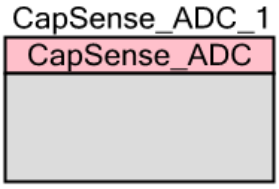
PSoC 4 Capacitive Sensing (CapSense®) ADC

3.0



Features

- Offers best-in-class signal-to-noise ratio (SNR)
- Supports Self-Capacitance (CSD) and Mutual-Capacitance (CSX) sensing methods
- Features SmartSense™ auto-tuning technology for CSD sensing to avoid complex manual tuning process
- Supports various Widgets, such as Buttons, Matrix Buttons, Sliders, Touchpads, and Proximity Sensors
- Provides ultra-low power consumption and liquid tolerant capacitive sensing technology
- Contains integrated graphical tuner for manual tuning, testing, and debugging
- Supports ADC function with:
  - Selectable 8- or 10-bit resolution
  - Sample rates of up to 11.6 ksps with 10-bit resolution
  - Input measurement range from VSSA to VDDA on any GPIO pin

Note This CapSense ADC v3.0 component (and any version that follows) is a new component and **not** backward compatible with CapSense_CSD_P4 v2.40 or older. If you are working on a project with the older component, Cypress recommends backing it up before replacing the component in your schematic. C code written for CapSense_CSD_P4 is not compatible with the new component. Refer to the *Migration Guide* in this datasheet for details on how the two components are different.

Limitations

This component supports all CapSense-enabled devices in the PSoC 4 family of devices, including Fourth generation CapSense: PSoC 4000S, PSoC 4100S, and PSoC Analog Coprocessor. However, some features are restricted in specific devices:

- The Export Register Map feature will be available in the next component version.
- The CSD2x functionality will be available in the next version of the component.

- The *CapSense Tuner* does not support ADC functionality. This feature will be added in a future component version.
- The IDAC sensing configuration feature will be available in the next component version.

General Description

CapSense is a Cypress capacitive sensing solution. It supports multiple widgets (group of sensors used to form an interface) using both CSX and CSD sensing methods.

The CapSense ADC component solution includes a configuration wizard to create and configure CapSense Widgets, APIs to control the component from application firmware, and a *CapSense Tuner* application for tuning, testing, and debugging.

This datasheet includes the following sections:

- *Quick Start* – Helps you quickly configure the component to create a simple demo.
- *Component Configuration Parameters* – Contains descriptions of the component's parameters in the configuration wizard.
- *CapSense Tuner* – Contains descriptions of all user interface controls in the tuner application.
- *Application Programming Interface* – Provides descriptions of all APIs in the firmware library, as well as descriptions of all data structures (Register map) used by the firmware library.
- *Electrical Characteristics* – Provides component performance specifications and other details such certification specifications.
- *Migration Guide* – Helps to manually transition designs from CapSense_CSD_P4 v2.40 or older versions to CapSense v3.0.

Note Important information such as the CapSense technology overview, appropriate Cypress device for the design, CapSense system and sensor design guidelines, different interfaces and tuning guideline necessary for a successful design of a CapSense system are available in the following documents. It is highly recommended to start a design using *Getting Started with CapSense®* and then use the product-specific design guide. These documents can be found on the Cypress Semiconductor web site at *www.cypress.com*. For details on application notes, code examples and kits, see the *References* section.

Quick Start CapSense with ADC

This section will help you create a PSoC Creator project with a *Button* interface using the CSD *Sensing Mode* and a button to start an analog measurement.

Refer to the following documents for more information on PSoC Creator to be able to use this component:

- PSoC Creator menu Help / Documentation / Quick Start Guide
- PSoC Creator menu Help / Documentation / PSoC Creator Help

Step-1: Create a Design in PSoC Creator

Create a project using PSoC Creator and select the desired CapSense_ADC-enabled PSoC 4 device (*Fourth generation CapSense*) from the drop-down menu in the New Project wizard.

Step-2: Place and Configure the CapSense Component

Drag and drop the CapSense_ADC component from the Component Catalog onto the design to add the component's functionality to the project.

Double-click on the dropped component in the schematic to open the Configure dialog.

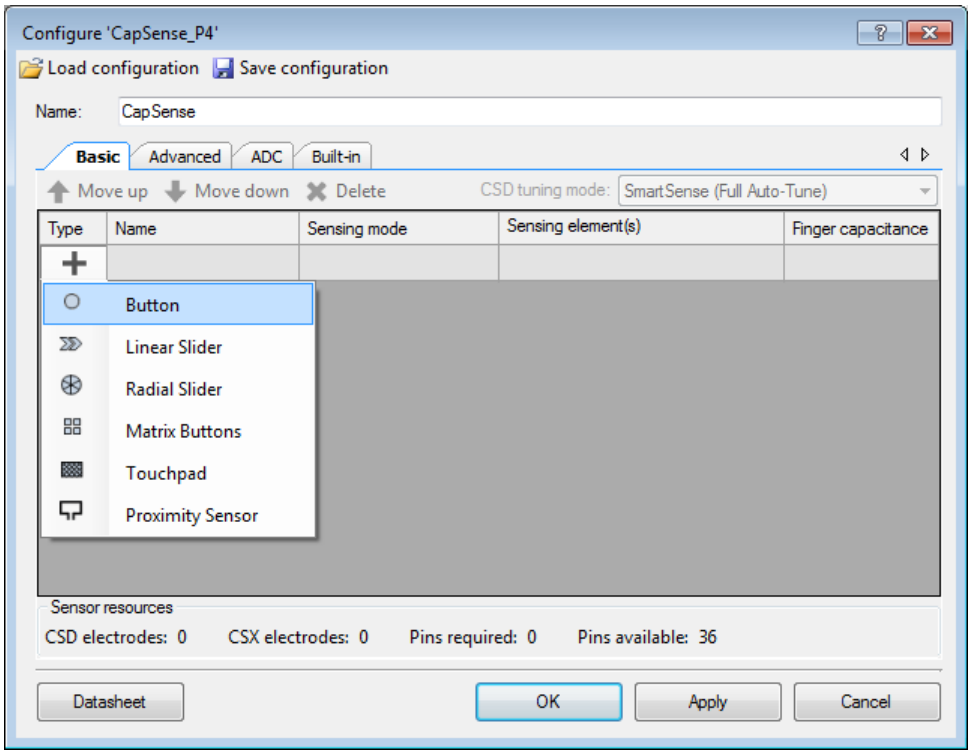
The *Component Configuration Parameters* are arranged over multiple tabs and sub-tabs.

Basic tab

Use this tab to select the *Widget Type*, *Sensing Mode*, and number of *Widget Sensing Element(s)* required for the design.

- Type the desired component name (in this case: *CapSense* for the code in *Step-6* to work).

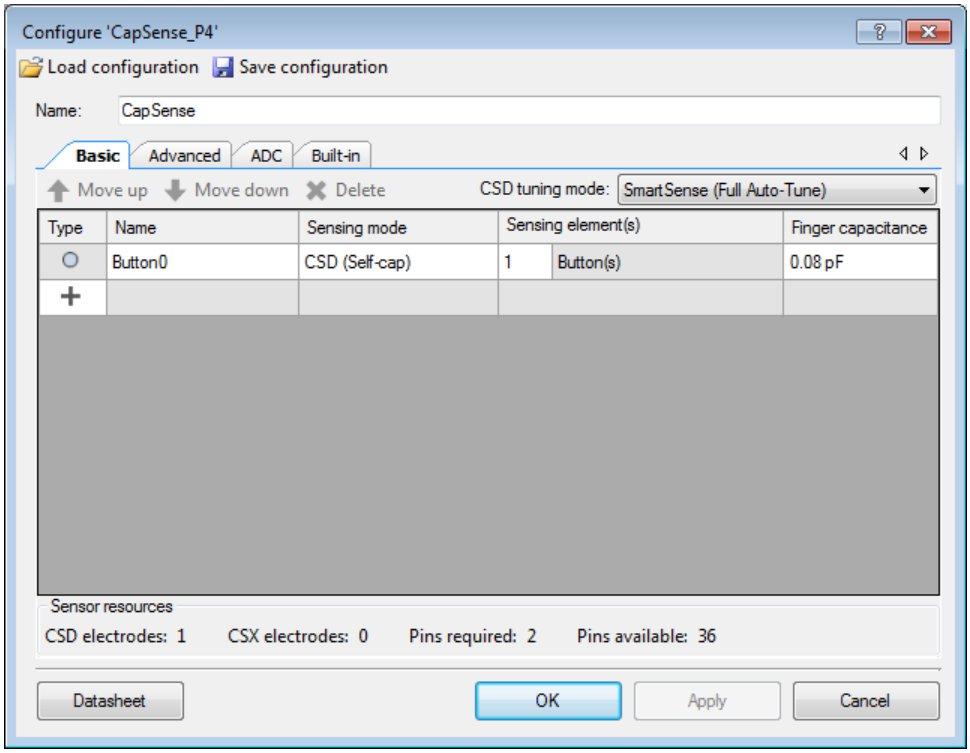
- Click '+' and select the *Widget Type* required from the drop-down list. This component offers six different types of widgets.



- Add a *Button* widget.

  Note Each widget consumes a specific set of port pins from the device. The number of *Pins required* should be always less than that of *Pins available* in the selected device to successfully build a project.

The *Basic Tab* contains a table with the following columns:



- Widget Type: Shows the selected widget type.
- Widget Name: Change the name of each widget if required (In this example, default name Button0 is used).
- Sensing Mode: Select a mode for each widget. This component supports both self-cap and mutual-cap sensing methods for Button, Matrix Buttons and Touchpad widgets. (In this example, the default (CSD) sensing mode is used). Refer to section “CapSense Technology” of *PSoC® 4 CapSense® Design Guide* for more details of these sensing methods.
- Widget Sensing Element(s): Select a number of sensing elements for each widget. The number of sensing elements is configurable to meet the application requirement (In this example, default value 1 is used).
- Finger capacitance: Select Finger capacitance between 0.1 pF and 1 pF to get 50 counts signal. Note that this parameter is available in SmartSense (Full Auto-Tune) and SmartSense (Hardware parameters only) tuning mode only and available for CSD (Self-cap) Sensing Mode.

