The Baseline is less sensitive to sudden changes in the Raw Count and provides a reference point for computing the Difference Count.

## **Button or Button Widget**

A widget with an associated sensor that can report the active or inactive state (that is, only two states) of the sensor. For example, it can detect the touch or no-touch state of a finger on the sensor.

## **Difference Count**

The difference between Raw Count and Baseline. If the difference is negative, or if it is below Noise Threshold, the Difference Count is always set to zero.

## **Capacitive Sensor**

A conductor and substrate, such as a copper button on a printed circuit board (PCB), which reacts to a touch or an approaching object with a change in capacitance.

## **CapSense®**

Cypress's touch-sensing user interface solution. The industry's No. 1 solution in sales by 4x over No. 2.

## **CapSense Mechanical Button Replacement (MBR)**

Cypress's configurable solution to upgrade mechanical buttons to capacitive buttons, requires minimal engineering effort to configure the sensor parameters and does not require firmware development. These devices include the CY8CMBR3XXX and CY8CMBR2XXX families.

## **Centroid or Centroid Position**

A number indicating the finger position on a slider within the range given by the Slider Resolution. This number is calculated by the CapSense centroid calculation algorithm.

## **Compensation IDAC**

A programmable constant current source, which is used by CSD to compensate for excess sensor  $C_p$ . This IDAC is not controlled by the Sigma-Delta Modulator in the CSD block unlike the Modulation IDAC.

## **CSD**

CapSense Sigma Delta (CSD) is a Cypress-patented method of performing self-capacitance (also called self-cap) measurements for capacitive sensing applications.

In CSD mode, the sensing system measures the self-capacitance of an electrode, and a change in the self-capacitance is detected to identify the presence or absence of a finger.

**Debounce**

A parameter that defines the number of consecutive scan samples for which the touch should be present for it to become valid. This parameter helps to reject spurious touch signals.

A finger touch is reported only if the Difference Count is greater than Finger Threshold + Hysteresis for a consecutive Debounce number of scan samples.

**Driven-Shield**

A technique used by CSD for enabling liquid tolerance in which the Shield Electrode is driven by a signal that is equal to the sensor switching signal in phase and amplitude.

**Electrode**

A conductive material such as a pad or a layer on PCB, ITO, or FPCB. The electrode is connected to a port pin on a CapSense device and is used as a CapSense sensor or to drive specific signals associated with CapSense functionality.

**Finger Threshold**

A parameter used with Hysteresis to determine the state of the sensor. Sensor state is reported ON if the Difference Count is higher than Finger Threshold + Hysteresis, and it is reported OFF if the Difference Count is below Finger Threshold – Hysteresis.

**Ganged Sensors**

The method of connecting multiple sensors together and scanning them as a single sensor. Used for increasing the sensor area for proximity sensing and to reduce power consumption.

To reduce power when the system is in low-power mode, all the sensors can be ganged together and scanned as a single sensor taking less time instead of scanning all the sensors individually. When the user touches any of the sensors, the system can transition into active mode where it scans all the sensors individually to detect which sensor is activated.

PSoC supports sensor-ganging in firmware, that is, multiple sensors can be connected simultaneously to AMUXBUS for scanning.

**Gesture**

Gesture is an action, such as swiping and pinch-zoom, performed by the user. CapSense has a gesture detection feature that identifies the different gestures based on predefined touch patterns. In the CapSense component, the Gesture feature is supported only by the Touchpad Widget.

**Guard Sensor**

Copper trace that surrounds all the sensors on the PCB, similar to a button sensor and is used to detect a liquid stream. When the Guard Sensor is triggered, firmware can disable scanning of all other sensors to prevent false touches.

**Hatch Fill or Hatch Ground or Hatched Ground**

While designing a PCB for capacitive sensing, a grounded copper plane should be placed surrounding the sensors for good noise immunity. But a solid ground increases the parasitic capacitance of the sensor which is not desired. Therefore, the ground should be filled in a special hatch pattern. A hatch pattern has closely-placed, crisscrossed lines looking like a mesh and the line width and the spacing between two lines determine the fill percentage. In case of liquid tolerance, this hatch fill referred as a shield electrode is driven with a shield signal instead of ground.

**Hysteresis**

A parameter used to prevent the sensor status output from random toggling due to system noise, used in conjunction with the Finger Threshold to determine the sensor state. See [Finger Threshold](#).

**IDAC (Current-Output Digital-to-Analog Converter)**

Programmable constant current source available inside PSoC, used for CapSense and ADC operations.

**Liquid Tolerance**

The ability of a capacitive sensing system to work reliably in the presence of liquid droplets, streaming liquids or mist.

**Linear Slider**

A widget consisting of more than one sensor arranged in a specific linear fashion to detect the physical position (in single axis) of a finger.

**Low Baseline Reset**

A parameter that represents the maximum number of scan samples where the Raw Count is abnormally below the Negative Noise Threshold. If the Low Baseline Reset value is exceeded, the Baseline is reset to the current Raw Count.

**Manual-Tuning**

The manual process of setting (or tuning) the CapSense parameters.

**Matrix Buttons**

A widget consisting of more than two sensors arranged in a matrix fashion, used to detect the presence or absence of a human finger (a touch) on the intersections of vertically and horizontally arranged sensors.

If M is the number of sensors on the horizontal axis and N is the number of sensors on the vertical axis, the Matrix Buttons Widget can monitor a total of M x N intersections using ONLY M + N port pins.

When using the CSD sensing method (self-capacitance), this Widget can detect a valid touch on only one intersection position at a time.

**Modulation Capacitor (CMOD)**

An external capacitor required for the operation of a CSD block in Self-Capacitance sensing mode.

