AN75999 - CY8CMBR2010

CapSense® Design Guide

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Contents

1. Introduction

1.1 Abstract

This document describes how to implement capacitive sensing functionality using Cypress's CapSense® Express™ CY8CMBR2010 device. The following topics are covered in this guide:

- Features of the CY8CMBR2010
- CapSense principles of operation
- Configuration options of the CY8CMBR2010 device
- Using the Design Toolbox with the CY8CMBR2010
- System electrical and mechanical design considerations for the CY8CMBR2010
- Low-power design considerations for the CY8CMBR2010
- Additional resources and support for designing CapSense into your system

1.2 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 needed 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 the supporting documents for each of the numbered tasks in Figure 1-1.

Figure 1-1. Typical CapSense Product Design Flow

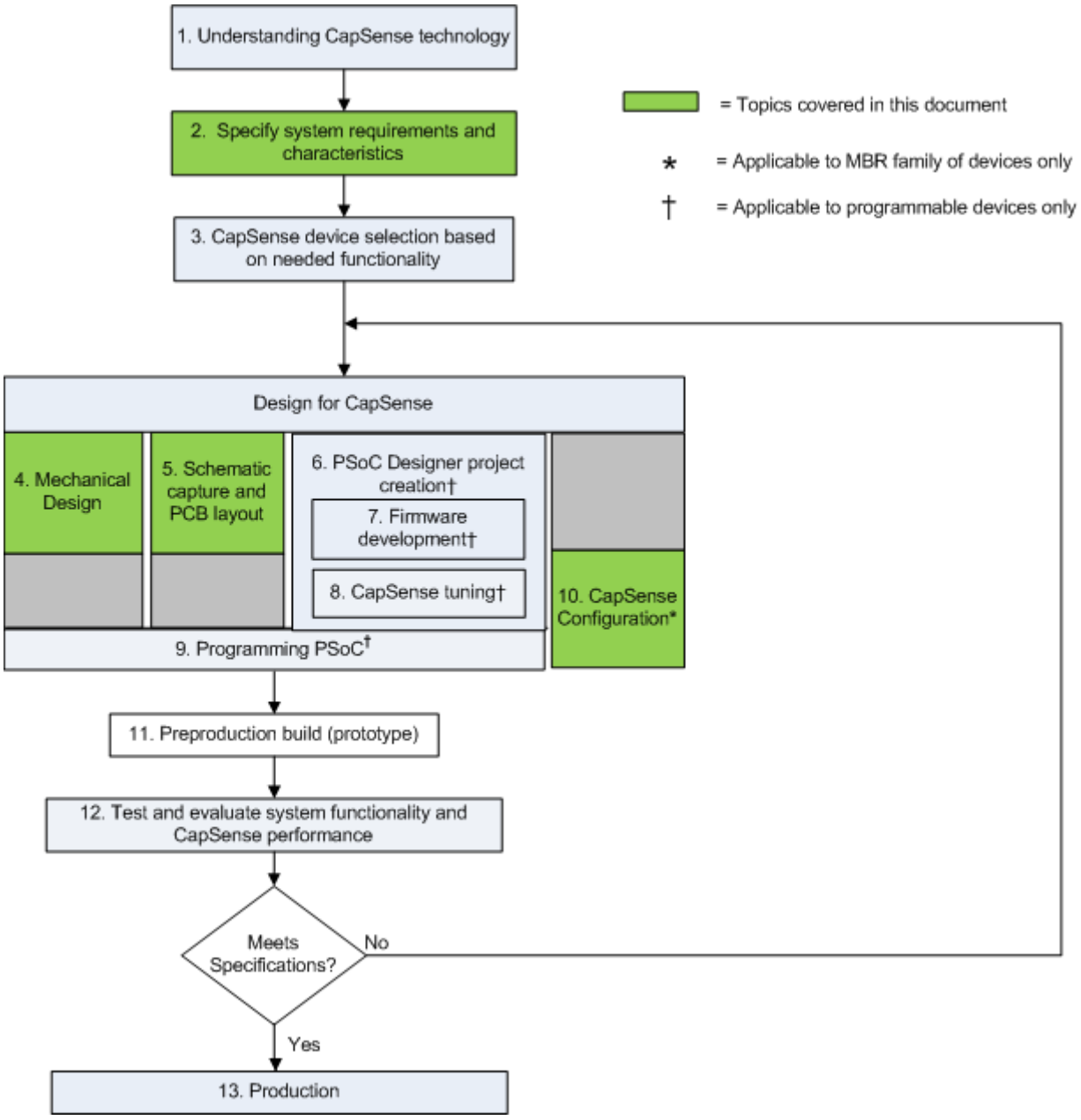


Table 1-1. Cypress Documents Supporting Numbered Design Tasks of Figure 1-1

Numbered Design Task of Figure 1-1	Supporting Cypress CapSense Documentation
1	Getting Started with CapSense
2	CY8CMBR2010 Device Datasheet
3	Getting Started with CapSense
4	This document
5	This document
6	Not applicable for CY8CMBR2010
7	Not applicable for CY8CMBR2010
8	Not applicable for CY8CMBR2010
9	Not applicable for CY8CMBR2010
10	This document
11	This document

1.3 CY8CMBR2010 CapSense® Express Device Features

Cypress's low-power CapSense controller can easily add capacitive touch sensing to your user interface. The device's features include:

- Hardware Configurable CapSense Controller
  - ☐ Does not require software tools or programming
  - ☐ Ten button solution configurable through hardware straps
  - ☐ Ten general-purpose outputs (GPOs)
  - ☐ GPOs are linked to CapSense buttons
  - ☐ GPOs support direct LED drive
- SmartSense™ Auto-Tuning
  - ☐ Maintains optimal button performance even in noisy environment
  - ☐ CapSense parameters dynamically set in runtime
  - ☐ Saves time and effort in device tuning
  - ☐ Wide parasitic capacitance (C_P) range (5—40 pF)
- Advanced Features
  - ☐ Robust sensing with closely spaced buttons – Flanking Sensor Suppression (FSS)
  - ☐ User-configurable LED Effects
    - ○ On-system power-on
    - ○ LED ON Time after button release
  - ☐ Analog voltage output
    - ○ Using external resistor bridge
  - ☐ Serial debug data output
    - ○ Simplifies production-line testing and system debug

- Noise Immunity
  - ☐ Specifically designed for superior noise immunity to external radiated and conducted noise
  - ☐ Low radiated noise emission
- System Diagnostics
  - ☐ Button shorts
  - ☐ Improper value of modulating capacitor (C_{MOD})
  - ☐ Parasitic capacitance (C_P) value out of range
- Wide operating voltage range
  - ☐ 1.71—5.5 V
  - ☐ Ideal for both regulated and unregulated battery applications
- Low power consumption
  - ☐ Average current consumption of 21 µA[1] per button
  - ☐ Deep sleep current: 100 nA
- Industrial temperature range: –40 °C to +85 °C.
- 32-pin QFN package (5 mm x 5 mm x 0.6 mm)

1.4 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 *sourcefile.hex* file in the *PSoC Designer User Guide*.
[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 **File** icon and then click **Open**.
Times New Roman	Displays an equation: 2 + 2 = 4
Text in gray boxes	Describes Cautions or unique functionality of the product.

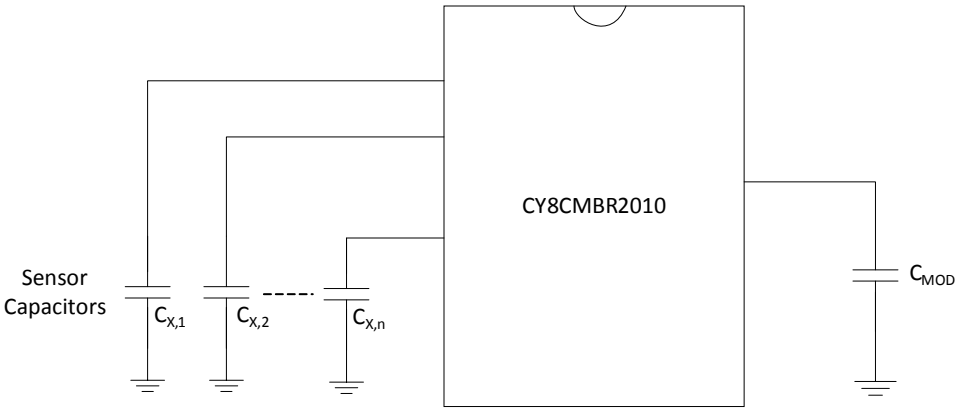
[1] Four buttons used, 3% touch time, 10 pF < (Cp of all buttons) < 20 pF, Button Scan Rate = 556 ms, power consumption optimized, Noise Immunity level "Normal", CS0 sensitivity "High"

2. CapSense Technology

2.1 CapSense Fundamentals

CapSense is a touch sensing technology that works by measuring the capacitance of each sensor input pin on the CapSense controller. The total capacitance on each of the sensor pins can be modeled as equivalent lumped capacitors with values of $C_{X,1}$ through $C_{X,n}$ as shown in Figure 2-1. Circuitry internal to the CY8CMBR2010 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} is discussed in more detail in Capacitive Sensing Method.

Figure 2-1. CapSense Implementation in a CY8CMBR2010 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 Equation 1:

$$C_F = \frac{\varepsilon_0 \varepsilon_r A}{D}$$ Equation 1

Where:

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

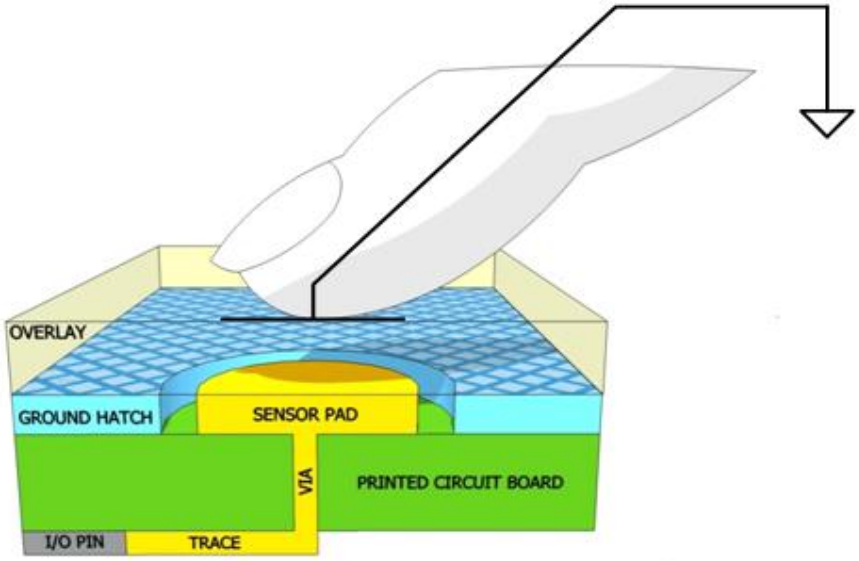
ε_0 = Free space permittivity

ε_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:

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

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—20 pF, but in extreme cases it can be as high as 40 pF. C_F usually ranges from 0.1—0.4 pF.