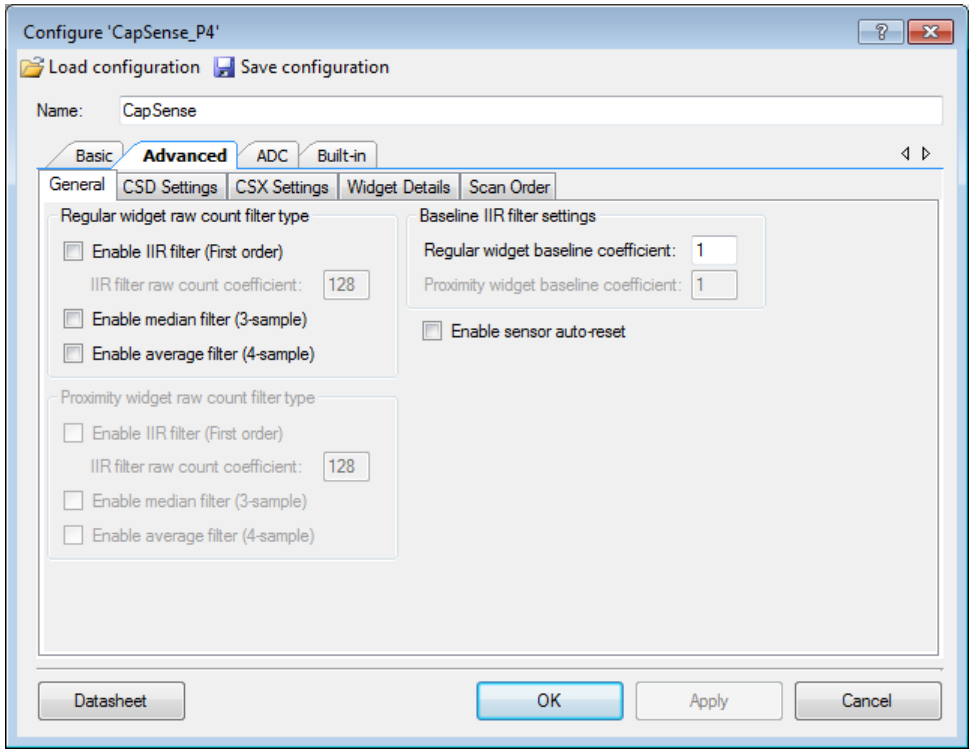
Use the CSD tuning mode pull-down (above the table) to select one of the following options:

- SmartSense (Full Auto-Tune) – With the full auto-tuning mode, the majority of configuration parameters in the Advanced Tab are automatically set by the SmartSense algorithm.
- SmartSense (Hardware parameters only)
- Manual tuning

Note SmartSense auto-tuning is available for widgets using the CSD *Sensing Mode* only. Widgets using the CSX mode must be configured manually. This example uses the *SmartSense (Full Auto-Tune)* tuning mode.

Advanced tab:

Use this tab to configure parameters required for an extensive level of manual tuning. This tab has multiple sub-tabs used to systematically arrange parameters. Refer to the *Component Configuration Parameters* section for details of these parameters.

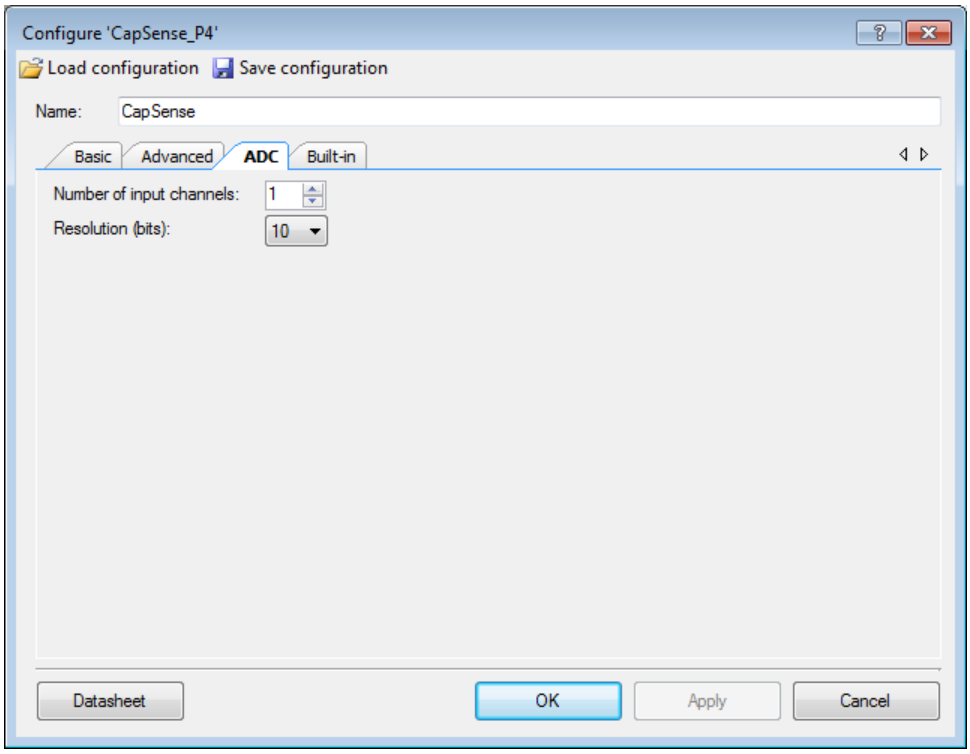


- *General*: This sub-tab contains the parameters which are common for all widgets in the component.
- *CSD Settings*: This sub-tab contains all parameters common for all CSD widgets.
- *CSX Settings*: This sub-tab contains all parameters common for all CSX widgets.

- *Widget Details*: This sub-tab contains all parameters specific for each widget and sensing element.
- *Scan Order*: This sub-tab has no editable content and provides the scan time for sensors.

ADC tab:

Use this tab to configure parameters required for using the analog-to-digital converter. This tab has two parameters:

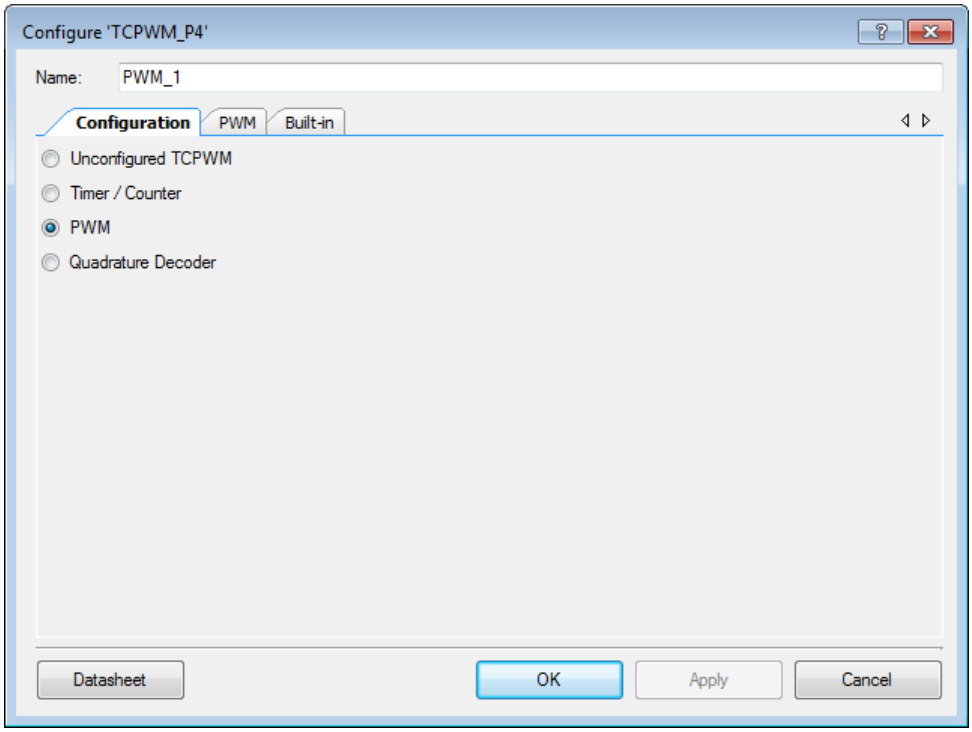


- Number of input channels: This is the number of ADC inputs. Up to ten (10) inputs are possible. The default value of one (1) is used in this quick start.
- Resolution (bits): This is the precision of ADC measurements. The component supports 8-bit and 10-bit resolutions. The default value of 10-bits is used in this quick start.

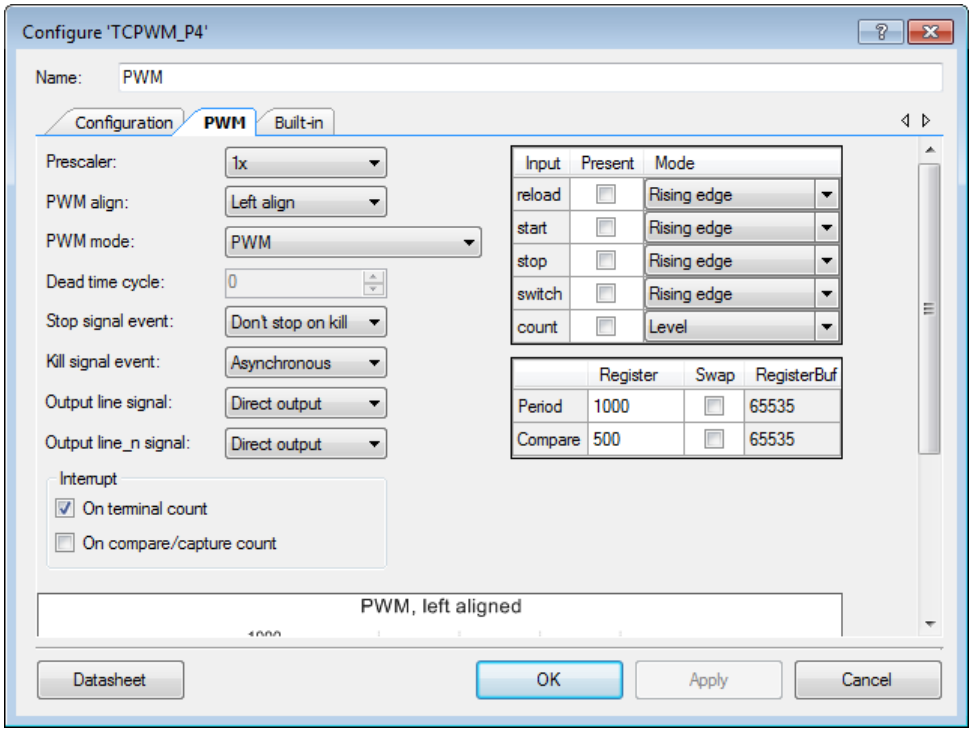
Step-3: Place and Configure a Timer Counter PWM (TCPWM) Component

1. Drag and drop the TCPWM component from the Component Catalog onto the design.

2. Double-click on the TCPWM component. You will see the **Configuration** tab.



3. On the PWM tab, set the following parameters.

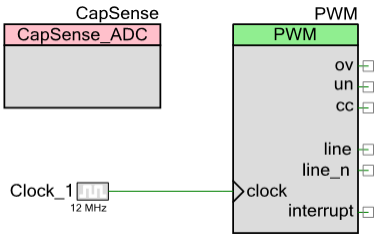


- Type the desired component name (in this case: *PWM* for the code in *Step-6* to work).

- Set the Period Register to 1000
- Set the Compare Register to 500

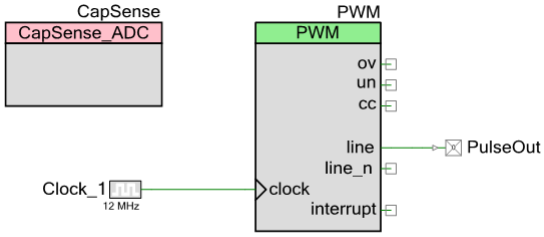
Step-4: Place Clock Component

1. Drag and drop the Clock component from the Component Catalog onto the design.
2. Connect it to the TCPWM's *clock* terminal using a wire.



Step-5: Place and Configure Digital Output Pin Component

1. Drag and drop the Digital Output Pin component from the Component Catalog onto the design.
2. Connect it to the TCPWM's *line* terminal using a wire.
3. Double click on the Digital Output Pin component and rename it as desired (in this case: *PulseOut* for the pins in the Pin Editor in *Step-7*.