**Modulator Clock**

A clock source that is used to sample the modulator output from a CSD block during a sensor scan. This clock is also fed to the Raw Count counter. The scan time (excluding pre and post processing times) is given by  $(2^N - 1) / \text{Modulator Clock Frequency}$ , where N is the Scan Resolution.

**Modulation IDAC**

Modulation IDAC is a programmable constant current source, whose output is controlled (ON/OFF) by the sigma-delta modulator output in a CSD block to maintain the AMUXBUS voltage at  $V_{REF}$ . The average current supplied by this IDAC is equal to the average current drawn out by the sensor capacitor.

**Mutual-Capacitance**

Capacitance associated with an electrode (say TX) with respect to another electrode (say RX) is known as mutual capacitance.

**Negative Noise Threshold**

A threshold used to differentiate usual noise from the spurious signals appearing in negative direction. This parameter is used in conjunction with the Low Baseline Reset parameter.

Baseline is updated to track the change in the Raw Count as long as the Raw Count stays within Negative Noise Threshold, that is, the difference between Baseline and Raw count (Baseline – Raw count) is less than Negative Noise Threshold.

Scenarios that may trigger such spurious signals in a negative direction include: a finger on the sensor on power-up, removal of a metal object placed near the sensor, removing a liquid-tolerant CapSense-enabled product from the water; and other sudden environmental changes.

**Noise (CapSense Noise)**

The variation in the Raw Count when a sensor is in the OFF state (no touch), measured as peak-to-peak counts.

**Noise Threshold**

A parameter used to differentiate signal from noise for a sensor. If Raw Count – Baseline is greater than Noise Threshold, it indicates a likely valid signal. If the difference is less than Noise Threshold, Raw Count contains nothing but noise.

**Overlay**

A non-conductive material, such as plastic and glass, which covers the capacitive sensors and acts as a touch-surface. The PCB with the sensors is directly placed under the overlay or is connected through springs. The casing for a product often becomes the overlay.

**Parasitic Capacitance ( $C_P$ )**

Parasitic capacitance is the intrinsic capacitance of the sensor electrode contributed by PCB trace, sensor pad, vias, and air gap. It is unwanted because it reduces the sensitivity of CSD.

**Proximity Sensor**

A sensor that can detect the presence of nearby objects without any physical contact.

**Radial Slider**

A widget consisting of more than one sensor arranged in a specific circular fashion to detect the physical position of a finger.

**Raw Count**

The unprocessed digital count output of the CapSense hardware block that represents the physical capacitance of the sensor.

**Refresh Interval**

The time between two consecutive scans of a sensor.

**Scan Resolution**

Resolution (in bits) of the Raw Count produced by the CSD block.

**Scan Time**

Time taken for completing the scan of a sensor.

**Self-Capacitance**

The capacitance associated with an electrode with respect to circuit ground.

**Sensitivity**

The change in Raw Count corresponding to the change in sensor capacitance, expressed in counts/pF. Sensitivity of a sensor is dependent on the board layout, overlay properties, sensing method, and tuning parameters.

**Sense Clock**

A clock source used to implement a switched-capacitor front-end for the CSD sensing method.

**Sensor**

See [Capacitive Sensor](#).

**Sensor Auto Reset**

A setting to prevent a sensor from reporting false touch status indefinitely due to system failure, or when a metal object is continuously present near the sensor.

When Sensor Auto Reset is enabled, the Baseline is always updated even if the Difference Count is greater than the Noise Threshold. This prevents the sensor from reporting the ON status for an indefinite period of time. When Sensor Auto Reset is disabled, the Baseline is updated only when the Difference Count is less than the Noise Threshold.

**Sensor Ganging**

See [Ganged Sensors](#).

**Shield Electrode**

Copper fill around sensors to prevent false touches due to the presence of water or other liquids. Shield Electrode is driven by the shield signal output from the CSD block. See [Driven-Shield](#).

**Shield Tank Capacitor ( $C_{SH}$ )**

An optional external capacitor ( $C_{SH}$  Tank Capacitor) used to enhance the drive capability of the CSD shield, when there is a large shield layer with high parasitic capacitance.

**Signal (CapSense Signal)**

Difference Count is also called Signal. See Difference Count.

**Signal-to-Noise Ratio (SNR)**

The ratio of the sensor signal, when touched, to the noise signal of an untouched sensor.

**Slider Resolution**

A parameter indicating the total number of finger positions to be resolved on a slider.

**Touchpad**

A Widget consisting of multiple sensors arranged in a specific horizontal and vertical fashion to detect the X and Y position of a touch.

**Trackpad**

See [Touchpad](#).

**Tuning**



The process of finding the optimum values for various hardware and software or threshold parameters required for CapSense operation.

 **$V_{REF}$** 

Programmable reference voltage block available inside PSoC used for CapSense and ADC operation.

**Widget**

A user-interface element in the CapSense component that consists of one sensor or a group of similar sensors. Button, proximity sensor, linear slider, radial slider, matrix buttons, and touchpad are the supported widgets.

# Revision History



## Document Revision History

Document Title: AN66308 - CY8CMBR2044 CapSense® Design Guide			
Document Number: 001-66308			
Revision	Issue Date	Origin of Change	Description of Change
**	12/30/2010	ANBA	New Design Guide.
*A	03/03/2011	ANBA	Multiple chapter enhancements for content and reader clarity.
*B	06/01/2012	UDYG	Multiple chapter enhancements for content and reader clarity.
*C	01/07/2013	SLAN	Added C <sub>P</sub> recommendations to PCB Layout Guidelines.
*D	01/21/2016	VAIR	Added Glossary.
*E	02/06/2017	SLAN	Updated to new template. Completing Sunset Review.
*F	07/04/2017	AESATP12	Updated logo and copyright.