# CY8CMBR2016

# Capacitive Button Controllers

## Features

- Easy to use capacitive button controller
  - Hardware configurable 16-button solution
  - Easy to decode Truth table based Output mode
  - Mechanical key scan interface for backward compatibility
- Robust noise performance
  - High sensitivity, low noise capacitive sensing algorithm
  - Strong immunity to radio frequency (RF) and alternating current (AC) noise
  - Low radiated noise emission
- SmartSense™ auto tuning
  - No manual tuning required (reduces time to market)
  - All CapSense® parameters are automatically set in runtime
  - Ensures signal to noise ratio (SNR) of 5:1 or greater
  - Supports wide range of input capacitance (5 pF to 40 pF)
- Advanced features
  - Multiple sensitivity options
  - Multi touch sense (MTS) for simultaneous key detections
  - Supports three different output modes
  - Variable scan rate for power optimization
  - Configurable auto reset for stuck sensors during runtime.
  - Simplified production line testing
    - Failure mode effect analysis (FMEA) of CapSense buttons
- Wide operating range
  - 1.71 V to 5.5 V ideal for unregulated battery applications [1]
- Low power consumption
  - Supply current in run mode as low as 20 µA [2] per button
  - Deep sleep current: 100 nA
- Industrial temperature range: –40 °C to + 85 °C
- 48-pin quad flat no leads (QFN) package (6 × 6 × 0.6 mm)

## Overview

CY8CMBR2016 is designed for simple and robust implementation of user interface solution using Cypress' CapSense technology with SmartSense auto-tuning. The device supports up to 16 capacitive touch buttons that can be organized in any format, such as a matrix array. With its backward compatible key scan interface, it can enable users to achieve quick-to-market (retrofit) designs in large keypad applications such as fire alarm control panels, security systems, and door locks. Any application that requires up to 16 CapSense buttons can utilize CY8CMBR2016.

**Notes**

1. Supply variation should not be more than 5% for proper CapSense operation.
2. Power consumption calculated with 250 ms scan time, 2% touch time and Cp of each sensor < 19 pF.

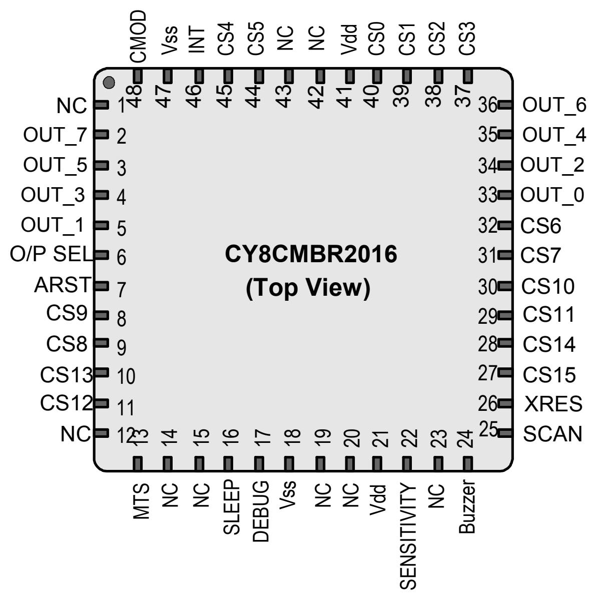
## Contents

## Pin Out

**Table 1. Pin Out for the Device**

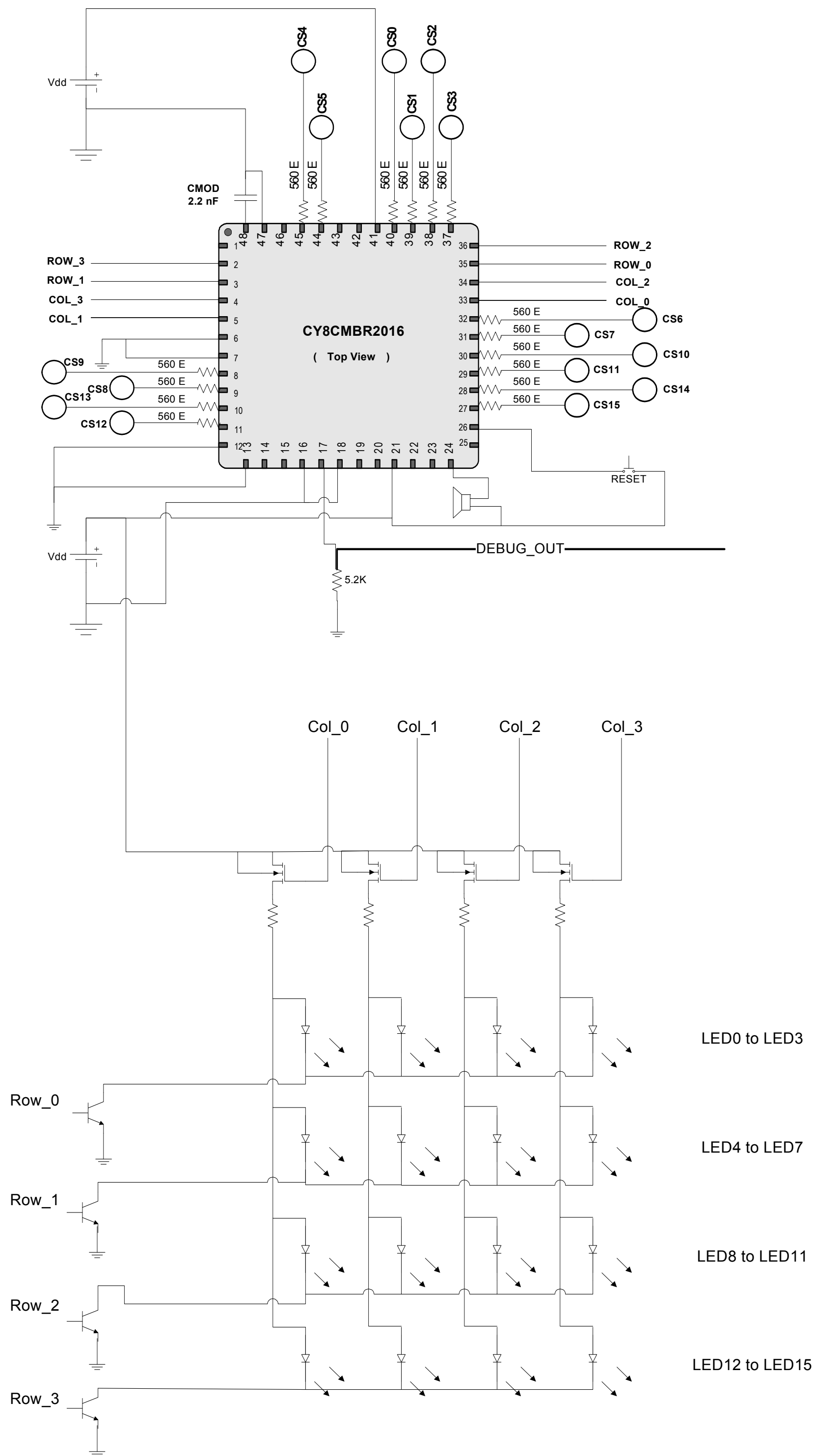
| Pin | Pin Name | Type | Description |
|---|---|---|---|
| 1 | NC | – | No connection |
| 2 | OUT_7 | DO | READ_3/TT_ROW_3/EO_3/ FMEA_CLK line - Output port interface pin 7 |
| 3 | OUT_5 | DO | READ_1/TT_ROW_1/EO_1 - Output port interface pin 5 |
| 4 | OUT_3 | DIO | SCAN_3/TT_COL_3 - Output port interface pin 3 |
| 5 | OUT_1 | DIO | SCAN_1/TT_COL_1 - Output port interface pin 1 |
| 6 | O/P SEL | AI | Selects the output interface |
| 7 | ARST | AI | Controls sensor auto reset time |
| 8 | CS9 | AI | CapSense button 9 |
| 9 | CS8 | AI | CapSense button 8 |
| 10 | CS13 | AI | CapSense button 13 |
| 11 | CS12 | AI | CapSense button 12 |
| 12 | NC | – | Reserved pin |
| 13 | MTS | DI | Selects multi touch sense feature |
| 14 | NC | – | No connection |
| 15 | NC | – | No connection |
| 16 | SLEEP | DI | Deep sleep pin of the device |
| 17 | DEBUG | DO | Debug out from the device (UART TX8 line) |
| 18 | Vss | – | GND |
| 19 | NC | – | No connection |
| 20 | NC | – | No connection |
| 21 | Vdd | – | Power supply |
| 22 | SENSITIVITY | AI | Selects the sensitivity of the CS system |
| 23 | NC | – | Reserved for shield out |
| 24 | BUZZER | DO | Connects to DC Buzzer for audio feedback |
| 25 | SCAN | AI | Controls the sleep rate of the system |
| 26 | XRES | DI | System reset pin |
| 27 | CS15 | AI | CapSense button 15 |
| 28 | CS14 | AI | CapSense button 14 |
| 29 | CS11 | AI | CapSense button 11 |
| 30 | CS10 | AI | CapSense button 10 |
| 31 | CS7 | AI | CapSense button 7 |
| 32 | CS6 | AI | CapSense button 6 |
| 33 | OUT_0 | DIO | SCAN_0/TT_COL_0 - Output port interface pin 0 |
| 34 | OUT_2 | DIO | SCAN_2/TT_COL_2 - Output port interface pin 2 |
| 35 | OUT_4 | DO | READ_0/TT_ROW_0/EO_0 - Output port interface pin 4 |
| 36 | OUT_6 | DO | READ_0/TT_ROW_0/EO_2/FMEA_DATA - Output port interface pin 6 |
| 37 | CS3 | AI | CapSense button 3 |
| 38 | CS2 | AI | CapSense button 2 |
| 39 | CS1 | AI | CapSense button 1 |
| 40 | CS0 | AI | CapSense button 0 |
| 41 | Vdd | – | Power supply |
| 42 | NC | – | No connection |
| 43 | NC | – | No connection |
| 44 | CS5 | AI | CapSense button 5 |
| 45 | CS4 | AI | CapSense button 4 |
| 46 | INT | DO | Interrupt line to Host |
| 47 | Vss | – | GND |
| 48 | CMOD | AI | CMOD capacitor, 2.2 nF |