Step-6: Write Application Code

Copy the following code into the *main.c* file:

```
#include <project.h>

int main()
{
    uint16 adcResult;

    CyGlobalIntEnable;                          /* Enable global interrupts. */

    PWM_Start();                                /* Initializes the TCPWM */
    CapSense_Start();                           /* Initializes the CapSense */
    CapSense_ScanAllWidgets();
    for(;;)
    {
        /* Do this only when a scan is done */
        if(CapSense_NOT_BUSY == CapSense_IsBusy())
        {
            CapSense_ProcessAllWidgets();       /* Process all widgets */
            if (CapSense_IsAnyWidgetActive())   /* Scan result verification */
            {
                adcResult = CapSense_AdcReadResult_mVolts(CapSense_AdcCHANNEL_0);
                PWM_WriteCompare((1000 * adcResult) / CYDEV_VDDA_MV);
            }
            CapSense_ScanAllWidgets();          /* Start next scan */
        }
    }
}
```

Step-7: Assign Pins in Pin Editor

Double-click the *<project>.cydwr* file (in the Workspace Explorer) and assign port pins for all CapSense sensors and external components to match with the hardware.

Step-8: Connect External Components to PSoC Device

1. Connect an oscilloscope or LED to the pin associated with the *PulseOut* component.
2. Connect a voltage source to the pin associated with the *\CapSense:AdcInput\ (Ch0)*.

Step-9: Build Design and Program PSoC Device

1. Select ***Build <project name>*** from the ***Build*** menu.
2. Select Program from ***Debug*** menu, and download the hex file to device. Ensure KitProg is connected to the hardware.

Step-10: Observe Project's Operation

The *PulseOut* signal will start with a 50% duty cycle. When the button is touched, an ADC measurement is performed, and the duty cycle is scaled to the chip's VDDA.

Input / Output Connections

This section describes the various input and output connections for the CapSense component. These are not exposed as connectable terminals on the component symbol but these terminals can be assigned to the port pins in the **Pins** tab of the Design-Wide Resources (cydwr) setting of PSoC Creator. Cydwr provides guidelines on the recommended pins for each terminal and does not allow an invalid pin assignment.

Name [1]	I/O Type	Description
C_{mod}[2]	Analog	External modulator capacitor. This capacitor is mandatory for operation of the CSD sensing method and required only if CSD sensing is used. The recommended value is 2.2nF/5v/X7R or an NPO capacitor.
$C_{int}A$ [2]	Analog	Integration capacitors. Mandatory for operation of the CSX sensing method and required only if CSX sensing is used. The recommended value is 470 pF/5v/X7R or NPO capacitors.
$C_{int}B$ [2]	Analog	
C_{sh} [2]	Analog	Shield tank capacitor for an improved shield electrode driver when CSD sensing is used. This capacitor is optional. The recommended value is 10 nF/5v/X7R or an NPO capacitor.
Shield	Analog	Shield electrode to reduce the effect of parasitic capacitance (Cp) of the sensor in the CSD sensing method. The number of shields depends on the user selection in the component configuration wizard.
Sns	Analog	Sensors of the CSD widgets. The number of sensors is based on the user selection of the CSD widgets.
Tx	Digital Output	Transmitter electrodes of the CSX widgets. The number of sensors is based on the user selection of the CSX widgets.
Rx	Analog	Receiver electrodes of the CSX widgets. The number of sensors is based on the user selection of the CSX widgets.
AdcInput	Analog	ADC voltage inputs. The number of inputs is set by the component parameter.

1 No input/output terminals described in the table are shown on the component symbol in the Schematic Editor.

2 Restricted placement rules apply dependent on devices used. Refer to the device datasheet or *<project>.cydwr file* of PSoC Creator.

Component Configuration Parameters

This section provides a brief description of all configurable parameters in the component Configure Dialog. This section does not provide design and tuning guidelines. For complete guidelines on the CapSense system design and CapSense tuning, refer to *PSoC® 4 CapSense® Design Guide*.

Drag a component onto the design canvas and double-click to open the dialog.

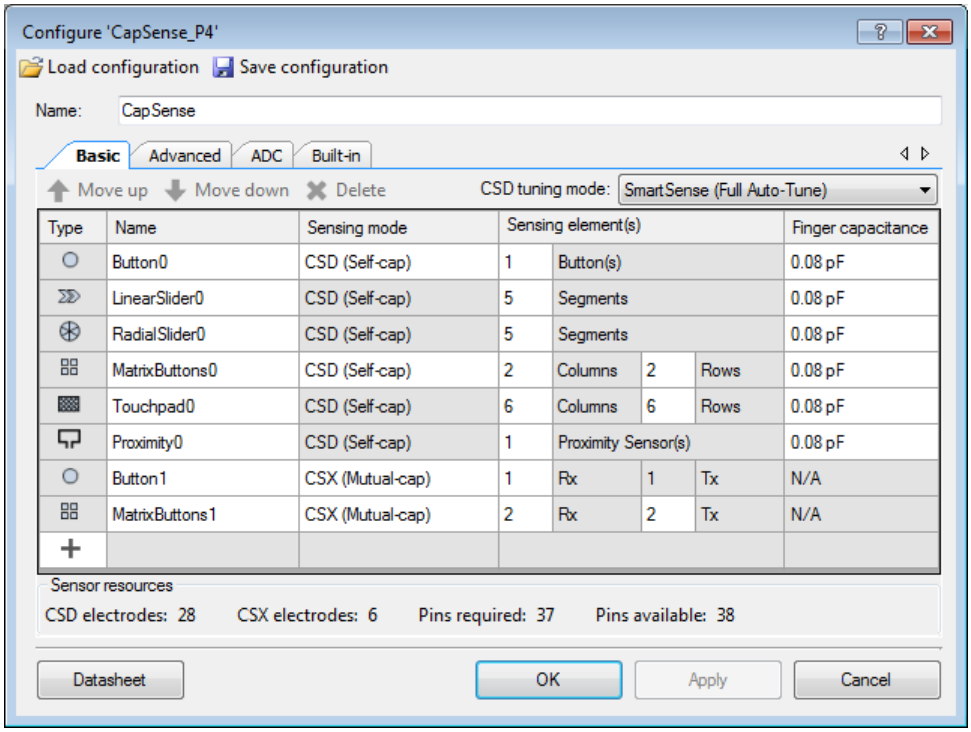
Common Controls

- **Load configuration** – Open (load) a previously saved configuration (XML) file for the CapSense component.
- **Save configuration** – Save the current component configuration into a (XML) file.
- **Export Register Map** [3] – The CapSense component firmware library uses a data structure (known as Register map) to store the configurable parameters, various outputs and signals of the component. The Export Register Map button creates an explanation for registers and bit fields in the register map in a PDF or XML file that can be used as reference for development.

3 The Export Register Map feature will be available in the next component version.

Basic Tab

The **Basic** tab defines the high-level component configuration. Use this tab to add various Widget Type and assign Sensing Mode, Widget Sensing Element(s) and Finger capacitance for each widget.



The following table provides descriptions of the various **Basic** tab parameters:

Name	Description

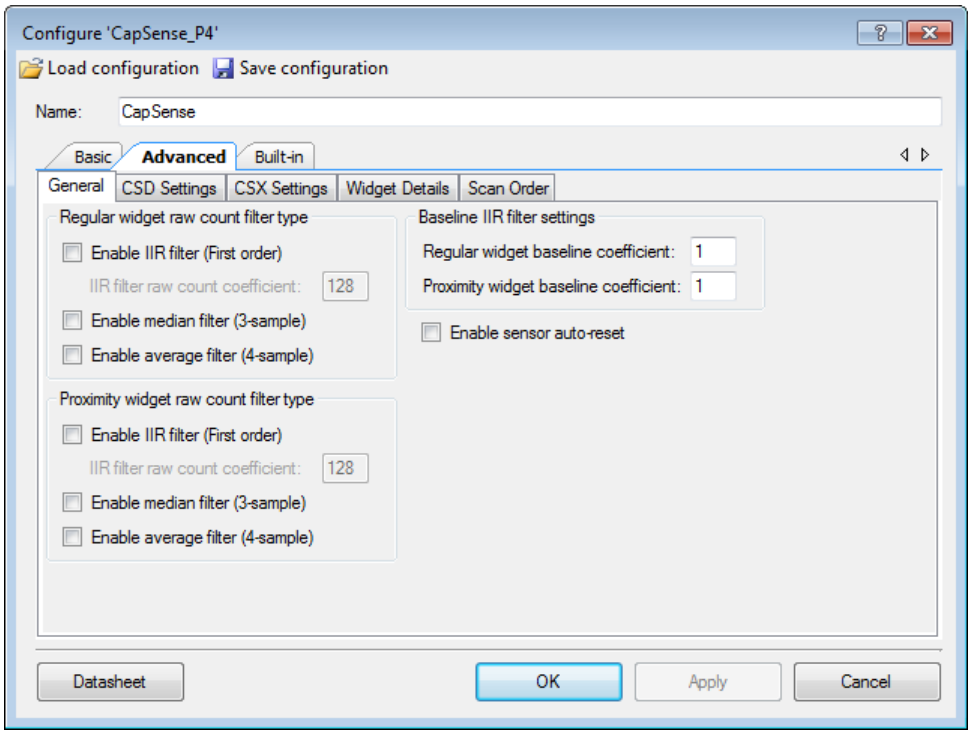
CSD tuning mode	Tuning is a process of finding appropriate values for configurable parameters (Hardware parameters and Threshold parameters) for proper functionality and optimized performance of the CapSense system.
	SmartSense Auto-tuning is an algorithm embedded in the component that automatically finds the optimum values for configurable parameters, based on the hardware properties of the capacitive sensors, therefore avoids the manual-tuning process by the user.
	Configurable parameters that affect the operation of sensing hardware are called Hardware parameters and parameters that affect the operation of the touch detection firmware algorithm are called Threshold parameters.
	This parameter is a drop-down box to select the tuning mode for CSD widgets.
	▪ **SmartSense (Full Auto-Tune)** – This is the quickest way to tune a design. Mostly all parameters (Hardware and Threshold parameters) are automatically tuned by the component and Customizer GUI displays them as *Set by SmartSense*. In this mode, the following parameters are automatically tuned:
	  ○ *CSD Settings* tab: *Enable common Sense clock*, *Enable IDAC auto-calibration* and *Sense clock frequency*
	  ○ *Widget Details* tab: All CSD related parameters of *Widget Hardware Parameters* and *Widget Threshold Parameters* groups.
	  ○ *Widget Details* tab: *Compensation IDAC value* parameter if *Enable compensation IDAC* is set.
	▪ **SmartSense (Hardware parameters only)** – Hardware parameters are automatically set by the component, all Threshold parameters can be manually set by the user. This mode consumes less memory and less CPU processing time, therefore leads to lower average power. In this mode, the following parameters are automatically tuned:
	  ○ *CSD Settings* tab: *Enable common Sense clock*, *Enable IDAC auto-calibration* and *Sense clock frequency*
	  ○ *Widget Details* tab: All CSD related parameters of *Widget Hardware Parameters* group.
	  ○ *Widget Details* tab: *Compensation IDAC value* parameter if *Enable compensation IDAC* is set.
	▪ **Manual** – SmartSense auto-tuning is disabled, all *Widget Hardware Parameters* and *Widget Threshold Parameters* must be manually tuned. The lowest memory and CPU process time consumption.