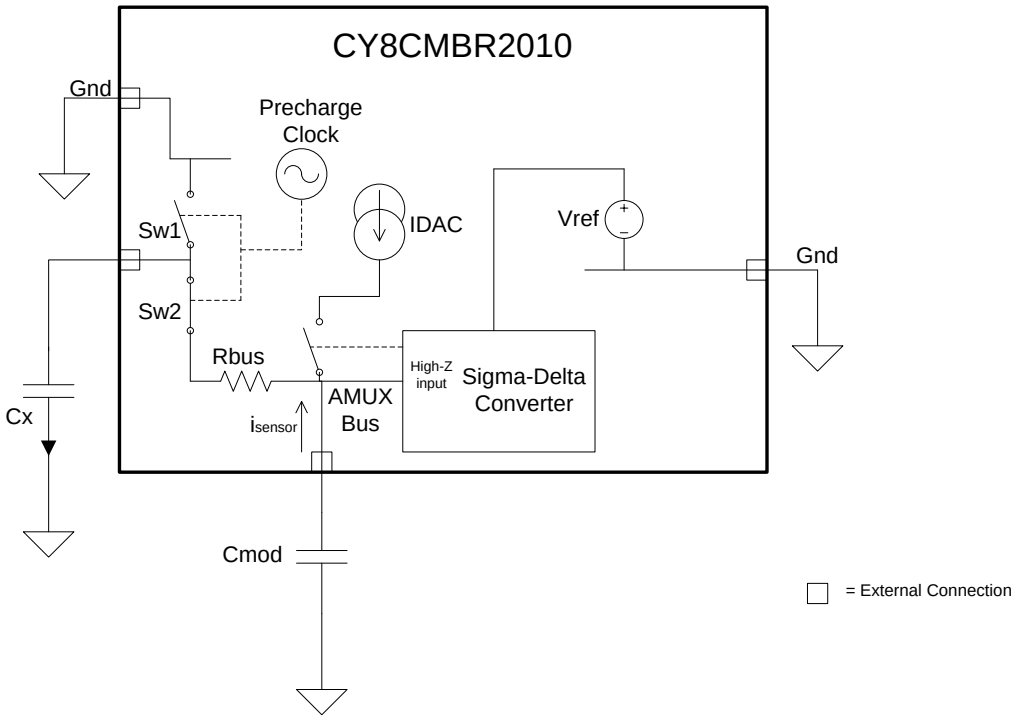
2.2 Capacitive Sensing Method

CY8CMBR2010 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.

2.2.1 CapSense Sigma-Delta (CSD)

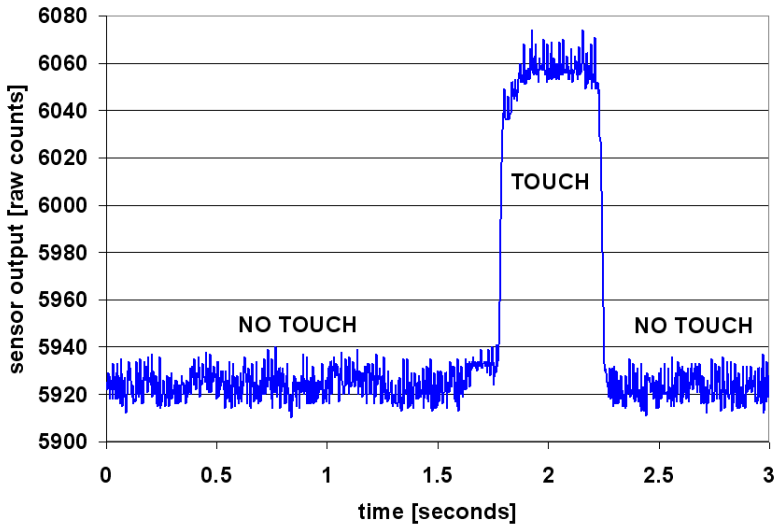
The CSD method in the CY8CMBR2010 device incorporates C_X into a switched capacitor circuit, as shown in Figure 2-3. C_X is alternatively connected to Gnd and the AMUX bus by the non-overlapping switches Sw1 and Sw2. Sw1 and Sw2 are driven by the Precharge clock to bleed a current, i_{sensor} from the AMUX bus. The magnitude of i_{sensor} is directly proportional to the magnitude of C_X. The sigma-delta converter samples the AMUX bus voltage and generates a modulating bit stream that controls the constant current source, IDAC. The IDAC charges AMUX such that the average AMUX bus voltage is maintained at Vref. The sensor bleeds off the charge i_{sensor} from Cmod which, in combination with Rbus, forms a low-pass filter that attenuates precharge switching transients at the sigma-delta converter input.

Figure 2-3. CSD Block Diagram



In order to maintain the AMUX bus voltage at Vref, the sigma-delta converter matches IDAC 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, 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. To learn more about Raw Counts, Finger Threshold, and Signal-to-Noise Ratio (SNR), refer to Getting Started with CapSense.

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



2.3 SmartSense Auto-Tuning

Tuning the touch-sensing user interface is critical for proper system operation and a pleasant user experience. Unfortunately, tuning is time-consuming because it is an iterative process. In a typical development cycle, the interface is tuned in the initial design phase, during system integration, and before production ramp. SmartSense Auto-Tuning was developed to simplify the user interface development cycle. It is easy to use and reduces design cycle time by eliminating manual tuning during the prototype and manufacturing stages. SmartSense Auto-Tuning tunes each CapSense button automatically at power up and maintains optimum button performance during runtime. SmartSense Auto-Tuning 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.

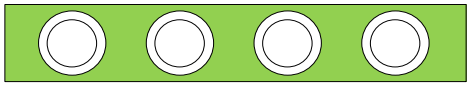
2.3.1 Process Variation

The CY8CMBR2010 device's SmartSense Auto-Tuning is designed to work with C_P values in the range of 5—40 pF. The sensitivity parameter for each button is set automatically, based on its characteristics. This parameter improves yield in mass production because every button maintains a consistent response regardless of C_P variation between the buttons. C_P 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 C_P; higher C_P values decrease sensitivity, resulting in decreased finger touch signal amplitude. A change in C_P can result in a button becoming too sensitive, not sensitive enough, or non-operational. When this happens, you must retune the system and, in some cases, re-qualify 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 parasitic capacitance of the CapSense buttons can vary in different models of the same platform design depending on the size of the laptop and the keyboard layout. In this example, a wide-screen laptop model would have larger spaces between the buttons than a standard-screen model. Therefore, a wide-screen model would have longer traces between each button and the CapSense controller, which would result in higher C_P values. 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 Multimedia Keys for a 21-Inch Model

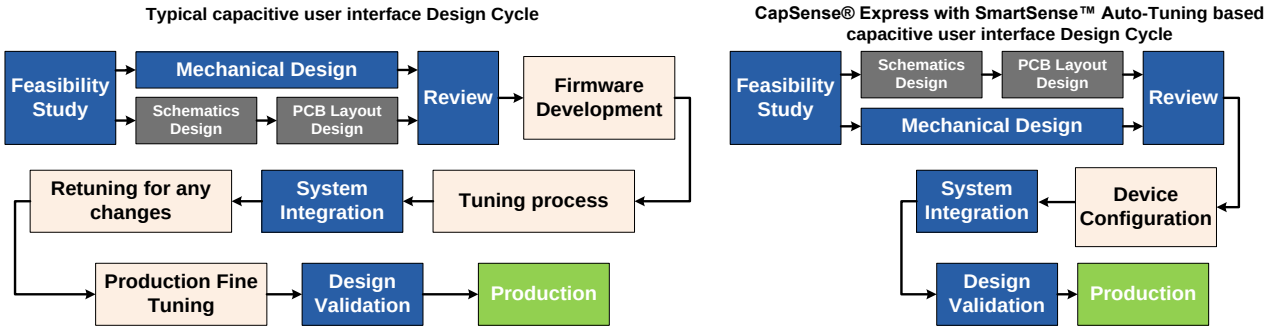
Figure 2-6. Design of Laptop Multimedia Keys for a 15-Inch Model with Identical Functionality and Button Size



2.3.2 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 does not require firmware development, manual tuning, or 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

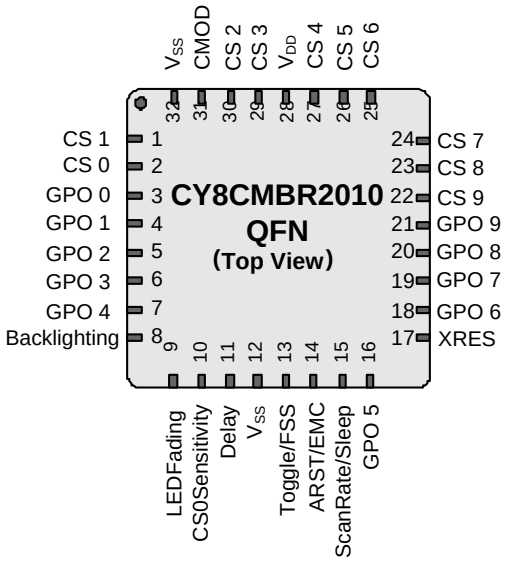


3. CapSense Schematic Design

Cypress's CY8CMBR2010 is hardware-configurable. This section gives an overview of the CapSense controller pins and how to configure them.

3.1 CY8CMBR2010 CapSense Controller Pins

Figure 3-1. CY8CMBR2010 Pin Diagram



3.1.1 CapSense Buttons (CSx Pins)

The CY8CMBR2010 controller has ten capacitive sense inputs, CS0—CS9. Each capacitive button requires a connection to one of the capacitive sense inputs. You must ground all unused CapSense (CSx) input pins.

3.1.2 General Purpose Outputs (GPOx Pins)

There are ten active low outputs on the CY8CMBR2010 controller, GPO0—GPO9. Each output is driven by its corresponding capacitive sensing input, CSx. You can use GPOs to directly drive LEDs or replace mechanical switches. GPOs are in strong drive[2] mode. All unused GPO pins must be floated.

3.1.3 Modulation Capacitor (CMOD Pin)

Connect a 2.2-nF (±10%) capacitor to the CMOD pin.

[2] When a pin is in strong drive mode, it is pulled up to V_{DD} when the output is HIGH and pulled down to Ground when the output is LOW.

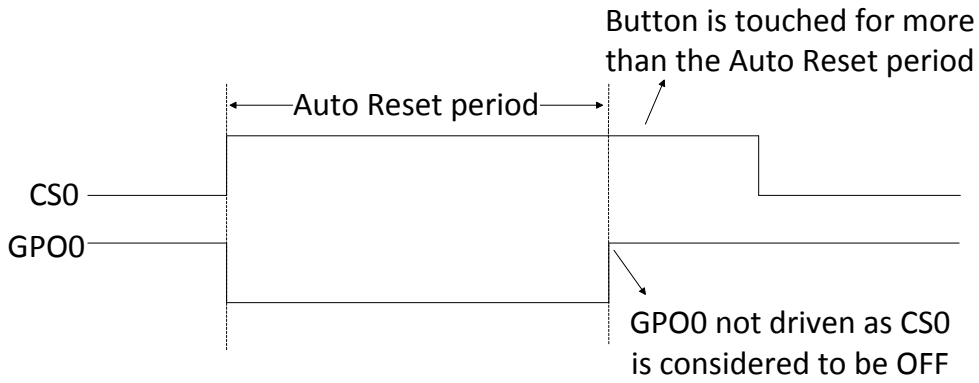
3.1.4 Button Auto Reset (ARST/EMC Pin)

Button Auto Reset determines the maximum time a button is considered to be ON when CSx is continuously touched. The button is turned OFF after the ARST period. This feature prevents a button from getting stuck if a metal object is placed too close to it. The Button Auto Reset period is defined in Table 3-1 and shown in Figure 3-2.