**Figure 1. Device Pin Out**



## Typical Circuits

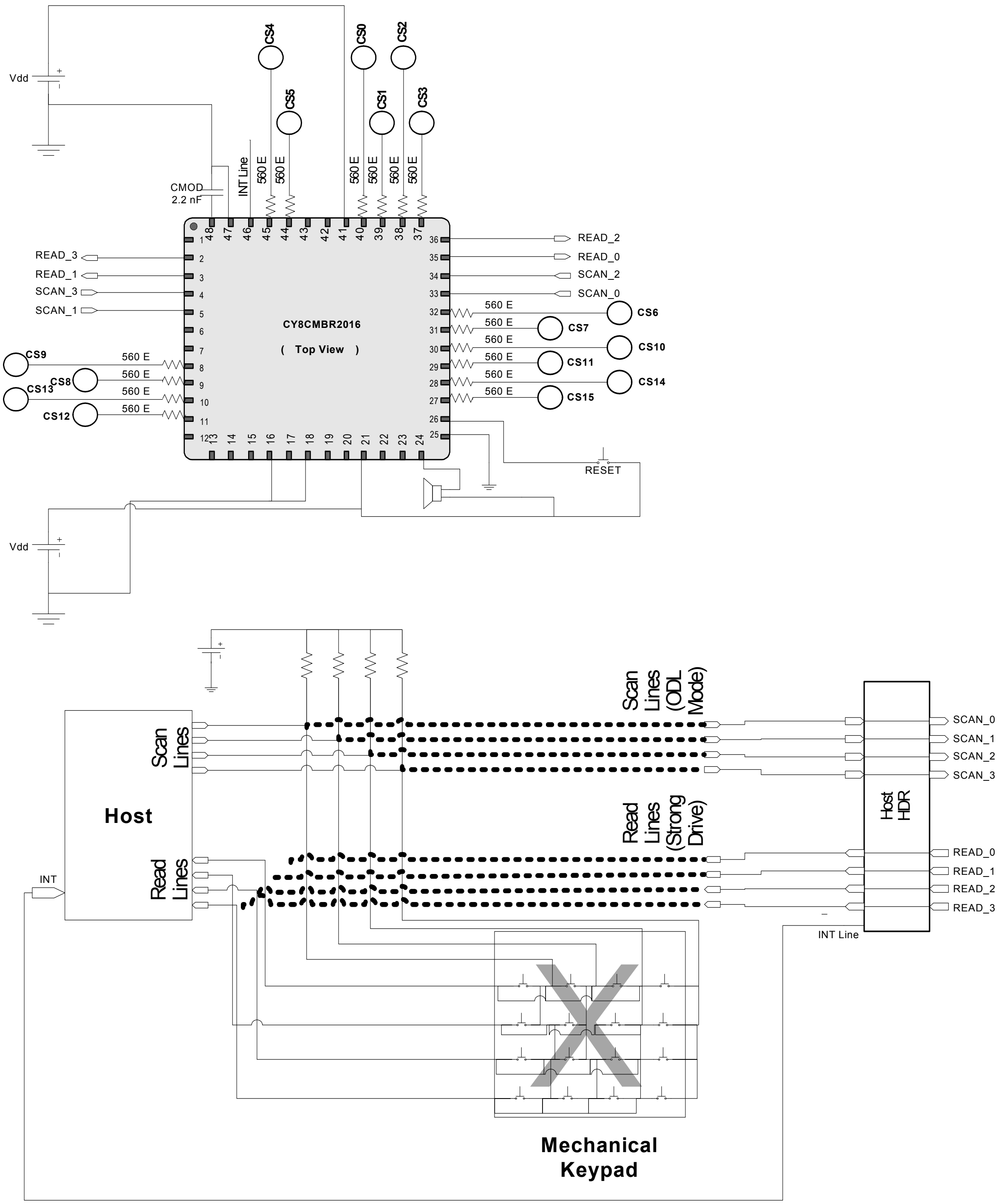
**Figure 2. Sample Schematics - Example 1**




Example 1 Configuration: Truth Table Mode + ARST 5 s + SCAN Continuous + Sensitivity 0.2 pF + MTS disabled

**Figure 3. Sample Schematics - Example 2**

Mechanical Matrix Retrofit - Key Scan mode + No auto reset + MTS enabled + Scan continuous + 0.2 pF sensitivity




Example Two Configuration: Mechanical Matrix Retrofit - Key Scan mode + No auto reset + MTS enabled + Scan continuous + 0.2 pF sensitivity.

## Device Features

**Table 2. Device Feature List**

| Feature | Description/Use |
|---|---|
| 16 CapSense buttons | Mechanical button/keypad replacement |
| Multi touch sense | Report simultaneous button touches |
| Key scan interface | Mechanical matrix replacement |
| Truth table output | Easy to decode Truth table based Output mode |
| 4 bit - Encoded output | Fewer number of Pins to output the button status |
| Sensor auto reset | Prevents sensors from getting stuck during run time |
| Scan/sleep rate | Configures the device based on power needs |
| Configurable sensitivity | Selects the sensitivity for the system – minimum change in capacitance to be detected |
| Deep sleep | Reduce power consumption by hibernating the device |
| Failure mode analysis | Supports for production testing and debugging |

### CapSense Buttons

- Device supports up to 16 CapSense Buttons.
- Ground the CSx Pin to disable CapSense input.
- 2.2 nF capacitor should be connected on CMOD pin for proper CapSense operation.

### SmartSense Auto Tuning

- Device supports auto tuning of CapSense sensor parameters.
- No manual tuning is required; all parameters are set by device automatically.
- The Parasitic Capacitance ($C_p$) of each button should be less than 40 pF for proper CapSense operation.