Name	Description
Widget Type	A widget is one or a group of sensors that perform a specific user-interface functionality. ▪ **Button** is a widget consisting of one or more sensors. Each sensor in the widget can detect a presence or absence (i.e. only two states) of a finger on the sensor. ▪ **Linear Slider** is a widget consisting of more than one sensor arranged in a specific fashion to detect the presence and movement of a finger on a linear axis. If a finger is present, the Linear Slider detects the physical position (single axis position) of the finger. ▪ **Radial Slider** is a widget consisting of more than one sensor arranged in a circular fashion to detect the presence and radial movement of a finger. If a finger is present, the Radial Slider detects the physical position of the finger. ▪ **Matrix Buttons** is a widget consisting of two or more sensors, each arranged in a specific horizontal and vertical order to detect the presence or absence of a finger on intersections of vertically and horizontally arranged sensors. If M and N are a number of sensors in the horizontal and vertical axis respectively, the total of M x N intersection positions can detect the finger touch. When using the *The CSD sensing method*, a simultaneous finger touch on more than one intersection is invalid and produces invalid results. This limitation does not apply when using the *The CSX sensing method* and all intersections can detect a valid touch simultaneously. ▪ **Touchpad** is a widget consisting of multiple sensors arranged in a specific horizontal and vertical order to detect the presence or absence of a human finger. If a finger is present, the widget will detect the physical position (both X and Y axis position) of the touch. More than one simultaneous touch in the *The CSD sensing method* is invalid. The *The CSX sensing method* supports with detection of up to 3 simultaneous finger touches shall be available in the next version of the component. ▪ **Proximity Sensor** is a widget consisting of one or more sensors. Each sensor in the widget can detect the proximity of conductive objects, such as a human hand or finger to the sensors. The proximity sensor has two thresholds: ○ *Proximity threshold*: To detect an approaching hand or finger. ○ *Touch threshold*: To detect a finger touch on the sensor.
Widget Name	A widget name can be defined to aid in referring to a specific widget in the design. A widget name does not have any effect on functionality or performance and a widget name is used throughout the source code to generate macro values and data structure variables. A maximum of 16 alphanumeric characters (first letter must be an alphabetic character) is acceptable for a widget name.
Sensing Mode	The parameter to select the sensing mode for each widget: ▪ The **CSD** sensing method (Capacitive Sigma Delta) is a Cypress patented method of performing self-capacitance measurements. All widget types support CSD sensing. ▪ The **CSX** sensing method is a Cypress patented method of performing mutual-capacitance measurements; only buttons, matrix buttons, and touchpad widgets support CSX sensing.

Name	Description
Widget Sensing Element(s)	The sensing element refers to component terminals assigned to port pins to connect to physical sensors on the user-interface panel (such as a pad or layer on a PCB, ITO, or FPCB). The following element numbers are supported by the *The CSD sensing method*: ▪ *Button* supports 1 to 32 sensors within a widget. ▪ *Linear Slider* supports 3 to 32 segments within a widget. ▪ *Radial Slider* supports 3 to 32 segments within a widget. ▪ *Matrix Buttons* support 2 to 16 rows and columns. The number of total intersections (sensors) is equal to that of rows x columns, limited to the maximum of 32. ▪ *Touchpad* supports 3 to 16 rows and columns. ▪ *Proximity* supports 1 to 16 sensors within a widget. The following element numbers are supported by the *The CSX sensing method*: ▪ *Button* – 1 to 32 Rx electrodes (for 1 to 32 sensors) and Tx is fixed to 1. ▪ *Matrix Buttons* – 2 to 16 Tx and Rx. The total intersections (node) number is equal to Tx × Rx, limited to the maximum of 32.
Finger capacitance	Finger capacitance is defined as capacitance introduced by a finger produceing signal not less than 50 counts. This parameter is used to indicate how a sensitive CSD widget should be tuned by the *SmartSense Auto-tuning* algorithm. The supported Finger capacitance range: ▪ In the *SmartSense (Full Auto-Tune)* mode it is 0.1 pF to 1 pF with a 0.02-pF step. ▪ In the *SmartSense (Hardware parameters only)* mode it is 0.02 pF to 20.48 pF on the exponential scale.
Move up / Move down	Moves the selected widget up or down by one on the list. It defines the widget scanning order. **Note** Widget deleting may break a pin assignment and you will need to repair the assignment in the *<project>.cydwr* file.
Delete	Deletes the selected widget from the list. **Note** Widget deleting may break a pin assignment and you will need to repair the assignment in the *<project>.cydwr* file.
CSD electrodes	Information: Indicates the total number of electrodes (port pins) used by the CSD widgets, including the *Cmod*, *Csh* and *Shield* electrodes.
CSX electrodes	Information: Indicates the total number of electrodes (port pins) used by the CSX widgets, including the *CintA* and *CintB* capacitors.
Pins required	Information**:** Indicates the total number of port pins required for the design. This does not include port pins used by other components in the project or SWD pins in the debug mode. The number of **Pins required** should always be less than or equal to that of *Pins available* for a project to build successfully.
Pins available	Information**:** Indicates the total number of port pins available for the selected device.

Advanced Tab

This tab provides advanced configuration parameters. In *SmartSense Auto-tuning,* most of the advanced parameters are automatically tuned by the algorithm and the user does not need to set values for these parameter by the *Manual* tuning process. When the manual tuning mode is selected, the **Advanced** tab allows the user to control and configure all the component parameters.

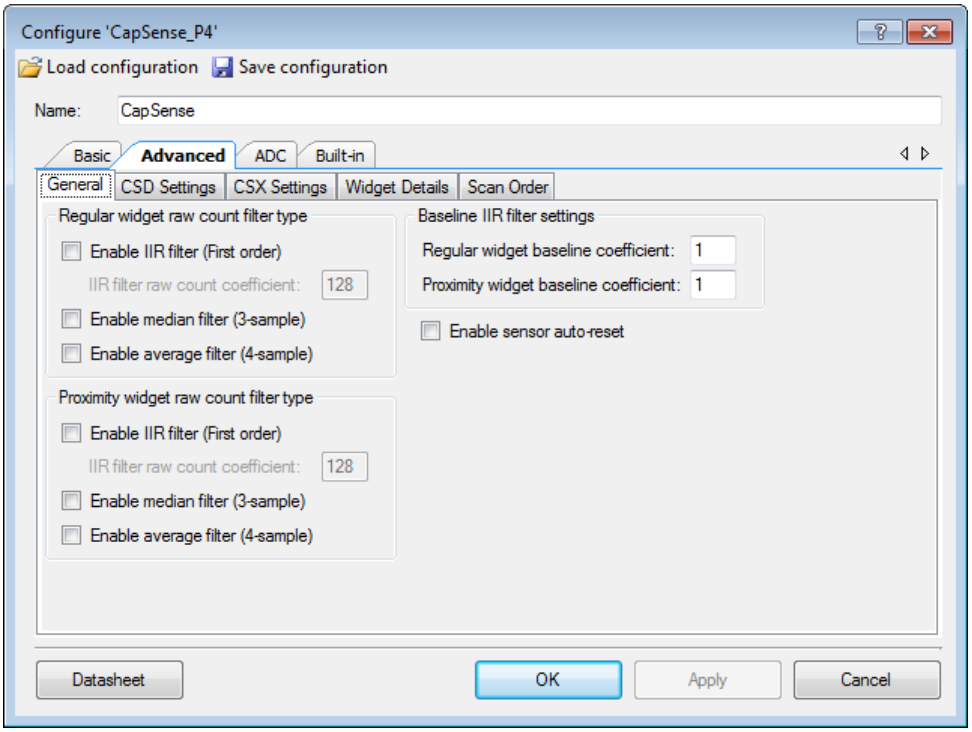


The parameters in the **Advanced** tab are systematically arranged in the five sub-tabs.

- *General:* Contains all parameters common for all widgets respective of the sensing method used for widgets.
- *CSD Settings*: Contains all parameters common for all widgets using the CSD sensing method. This tab is relevant only if one or more widget use the CSD sensing method.
- *CSX Settings*: Contains all parameters common for all widgets using the CSX sensing method. This tab is relevant only if one or more widget use the CSX sensing method.
- *Widget Details*: Contains parameters specific to widgets and/or sensors.
- *Scan Order*: This tab provides information such as scan time for each sensor and total scan time for all sensors.

General Sub-tab

Contains all parameters common for all widgets respective of *Sensing Mode* used for widgets.



This **Sub-tab** contains the following sections:

Regular widget raw count filter type

The egular widget raw count filter applies to raw counts of sensors belonging to non-proximity widgets, so these parameters can be enabled only when one or more non-proximity widgets are added on the **Basic** tab. The filter algorithm is executed when any processing API is called by the application layer. When enabled, each filter consumes RAM to store a previous raw count (filter history). If multiple filters are enabled, the total filter history is correspondingly increased so that the size of the total filter history is equal to a sum of all enabled filter histories.

Name	Description
Enable IIR filter (First order)	Enables the infinite-impulse response filter (See equation below) with a step response similar to an RC low-pass filter, thereby passing the low-frequency signals (finger touch responses). $Output = \frac{N}{K} \times input + \frac{(K - N)}{K} \times previousOutput$ Where: *K* is always 256, *N* is the IIR filter raw count coefficient selectable from 1 to 128 in the customizer. A lower N (set in *IIR filter raw count coefficient* parameter) results in lower noise, but slows down the response. This filter eliminates high-frequency noise. Consumes 2 bytes of RAM per each sensor to store a previous raw count (filter history).
IIR filter raw count coefficient	The coefficient (N) of IIR filter for raw counts as explained in the *Enable IIR filter (First order)* parameter. The range of valid values: 1-128.
Enable median filter (3-sample)	Enables a non-linear filter that takes three of most recent samples and computes the median value. This filter eliminates spikes noise typically caused by motors and switching power supplies. Consumes 4 bytes of RAM per each sensor to store a previous raw count (filter history).
Enable average filter (4-sample)	The finite-impulse response filter (no feedback) with equally weighted coefficients. It takes four of most recent samples and computes their average. Eliminates the periodic noise (e.g. noise from AC mains). Consumes 6 bytes of RAM per each sensor to store a previous raw count (filter history).

Note If multiple filters are enabled, the execution order is the following:

- Median filter
- IIR filter
- Average filter

However, the component provides the ability to change the order using a low-level processing API. Refer to *Application Programming Interface* for details.