Table 3-1. ARST/EMC Pin Configuration

ARST/EMC Pin Connection	Button Auto Reset Period (seconds)	Noise Immunity Level
Ground / Floating[3]	No Limit	Normal
1.5 kΩ (±5%) resistor to ground	20	Normal
5.1 kΩ (±5%) resistor to ground	No Limit	High
V_{DD}	20	High

Figure 3-2. Button Auto Reset



After the CSx is turned off because of Button Auto Reset and after the button is released, do not touch CSx for a specific amount of time (T), where:

- T = 550 ms
  if CSx is released within 15 seconds of the Auto Reset period elapsing
- T = 550 ms + (Scan Rate)
  if CSx is released after 15 seconds after the Auto Reset period elapsed

3.1.5 Noise Immunity (ARST/EMC Pin)

This setting determines the device's immunity to external radiated and conducted noise such as audio frequency noise from power amplifiers, radio frequency noise from wireless transmitters, ESD, and power line surges.

In a system without major noise concerns, select "Normal" Noise Immunity. For a system in a high-noise environment, select "High" Noise Immunity. Power consumption and response time increase when Noise Immunity is "High". Noise Immunity configuration is defined in Table 3-1.

[3] Floating is not recommended in high noise environment, except for LEDFading pin.

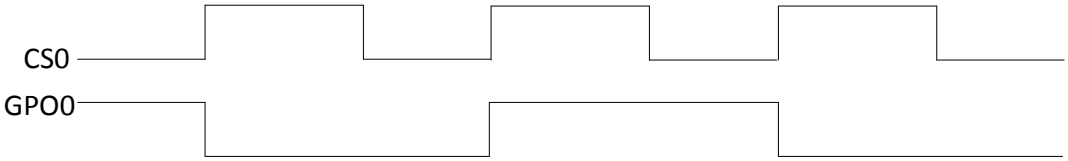
3.1.6 Toggle ON/OFF (Toggle/FSS Pin)

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 / Floating[3]	Disabled	Disabled
1.5 kΩ (±5%) resistor to ground	Enabled	Disabled
5.1 kΩ (±5%) resistor to ground	Disabled	Enabled
V_{DD}	Enabled	Enabled

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



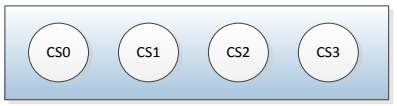
3.1.7 Flanking Sensor Suppression (Toggle/FSS Pin)

FSS allows only one CSx to be in the TOUCH state at a time. This means you can distinguish TOUCH states for closely spaced buttons. If a finger contacts multiple CSx buttons, only the first one to sense a TOUCH state will turn ON.

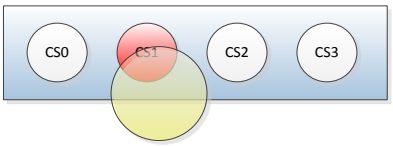
FSS also is useful when nearby buttons can produce opposite effects such as an interface with two buttons for brightness control (UP or DOWN).

FSS configuration is defined in Table 3-2 and shown in Figure 3-4 and Figure 3-5.

Figure 3-4. FSS When Only One Button is Touched

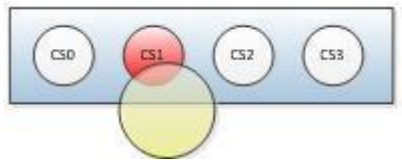


No button is ON prior to the touch

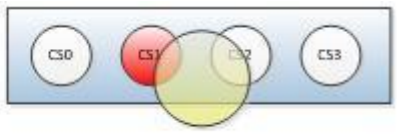


CS1 is reported as ON upon touch

Figure 3-5. FSS When Multiple Buttons are Touched With One Button ON Previously



CS1 is touched; reported ON

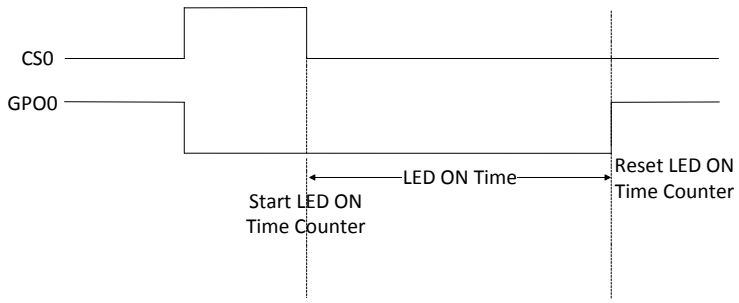


CS2 also touched along with CS1; only CS1 is reported ON

3.1.8 LED ON Time (Delay Pin)

LED ON Time specifies the duration for which GPOx is driven low after CSx is released as shown in Figure 3-6. LED ON Time can range from 0—2000 ms, with a resolution of 20 ms.

Figure 3-6. LED ON Time



LED ON Time, D, is configured by connecting a resistor, R_{DELAY}, between the Delay pin and ground.

Equation 4

$$R_{DELAY} = \left(\frac{D}{20} \times 30\right) + 300\,\Omega \quad \text{if Serial Debug Data Out disabled}$$

$$R_{DELAY} = \left(\frac{D}{20} \times 30\right) + 7000\,\Omega \quad \text{if Serial Debug Data Out enabled}$$

Where D is a multiple of 20 ms

Table 3-3 provides some example values for R_{DELAY}. Resistor tolerance R_{DELAY} should be less than 1 percent.

Table 3-3. Delay Pin Configuration

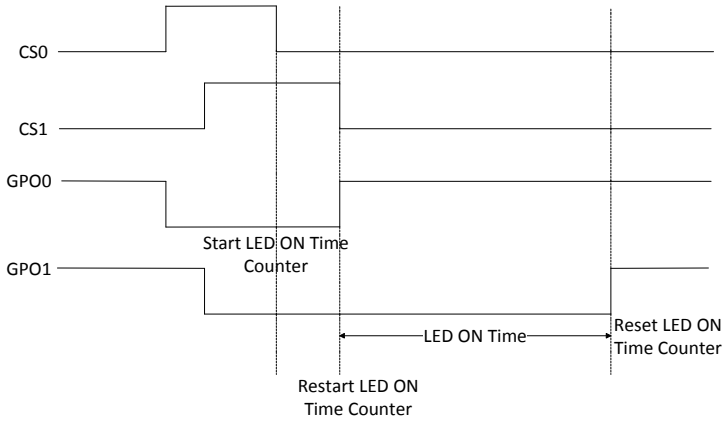
Delay Pin Connection	Approx. LED ON Time (ms)	Serial Debug Data
Ground / 300 Ω (±1%) resistor to ground	0	Disabled
330 Ω (±1%) resistor to ground	20	
360 Ω (±1%) resistor to ground	40	
390 Ω (±1%) resistor to ground	60	
…	…	
3300 Ω (±1%) resistor to ground	2000	
7000 Ω (±1%) resistor to ground	0	Enabled
7030 Ω (±1%) resistor to ground	20	
7060 Ω (±1%) resistor to ground	40	
7090 Ω (±1%) resistor to ground	60	
…	…	
10000 Ω (±1%) resistor to ground	2000	

LED ON Time varies from device to device. Accuracy is ±25% at a range of -40 °C to +85 °C (excluding resistor tolerance).

If a Button Auto Reset (ARST/EMC Pin) 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 when multiple buttons are touched. CS1 resets the LED ON Time counter, causing GPO0 to turn OFF prematurely.

Figure 3-7. LED ON Timing for Multiple Buttons



3.1.9 Power-On LED Effects (LEDFading Pin)

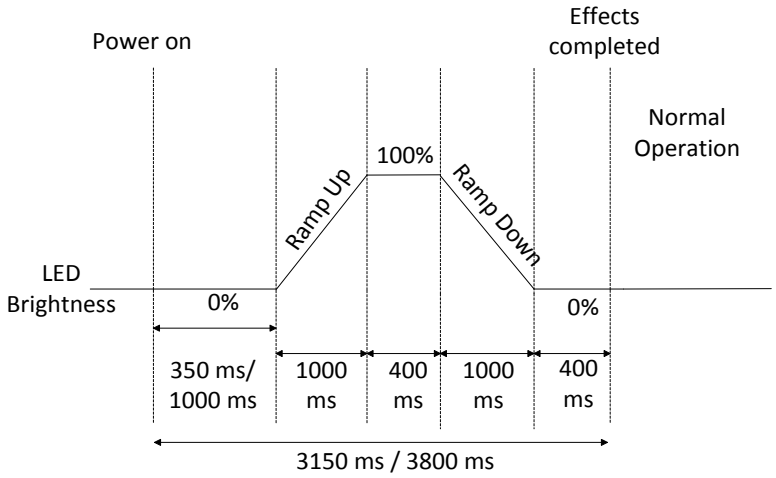
If this feature is enabled, all LEDs connected to GPOs show one of three selectable brightening and fading effects for an initial time, at system power-on. All CapSense buttons are disabled during this time. The device responds to any button touch only after the effects are complete.

Power-On LED Effects use the following parameters:

- Low-brightness: Minimum LED intensity
- Low-brightness time: The time period the LED remains in a low-brightness state
- Ramp-up time: The time period the LED transitions from low-brightness to high-brightness
- High-brightness: Maximum LED intensity
- High-brightness time: The time period the LED remains in a high-brightness state
- Ramp-down time: The time period the LED transitions from high-brightness to low-brightness
- Repeat rate: The number of times the effects are repeated

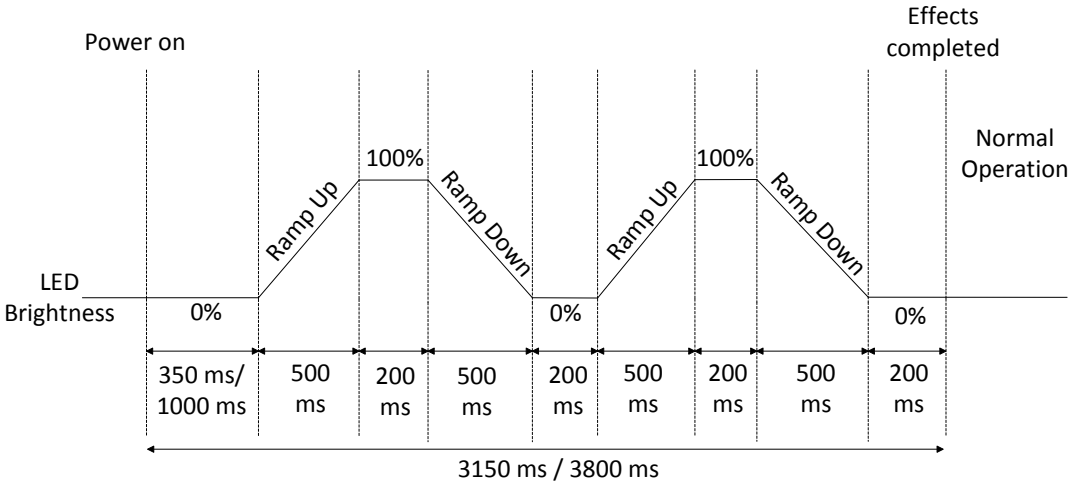
Power-On LED Effect 1: All LEDs go to high brightness and return to low brightness simultaneously one time as shown in Figure 3-8.