### Multi Touch Sense

- Enables simultaneous button touches.
- To enable the feature, connect the MTS pin to GND. Else connect to $V_{DD}$ or leave floating to disable the feature.
- When disabled, helps discriminate between closely spaced sensors
- When disabled the first sensor pressed will be reported ON till it is released, even if other sensors are pressed (Figure 4)

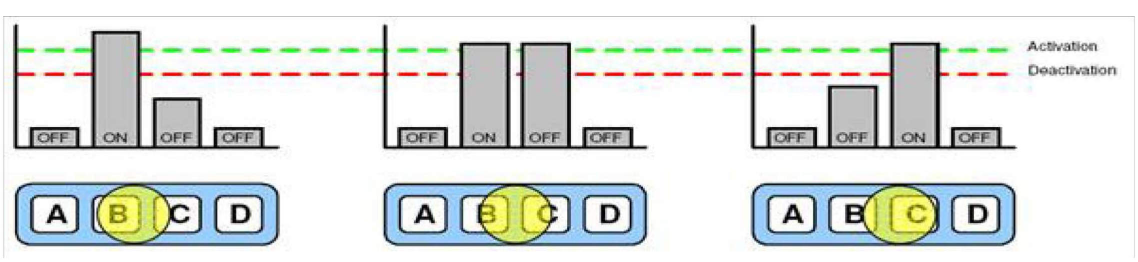
### Key Scan Interface

- Mimics legacy mechanical keypads - 4 Scan lines (I/P) and 4 read lines (O/P)
- Reads the Scan lines and updates the Read lines based on the button status
- 'Plug' n 'Play' replacement for mechanical keypads.
- When sensors are disabled or found to be invalid, Table 3 helps identifying the scan and read lines.
- When the scan lines are not used, they should be connected to $V_{DD}$
- SCAN_0 to SCAN_3 in the pin out form the SCAN lines and READ_0 to READ_3 form the READ lines
- Refer Figure 6 for scan line waveform details.

**Table 3. Key Scan interface Selection based on # of sensors**

| No. of Sensors | SCAN × READ Lines | Scan Lines |
|---|---|---|
| (>12) | 4 × 4 | SCAN 0 to 3 |
| (<=12) && (>8) | 3 × 4 | SCAN 0 to 2 |
| (<=8) && (>4) | 2 × 4 | SCAN 0 to 1 |
| (<=4) | 1 × 4 | SCAN 0 |

**Figure 4. Sensor Status** [3]




**Note**
3. When finger moves from one button to other (MTS disabled).

**Figure 5. Key Scan interface Retrofit**

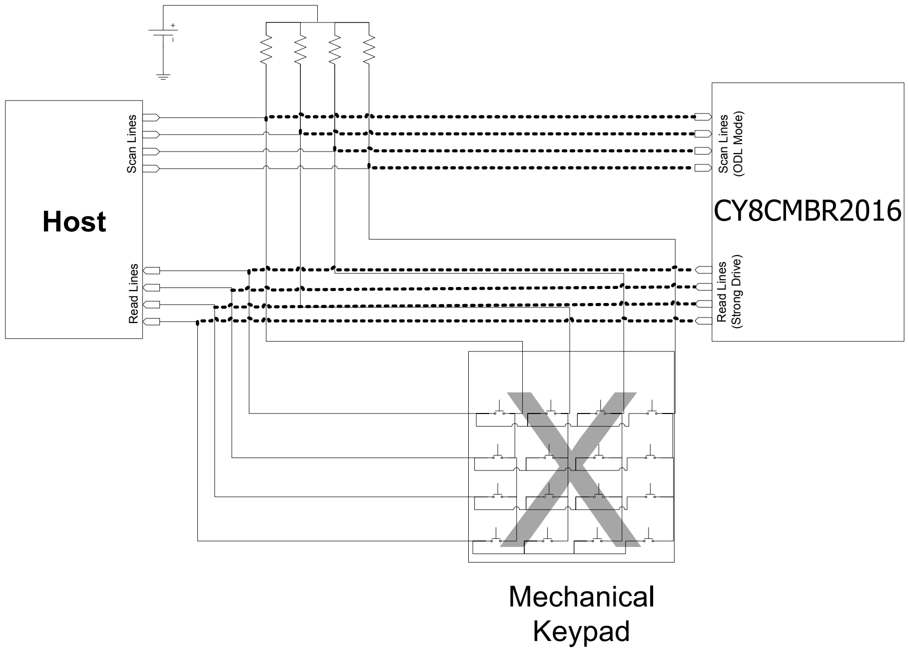
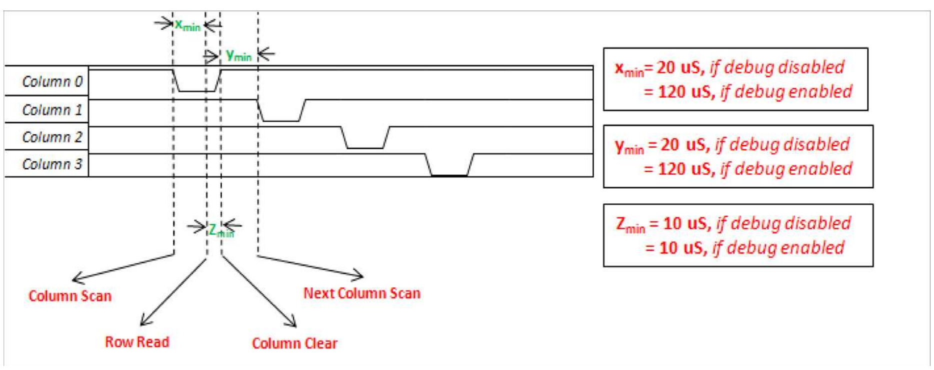



**Figure 6. SCAN Line Waveform Details**




## Truth Table Output

- Another output interface providing matrix style output.
- All pins are output pins - divided into ROW/COLUMN.
- Only one button can be reported at a time - cannot be used in conjunction with MTS enabled.
- Button status is reported in an encoded ROW/COLUMN fashion as shown in Figure 7.
- Each button has its own ROW-COLUMN code.
- Easy to integrate into a system requiring a simple interface with single key press requirement.
- TT_ROW_0 to TT_ROW_3 in the pin out form the ROW lines and TT_COL_0 to TT_COL_3 form the COLUMN lines.

**Figure 7. Truth Table Output**

| 4x4 | Matrix Code | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Buttons | Rows 3 | Rows 2 | Rows 1 | Rows 0 | Columns 3 | Columns 2 | Columns 1 | Columns 0 |
| 1 | | | | ● | | | | ● |
| 2 | | | | ● | | | ● | |
| 3 | | | | ● | | ● | | |
| 4 | | | | ● | ● | | | |
| 5 | | | ● | | | | | ● |
| 6 | | | ● | | | | ● | |
| 7 | | | ● | | | ● | | |
| 8 | | | ● | | ● | | | |
| 9 | | ● | | | | | | ● |
| 10 | | ● | | | | | ● | |
| 11 | | ● | | | | ● | | |
| 12 | | ● | | | ● | | | |
| 13 | ● | | | | | | | ● |
| 14 | ● | | | | | | ● | |
| 15 | ● | | | | | ● | | |
| 16 | ● | | | | ● | | | |

### Encoded 4-bit Output

- Only 4 pins to report a button press out of 16 buttons.
- Each button has its own code.
- Only one button can be reported at a time using this interface.
- Table 4 define the decode table.

**Table 4. Encoded Output**

| Keypress Detected By CapSense | EO[3:0] | Interrupt Time |
|---|---|---|
| Key #1 | 0000 | 1 |
| Key #2 | 0001 | 1 |
| Key #3 | 0010 | 1 |
| Key #4 | 0011 | 1 |
| … | … | 1 |
| Key #16 | 1111 | 1 |
| No keys pressed | XXXX | 0 |

### Buzzer Output

- A dedicated pin for buzzer output is provided in the device.
- Buzzer output can be used to drive an p-type transistor driving a buzzer or directly a DC buzzer up to 10 mA sink current.

### Interrupt Line

- An interrupt line to the host controller.
- The pin go high whenever one or more sensors are found active. And remains high till those sensors are released
- Can be used as a latch input at the host side to read the OUT lines.
- Can also be used as an interrupt line for the host controller to read the OUT lines.

### Hardware Configurability

- Advanced features like auto reset, scan rate, output select are configured using an external resistor at predefined pins (refer Figure 1 and Table 1)
- These features are configured once on reset by reading/measuring the resistors connected at the pins.