Proximity widget raw count filter type

The proximity widget raw count filter applies to raw counts of sensors belonging to the proximity widgets, so these parameters can be enabled only when one or more proximity widgets are added on the *Basic Tab*

Parameter Name	Description
Enable IIR filter (First order)	The design of these parameters is the same as the *Regular widget raw count filter type* parameters. The *Proximity* sensors require a high-noise reduction, these dedicated parameters allow the setting proximity filter configuration and behavior differently compared to other widgets.
IIR filter raw count coefficient	
Enable median filter (3-sample)	
Enable average filter (2-sample)	

Baseline filter settings

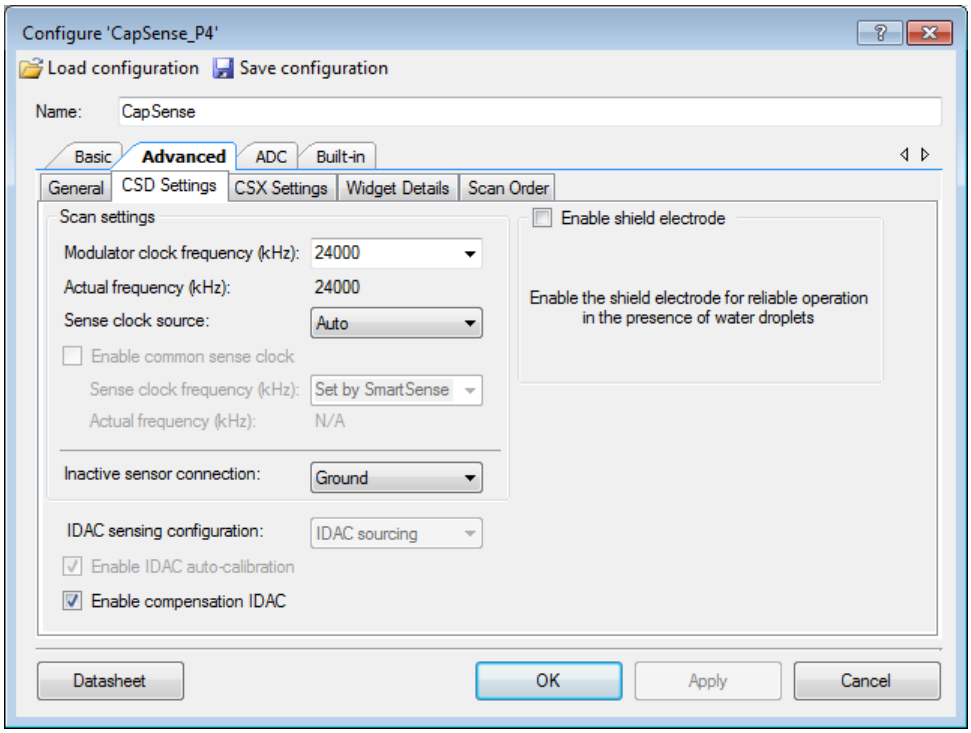
The Baseline filter settings are applied to all sensors baselines. However, the filter coefficients for proximity and regulator widgets can be controlled independently from each other.

The design-baseline IIR filter is the same as the raw count *Enable IIR filter (First order)* parameter, but, the filter coefficients can be separate for both baseline filter and raw count filters to produce a different roll off. The baseline filter is applied to the filtered rawcount (if the widget raw count filters are enabled).

Name	Description
Regular widgetbaseline coefficient	Baseline IIR filter co-efficient selection for sensors in non-proximity widgets. The range of valid values: 1-255.
Proximity widget baseline coefficient	The design of these parameters is the same as *Regular widgetbaseline coefficient*, but with a dedicated parameter allows controlling the baseline update=-rate of proximity sensors differently compared to other widgets.
Enable sensor auto-reset	When enabled, the baseline is always updated and when disabled, the baseline is updated only when the difference between the baseline and raw count is less than the noise threshold. When enabled, it prevents the sensors from permanently turning on when the raw count accidentally rises because of a large power-supply voltage fluctuation or due to other spurious conditions.

CSD Settings Sub-tab

Contains all parameters common for all widgets using the *The CSD sensing method*. This **Sub-tab** is relevant only if one or more widgets use the CSD sensing method.



This **Sub-tab** contains the following parameters:

Name	Description
Modulator clock frequency	Selects the modulator clock frequency used for the *The CSD sensing method*. The minimum value is 1000 kHz independently from the device selected for the project. The maximum value is device-dependent as follows: ▪ PSoC 4000S/PSoC 4100S/PSoC Analog Coprocessor: 48000 kHz or HFCLK, whichever is lower. Enter any value between the min and max limits based on the availability of the clock divider, the next valid lower value is selected by the component, and the actual frequency is shown in the read-only label below the drop-down list. The default value is the highest modulator clock. A higher modulator clock-frequency reduces the sensor scan time, therefore, results in lower power and reduces the noise in the raw counts, so it is recommended to use the highest possible frequency.

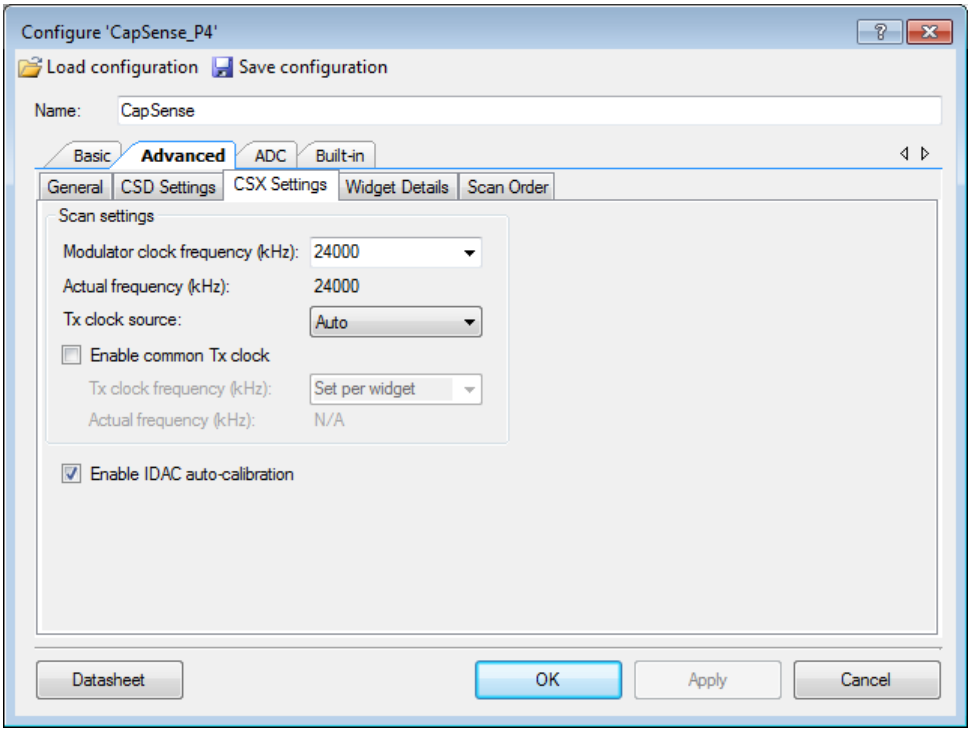
Name	Description
Sense clock source	*Sense clock frequency* is used to sample the input sensor. Both the type of the clock source and the clock frequency are configurable. The Spread Spectrum Clock (SSC) provides a dithering clock source with a center frequency equal to the frequency set in the *Sense clock frequency* parameter, PRS clock source spreads the clock using pseudo-random sequencer and Direct source disables both SSC and PRS sources and uses a fixed-frequency clock. Both PRS and SSC reduce the radiated noise by spreading the clock, increasing the number of bits, reducing the radiation and higher immunity against external noise. *Sense clock frequency* is derived from *Modulator clock frequency* using a Sense clock-divider. The following sources are available: ▪ *Direct* – PRS and SSC are disabled and a fixed clock is used. ▪ *PRS8* – Clock spread using PRS to Modulator Clock / 256. ▪ *PRS12* – Clock spread using PRS to Modulator Clock / 4096. ▪ *SSC2* to SSC5 – Clock spread using 2-bit to 5-bit of the sense clock divider respectively. SSC should be selected so that 2^{SSCn} should be less than or equal to 10% of the ratio between *Modulator clock frequency* and *Sense clock frequency*. ▪ *Auto* – The component automatically selects optimal SSC or PRS sources. Auto is the recommended clock source selection.
Enable common Sense clock	When selected, all CSD widgets share the same sense clock with a frequency specified in the *Sense clock frequency (kHz)* parameter, otherwise *Sense clock frequency* can be entered separately for each CSD widget in the *Widget Details* tab. Using a common Sense clock for all CSD widgets results in lower power consumption and optimized memory usage, but, if the sensor parasitic capacitance is significantly different for each widget, then a common Sense clock may not produce the optimal performance. To enable *SmartSense Auto-tuning*, this parameter should be unselected because SmartSense will set a Sense clock for each widget based on the sensor properties for the optimal performance.
Sense clock frequency	Sets the CSD Sense clock frequency. The minimum value is 100 kHz for all device families. The maximum value depends on the selected device: ▪ PSoC 4000S / PSoC 4100S / PSoC Analog Coprocessor: 6000 kHz or HFCLK/2, whichever is lower. Enter any value between the min and max limits, based on availability of the clock divider, the next valid lower value is selected by the component, and the actual frequency is shown in the read-only label below the drop-down list. For more information on selecting the proper divider, see the *PSoC® 4 CapSense® Design Guide*. When SmartSense is selected in *CSD tuning mode*, the Sense Clock frequency is automatically set by the component to the optimal value by following the (2*5*R*C) rule and this control is grayed out . When *Enable common Sense clock* is unselected, the Sense clock frequency can be set individually for each widget in the *Widget Details* tab, and this control is grayed out. **Note** If the HFCLK or *Modulator clock frequency* is changed, the component automatically recalculates a next closest Sense clock frequency value to a possible one.

Name	Description
Inactive sensor connection	Selects the state of the sensor when not being scanned. ▪ **Ground (default)** – All inactive sensors are connected to ground. ▪ **High-Z** – All inactive sensors are floating (not connected to GND or Shield). ▪ **Shield** - All inactive sensors are connected to Shield. This option is available only if the *Enable shield electrode* check box is set. **Ground** is the recommended selection for this parameter when water tolerance is not required for the design. Select Shield when the design needs water-tolerance or sensor-parasitic-capacitance reduction in a design.
IDAC sensing configuration	The IDAC sensing configuration feature will be available in the next component version. Selects the type of IDAC switching: ▪ **IDAC Sourcing (default)** – ources current into the modulator capacitor (*Cmod*). The analog switches are configured to alternate between the *Cmod* and GND. IDAC Sourcing is recommended for most designs because of the better signal-to-noise ratio ▪ **IDAC sinking** – Sinks current from the modulator capacitor (*Cmod*). The analog switches are configured to alternate between V_{DD} and *Cmod*. IDAC sinking provides better robustness to some tests.
Enable IDAC auto-calibration	When enabled, values of the IDACs of CSD widgets are automatically set by the component. It is recommended to select Enable IDAC auto-calibration for robust operation and *SmartSense Auto-tuning* can be enabled only when Enable IDAC auto-calibration is selected.
Enable compensation IDAC	Enabling the compensation IDAC is recommended unless one IDAC is required for other purpose in the project. The compensation IDAC is used to compensate for parasitic capacitance of the sensor to improve the performance.
Enable shield electrode	The shield electrode is used to reduce the sensor parasitic capacitance, enable water tolerant CapSense designs and enhance the detection range for the *Proximity* sensors. When the shield electrode is disabled, all configurable parameters associated with the shield electrode are hidden.
Enable shield tank (Csh) capacitor	The shield tank capacitor is used to increase the drive capacity of the shield electrode driver. It should be enabled when the shield electrode capacitance is higher than 100 pF. The recommended value for a shield tank capacitor is 10 nF/5v/X7R or an NPO capacitor. The Shield tank capacitor is not supported in a configuration which includes both CSD- and CSX-sensing based widgets.
Csh initialization source	Selects the initialization source for the shield tank electrode, when *Enable shield tank (Csh) capacitor* is enabled. The two options are available: ▪ **Vref** – Precharge the shield tank by connecting Vref to the Csh capacitor. ▪ **IO Buffer** – Precharge the shield tank by connecting the VDD supply to the Csh capacitor and turning it off using the feedback system when the Csh voltage reaches Vref. This option is available only when the Csh capacitor is assigned to one of the dedicated Csh pins (refer to the device datasheet for pin details) and these dedicated pins are available for Csh when the *The CSX sensing method* is not used in the project. The recommended source of precharge is the IO buffer.