Figure 3-8. Power-on LED Effect 1



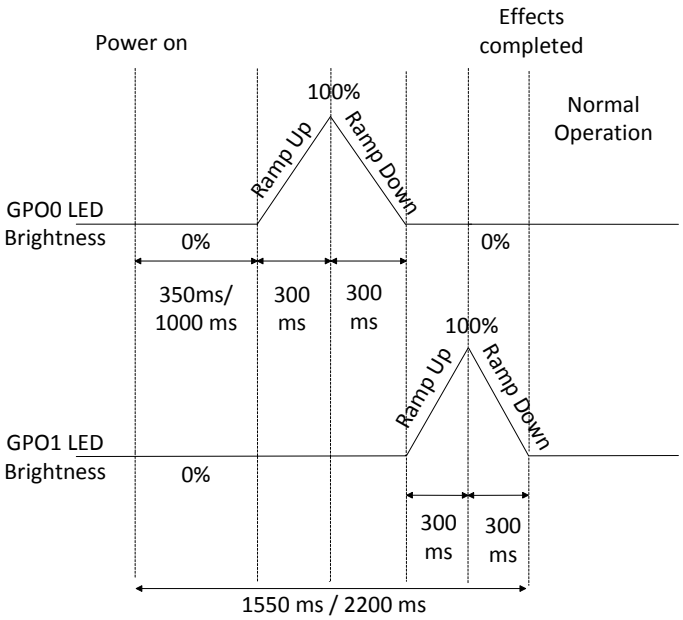
Power-On LED Effect 2: All LEDs go to high brightness and return to low brightness simultaneously two times as shown in Figure 3-9.

Figure 3-9. Power-on LED Effect 2



Power-On LED Effect 3: All LEDs go to high brightness and return to low brightness sequentially one time as shown in Figure 3-10.

Figure 3-10. Power-on LED Effect 3 with Two Button Design



Power-on LED effects are configured using the LEDFading pin as shown in Table 3-4.

Table 3-4. LEDFading Pin Configuration

LEDFading Pin Connection	Power-on LED Effects	Analog Voltage Support LED Backlighting
Ground	Disabled	Enabled
1.5 kΩ (±5%) resistor to ground	Effect 1	Disabled
5.1 kΩ (±5%) resistor to ground	Effect 2	Disabled
V_{DD}	Effect 3	Disabled
Floating	Disabled	Disabled

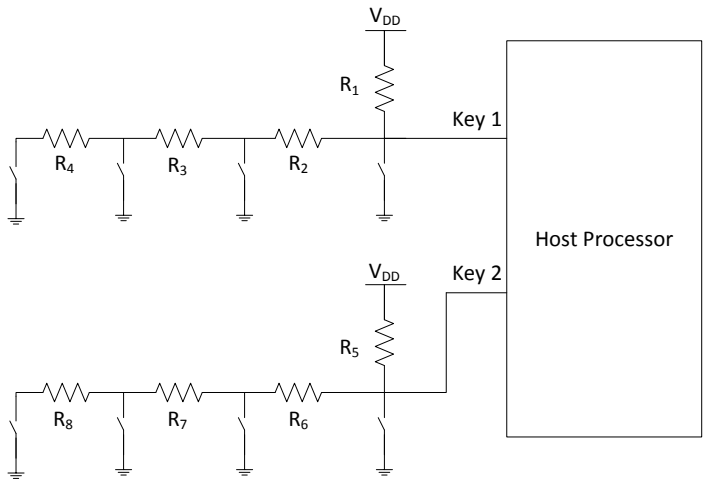
The effects are seen after the device initialization time from power-on. This time is less than 350 ms if Noise Immunity is “Normal” and less than 1000 ms if Noise Immunity is “High”.

After power-on, system diagnostics, including a Power-on Self Test are performed. If any CapSense button fails, the effects are not seen on the corresponding GPO. To learn more about this test, see System Diagnostics.

3.1.10 Analog Voltage Support (LEDFading Pin)

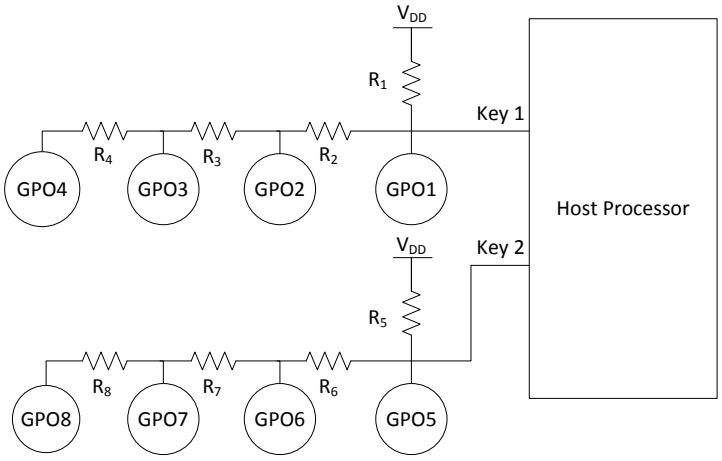
A general external resistive network with a host processor, such as the one shown in Figure 3-11, can configure the host to perform different functions based on the voltage level seen at the input pin. Vary this voltage level by using a combination of resistors and switches between V_{DD} and ground.

Figure 3-11. A General External Resistive Network



The analog voltage support feature of CY8CMBR2010 gives you the option to control these switches using CapSense buttons. Each switch can be replaced with one GPOx. When a CSx button is touched, the corresponding GPOx goes low; therefore, the switch is closed (shorted to ground). When the button is released, the corresponding switch is left open. This is shown in Figure 3-12.

Figure 3-12. Analog Voltage Support from CY8CMBR2010



If this feature is enabled, the GPOs cannot be used simultaneously in the external resistive network and for the LED drive. Instead, the Backlighting pin acts as a common GPO for LED drive, controlled by all the CSx buttons. If only one button needs to be ON for analog voltage support, enable FSS along with this feature.

Usually, the GPOs are in strong drive mode. But when this feature is enabled, the GPOs are in Open Drain Low drive mode. Analog voltage support is configured using the LEDFading pin as shown in Table 3-4.

3.1.11 Backlighting (Backlighting Pin)

When analog voltage support is enabled, the Backlighting pin acts as a common GPO for the LED drive, as the GPOx cannot be used for LED drive. This pin can be controlled by all CSx inputs.

Backlighting is a strong drive, active low output and it goes low if any button is touched. This pin is disabled if analog voltage support is disabled.

3.1.12 CS0 Sensitivity (CS0Sensitivity Pin)

The capacitive sense input CS0 can be used for special functions in a design. Unlike other inputs, CS0's sensitivity and debounce settings are configurable. For example, if CS0 is being used as the system power button it needs to be less sensitive to avoid falsely switching the power ON and OFF.

The configuration for CS0Sensitivity is shown in Table 3-5.

Table 3-5. CS0Sensitivity Pin Configuration

CS0Sensitivity Pin Connection	CS0Sensitivity	CS0 Debounce
Ground / Floating[4]	High	3
1.5 kΩ (±5%) resistor to ground	High	24
5.1 kΩ (±5%) resistor to ground	High	48
V_{DD}	Low	99

3.1.13 CS0 Debounce (CS0Sensitivity Pin)

Debounce avoids false button triggering from noise spikes or system glitches, by specifying the minimum time a CS0 has to be touched for a valid touch input. CS0's debounce time can vary depending on the button's function. For example, the power button should have a long debounce time to avoid inadvertently switching the system ON/OFF. Shorter debounce times speed up the device's response to a button touch.

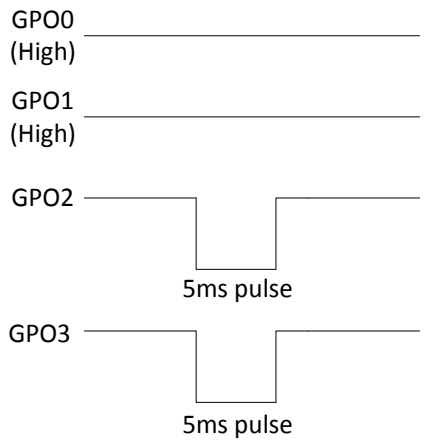
Configurable debounce can provide added functionality to the design. For example, a system may reset when a particular button is touched for a specific time. In such a case, CS0 can be used with the highest debounce value, to provide that functionality. Such functionalities can be implemented at the user end applications.

The configuration for CS0 Debounce is shown in Table 3-5.

3.1.14 System Diagnostics

A built-in Power-on Self Test (POST) mechanism performs five tests at power-on reset (POR), which can be useful in production testing. If any button fails, a 5 ms pulse is sent out on the corresponding GPO within 350 ms if Noise Immunity is "Normal" or 1000 ms if Noise Immunity is "High" as shown in Figure 3-13**Error! Reference source not found.**.

Figure 3-13. Example Showing CS0, CS1 Passing the POST and CS2, CS3 Failing

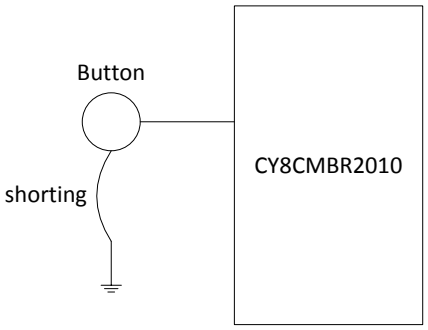


[4] Floating is not recommended in high noise environment, except for LEDFading pin.

3.1.14.1 Button Shorted to Ground

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

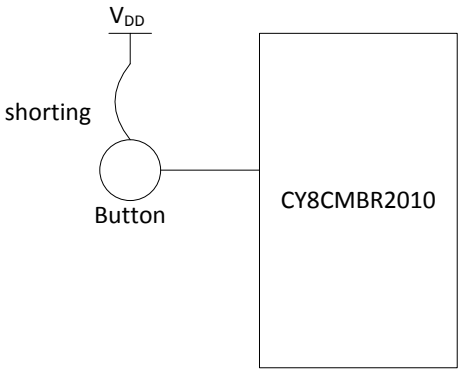
Figure 3-14. Button Shorted to Ground



3.1.14.2 Button Shorted to V_{DD}

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

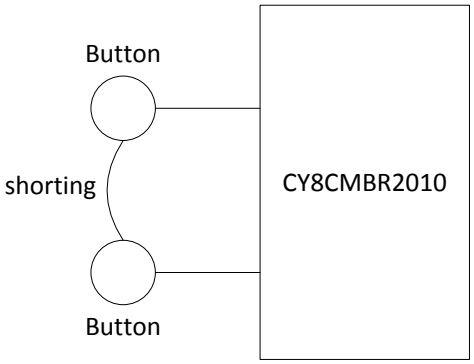
Figure 3-15. Button Shorted to V_{DD}



3.1.14.3 Button to Button Short

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

Figure 3-16. Button to Button Short



3.1.14.4 Improper Value of C_{MOD}

Recommended value of C_{MOD} is 2.2 nF ±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.

3.1.14.5 Button C_P > 40 pF

If any button's C_P is found to be more than 40 pF, that button is disabled.

3.1.15 Button Scan Rate (ScanRate/Sleep Pin)

The button scan rate specifies the time between successive button scans by the device.