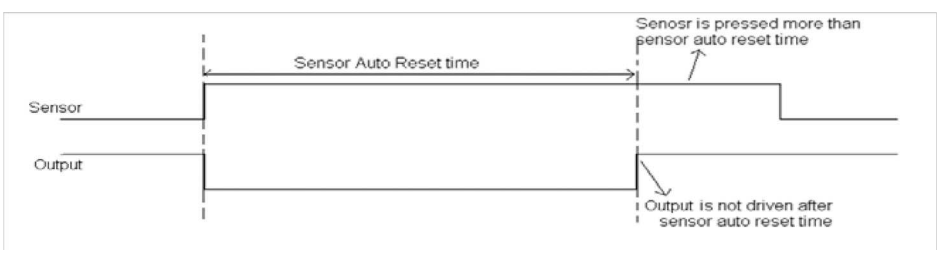
### Auto Reset

- The sensor auto reset time is controlled by the hardware configuration on the ARST pin. Refer Table 5 for details.
- This time dictates the maximum time for which the sensor will be treated as active from the time it was touched.
- After the sensor is released the CSx will be hold for 440 ms [4]

**Table 5. ARST Pin Configuration**

| ARST pin | Auto Reset Delay |
|---|---|
| Pin connected to ground | 5 sec |
| 1.5 K(5%) ohms resistor to ground | 20 sec |
| 5 K (5%) resistor to ground | 40 sec |
| Pin connected to $V_{DD}$ or left floating | No auto reset |

**Figure 8. Sensor Auto Reset**




### Output Select

- One among the three output interfaces defined earlier in the section can be selected by the hardware configuration on the OUT_SEL pin. Refer Table 6 for details.
- Only one of the output can be used at a given time with a defined resistor.

**Table 6. Output Select**

| Output Selection | Interface Selected |
|---|---|
| Pin connected to ground | Truth table I/F |
| 1.5 K (5%) ohms resistor to ground | Encoded 4-bit output |
| Connected to $V_{DD}$ or left floating | Keypad scanning interface output |

**Note**

4. Power consumption calculated with 250 ms scan time, 2% touch time and Cp of each sensor < 19 pF.

## Scan/Sleep Rate

- The device scan/sleep rate is defined by the hardware configuration on the SCAN pin. Refer Table 7 for details.
- The scan rate or sleep rate dictates the rate at which the device sleeps, wakes up and then does a special scan of the sensors after being idle (no sensor active) for two seconds.
- The power consumed by the device is inversely proportional to the time for which the device sleeps (Refer the design guide tool for power info).

**Table 7. Scan Rate Configuration**

| Scan Rate pin | Scan rate |
|---|---|
| Pin connected to ground | Low, 250 ms |
| 1.5 K (5%) ohms resistor to ground | Medium, 150 ms |
| 5 K (5%) resistor to ground | High, 40 ms |
| Pin connected to $V_{DD}$ or left floating | Continuous |

## Sensitivity

- The sensitivity of the CapSense system is controlled by the hardware configuration on the SENSITIVITY pin. Refer to Table 8 for details
- The sensitivity of the CapSense system dictates the smallest increase in capacitance that can be detected clearly as a signal by the CapSense
- While selecting this parameter, care should be taken and noise should be studied - with extreme sensitivity system can pick up noise and give false triggers.

**Table 8. Sensitivity Configuration**

| Sensitivity pin | Sensitivity |
|---|---|
| Pin connected to ground | Low (0.4 pF) |
| 1.5 K (5%) ohms resistor to ground | Medium (0.3 pF) |
| Connected to $V_{DD}$ or left floating | High (0.2 pF) |

## Noise Filtering

- Device supports inbuilt noise filtering techniques.
- A second order IIR filter is applied to the raw counts before it is processed
- The feature is in built and not given to the user to configure the coefficients of the filter

## Failure Mode Analysis

A built-in power on self test (POST) mechanism detects the following at power on reset (POR), which can be useful in production testing.

*Sensor Shorted to Ground*

If a sensor is disabled/found short to GND, then the corresponding bit field in the sensor mask is set and the same will be sent out serially through OUT_6 pin with the synchronizing clock at OUT_7. The clock is a 2 kHz clock, if no clock is sensed till 300 ms after power ON, then all the sensors are fine. If a clock is sensed, then starting from the first falling edge of the clock each sensor will occupy every clock slot. With the data line reading high during the falling edge, indicates a failure of the sensor in that clock slot. And the clock will stop after indicating the failure of the nth sensor in its clock slot - where 'n' is the highest index among the disabled sensor. For instance, if Sensor 1, 3 and 5 are disabled - then as shown in Figure 9, the FMEA data will be transmitted. The first failure corresponding to Sensor 1 will be marked by a HIGH on OUT_6 in the 0.5 ms to 1 ms slot. Sensor 3 failure will be marked by a HIGH on OUT_6 in the 1.5 ms to 2 ms slot. And Sensor 5 will be marked in the 2.5 to 3 ms slot. After indicating the failure of Sensor 5, since no further sensors have failed - clock signal will be ceased in the subsequent cycles. Figure 10 shows the scenario where 1, 3 and 15 fails.

**Figure 9. FMEA of Disabled Sensor - Scenario 1**

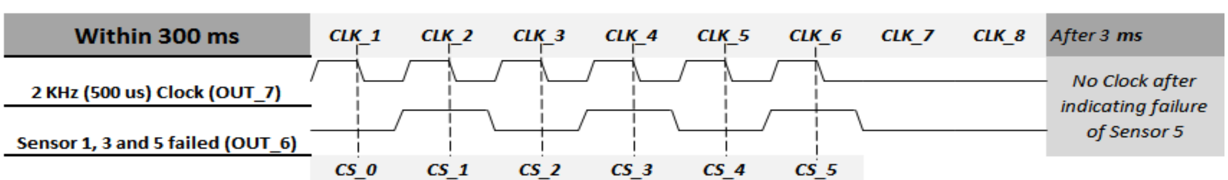



**Figure 10. FMEA of Disabled Sensor - Scenario 2**

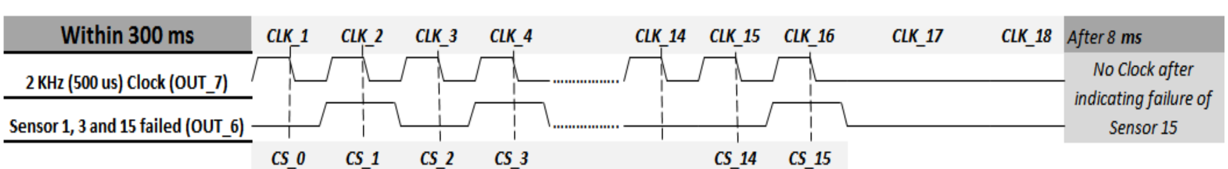
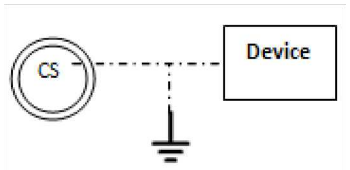


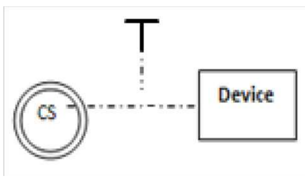
**Figure 11. Sensor Shorted to GND**




*Sensor Shorted to VDD*

If any sensor is shorted to VDD that sensor is disabled and the corresponding bit field is set and FMEA signal is sent as defined in Sensor to GND short section.

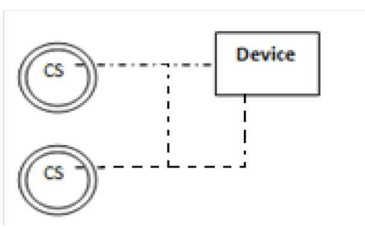
**Figure 12. Sensor Shorted to VDD**




*Sensor to Sensor Short*

Any Sensors that are shorted together is disabled and the corresponding bit field is set and FMEA signal is sent as defined in Sensor to GND short section.

**Figure 13. Sensor to Sensor Short**




*Proper Value of CMOD*

- Recommended value of CMOD is 2 nF to 2.4 nF.
- If CMOD of < 1 nF or > 4 nF is connected, all sensors are disabled and the status output will be logic high on all slots.

*Sensor CP > 40 pF*

If the parasitic capacitance (CP) of any sensor exceeds 40 pF that sensor is disabled and the corresponding bit field is set and FMEA signal is sent as defined in Sensor to GND short section.

## Debug Data Out

- To enable this feature, the DEBUG pin is pulled down with a 5.6 K resistor.
- The Cypress multi chart tool (AN2397) can be used to view the debug data for each button
- Serial data is sent out at ~115,200 baud rate
- Firmware revision, CapSense status, baseline, raw counts, difference counts and parasitic capacitances of all sensors are sent out
- The Debug data sent out is defined in Table 9 and Table 10.