Name	Description
Shield electrode delay	Configures the delay between the sensor signal and shield electrode signal for phase alignment. The following options available for selection: ▪ **No Delay** ▪ **5 ns** ▪ **10 ns** ▪ **20 ns** Most designs work with the **No Delay** option and it is the recommended value.
Number of shield electrodes	Select the number of shield electrodes required in the design. Most designs work with one dedicated shield electrode; but, some designs require multiple dedicated shield electrodes to ease the PCB layout routing or to minimize the PCB real-estate used for the shield layer. The minimum value is 0 (i.e. shield signal could be routed to sensors using the *Inactive sensor connection* parameter) and the maximum value is equal to the total number of CapSense-enabled port pins available for the selected device.

CSX Settings Sub-tab

The parameters in this sub-tab apply to all widgets that use the *The CSX sensing method.* If no widgets use the CSX sensing method, all the configuration parameters in this sub-tab are grayed out and not configurable.



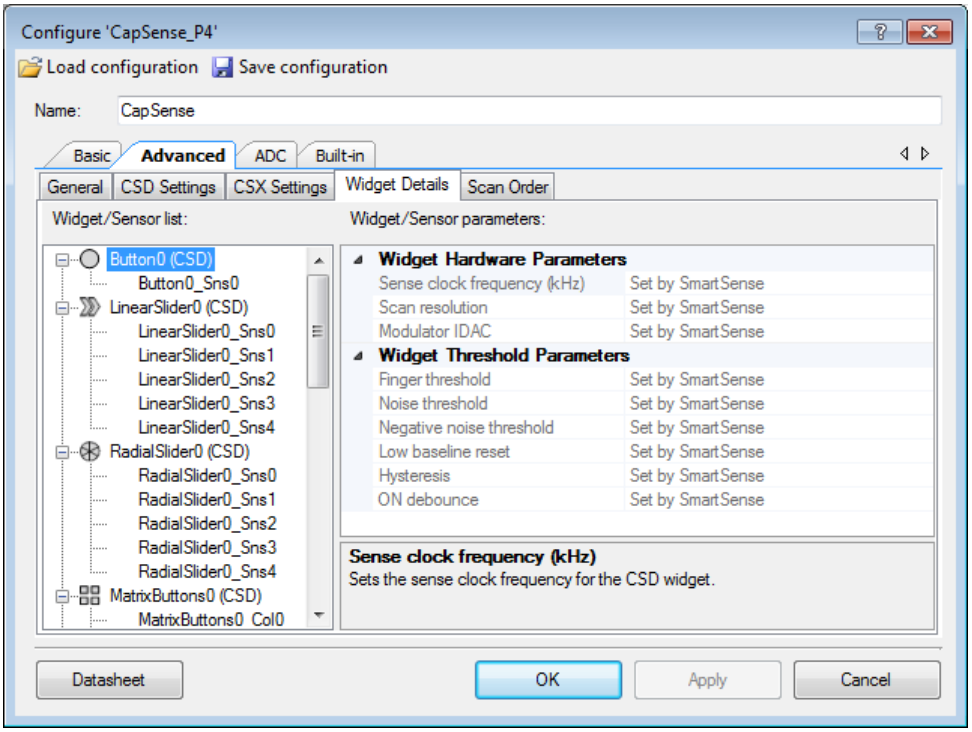
This sub-tab contains the following parameters:

Name	Description
Modulator clock frequency	Selects the modulator clock-frequency used for the *The CSX sensing method*. The minimum value is 1000 kHz independently from the device selected for the project. The maximum value is device-dependent as follows: ▪ PSoC 4000S/PSoC 4100S/PSoC Analog Coprocessor: 48000 kHz or HFCLK, whichever is lower. Enter any value between the min and max limits, based on the availability of the clock divider, the next valid lower value is selected by the component, and the actual frequency is shown in the read-only label below the drop-down list. A higher modulator clock-frequency reduces the sensor scan time, therefore, results in lower power and reduces the noise in the raw counts, so it is recommended to use the highest possible frequency.
Tx clock source	*Tx clock frequency* is used to sample the input sensor. Both the type of the clock source and the clock frequency are configurable in *Fourth generation CapSense* devices. The Spread Spectrum Clock (SSC) provides a dithering clock source with a center frequency equal to the frequency set in the Tx Clock frequency parameter and Direct source disables the SSC source and uses a fixed frequency clock. The SSC reduces the radiated noise by spreading the clock, SSC5 has lower radiated noise and higher immunity against external noise compared to SSC2. *Tx clock frequency* is derived from *Modulator clock frequency* using a sense clock divider. Clock sources are available in *Fourth generation CapSense*: ▪ *SSC2* to SSC5 – The clock spreads using 2-bit to 5-bit of the sense clock divider respectively. ▪ *Direct* – SSC are disabled and a fixed clock is used. ▪ *Auto* – The component automatically selects the optimal SSC sources. SSC should be selected so that 2^{SSCn} should be less than or equal to 10% of the ratio between Modulator Clock and Tx Clock. Auto is the recommended clock source selection.
Enable common Tx clock	When selected, all CSX widgets share the same Tx clock with the frequency specified in the *Tx clock frequency* (kHz) parameter, otherwise *Tx clock frequency* can be entered separately for each CSX widget in the *Widget Details* tab. Using common Tx clock for all CSX widgets results in lower power consumption and optimized memory usage and it is the recommended setting for the CSX widgets. But, in rare cases, if the electrode properties capacitance is significantly different for each widget, a common Tx clock may not produce the optimal performance.

Name	Description
Tx clock frequency	Sets the CSX Tx clock frequency. The minimum value is 100 kHz for all device families. The maximum value is 3000 kHz. Enter any value between the min and max limits, based on availability of the clock divider, the next valid lower value is selected by the component, and the actual frequency is shown in the read-only label below the drop-down list. The highest Tx clock frequency produces the maximum signal and is the recommended setting. When *Enable common Tx clock* is unselected, the Tx Clock frequency can be set individually for each widget in the *Widget Details* tab, and this control is grayed out. **Note** If the HFCLK or *Modulator clock frequency* is changed, the component automatically recalculates the next closest Tx clock frequency value to a possible one.
Enable IDAC auto-calibration	When enabled, values of IDACs for CSX widgets are automatically set by the component. It is recommended to select the Enable IDAC auto-calibration for robust operation.

Widget Details Sub-tab

This sub-tab contains parameters specific to each widget and sensor. These parameters must be set when *SmartSense Auto-tuning* is not enabled. The parameters are unique for each widget type.



This sub-tab contains the following parameters:

Name	Description
Widget General Parameters	
Diplexing	Enabling Diplexing allows doubling the slider physical touch sensing area by using a specific duplexing sensor pattern and without using additional port pins and sensors in the component.
Maximum position	Represents the maximum Centroid position for the slider. A touch on the slider would produce a position value from 0 to the maximum-position-value set. A **No Touch** would produce 0xffff.
Maximum X-axis position Maximum Y-axis position	Represents the maximum column (X-axis) Centroid position and row (Y-axis) Centroid positions for touchpad. A touch on the touchpad would produce a position value from 0 to the maximum position set. A **No Touch** would produce 0xffff.
Position filter	Enables the specific filter on a Centroid position value to reduce noise due to varying finger touches. ▪ **None (default)** - No filter is implemented ▪ **IIR Filter** - Enables the infinite-impulse response filter (See equation below) with a step response similar to an RC low-pass filter. $Output = \frac{N}{K} \times input + \frac{(K - N)}{K} \times previousOutput$ Where: K = 256, *N* = 128. $Output = (input + previousOutput) / 2$ Consumes 2 bytes of RAM per each position (filter history). ▪ **Median Filter (3 sample)** - Enables a non-linear filter that takes three of most recent samples and computes the median value. This filter eliminates the spikes noise typically caused by motors and switching power supplies. Consumes 4 bytes of RAM per each position (filter history). ▪ **Average Filter (2 sample)** – Enables the finite-impulse response filter (no feedback) with equally weighted coefficients. It takes two of most recent samples and computes their average. Eliminates the periodic noise (e.g. noise from AC mains) Consumes 2 bytes of RAM per each position (filter history). ▪ **Jitter Filter** - This filter eliminates the noise in the position data that toggles between the two most recent values. If the most recent position value is greater than the previous one, the current position is decremented by 1; if it is less, the current position is incremented. The filter is most effective at low noise. Consumes 2 bytes of RAM per each position (filter history).
Widget Hardware Parameters **Note** All the Widget Hardware parameters for the CSD widgets are automatically set when *SmartSense Auto-tuning* is selected in the *CSD tuning mode*.	
Sense clock frequency	This parameter is identical to the *Sense clock frequency* parameter in *CSD Settings* tab. When *Enable common Sense clock* is unselected in the *CSD Settings* tab, set sense clock frequency for each widget is set here.

Name	Description
Row sense clock frequency	These parameters are identical to the *Sense clock frequency* parameter, and are used to set the sense cock frequency for row and column sensors of *Matrix Buttons* and *Touchpad* widgets.
Column sense clock frequency	
Tx clock frequency	This parameter is identical to *Tx clock frequency* parameter in the *CSX Settings* tab. When *Enable common Tx clock* is unselected in *CSX Settings* tab, set Tx clock frequency for each widget is set here.
Scan resolution	Selects the scan resolution of CSD widgets (Resolution of capacitance to digital conversion). Acceptable values are from 6 to 16 bits.
Number of sub-conversions	Selects the number of sub-conversions in the *The CSX sensing method*. Acceptable values are in range: $\left[1 .. \left(\frac{ModClk}{TxClk} \bullet NumSubConversions \right) < 2^{16} \right]$ where, *ModClk* = CSX *Modulator clock frequency* *TxClk* = *Tx clock frequency* *NumSubConversions* = the value of this parameter.
Modulator IDAC	Sets the modulator IDAC value for the CSD Button, Slider, or Proximity widget. The value of this parameter is automatically set when *Enable IDAC auto-calibration* is selected in the *CSD Settings* tab.
Row modulator IDAC	Sets a separate modulator IDAC value for the row and column sensors of the CSD *Matrix Buttons* and *Touchpad* widget. The values of these parameters are automatically set when *Enable IDAC auto-calibration* is checked in the *CSD Settings* tab.
Column modulator IDAC	
Widget Threshold Parameters **Note** All the threshold parameters for the CSD widgets are automatically set when *SmartSense (Full Auto-Tune)* is selected in the *CSD tuning mode* parameter.	