Button Scan Rate = Button Scan Rate constant + Button Scan Rate offset Equation 5

An external resistor on the ScanRate/Sleep pin determines the Button Scan Rate offset for the device. You can use Table 3-6 to determine the resistor value. The Button Scan Rate constant is given in Table 3-7. The button scan rate is configurable from 25—556 ms.

The button scan rate constant depends on how you optimize your design:

Response Time Optimization: The time between consecutive button scans is shorter. As more scans occur in a fixed time, the device responds more quickly to a button touch. However, power consumption increases.

Power Consumption Optimization: The time between consecutive button scans is longer. As fewer scans occur in a fixed time, the device takes longer to respond to a button touch. As a result, power consumption decreases.

As an example, consider a design with four buttons and the following parameters:

- C_P between 10—20 pF for all buttons
- Sensitivity is high for all buttons
- Noise Immunity is "Normal"
- Button touch time of 3%
- Button Scan Rate offset = 0.

The current consumption per button is:

Response Time Optimized = 0.3603 mA

Power Consumption Optimized = 0.1803 mA

The response times for first button touch as well as consecutive button touches are:

Response Time Optimized = 50 ms

Power Consumption Optimized = 100 ms

Notice that the response time optimized design consumes a lot more power and responds more quickly to a button touch when compared to the power consumption optimized design. To find the response time for your design, refer to the Design Toolbox.

Table 3-6. ScanRate/Sleep Pin Configuration versus Button Scan Rate Offset

ScanRate/Sleep Pin Connection		Button Scan Rate Offset (ms)
Response Time Optimized	**Power Consumption Optimized**	
Ground	6800 Ω (±1%) resistor to ground	0
100 Ω (±1%) resistor to ground	6900 Ω (±1%) resistor to ground	0
200 Ω (±1%) resistor to ground	7000 Ω (±1%) resistor to ground	6
300 Ω (±1%) resistor to ground	7100 Ω (±1%) resistor to ground	12
400 Ω (±1%) resistor to ground	7200 Ω (±1%) resistor to ground	20
500 Ω (±1%) resistor to ground	7300 Ω (±1%) resistor to ground	29
600 Ω (±1%) resistor to ground	7400 Ω (±1%) resistor to ground	39
700 Ω (±1%) resistor to ground	7500 Ω (±1%) resistor to ground	49

ScanRate/Sleep Pin Connection		Button Scan Rate Offset (ms)
Response Time Optimized	**Power Consumption Optimized**	
800 Ω (±1%) resistor to ground	7600 Ω (±1%) resistor to ground	61
900 Ω (±1%) resistor to ground	7700 Ω (±1%) resistor to ground	73
1000 Ω (±1%) resistor to ground	7800 Ω (±1%) resistor to ground	86
1100 Ω (±1%) resistor to ground	7900 Ω (±1%) resistor to ground	99
1200 Ω (±1%) resistor to ground	8000 Ω (±1%) resistor to ground	114
1300 Ω (±1%) resistor to ground	8100 Ω (±1%) resistor to ground	128
1400 Ω (±1%) resistor to ground	8200 Ω (±1%) resistor to ground	144
1500 Ω (±1%) resistor to ground	8300 Ω (±1%) resistor to ground	160
1600 Ω (±1%) resistor to ground	8400 Ω (±1%) resistor to ground	176
1700 Ω (±1%) resistor to ground	8500 Ω (±1%) resistor to ground	194
1800 Ω (±1%) resistor to ground	8600 Ω (±1%) resistor to ground	211
1900 Ω (±1%) resistor to ground	8700 Ω (±1%) resistor to ground	229
2000 Ω (±1%) resistor to ground	8800 Ω (±1%) resistor to ground	248
2100 Ω (±1%) resistor to ground	8900 Ω (±1%) resistor to ground	267
2200 Ω (±1%) resistor to ground	9000 Ω (±1%) resistor to ground	287
2300 Ω (±1%) resistor to ground	9100 Ω (±1%) resistor to ground	307
2400 Ω (±1%) resistor to ground	9200 Ω (±1%) resistor to ground	327
2500 Ω (±1%) resistor to ground	9300 Ω (±1%) resistor to ground	348
2600 Ω (±1%) resistor to ground	9400 Ω (±1%) resistor to ground	369
2700 Ω (±1%) resistor to ground	9500 Ω (±1%) resistor to ground	391
2800 Ω (±1%) resistor to ground	9600 Ω (±1%) resistor to ground	413
2900 Ω (±1%) resistor to ground	9700 Ω (±1%) resistor to ground	436
3000 Ω (±1%) resistor to ground	9800 Ω (±1%) resistor to ground	459
3100 Ω (±1%) resistor to ground	9900 Ω (±1%) resistor to ground	482
3200 Ω (±1%) resistor to ground	10000 Ω (±1%) resistor to ground	506

Table 3-7. Button Scan Rate Constant

Button Count	Button Scan Rate Constant (ms)	
	Response Time Optimized	**Power Consumption Optimized**
≤5	25	50
>5	50	50

Button scan rate varies from device to device, and it is ±25% accurate (excluding resistor tolerance) at a temperature range of -40 °C to +85 °C.

3.1.16 Sleep Modes (ScanRate/Sleep Pin)

There are two possible configurations:

1. Connect the ScanRate/Sleep pin to ground. This enables low power sleep mode
2. Connect the ScanRate/Sleep pin to V_{DD}. This enables deep sleep mode.

Further details are in the Sleep Modes section.

3.1.17 Serial Debug Data Out (Delay Pin)

Serial debug data reports firmware revision, CapSense status, GPO status, System Diagnostics data, compensated IDAC, raw counts, baseline, difference counts, parasitic capacitance, and SNR for all buttons. When serial debug data is enabled this information is output on the Delay pin. This feature can be used by the host controller to read the CapSense status when there are not enough host pins available to interface with all of the GPOs. This feature is enabled using a resistor connected between the Delay pin and ground as described in Equation 4 and Table 3-3.

The Cypress MultiChart Tool can be used to view the data. The serial debug data is sent by the device in the order according to Table 3-8. The MultiChart tool arranges the data in the format as shown in Table 3-9.

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

Table 3-8. Serial Debug Data Output sent by CY8CMBR2010

Byte	Data	Notes
0	0x0D	Dummy data for multi chart
1	0x0A	
2	0x80	–
3	FW Revision	Firmware Revision
4	CS0_Cp	CS0 parasitic capacitance (pF) in Hex
5	CS1_Cp	CS1 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	
24	CS9_RawCount_MSB	Unsigned 16-bit integer
25	CS9_RawCount_LSB	
26	CS2_Cp	CS2 parasitic capacitance (pF) in Hex
27	CS3_Cp	CS3 parasitic capacitance (pF) in Hex
28	0x00	–
29	CS0_CS1_SNR	CS0 and CS1 SNR
30	0x00	–
31	CS2_CS3_SNR	CS2 and CS3 SNR
32	VDD_Short_Mask_MSB	System Diagnostics data for CS pins shorted to V_{DD}
33	VDD_Short_Mask_LSB	
34	0x00	–
35	0x01	
36	0x00	
37	CS_Status_MSB	Gives CS status for CS8—CS9
38	0x00	–
39	CS_Status_LSB	Gives CS status for CS0—CS7
40	CS0_Baseline_MSB	Unsigned 16-bit integer
41	CS0_Baseline_LSB	

Byte	Data	Notes
42	CS1_Baseline_MSB	Unsigned 16-bit integer
43	CS1_Baseline_LSB	
58	CS9_Baseline_MSB	Unsigned 16-bit integer
59	CS9_Baseline_LSB	
60	CS4_Cp	CS4 parasitic capacitance (pF) in Hex
61	CS5_Cp	CS5 parasitic capacitance (pF) in Hex
62	CS6_Cp	CS6 parasitic capacitance (pF) in Hex
63	CS4_CS5_SNR	CS4 and CS5 SNR
64	0x00	–
65	CS6_CS7_SNR	CS6 and CS7 SNR
66	GND_Short_Mask_MSB	System Diagnostics data for CS pins shorted to GND
67	GND_Short_Mask_LSB	
68	0x00	–
69	0x02	
70	IDAC_Comp	Compensated IDAC
71	GPO_Status_Mask_MSB	Gives GPO status for GPO8—GPO9
72	0x00	–
73	GPO_Status_Mask_LSB	Gives GPO status for GPO0—GPO7
74	CS0_DiffCount_MSB	Unsigned 16-bit integer
75	CS0_DiffCount_LSB	
76	CS1_DiffCount_MSB	Unsigned 16-bit integer
77	CS1_DiffCount_LSB	
92	CS9_DiffCount_MSB	Unsigned 16-bit integer
93	CS9_DiffCount_LSB	
94	CS7_Cp	CS7 parasitic capacitance (pF) in Hex
95	CS8_Cp	CS8 parasitic capacitance (pF) in Hex
96	CS9_Cp	CS9 parasitic capacitance (pF) in Hex
97	CS8_CS9_SNR	CS8 and CS9 SNR
98	0x00	–
99	CMOD_Mask	System Diagnostics data for C_{MOD} out of range
100	Pin_to_Pin_shorted_Mask_MSB	System Diagnostics data for CS pin to pin short
101	Pin_to_Pin_shorted_Mask_LSB	
102	Cp_High_Mask_MSB	System Diagnostics data for CS button Cp > 40 pF
103	Cp_High_Mask_LSB	
104	0x00	Dummy data for MultiChart
105	0xFF	
106	0xFF	

Table 3-9. Serial Debug Data Arranged in MultiChart

#	Raw Count Array		Baseline Array		Signal array	
	MSB	LSB	MSB	LSB	MSB	LSB
0	0x80	FW Revision	0x00	CS_status_MSB	IDAC_Comp	GPO_Status_MSB
1	CS0_Cp	CS1_Cp	0x00	CS_status_LSB	0x00	GPO_Status_LSB
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	
6	CS4_RawCount		CS4_Baseline		CS4_DiffCount	
7	CS5_RawCount		CS5_Baseline		CS5_DiffCount	
8	CS6_RawCount		CS6_Baseline		CS6_DiffCount	
9	CS7_RawCount		CS7_Baseline		CS7_DiffCount	
10	CS8_RawCount		CS8_Baseline		CS8_DiffCount	
11	CS9_RawCount		CS9_Baseline		CS9_DiffCount	
12	CS2_Cp	CS3_Cp	CS4_Cp	CS5_Cp	CS7_Cp	CS8_Cp
13	0x00	CS0_CS1_SNR	CS6_Cp	CS4_CS5_SNR	CS9_Cp	CS8_CS9_SNR
14	0x00	CS2_CS3_SNR	0x00	CS6_CS7_SNR	0x00	CMOD_Mask
15	VDD_Short_Mask		GND_Short_Mask		Pin_to_Pin_Short_Mask	
16	0x00	0x01	0x00	0x02	Cp_High_Mask	

System Diagnostics data contains the POST results. This is as follows:

- VDD_Short_Mask: This contains the information about any button short to V_{DD}.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
VDD_Short_Mask_LSB	CS7	CS6	CS5	CS4	CS3	CS2	CS1	CS0
VDD_Short_Mask_MSB							CS9	CS8

For CSx, the corresponding bit is written as:

0 If the CSx is not shorted to V_{DD}

1 If the CSx is shorted to V_{DD}

- GND_Short_Mask: This contains the information about any button short to Ground.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GND_Short_Mask_LSB	CS7	CS6	CS5	CS4	CS3	CS2	CS1	CS0
GND_Short_Mask_MSB							CS9	CS8

For CSx, the corresponding bit is written as:

0 If the CSx is not shorted to ground

1 If the CSx is shorted to ground

- CMOD_Mask: This contains the information about the C_{MOD} value within range. This byte is written as:
  - 0 If the C_{MOD} value is within range (1—4 nF)
  - 1 If the C_{MOD} value > 4 nF
  - 2 If the C_{MOD} value < 1 nF
- Pin_to_Pin_Short_Mask: This contains the information about any button to button short.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Pin_to_Pin_Short_Mask_LSB	CS7	CS6	CS5	CS4	CS3	CS2	CS1	CS0
Pin_to_Pin_Short_Mask_MSB							CS9	CS8

For CSx, the corresponding bit is written as:

- 0 If the CSx pin is not shorted to any other CSy pin
- 1 If the CSx pin is shorted to another CSy pin

- Cp_High_Mask: This contains the information about the CS button C_P value within range.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Cp_High_Mask_LSB	CS7	CS6	CS5	CS4	CS3	CS2	CS1	CS0
Cp_High_Mask_MSB							CS9	CS8

For CSx, the corresponding bit is written as:

- 0 If the CSx C_P value < 40 pF
- 1 If the CSx C_P value > 40 pF

3.2 Design Toolbox

The Design Toolbox helps you to design a CY8CMBR2010 CapSense solution. It offers basic information about the board layout and feature settings and recommends whether the design is fit for mass production.