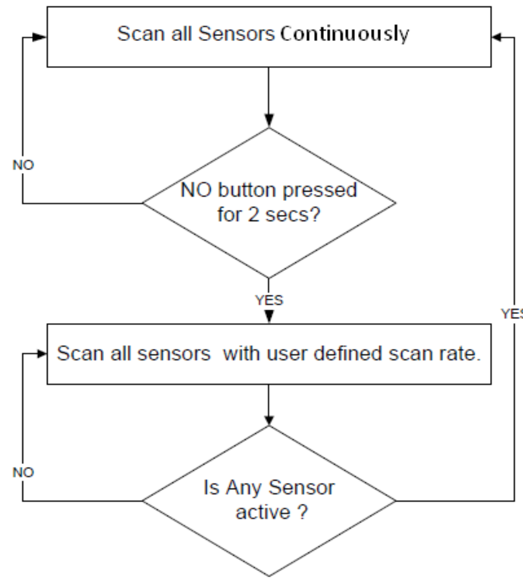
## Device Operating Modes

There are two device operating modes:

- Low power sleep mode
- Deep sleep mode

*Low Power Sleep Mode*

The following flow chart describes the low power sleep mode operation.




For details on Low power sleep look at the scan rate section.

## Deep Sleep Mode

- To enable the deep sleep mode, the hardware configuration pin Sleep should be connected to the master device.
- Sleep pin should be connected to VDD for the device to go into deep sleep.
- In deep sleep mode, all blocks are turned off and the device power consumption is 0.1 µA.
- There is no CapSense scanning in deep sleep mode.
- Sleep pin should be pulled low for the device to wake up from deep sleep.
- When device comes out of deep sleep mode, the CapSense system is reinitialized. Typical time for re-initialization is 8 ms.Any button press within this time is not reported.
- After the device comes out of deep sleep, the device operates in low power sleep mode.
- If the Sleep pin is pulled high at power on, then the device does not go to deep sleep immediately. The device goes to deep sleep after initializing all internal blocks and scanning all sensors once.
- If the Sleep pin is pulled high at power on, then the scan rate is calculated when the device is taken out of Deep Sleep by the master.

**Table 9. Data Format in Multi Chart**

| Sl. No. | Raw Count Array | | Baseline Array | | Difference Count array | |
|---|---|---|---|---|---|---|
| | MSB | LSB | MSB | LSB | MSB | LSB |
| 0 | CS0_RC | | CS0_BL | | CS0_DIFF | |
| 1 | CS1_RC | | CS1_BL | | CS1_DIFF | |
| 2 | CS2_RC | | CS2_BL | | CS2_DIFF | |
| 3 | CS3_RC | | CS3_BL | | CS3_DIFF | |
| 4 | CS4_RC | | CS4_BL | | CS4_DIFF | |
| 5 | CS5_RC | | CS5_BL | | CS5_DIFF | |
| 6 | CS6_RC | | CS6_BL | | CS6_DIFF | |
| 7 | CS7_RC | | CS7_BL | | CS7_DIFF | |
| 8 | CS8_RC | | CS8_BL | | CS8_DIFF | |
| 9 | CS9_RC | | CS9_BL | | CS9_DIFF | |
| 10 | CS10_RC | | CS10_BL | | CS10_DIFF | |
| 11 | CS11_RC | | CS11_BL | | CS11_DIFF | |
| 12 | CS12_RC | | CS12_BL | | CS12_DIFF | |
| 13 | CS13_RC | | CS13_BL | | CS13_DIFF | |
| 14 | CS14_RC | | CS14_BL | | CS14_DIFF | |
| 15 | CS15_RC | | CS15_BL | | CS15_DIFF | |
| 16 | 0x00 | F/W Rev | CS_Status | | 0x00 | CS10_CP |
| 17 | 0x00 | CS0_CP | 0x00 | CS5_CP | 0x00 | CS11_CP |
| 18 | 0x00 | CS1_CP | 0x00 | CS6_CP | 0x00 | CS12_CP |
| 19 | 0x00 | CS2_CP | 0x00 | CS7_CP | 0x00 | CS13_CP |
| 20 | 0x00 | CS3_CP | 0x00 | CS8_CP | 0x00 | CS14_CP |
| 21 | 0x00 | CS4_CP | 0x00 | CS9_CP | 0x00 | CS15_CP |

**Table 10. Serial Data Out**

| BYTE | DATA | Notes |
|---|---|---|
| 0 | 0x0D | Dummy variables for multi chart tool |
| 1 | 0x0A | |
| 2 | CS0_RC | CS0 Raw counts, unsigned 16-bit integer |
| 3 | | |
| 4 | CS1_RC | CS1 Raw counts, unsigned 16-bit integer |
| 5 | | |
| 6 | CS2_RC | CS2 Raw counts, unsigned 16-bit integer |
| 7 | | |
| ----- | ------------ | ------------------------------------------------------ |
| 32 | CS15_RC | CS15 Raw counts, unsigned 16-bit integer |
| 33 | | |
| 34 | 0x00 | – |

Table 10. Serial Data Out *(continued)*

| BYTE | DATA | Notes |
|---|---|---|
| 35 | FW_REV | Firmware revision |
| 36 | 0x00 | – |
| 37 | CS0_CP | Parasitic capacitance of CS0 |
| 38 | 0x00 | – |
| 39 | CS1_CP | Parasitic capacitance of CS1 |
| 40 | 0x00 | – |
| 41 | CS2_CP | Parasitic capacitance of CS2 |
| 42 | 0x00 | – |
| 43 | CS3_CP | Parasitic capacitance of CS3 |
| 44 | 0x00 | – |
| 45 | CS4_CP | Parasitic capacitance of CS4 |
| 46 | CS0_BL | CS0 Baseline, unsigned 16-bit integer |
| 47 | | |
| 48 | CS1_BL | CS1 Baseline, unsigned 16-bit integer |
| 49 | | |
| 50 | CS2_BL | CS2 Baseline, unsigned 16-bit integer |
| 51 | | |
| | ------------ | ----------------------------------------------------- |
| 76 | CS15_BL | CS15 Baseline, unsigned 16-bit integer |
| 77 | | |
| 78<br>79 | CS_Status | CapSense Status, unsigned 16 bit integer<br>– |
| 80 | 0x00 | – |
| 81 | CS5_CP | Parasitic capacitance of CS5 |
| 82 | 0x00 | – |
| 83 | CS6_CP | Parasitic capacitance of CS6 |
| 84 | 0x00 | – |
| 85 | CS7_CP | Parasitic capacitance of CS7 |
| 86 | 0x00 | – |
| 87 | CS8_CP | Parasitic capacitance of CS8 |
| 88 | 0x00 | – |
| 89 | CS9_CP | Parasitic capacitance of CS9 |
| 90 | CS0_DIFF | CS0 difference counts, unsigned 16-bit integer |
| 91<br>92 | CS1_ DIFF | CS1 difference counts, unsigned 16-bit integer |
| 93<br>94 | CS2_ DIFF | CS2 difference counts, unsigned 16-bit integer |
| | ------------ | ----------------------------------------------------- |
| 121 | CS15_ DIFF | CS15 difference counts, unsigned 16-bit integer |
| 122 | | |
| 123 | 0x00 | – |

**Table 10. Serial Data Out** *(continued)*

| BYTE | DATA | Notes |
|---|---|---|
| 124 | CS10_CP | Parasitic capacitance of CS10 |
| 125 | 0x00 | – |
| 126 | CS11_CP | Parasitic capacitance of CS11 |
| 127 | 0x00 | – |
| 128 | CS12_CP | Parasitic capacitance of CS12 |
| 129 | 0x00 | – |
| 130 | CS13_CP | Parasitic capacitance of CS13 |
| 131 | 0x00 | – |
| 132 | CS14_CP | Parasitic capacitance of CS14 |
| 133 | 0x00 | – |
| 134 | CS15_CP | Parasitic capacitance of CS15 |
| 135 | 0x00 | Dummy variable for multi chart tool |
| 136 | 0xFF | |
| 137 | 0xFF | |

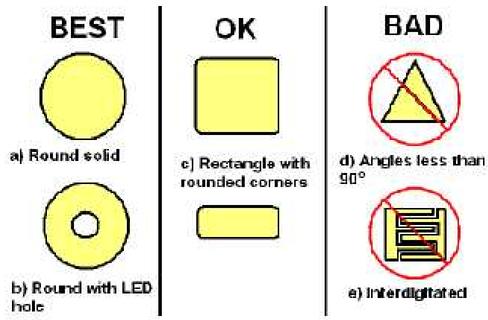
**Table 11. Layout Guidelines**

| 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 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/slider 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 | – | 10 mm | Place CapSense series resistors close to the device for noise suppression.CapSense resistors have highest priority compared to other resistors, so place them first. |