Name	Description
Finger threshold	The finger threshold parameter is used along with the hysteresis parameter to determine the sensor state as follows: The sensor state: ▪ ON: Signal > (Finger Threshold + Hysteresis) ▪ OFF: Signal ≤ (Finger Threshold – Hysteresis). Note that “Signal” in the above equations refers to: Difference Count = Raw Count – Baseline. It is recommended to set the Finger threshold parameter value to be equal to the 80% touch signal. The Finger Threshold parameter is not available for the *Proximity* widget. Instead, Proximity has two thresholds: ▪ *Proximity threshold* ▪ *Touch threshold*
Noise threshold	The noise threshold parameter sets the raw count limit below which raw count is considered as noise, when the raw count is above the Noise Threshold difference count is produced and the baseline is updated only if *Enable sensor auto-reset* is selected (In other words, the baseline remains constant as long as the raw count is above the baseline + noise threshold. This prevents the baseline from following the raw counts during a finger touch detection event). It is recommended to set the noise threshold parameter value to be equal to 2x noise in the raw count or 40% of signal. For the *Linear Slider*, *Radial Slider* and *Touchpad* widgets, the centroid position is calculated by subtracting the noise threshold from the signals. It provides a more accurate position.
Negative noise threshold	The negative noise threshold parameter sets the raw count limit below which the baseline is not updated for the number of samples specified by the *Low baseline reset* parameter. The negative noise threshold ensures that the baseline does not fall low because of any high-amplitude repeated negative-noise spikes on the raw count caused by different noise sources such as ESD events. It is recommended to set the negative noise threshold parameter value to be equal to the *Noise threshold* parameter value.
Low baseline reset	This parameter is used along with the *Negative noise threshold* parameter. It counts the number of abnormally low raw counts required to reset the baseline. If a finger is placed on the sensor during a device startup, the baseline gets initialized to the high raw count value at a startup. When the finger is removed, raw counts fall to a lower value. In this case, the baseline should track the low raw counts. The Low Baseline Reset parameter helps to handle this event. It resets the baseline to the low raw count value when the number of low samples reaches the low-baseline reset number. Note that in this case, once the finger is removed from the sensor, the sensor will not respond to finger touches for low baseline-reset time. The recommended value is 30 which works for most designs.

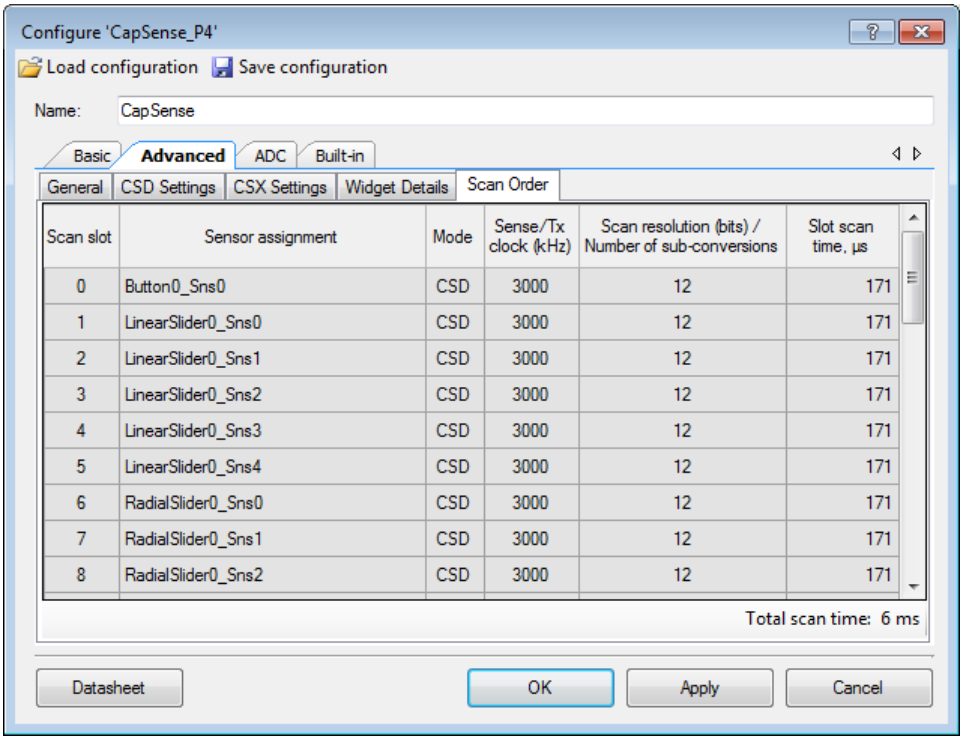
Name	Description
Hysteresis	The hysteresis parameter is used along with the *Finger threshold* parameter (*Proximity threshold* and *Touch threshold* for Proximity sensor) to determine the sensor state. The hysteresis provides immunity against noisy transitions of the sensor state. See the description of *Finger threshold* parameter for details. The recommend value for the hysteresis is the 10% *Finger threshold*.
ON debounce	This parameter selects a number of consecutive CapSense scans during which a sensor must be active to generate an ON state from the Component. Debounce ensures that high-frequency, high-amplitude noise does not cause false detection ▪ Buttons/matric button/proximity: An ON status is reported only when the sensor is touched for a consecutive debounce number of samples. ▪ Sliders/Touchpads: the position status is reported only when any of the sensors is touched for a consecutive debounce number of samples. The recommended value for the Debounce parameter is 3 for reliable sensor status detection.
Proximity threshold	The design of these parameters is the same as for the *Finger threshold* parameters. The proximity sensor requires a higher noise reduction, and supports two levels of detection: ▪ The proximity level to detect an approaching hand or finger. ▪ The touch level to detect a finger touch on the sensor similarly to other *Widget Type* sensors. Note that for valid operation, the Proximity threshold should be higher than the Touch threshold. The threshold parameters such as *Hysteresis* and *ON debounce* are applicable to both detection levels.
Touch threshold	
Sensor parameters	
Compensation IDAC value	Sets Compensation IDAC value for each CSD sensor when *Enable compensation IDAC* is selected on *CSD Settings* tab. If *CSD tuning mode* is set to *SmartSense Auto-tuning* or *Enable IDAC auto-calibration* is selected on the *CSD Settings* tab, the value of this parameter is set equal to Modulator IDAC value at a device power-up for the maximum performance from the sensor. It is recommended to select *Enable IDAC auto-calibration* for robust operation.
IDAC Values	Sets the IDAC value for each CSX sensor/node, a lower value of IDAC without saturating the raw counts provides better performance for sensor/nodes. When *Enable IDAC auto-calibration* is selected on the *CSX Settings* tab, the value of this parameter is automatically set to the lowest possible value at a device power-up for the best performance. It is recommended to select *Enable IDAC auto-calibration* for reliable operation.
Selected pins	Selects a port pin for the sensor (CSD sensing) and electrode (CSX sensing). The available options are using a dedicated pin for a sensor or reusing one or more pins from any other sensor in the component. Reusing the pins of any other sensor from any widgets helps to create a ganged sensor.

The following table shows which parameters belong to a given widget:

Widget Type		Parameters																								
		Widget General					Widget Hardware								Widget Threshold								Sensor		
		Diplexing	Maximum position	Maximum X-axis position	Maximum Y-axis position	Position filter	Sense clock frequency	Row sense clock frequency	Column sense clock frequency	Tx clock frequency	Scan resolution	Number of sub-conversions	Modulator IDAC	Row modulator IDAC	Column modulator IDAC	Finger threshold	Noise threshold	Negative noise threshold	Low baseline reset	Hysteresis	ON debounce	Proximity threshold	Touch threshold	Compensation IDAC value	IDAC Values	Selected pins
CSD Widget	*Button*						√				√		√			√	√	√	√	√	√			√		√
	Linear Slider	√	√			√	√				√		√			√	√	√	√	√	√			√		
	Radial Slider		√			√	√				√		√			√	√	√	√	√	√			√		
	Matrix Buttons							√	√		√			√	√	√	√	√	√	√	√			√		√
	Touchpad			√	√	√		√	√		√			√	√	√	√	√	√	√	√			√		
	Proximity						√				√		√				√	√	√	√	√	√	√	√		√
CSX Widget	*Button*									√		√				√	√	√	√	√	√					√
	Matrix Buttons									√		√				√	√	√	√	√	√				√	√

Scan Order Sub-tab

This tab allows adjusting the scanning order of sensors in dual-channel CSD mode (CSD2x). CSD2x functionality will be available in the next version of the component. Use the **Move up/Move down/Move left/Move right** buttons to move sensors and widgets to appropriate scan slots.

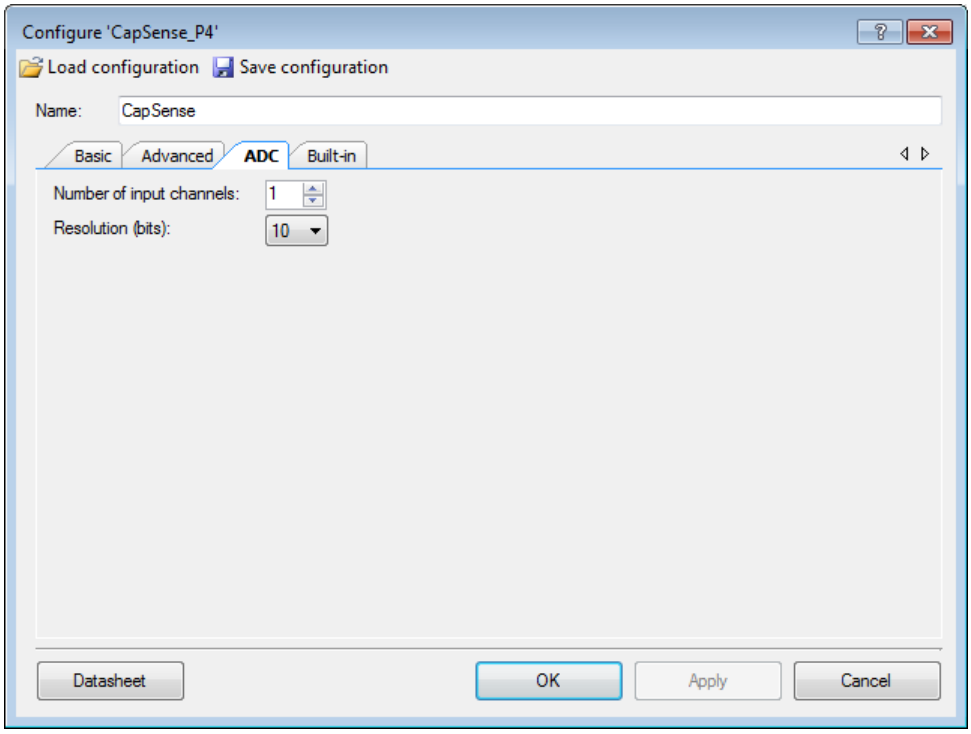


For the optimal performance, sensors scanned in parallel using two CSD blocks (dual-channel CSD) must use the same sense clock frequency and scan resolution. This tab provides error and warning messages when the sensor assignment rules are violated. In addition, this tab also provides Total time required to scan all the sensors (does not include the data processing execution time) and scan time for each sensor slot.

When using CSX-sensing-based widgets or CSD2x is unselected, Scan Order has no editable content and provides the scan time for sensors.

ADC Tab

The parameters in this tab apply to the ADC functionality only.



Name	Description
Number of input channels	Increment/decrement this value to specify the total input channels for the ADC. The range of valid values is 0-10. To place the CapSense_ADC catalog, it is possible to set the number of ADC input channels to 0 to disable the ADC functionality.
Resolution (bits)	This drop-down is used to select the ADC resolution. The possible options are: ▪ 8 bits ▪ 10 bits

Application Programming Interface

Application Programming Interface (API) routines allow you to control and execute specific tasks using the component firmware. The following sections list and describe each function and dependency.