3.2.1 General Layout Guidelines

Table 3-10 summarizes the layout guidelines for the CY8CMBR2010. These guidelines are discussed in Electrical and Mechanical Design Considerations. For a thorough treatment of this material, see Getting Started with CapSense.

Table 3-10. 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	5 mm	15 mm	Given in Layout Estimator sheet
3.	Button-button spacing	equal to button ground clearance		8 mm
4.	Button-ground clearance	0.5 mm	2 mm	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 mm	450 mm is for FR4 PCB, with a button diameter of 5 mm and a pin capacitance of 7 pF. For a different design, refer to 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 the 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.	Number of via on sensor trace	1	2	1
13.	CapSense series resistor placement		10 mm	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 the sensor. The CapSense trace length between the device and the 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, 2nd Layer – CapSense traces & Vdd and avoid the Vdd traces below the sensors, 3rd Layer-hatched ground, Bottom layer- device other components and non CapSense traces
18.	Overlay thickness	0 mm	5 mm	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 backlighting			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.

3.2.2 Layout Estimator

The Layout Estimator provides minimum button size and maximum trace length recommendations based on the intended end-system requirements and industrial design. The inputs include the overlay material, overlay thickness, trace capacitance of circuit board material, whether CS0 is used in the design, and if so, its sensitivity. Figure 3-17, Table B, lists the dielectric constants for different overlay materials as well as 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 system noise conditions. “Low”, “Medium”, and “High” noise conditions are relative figures of merit to help you with button development. Noise conditions can vary from button to button based on the end-system environment. If the noise conditions are unknown, use “Medium” as a starting point. The actual noise for each button will be determined during Design Validation .

Use the outputs of this sheet to guide your button board layout process, and then check the design prior to prototyping using the CP, Power Consumption, and Response Time Calculator.

Figure 3-17. Layout Estimator

TableA- Estimator

Input Parameters	Value	Units	Comments
Overlay Thickness	1.5	mm	
Overlay - Dielectric constant	8	farad/m	
Capacitance of trace per inch	2	pF	
Is CS0 used in design	No		The CapSense button, CS0, can be used for special purpose functions in a design. Unlike other buttons, CS0 sensitivity and debounce values are configurable. As an example usage, the power button needs to be less sensitive and have higher debounce value than the other buttons, to avoid false switch ON/OFF of the device. Use CS0 here.
CS0 Sensitivity (if CS0 used)	Low		If the power consumption is critical, select "Low" sensitivity. If the board form factor is critical, select "High" sensitivity.
Minimum Recommended Button Diameter (based on minimum 0.25pF Finger response)			
CS1 - CS9			
Noise Conditions - Low (0.05 pF Noise)	5	mm	
Noise Conditions - Medium (0.075 pF Noise)	5	mm	
Noise Conditions - High (0.1 pF Noise)	5	mm	
CS0			
Noise Conditions - Low (0.05 pF Noise)	5	mm	
Noise Conditions - Medium (0.075 pF Noise)	5	mm	
Noise Conditions - High (0.1 pF Noise)	6	mm	
Maximum Trace length			
CS1 - CS9			
Noise Conditions - Low (0.05 pF Noise)	412	mm	
Noise Conditions - Medium (0.075 pF Noise)	412	mm	
Noise Conditions - High (0.1 pF Noise)	412	mm	
CS0			
Noise Conditions - Low (0.05 pF Noise)	412	mm	
Noise Conditions - Medium (0.075 pF Noise)	412	mm	
Noise Conditions - High (0.1 pF Noise)	406	mm	
Button to Ground clearance	1.5	mm	

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

Note: Button diameter of all the buttons CS1 to CS9 will be same with respect to overlay thickness, but can differ with respect to noise 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
- Is CS0 used in design
- If CS0 is used, its sensitivity

Outputs

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

The diameter of each button can differ based on whether the noise varies from button to button.

3.2.3 C_P, Power Consumption, and Response Time Calculator

After board layout is complete, use the Power Consumption and Response Time Calculator to check your design before building a prototype, as shown in Figure 3-18. To verify the C_P 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_P range of 5—40 pF.

The power calculator in Table B is used to optimize power consumption. Power consumption is a function of the button scan rate, noise immunity level, and the percentage of time the finger is on the button. See Button Scan Rate, Table 3-6, and Table 3-7.

Table C outputs the button response time based on the inputs in Tables A and B. CS0's debounce value affects its response time.

Figure 3-18. C_P, 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	
CS4		mm		mm	0	pF	
CS5		mm		mm	0	pF	
CS6		mm		mm	0	pF	
CS7		mm		mm	0	pF	
CS8		mm		mm	0	pF	
CS9		mm		mm	0	pF	
Total No of buttons	0	Nos					

Table B: Power calculator

Select Scan Rate resistor value	0	ohms
Approximate Button Scan Rate value	25	ms
% of time finger is on the sensors	5	%
Select Noise Immunity level	High	
Select CS0 Debounce value, if CS0 used	99	
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

CS0 First button press	850	ms
CS0 Consecutive button press	850	ms
CS1-CS9 First button press	50	ms
CS1-CS9 Consecutive button press	50	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—CS9 as designed in layout
- Scan rate resistor value
- The percentage of time a finger is on the buttons
- Noise Immunity level
- CS0 debounce value (if CS0 used in design)

Outputs

- Parasitic capacitance (C_P) for each button. Confirms whether the C_P values are within the specified range of 5—40 pF
- Power consumption per button
- Button response time

3.2.4 Design Validation

After you have built and tested your prototype board, you can use Serial Debug Data Out test mode to capture the raw count, noise count, and C_P for each of the buttons. You can then enter this information into Table C of the Design Validation Sheet shown in Figure 3-19 to validate your design

Figure 3-19. Design Validation

Table A: Actual Design values

Input Parameters	Initial value	New value	Units
Overlay Thickness (in mm)	1.5		mm
Dielectric constant, overlay	8		farad/m
Capacitance of trace per inch in pF	2		pF
Is CS0 used in design	No	No	
CS0 sensitivity (if CS0 used)	Low		
Scan Rate Resistor	0		ohms
Button Scan Rate Value	25		ms
No of buttons	0	0	Nos
% of time finger is on the sensors	5		%
Noise Immunity Level	High		
CS0 Button diameter actual			mm
CS1 Button diameter actual			mm
CS2 Button diameter actual			mm
CS3 Button diameter actual			mm
CS4 Button diameter actual			mm
CS5 Button diameter actual			mm
CS6 Button diameter actual			mm
CS7 Button diameter actual			mm
CS8 Button diameter actual			mm
CS9 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

	input cells, edit with actuals
	output cells, based on inputs
	constant cells, same as previous 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.

Table C: 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
CS3	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
CS4	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
CS5	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
CS6	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
CS7	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
CS8	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
CS9	0	counts	0	pF	0	counts	0	mA	0	mm		0 mm
			Actual average current consumption				0	mA				

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

To capture and enter the data use the following steps:

1. Enable the Serial Debug Data Out feature by connecting a resistor (7—10 kΩ) to ground on the Delay pin.
2. Power on the device and connect the Delay pin to the computer through a COM/RS232 port.
3. Open MultiChart (see AN2397, CapSense Data Viewing Tools) and cofigure the following:
   a. Select PORT = <Specify Port number>
   b. Port Speed = 115200
   c. Visible points = 1000
   d. Log file name = "C:\Program Files\Cypress\CY8CMBR2010.csv"
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.

Inputs

- Raw Counts
- Noise Counts
- Button C_P
- If the design fails, note the following:
  - ☐ New overlay thickness, overlay material permittivity, and button diameter for each individual button, and trace capacitance
  - ☐ Scan rate resistor value used in the design
  - ☐ Percentage of time a finger is on the buttons
  - ☐ If CS0 is used in design enter CS0 sensitivity
  - ☐ Noise Immunity Level

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 offer recommendations to guide you to a passing outcome. You can change four areas 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, thickness, or both, may result in a passing design. The best solution depends on where your design is in the development cycle as well as your end-system requirements.

4. Electrical and Mechanical Design Considerations

When designing a capacitive touch sense technology into your application, it is crucial to remember 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.

4.1 Overlay Selection

In CapSense Fundamentals, Equation 1 describes finger capacitance:

$$C_F = \frac{\varepsilon_0 \varepsilon_r A}{D}$$

Where:

ε_0 = Free space permittivity

ε_r = Dielectric constant of overlay

A = Area of finger and button 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 CY8CMBR2010 solution, as discussed in the chapter CapSense Schematic Design.

Table 4-1. Overlay Material Dielectric Strength

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

4.1.1 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 air 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).

4.2 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 damaging 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 that are required to protect the CapSense buttons 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, then clamp.

4.2.1 Prevent

Make sure all paths on the touch surface have a breakdown voltage greater than potential high-voltage contacts. Also, 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 can withstand 18 kV.

4.2.2 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, providing a hatched ground plane around the button or slider can redirect the ESD event away from the button and CapSense controller.

4.2.3 Clamp

Because CapSense buttons 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 Ω.

A more effective method is to provide special-purpose ESD protection devices on the vulnerable traces. 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				
Littelfuse	SP723	5 pF	2 nA	8 kV	15 kV
Vishay	VBUS05L1-DD1	0.3 pF	0.1 µA	±15 kV	±16 kV
NXP	NUP1301	0.75 pF	30 nA	8 kV	15 kV

4.3 Electromagnetic Compatibility (EMC) Considerations

4.3.1 Radiated Interference

Radiated electrical energy can influence system measurements and the operation of the processor core. The interference enters the CY8CMBR2010 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 include:

- **Ground Plane**: providing a ground plane on the PCB.
- **Series Resistor**: series resistors should be placed within 10 mm of the CapSense controller pins
  - The recommended series resistance for CapSense input lines is 560 Ω.
- **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.