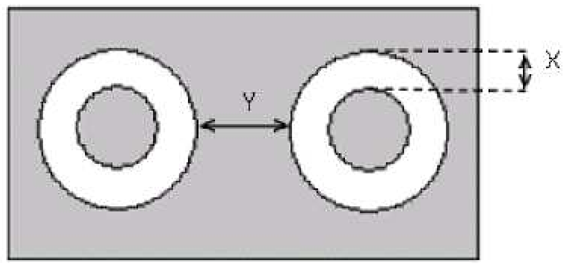
**Table 11. Layout Guidelines** *(continued)*

| Sl. No. | Category | Min | Max | Recommendations/Remarks |
|---|---|---|---|---|
| 14. | Distance between any CapSense trace to ground flood | 0.243 mm | 0.486 mm | 0.486 mm |
| 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, second layer – CapSense traces & Vdd and avoid the Vdd traces below the sensors, third 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 to 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. 467 MP and 468 MP adhesives made by 3 M are recommended. |
| 21. | Board thickness | – | – | Standard board thickness for CapSense FR4 based designs is 1.6 mm. |

## CapSense Button Shapes

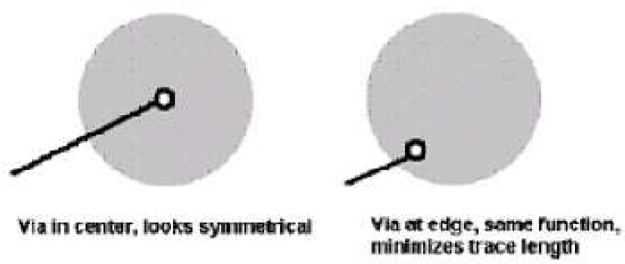



## Button Layout Design




X: Button to ground clearance (Refer to Layout Guidelines and Best Practices (AN2292) on page 16)
Y: Button to button clearance (Refer to Layout Guidelines and Best Practices (AN2292) on page 16)