4.3.2 Conducted Immunity and Emissions

Noise entering a system through interconnections with other systems is referred to as conducted noise. These interconnections 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 the conducted emission and immunity:

- Use decoupling capacitors.
- Add a bidirectional filter on the input connected to the system power supply. The filter is effective for both conducted emissions and immunity. A pi-filter can prevent power supply noise from affecting the sensitive parts, while they 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.

4.4 PCB Layout Guidelines

The Design Toolbox will help you design a robust CY8CMBR2010 CapSense PCB layout, as discussed in the General Layout Guidelines.

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 pF ≤ C_P ≤ 12 pF	25 mA	120 mA
12 pF ≤ C_P ≤ 21 pF	20 mA	20 mA
21 pF ≤ C_P ≤ 40 pF	6 mA	6 mA

Detailed PCB layout guidelines are available in Getting Started with CapSense.

5. Low-Power Design Considerations

5.1 System Design Recommendations

Cypress's CY8CMBR2010 is designed to meet the low-power requirements for battery-powered applications.

To minimize power consumption:

- Ground all unused CapSense inputs
- Minimize C_P using the design guidelines in Getting Started with CapSense
- Lower supply voltage
- Reduce sensitivity of CS0 button, refer to CS0 Sensitivity
- Configure design to be power consumption optimized, refer to Button Scan Rate
- Use "High" noise immunity level only if required, refer to Noise Immunity
- Use a higher Button Scan Rate or Deep Sleep operating mode, refer to Button Scan Rate

5.2 Calculating Average Power

The Design Toolbox automates the power optimization calculations described in this section. The average power consumed by the CY8CMBR2010 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 use current, I_{AVE_U}
6. Average current, I_{AVE}
7. Average power, P_{AVE}

5.2.1 Button Scan Rate (T_R)

The button scan rate, T_R, is calculated using the following equation:

$$T_R = Button\ Scan\ Rate\ Constant + Button\ Scan\ Rate\ Offset$$ Equation 6

Where:

Button Scan Rate Constant: The constant is based on design optimization and is given in Table 3-7. For a response time optimized design, the button scans occur quickly, unlike power consumption optimized design.

Button Scan Rate Offset: The offest is based on the value of an external resistor placed between the CY8MBR2010's ScanRate/Sleep pin and ground. A list of offset values for different resistor values is given in Table 3-6. The range of the offset is 0—506 ms.

5.2.1.1 Response Time

Response time is the minimum time the button CSx should be touched for the device to detect a valid button touch and produce a signal on GPOx.

Response times are calculated using the following equations:

Equation 7

$$RT_{CBT} = Button\ Scan\ Rate\ constant + \left[Button\ Scan\ Rate\ constant \times \left\{Round_{down}\left((Debounce - 1)/3\right) + 1\right\}\right]$$

$$RT_{FBT} = Button\ Scan\ Rate + \left[Button\ Scan\ Rate\ constant \times \left\{Round_{down}\left((Debounce - 1)/3\right) + 1\right\}\right]$$

Where:

RT_{CBT} is Response time for consecutive button touch after first button touch

RT_{FBT} is Response time for First button touch

Debounce for CS1—CS9 = 3

Debounce for CS0 can be one of 3 / 24 / 48 / 99

$Round_{down}$ is the largest integer less than or equal to $\left(\frac{Debounce-1}{3}\right)$

5.2.2 Scan Time (T_S)

To calculate approximate scan time, use the following equation:

When Noise Immunity is “Normal”:

$$T_S = [0.375\ ms \times (K_{CS0} + K_{CS1} + K_{CS2} + \cdots + K_{CS9})] + T_{FW}$$ Equation 8

When Noise Immunity is “High”:

$$T_S = [0.375\ ms \times (K_{CS0} + K_{CS1} + K_{CS2} + \cdots + K_{CS9}) \times 3] + T_{FW}$$ Equation 9

Where:

K_{CSX} = button sensitivity constant for CSx, from Table 5-1

T_{FW} = Firmware execution time, from

Table 5-2

Table 5-1. Button Sensitivity Constant

CSx Sensitivity	CP (pF)	Button Sensitivity Constant (K)
High	Button connected to GND	0
	5 pF ≤ CP ≤ 9 pF	1
	9 pF < CP ≤ 20 pF	2
	20 pF < CP ≤ 40 pF	4
Low	Button connected to GND	0
	5 pF ≤ CP ≤ 9 pF	0.5
	9 pF < CP ≤ 20 pF	1
	20 pF < CP ≤ 40 pF	2

Table 5-2. Average Current Parameters

Parameter	Typ	Max
T_{FW}	6.00 ms	6.50 ms
T_S	From Equation 7	+5% from TYP value
T_R	From Equation 5	±10 from Value
I_{SLEEP}	1.07 µA	1.50 µA
I_{ACTIVE}	3.4 mA	4.00 mA

5.2.3 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 10

Where:

T_R = button scan rate

T_S = scan time

I_{SLEEP} = current consumed by CY8CMBR2010 during low-power sleep mode, from

Table 5-2

I_{ACTIVE} = current consumed by CY8CMBR2010 during active operation, from

Table 5-2

5.2.4 Average Current in TOUCH State (I_{AVE_T})

$$I_{AVE\_T} = \left(\frac{C_{BS} - T_S}{C_{BS}} \times I_{SLEEP}\right) + \left(\frac{T_S}{C_{BS}} \times I_{ACTIVE}\right)$$ Equation 11

Where:

T_S = scan time

C_{BS} = button scan rate constant, from Table 3-7

I_{SLEEP} = current consumed by CY8CMBR2010 during low-power sleep mode, from Table 5-2

I_{ACTIVE} = current consumed by CY8CMBR2010 during active operation, from Table 5-2

5.2.5 Average Use Current (I_{AVE_U})

$$I_{AVE\_U} = \left(\frac{100-P}{100} \times I_{AVE\_NT}\right) + \left(\frac{P}{100} \times I_{AVE\_T}\right)$$ Equation 12

Where

P = percentage of time CapSense button CSx is in the TOUCH state compared to total time CY8CMBR2010 is ON

I_{AVG_NT} = average current in the NO TOUCH state

I_{AVG_T} = average current in the TOUCH state

5.2.6 Average Current (I_{AVE})

$$I_{AVE} = \left[I_{AVE\_U} \times \left(\frac{T_{SA}}{T_{DS}+T_{SA}}\right)\right] + 0.1\ \mu A$$ Equation 13

Where:

T_{SA} = time device is not in deep sleep mode

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

5.2.7 Average Power (P_{AVE})

$$P_{AVE} = V_{DD} \times I_{AVE}$$ Equation 14

Where:

I_{AVE} = average current

V_{DD} = supply voltage

5.2.8 Example Calculation

As an example of how to calculate average power, consider a CapSense user interface with eight well-designed buttons and the following parameters:

- C_P for all eight buttons is between 10—20 pF
- Sensitivity of each button is high
- Design is response time optimized
- Noise Immunity is “Normal”
- Button scan rate offset is set to 506 ms by connecting the ScanRate/Sleep pin to ground through a 3.2 kΩ resistor

The Button scan rate constant can be obtained from Table 3-7:

$C_{BS} = 50\ ms$

The button scan rate is calculated using Equation 7:

$T_R = 50 + 506 = 556\ ms$

The scan time can be calculated from Equation 9, with the button sensitivity constant obtained from Table 5-1, and the typical value for firmware execution time from Table 5-2:

$T_S = [0.375 \times (8 \times 2)] + 6.00 = 12.0\ ms$

The average current in NO TOUCH state is calculated using Equation 11 and the maximum values for I_{SLEEP} and I_{ACTIVE} from Table 5-2:

$$I_{AVE\_NT} = \left(\frac{556-12}{556} \times 1.50\ \mu A\right) + \left(\frac{12}{556} \times 4.0\ mA\right) = 87.79\ \mu A$$

The average current in TOUCH state is calculated using Equation 12.

$$I_{AVE\_T} = \left(\frac{50-12}{50} \times 1.50\ \mu A\right) + \left(\frac{12}{50} \times\ 4.0\ mA\right) = 961.14\ \mu A$$

The average current is calculated using Equation 13. For this calculation, assume the user touches a CapSense button for three seconds every minute. This means your design operates in a TOUCH state about 5% of the day during which the device is turned on.

$$I_{AVE\_U} = \left(\frac{100-5}{100} \times\ 87.79\ \mu A\right) + \left(\frac{5}{100} \times\ 961.14\ \mu A\right) = 131.46\ \mu A$$

Average power is calculated using Equation 15. For this calculation, assume the design does not utilize deep sleep mode and operates at 1.71 V.

$$P_{AVE} =\ 1.71 \times 131.46\ \mu A = 224.80\ \mu W$$

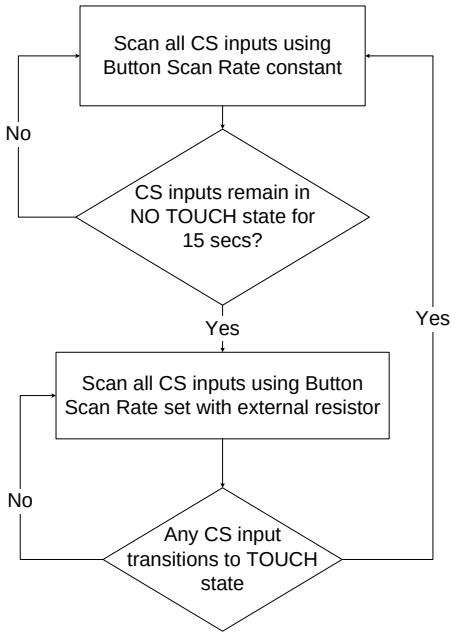
5.3 Sleep Modes

Cypress's CY8CMBR2010 can be configured to operate in either low-power or deep sleep mode. These modes reduce the power consumption of the device.

5.3.1 Low-Power Sleep Mode

The behavior of CY8CMBR2010 controller in low-power sleep mode is described in Figure 5-1.

Figure 5-1. Low-Power Sleep Mode



5.3.2 Deep Sleep Mode

If you use the CY8CMBR2010 in a system with a host processor, the ScanRate/Sleep pin can be used to operate the device in deep sleep mode.

When the host processor provides logic high to the ScanRate/Sleep pin, the CY8CMBR2010 enters deep sleep mode. In this mode all ongoing communication is suspended and the device consumes ~0.1 µA current.

To wake up from deep sleep, the ScanRate/Sleep line is pulled low by the host. After the CY8CMBR2010 wakes up from deep sleep, it operates in low-power sleep mode. After waking up, the device takes some time, called re-initialization, before button scanning resumes. During this time, any button touch is not reported. Re-initialization time is 20 ms if Noise Immunity is "Normal" or 50 ms if Noise Immunity is "High"

6. Resources

6.1 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 CY8CMBR2010 web page.

6.2 Datasheet

The datasheet for the CapSense CY8CMBR2010 device is available at www.cypress.com.

- CY8CMBR2010

6.3 Design Toolbox

Cypress has created an interactive spreadsheet, the Design Toolbox, to help you rapidly design a robust and reliable CY8CMBR2010 CapSense solution.