## Recommended via Hole Placement

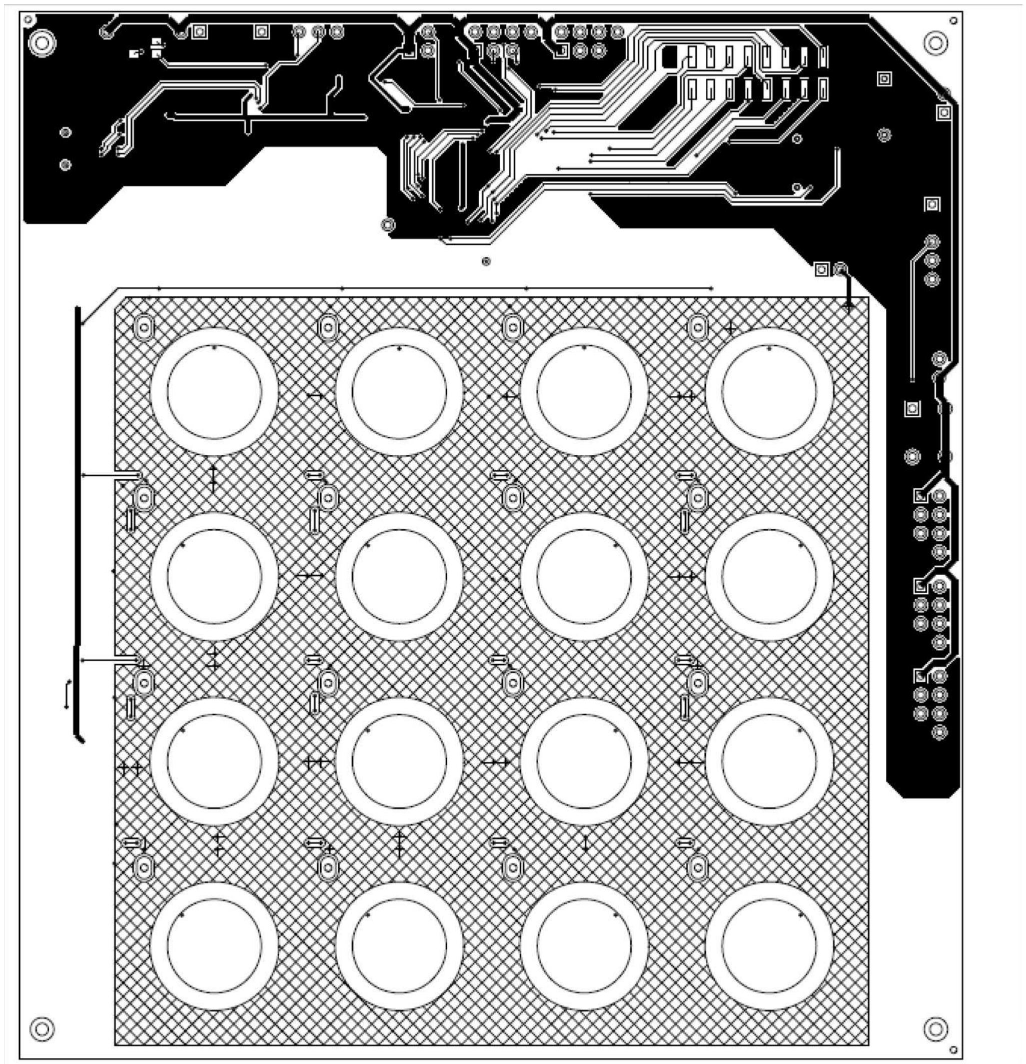




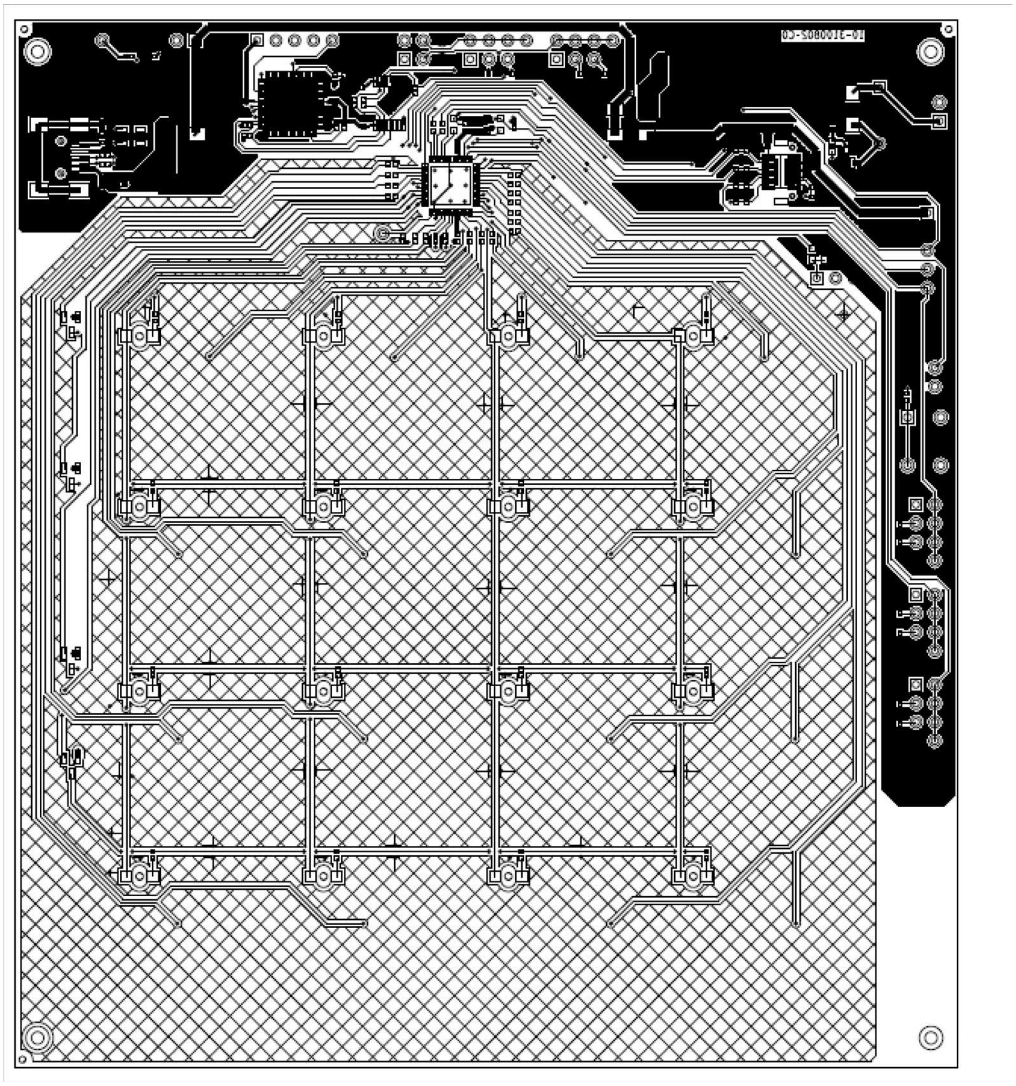

[+] Feedback

## Sample Layout

**Top**



**Bottom**



# Electrical Specifications

## Absolute Maximum Ratings

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| $T_{STG}$ | Storage temperature | –55 | 25 | +125 | °C | Higher storage temperatures reduce data retention time. Recommended storage temperature is +25 °C ± 25 °C. Extended duration storage temperatures above 85 °C degrade reliability. |
| $V_{DD}$ | Supply voltage relative to $V_{SS}$ | –0.5 | – | +6.0 | V | – |
| $V_{IO}$ | DC voltage on CapSense inputs and digital output pins | $V_{SS}$ – 0.5 | – | $V_{DD}$ + 0.5 | V | – |
| $I_{MIG}$ | Maximum current into any GPO output pin | –25 | – | +50 | mA | – |
| ESD | Electro static discharge voltage | 2000 | – | – | V | Human body model ESD |
| LU | Latch up current | – | – | 200 | mA | In accordance with JESD78 standard |

## Operating Temperature

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| $T_A$ | Ambient temperature | –40 | – | +85 | °C | – |
| $T_J$ | Operational die temperature | –40 | – | +100 | °C | – |

## DC Electrical Characteristics

*DC Chip Level Specifications*

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| $V_{DD}$[5, 6, 7] | Supply voltage | 1.71 | – | 5.5 | V | – |
| $I_{DD}$ | Supply current | – | 3.3 | 4.0 | mA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C |
| $I_{DA}$ | Active current | – | 3.3 | 4.0 | mA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C, continuous sensor scan |
| $I_{DS}$ | Deep sleep current | – | 100 | 500 | nA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C |
| $I_{AV1}$ | Average current | – | 0.25 | – | mA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C and 16 buttons used, with 0% touch time, Cp of all sensors < 19 pFand scan rate = 250 ms |
| $I_{AV2}$ | Average current | – | 2.13 | – | mA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C and 16 buttons used, with 50% touch time, Cp of all sensors < 19 pFand scan rate = 250 ms, Key Scan mode enabled |
| $I_{AV3}$ | Average current | – | 0.42 | – | mA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C and 16 buttons used, with 0% touch time, Cp of all sensors >19 pF and < 40 pF and scan rate = 250 ms |
| $I_{AV4}$ | Average current | – | 2.2 | – | mA | Conditions are $V_{DD}$ = 3.0 V, TA = 25 °C and 16 buttons used, with 50% touch time, Cp of all sensors >19 pF and < 40 pF and scan rate = 250 ms, Key Scan mode enabled |

**Notes**

5. When VDD remains in the range from 1.75 V to 1.9 V for more than 50 µs, the slew rate when moving from the 1.75 V to 1.9 V range to greater than 2 V must be slower than 1 V/500 µs. This helps to avoid triggering POR. The only other restriction on slew rates for any other voltage range or transition is the SRPOWER_UP parameter.
6. If you power down the device, make sure that VDD falls below 100 mV before powering backup.
7. For proper CapSense block functionality, if the drop in VDD exceeds 5% of the base VDD, the rate at which VDD drops should not exceed 200 mV/s. Base VDD can be between 1.8 V and 5.5 V

*DC General Purpose I/O Specifications*

These tables list guaranteed maximum and minimum specifications for the voltage and temperature ranges: 3.0 V to 5.5 V and –40 °C = TA = 85 °C, 2.4 V to 3.0 V and –40 °C = TA = 85 °C, or 1.71 V to 2.4 V and –40 °C = TA = 85 °C, respectively. Typical parameters apply to 5 V and 3.3 V at 25 °C and are for design guidance only.

3.0 V to 5 V DC General Purpose I/O Specification

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| VOH1 | High output voltage on all output pins | VDD – 0.2 | – | – | V | IOH < 10 µA, Maximum of 40 µA source in all I/Os |
| VOH2 | High output voltage on OUT pins | VDD – 0.9 | – | – | V | IOH = 1 mA, Maximum of 2 mA source in all I/Os |
| VOH3 | High output voltage on INT and BUZZ pins | VDD – 0.9 | – | – | V | IOH = 5 mA, Maximum of 10 mA source in all I/Os |
| VOL | Low output voltage | – | – | 0.75 | V | IOL = 25 mA/pin, $V_{DD}$ > 3.3 V, Maximum of 60 mA source in all I/Os |

2.4 V to 3.0 V DC General Purpose I/O Specifications

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| VOH1 | High output voltage on all outputs | VDD – 0.2 | – | – | V | IOH < 10 µA, Maximum of 40 µA Source in all I/Os |
| VOH2 | High output voltage on OUT pins | VDD – 0.4 | – | – | V | IOH = 0.2 mA, Maximum of 0.4 mA source in all I/Os |
| VOH3 | High output voltage on INT and BUZZ | VDD – 0.5 | – | – | V | IOH = 2 mA, Maximum of 4 mA source in all I/Os |
| VOL | Low output voltage | – | – | 0.72 | V | IOL = 10 mA/pin, $V_{DD}$ > 3.3 V, Maximum of 30 mA source in all I/Os |

1.71 V to 2.4 V DC General Purpose I/O Specifications

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| VOH1 | High output voltage on OUT pins | VDD – 0.2 | – | – | V | IOH =10 µA, maximum of 20 µA source in all I/Os |
| VOH2 | High output voltage on OUT pins | VDD – 0.5 | – | – | V | IOH = 0.5 mA, maximum of 1 mA source in all I/Os |
| VOH3 | High output voltage on INT and BUZZ | VDD – 0.2 | – | – | V | IOH =100 µA, maximum of 200 µA source in all I/Os |
| VOH4 | High output voltage on INT and BUZZ | VDD – 0.5 | – | – | V | IOH = 2 mA, maximum of 4 mA source in all I/Os |
| VOL | Low output voltage | – | – | 0.4 | V | IOL = 5 mA/pin, $V_{DD}$ > 3.3 V, maximum of 20 mA source in all I/Os |

## AC Electrical Specifications

*AC Chip-Level Specifications*

| Parameter | Description | Min | Max | Unit | Notes |
|---|---|---|---|---|---|
| SRPOWER_UP | Power supply slew rate | – | 250 | V/ms | VDD slew rate during power-up |
| TXRST | External reset pulse width at power-up | 1 | – | ms | After supply voltage is valid |
| TXRST2 | External reset pulse width after power-up | 10 | – | ?s | Applies after part has booted |

*AC General Purpose I/O Specifications*

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| TRise1 | Rise time on OUT pins, Cload = 50 pF | 15 | – | 80 | ns | $V_{DD}$ = 3.0 to 3.6 V, 10%–90% |
| TRise2 | Rise time on INT and BUZZ pins, Cload = 50 pF | 10 | – | 50 | ns | $V_{DD}$ = 3.0 to 3.6 V, 10%–90% |
| TRise3 | Rise time on OUT pins, Cload = 50 pF | 15 | – | 80 | ns | $V_{DD}$ = 1.71 to 3.0 V, 10%–90% |
| TRise2 | Rise time on INT and BUZZ pins, Cload = 50 pF | 10 | – | 80 | ns | $V_{DD}$ = 1.71 to 3.0 V, 10%–90% |
| TFall | Fall time, Cload = 50 pF all outputs | 10 | – | 50 | ns | $V_{DD}$ = 3.0 to 3.6 V, 90%–10% |
| TFallL | Fall time, Cload = 50 pF all outputs | 10 | – | 70 | ns | $V_{DD}$ = 1.71 to 3.0 V, 90%–10% |

## CapSense Specification

| Parameter | Description | Min | Typ | Max | Unit | Notes |
|---|---|---|---|---|---|---|
| $C_P$ | Parasitic capacitance | 5.0 | – | $(C_P+C_F)<40$ | pF | $C_P$ is the total capacitance seen by the pin when no finger is present. $C_P$ is sum of C_sensor, C_trace, and Capacitance of the vias and $C_{PIN}$ |
| $C_F$ | Finger capacitance | 0.25 | – | $(C_P+C_F)<40$ | pF | $C_F$ is the capacitance added by the finger touch |
| $C_{PIN}$ | Capacitive load on pins as input | 0.5 | 1.7 | 7 | pF | Mandatory for CapSense to work |
| CMOD | External integrating capacitor | 2 | 2.2 | 2.4 | nF | Mandatory for CapSense to work |
| Rs | Series resistor between pin and the sensor | – | 560 | 616 | Ω | Reduces the RF noise |

## Package information

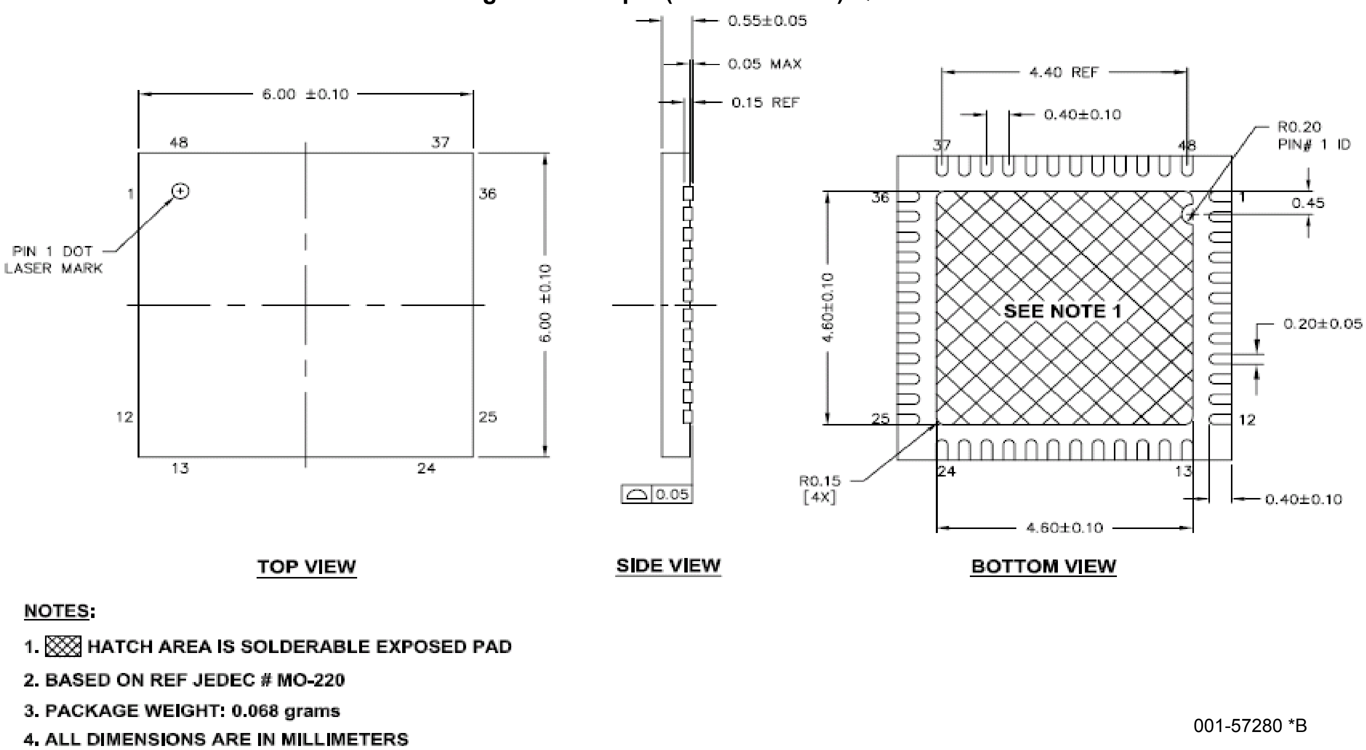
### Thermal Impedances by Package

| Package | Typical $\theta_{JA}$ [8] |
|---|---|
| 48-pin QFN [9] | 19 °C/W |

### Solder Reflow Peak Temperature

| Package | Minimum Peak Temperature [10] | Maximum Peak Temperature | Time at Max Temperature |
|---|---|---|---|
| 48-pin QFN | 240 °C | 260 °C | 30 s |

**Figure 14. 48-pin (6 × 6 × 0.6 mm) QFN**




**Notes**

8. $T_J = T_A + \text{Power} \times \theta_{JA}$
9. To achieve the thermal impedance specified for the QFN package, the center thermal pad must be soldered to the PCB ground plane
10. Higher temperatures may be required based on the solder melting point. Typical temperatures for solder are 220 ± 5 °C with Sn-Pb or 245 ± 5 °C with Sn-Ag-Cu paste. Refer to the solder manufacturer specifications

## Ordering information

| Ordering Code | Package Type | Operating Temperature | CapSense Block | CapSense Inputs | Other I/Os | XRES pin |
|---|---|---|---|---|---|---|
| CY8CMBR2016-24LQXI | 48-pin (6 × 6 × 0.6 mm) QFN | Industrial | Yes | 17 [11] | 17 [12] | Yes |
| CY8CMBR2016-24LQXIT | 48-pin (6 × 6 × 0.6 mm) QFN (Tape & Reel) | Industrial | Yes | 17 [11] | 17 [12] | Yes |

### Ordering Code Definitions

CY 8 C MBR 2016 - 24 LQX I (T)

- **T** = Tape and Reel, Blank = Standard
- **Temperature Range:** I = Industrial
- **Package Code:** LQX = QFN Pb-free
- **Speed:** 24 MHz
- **Part Number:** 2016
- **MBR** = Mechanical Button Replacement
- **Technology Code:** C = CMOS
- **Marketing Code:** 8 = PSoC
- **Company ID:** CY = Cypress

**Notes**

11. 16 CapSense input + 1 CMOD pin
12. 8 Configurable GPIOs + 1 buzzer output + 1 Sleep line + 1 Interrupt line + 1 Debug line + 5 configuration pins

## Acronyms

| Acronym | Description |
|---|---|
| AC | alternating current |
| $C_F$ | finger capacitance |
| $C_{MOD}$ | Modulator capacitor |
| $C_P$ | parasiitic capacitance |
| EO_x | Encoded Output - Bit ‘x’ |
| FMEA | Failure Mode Effect Analysis |
| MTS | multi touch sense |
| POR | power on reset |
| POST | power on self test |
| QFN | quad flat no leads |
| RF | radio frequency |
| READ_x | KeyScan Interface - ‘x’th Read line |
| SCAN_x | KeyScan Interface - ‘x’th Scan line |
| SNR | signal to noise ratio |
| TT_COL_x | Truth Table Column output - ‘x’th Column |
| TT_ROW_x | Truth Table Row output - ‘x’th Row |

## Document Conventions

### Units of Measure

| Symbol | Unit of Measure |
|---|---|
| °C | degree Celsius |
| kHz | kilohertz |
| kΩ | kilohm |
| MHz | megahertz |
| MΩ | megaohm |
| µA | microampere |
| µF | microfarad |
| µs | microsecond |
| mA | milliampere |
| ms | millisecond |
| mV | millivolt |
| nA | nanoampere |
| nF | nanofarad |
| ns | nanosecond |
| Ω | ohm |
| pF | picofarad |
| ppm | parts per million |
| s | second |
| V | volt |
| W | watt |

## Document History Page

| Document Title: CY8CMBR2016, Capacitive Button Controllers<br>Document Number: 001-67921 | | | | |
|---|---|---|---|---|
| **Revision** | **ECN** | **Orig. of Change** | **Submission Date** | **Description of Change** |
| ** | 3202566 | MSUR | 03/22/2011 | New datasheet |
| *A | 3387102 | MSUR | 10/10/2011 | Changed status from Preliminary to Final.<br>Added Char data into the table and some minor edits to the document. |
| *B | 3473096 | MSUR | 12/22/2011 | No technical updates. |

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