6.4 Design Support

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

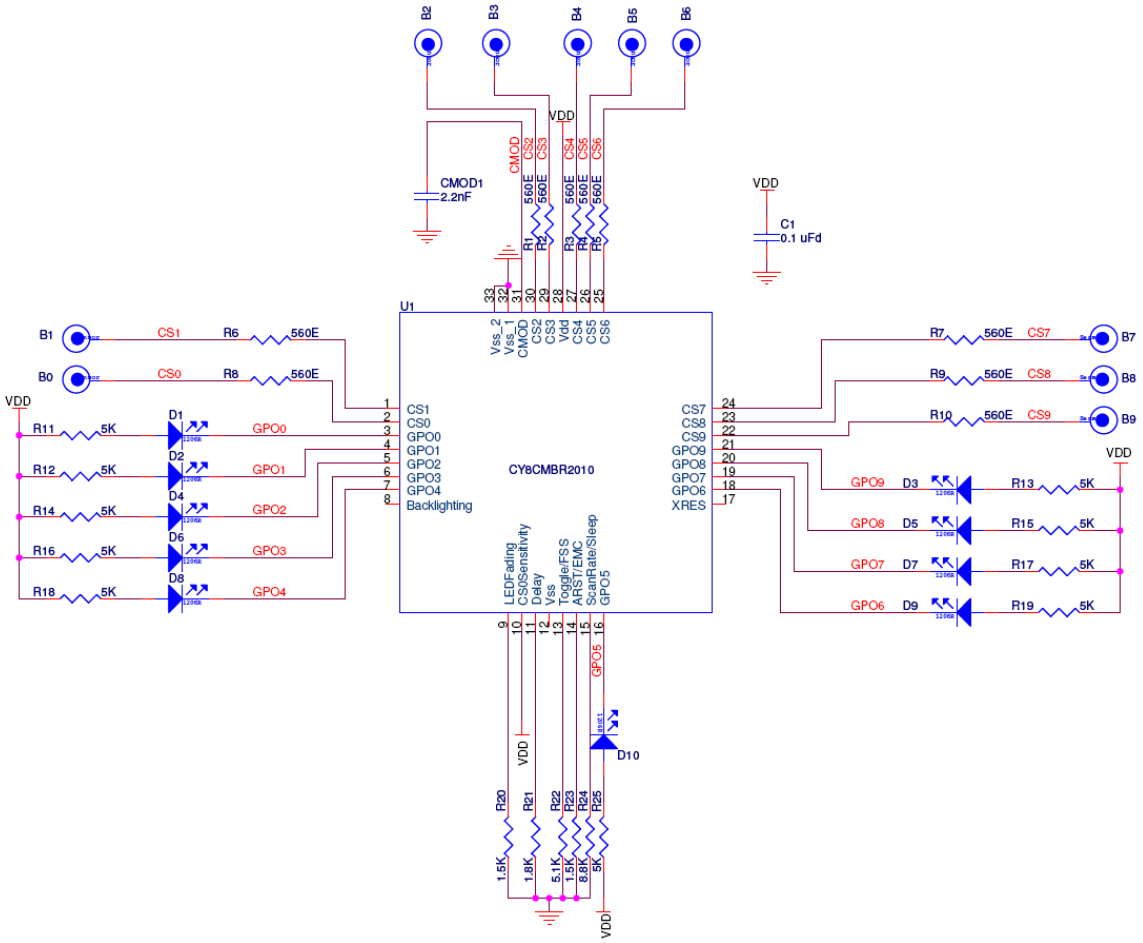
- Knowledge Based Articles –Browse technical articles by product family or perform a search on various CapSense topics.
- CapSense Application Notes – a wide variety of application notes built on information presented in this document.
- White Papers – Learn about advanced capacitive touch interface 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
- Quality & Reliability – Cypress is committed to customer satisfaction. At our Quality website, you can find reliability and product qualification reports.
- Technical Support – World-class technical support is available online.

7. Appendix

7.1 Schematic Example

7.1.1 Schematic 1: Ten Buttons and Ten GPOs

Figure 7-1. Schematic Featuring Ten Buttons and Ten GPOs



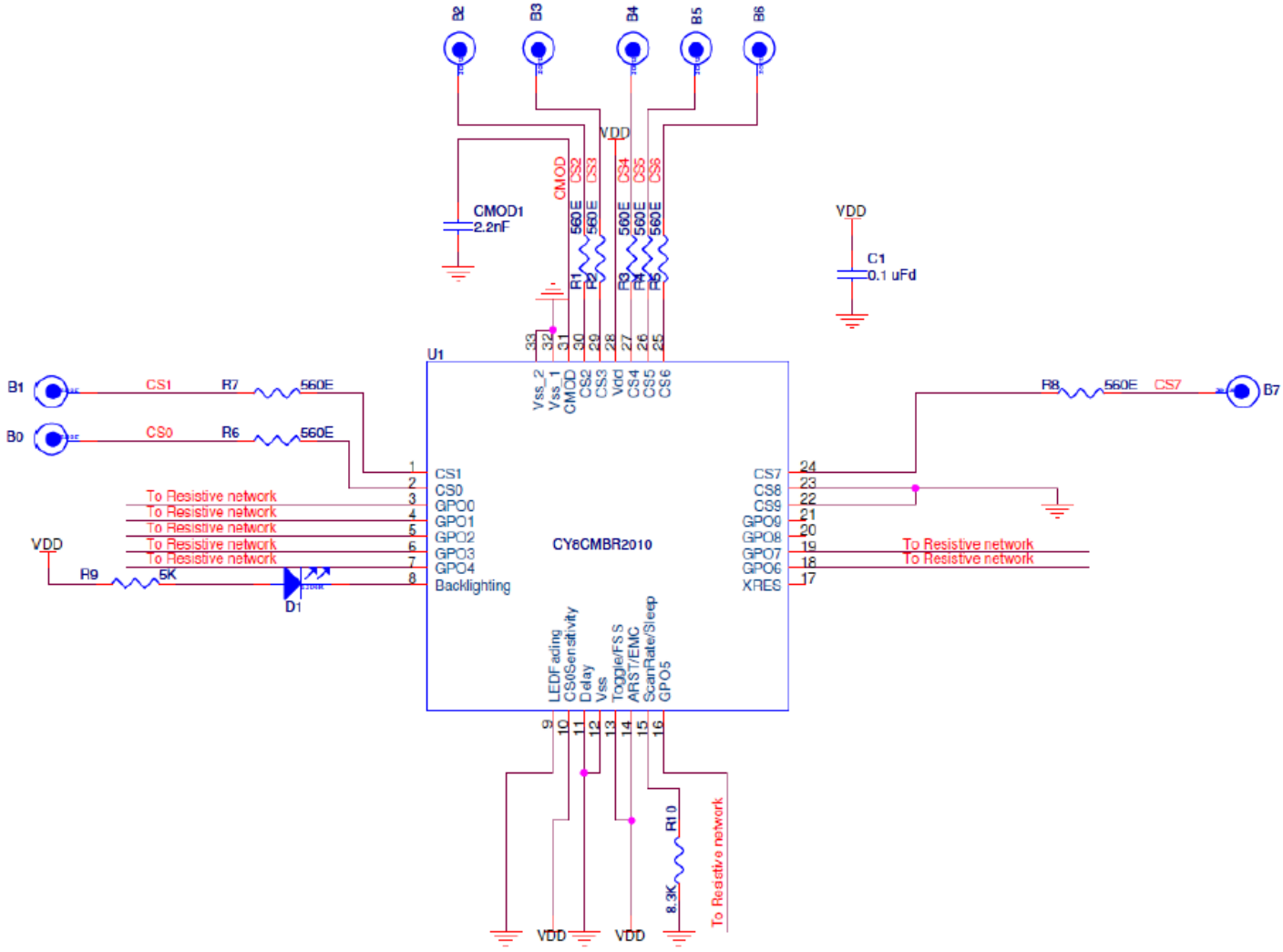
In Schematic 1, the CY8CMBR2010 is configured as follows:

- CS0—CS9 pins: 560 Ω to CapSense buttons
  - Ten CapSense buttons (CS0—CS9)
- GPO0—GPO9 pins: LED and 5 kΩ to V_{DD}
  - CapSense buttons driving ten LEDs (GPO0—GPO9)

- C_{MOD} pin: 2.2 nF to Ground
  - ☐ Modulating capacitor
- XRES pin: Floating
  - ☐ For external reset
- Toggle/FSS pin: 5.1 kΩ to Ground
  - ☐ Toggle ON/OFF disabled
  - ☐ FSS enabled
- ARST/EMC pin: 1.5 kΩ to Ground
  - ☐ Button Auto Reset enabled
  - ☐ Noise Immunity level “Normal”
- LEDFading pin: 1.5 kΩ to Ground
  - ☐ Analog Voltage Support disabled
  - ☐ Power-on LED Effects 1
- Backlighting pin: Floating
  - ☐ No LED Backlighting output, as Analog Voltage Support disabled
- Delay pin: 1.8 kΩ to Ground
  - ☐ LED ON Time = 1000 ms
  - ☐ Serial Debug Data out disabled
- CS0Sensitivity pin: V_{DD}
  - ☐ CS0 Sensitivity “Low”
  - ☐ CS0 Debounce = 99
- ScanRate/Sleep pin: 8.8 kΩ to Ground
  - ☐ Power consumption optimization
  - ☐ Button scan rate = 298 ms

7.1.2 Schematic 2: Eight Buttons and Eight GPOs

Figure 7-2. Schematic Featuring Eight Buttons and Eight GPOs



In Schematic 2, the CY8CMBR2010 is configured as follows:

- CS0—CS7 pins: 560 Ω to CapSense buttons; CS8, CS9 pins: Ground
  - Eight CapSense buttons (CS0—CS7)
  - CS8, CS9 buttons not used in design
- GPO0—GPO9 pins: Connect to external resistive network
  - Eight GPOs (GPO0—GPO7) used for Analog Voltage Output
  - GPO8, GPO9 not used in design
- C_{MOD} pin: 2.2 nF to Ground
  - Modulating capacitor
- XRES pin: Floating
  - For external reset

- Toggle/FSS pin: V_{DD}
  - ☐ Toggle ON/OFF enabled
  - ☐ FSS enabled
- ARST/EMC pin: V_{DD}
  - ☐ Button Auto Reset enabled
  - ☐ Noise Immunity level “High”
- LEDFading pin: Ground
  - ☐ Analog Voltage Support enabled
  - ☐ Power-on LED effects disabled
- Backlighting pin: LED and 5 kΩ to V_{DD}
  - ☐ LED Backlighting output, as Analog Voltage Support enabled
- Delay pin: Ground
  - ☐ LED ON Time disabled
  - ☐ Serial Debug Data out disabled
- CS0Sensitivity pin: V_{DD}
  - ☐ CS0 Sensitivity “Low”
  - ☐ CS0 Debounce = 99
- ScanRate/Sleep pin: 8.3 kΩ to Ground
  - ☐ Power consumption optimization
  - ☐ Button scan rate = 210 ms

7.2 Acronyms

Acronym	Description
AC	Alternating current
ARST	Auto Reset
C_F	Finger capacitance
C_P	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 $(2^N - 1)$/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

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Revision	**Issue Date**	**Origin of Change**	**Description of Change**
**	04/04/2012	UDYG	New Design Guide
*A	04/27/2012	GNKK	Corrected phone number in the title page
*B	09/26/2012	UDYG	Overall content update for reader clarity. Updated Table 3-8, Figure 3-17, Section 4.4, and Schematic 2. Updated hyperlinks.
*C	03/03/2014	UDYG	Added the CapSense MBR Design Toolkit. Updated document template.
*D	01/21/2016	VAIR	Added Glossary.