The CapSense firmware library supports the following compilers:

- ARM GCC compiler
- ARM MDK compiler
- IAR C/C++ compiler

In order to use the IAR Embedded Workbench refer to:

- PSoC Creator menu Help / Documentation / PSoC Creator User Guide
  Section: Export a Design to a 3rd Party IDE > Exporting a Design to IAR IDE

Note When using the IAR Embedded Workbench, set the path to the static library. This library is located in the following PSoC Creator installation directory:

PSoC Creator\psoc\content\CyComponentLibrary\CyComponentLibrary.cylib\CortexM0\IAR

By default, the instance name of the component is “CapSense_1” for a first instance of a component in a given design. It can be renamed to any unique text that follows the syntactic rules for identifiers and the instance name is prefixed to every API function, variable, and constant names. For readability, this section assumes “CapSense” as the instance name.

CapSense High Level APIs

Description

High-level APIs represent the highest abstraction layer of the component APIs. These APIs perform tasks such as scanning, data processing, data reporting and tuning interfaces. When performing a task, different initialization required based on a sensing method (CSD or CSX) or type of widgets is automatically handled by these APIs, therefore these APIs are sensing methods, features and widget type agnostics.

All the tasks required to implement a capacitive user-interface can be fulfilled by the high level APIs, But, there is a set of CapSense Low Level APIs which provides access to lower level and specific tasks. If a design require access to low-level tasks, these APIs can be used.

Functions

- cystatus CapSense_Start(void)
  Initializes component hardware and firmware modules. This function should be called by the application program prior to calling any other function of the component.
- cystatus CapSense_Stop(void)
  Stops the component operation.
- cystatus CapSense_Resume(void)
  Resumes the component operation if CapSense_Stop() function was called previously.
- cystatus CapSense_ProcessAllWidgets(void)
  Performs full data processing of all enabled widgets.
- cystatus CapSense_ProcessWidget(uint32 widgetId)
  Performs full data processing of the specified widget if it is enabled.
- void CapSense_Sleep(void)
  Prepares the component to deep sleep.
- void CapSense_Wakeup(void)
  Currently this function is empty and exists as a place for future updates, this function shall be used to resume the component after exiting deep sleep.
- cystatus CapSense_SetupWidget(uint32 wdgtIndex)
  Performs the initialization required to scan the specified widget.
- cystatus CapSense_Scan(void)
  Initiates scan of all sensors in the widget which is initialized by CapSense_SetupWidget(), if the no scan is in progress.
- cystatus CapSense_ScanAllWidgets(void)
  Initializes the first enabled widget and scans of all the sensors in the widget, then the same process is repeated for all widgets in the component. I.e. scan all the widgets in the component.
- uint32 CapSense_IsBusy(void)
  Returns the current status of the component (scan completed or scan in progress).
- uint32 CapSense_IsAnyWidgetActive(void)
  Reports if any widget has detected a touch.
- uint32 CapSense_IsWidgetActive(uint32 widgetId)
  Reports if the specified widget detects a touch on any of its sensors.
- uint32 CapSense_IsSensorActive(uint32 widgetId, uint32 sensorId)
  Reports if the specified sensor in the widget detects a touch.
- uint32 CapSense_IsMatrixButtonsActive(uint32 widgetId)

Reports the status of the specified matrix button widget.

- uint32 CapSense_IsProximitySensorActive(uint32 widgetId, uint32 proxId)
  Reports the finger detection status of the specified proximity widget/sensor.
- uint32 CapSense_GetCentroidPos(uint32 widgetId)
  Reports the centroid position for the specified slider widget.
- uint32 CapSense_GetXYCoordinates(uint32 widgetId)
  Reports the X/Y position detected for the specified touchpad widget.
- uint32 CapSense_RunTuner(void)
  Establishes synchronized communication with the Tuner application.

Function Documentation

cystatus CapSense_Start (void)

This function initializes the component hardware and firmware modules and should be called by the application program prior to calling any other API of the component. When this function is called, the following tasks are executed as part of the initialization process:

1. Initialize the registers of the Data Structure variable CapSense_dsRam based on the user selection in component configuration wizard.
2. Configure the hardware to perform capacitive sensing.
3. If SmartSense Auto-tuning is selected for the CSD Tuning mode in the Basic tab, the auto-tuning algorithm is executed to set the optimal values for the hardware parameters of the widgets/sensors.
4. Calibrate the sensors and find the optimal values for IDACs of each widget / sensor, if the Enable IDAC auto-calibration is enabled in the CSD Setting or CSX Setting tabs.
5. Perform a scan for all sensors and initialize the baseline history. During the scan, CPU is in the sleep mode to save power.
6. If the firmware filters are enabled in the Advanced General tab, the filter histories are also initialized.

Any next call of this API repeats an initialization process except for data structure initialization. Therefore, it is possible to change the component configuration from the application program by writing to the data structure registers and calling this function again. This is also done inside the CapSense_RunTuner() function when a restart command is received.

When the component operation is stopped by the CapSense_Stop() function, the CapSense_Start() function repeats an initialization process including data structure initialization.

Returns:

Returns the status of the initialization process. If CYRET_SUCCESS is not received, some of the initialization fails and the component may not operate as expected.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_Stop (void)

This function stops the component operation, no sensor scanning can be executed when the component is stopped. Once stopped, the hardware block may be reconfigured by the application program for any other special usage. The component operation can be resumed by calling the CapSense_Resume() function or the component can be reset by calling the CapSense_Start() function.

This function should be called when no scanning is in progress. I.e. CapSense_IsBusy() returns a non-busy status.

Returns:

Returns the status of the stop process. If CYRET_SUCCESS is not received, the stop process fails and retries may be required.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_Resume (void)

This function resumes the component operation if the operation is stopped previously by the CapSense_Stop() function. The following tasks are executed as part of the operation resume process:

1. Reset all Widgets/Sensors status.
2. Configure the hardware to perform capacitive sensing.

Returns:

Returns the status of the resume process. If CYRET_SUCCESS is not received, the resume process fails and retries may be required.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_ProcessAllWidgets (void)

This function performs all data processes for all enabled widgets in the component. The following tasks are executed as part of processing all the widgets:

1. Apply raw0count filters to raw counts, if they are enabled in the customizer.
2. Update thresholds if the SmartSense uFll Auto-Tuning is enabled in the customizer.
3. Update the Baselines and Difference counts for all sensors.
4. Update the sensor and widget status (on/off), update centroid for sliders and X/Y position for touchpads.

Disabled widgets are not processed. To disable/enable a widget, set appropriate values in the CapSense_WDGT_ENABLE<RegisterNumber>_PARAM_ID register using the CapSense_SetParam() function. This function should be called only after all the sensors in the component are scanned. Calling this function multiple times without sensor scanning causes unexpected behavior.

Returns:

Returns the status of the process operation. If CYRET_SUCCESS is not received, the process failed.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_ProcessWidget (uint32 *widgetId*)

This function performs exactly the same tasks as CapSense_ProcessAllWidgets(), but only for a specified widget. This function can be used along with the CapSense_SetupWidget() and CapSense_Scan() functions to scan and process data for a specific widget. This function should be called only after all the sensors in the widgets are scanned. A disabled widget is not processed by this function.

The pipeline scan method (i.e. during scanning of a widget perform processing of the previously scanned widget) can be implemented using this function and it may reduce the total scan/process time, increase the refresh rate and decrease the power consumption.

Parameters:

widgetId	Specify the ID number of the widget to be processed. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID

Returns:

Returns the status of the widget processing:

- CYRET_SUCCESS if operation is successfully completed.
- CYRET_BAD_PARAM if the input parameter is invalid.
- CYRET_INVALID_STATE if the specified widget is disabled.

Go to the top of the CapSense High Level APIs section.

void CapSense_Sleep (void)

Currently this function is empty and exists as a place for future updates, this function shall be used to prepare the component to enter deep sleep.

Go to the top of the CapSense High Level APIs section.

void CapSense_Wakeup (void)

This function resumes the component after sleep.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_SetupWidget (uint32 *wdgtIndex*)

This function prepares the component to scan all sensors in the specified widget, by executing the following tasks.

1. Re-initialize the hardware if it is not configured to perform the sensing method used by the specified widget, this happens only if the CSD and CSX methods are used in the component.
2. Initialize the hardware with specific sensing configuration (e.g. sensor clock, scan resolution) used by the widget.
3. Disconnect all previously connected electrodes, if the electrodes connected by the CapSense_CSDSetupWidgetExt(), CapSense_CSXSetupWidgetExt() or CapSense_CSDConnectSns() functions and not disconnected.

This function does not start sensor scanning, the CapSense_Scan() function must be called to start the scan sensors in the widget. If this function is called more than once, it does not break the component operation, but only the last initialized widget is in effect.

Parameters:

wdgtIndex	Specify the ID number of the widget to be initialized for scanning. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID

Returns:

Returns the status of the widget setting up operation:

- CYRET_SUCCESS if the operation is successfully completed.
- CYRET_BAD_PARAM if the widget is invalid or if the specified widget is disabled
- CYRET_INVALID_STATE if the previous scanning is not completed and the hardware block is busy.
- CYRET_UNKNOWN if an unknown sensing method is used by the widget or other spurious errors.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_Scan (void)

This function should be called only after the CapSense_SetupWidget() function is called to start the scanning of the sensors in the widget. The status of a sensor scan must be checked using the CapSense_IsBusy() API prior to starting a next scan or setting up another widget.

Returns:

Returns the status of the scan initiation operation:

- CYRET_SUCCESS if scanning is successfully started.
- CYRET_INVALID_STATE if the previous scanning is not completed and the hardware block is busy.
- CYRET_UNKNOWN if an unknown sensing method is used by the widget.

Go to the top of the CapSense High Level APIs section.

cystatus CapSense_ScanAllWidgets (void)

This function initializes a widget and scans all the sensors in the widget, and then repeats the same for all the widgets in the component. The tasks of the CapSense_SetupWidget() and CapSense_Scan() functions are executed by these functions. The status of a sensor scan must be checked using the the CapSense_IsBusy() API prior to starting a next scan or setting up another widget.

Returns:

Returns the status of operation:

- CYRET_SUCCESS if scanning is successfully started.
- CYRET_BAD_PARAM if all the widgets are disabled.
- CYRET_INVALID_STATE if the previous scanning is not completed and the HW block is busy.

- CYRET_UNKNOWN if there are unknown errors.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_IsBusy (void)

This function returns the status of the hardware block whether a scan is currently in progress or not. If the component is busy, no new scan or setup widgets should be made. It is recommended to use the critical section (i.e. disable global interrupt) in the application when the device transitions from the active mode to sleep or deep sleep mode.

Returns:

Returns the current status of the component:

- CapSense_NOT_BUSY if there is no scan in progress and a next scan can be initiated.
- CapSense_SW_STS_BUSY if the previous scanning is not completed and the hardware block is busy.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_IsAnyWidgetActive (void)

This function reports if any widget has detected a touch or not by extracting the information from the wdgtStatus registers (CapSense_WDGT_STATUS<X>_VALUE). This function does not process any widget but extracts the processed results from the Data Structure.

Returns:

Returns the touch detection status of all widgets:

- Zero if no touch is detected in all widgets or sensors.
- Non-zero if at least one widget or sensor detected a touch.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_IsWidgetActive (uint32 *widgetId*)

This function reports if the specified widget has detected a touch or not by extracting the information from the wdgtStatus registers (CapSense_WDGT_STATUS<X>_VALUE). This function does not process the widget, but extracts the processed results from the Data Structure.

Parameters:

widgetId	Specify the ID number of the widget to get its status. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.

Returns:

Returns the touch detection status of the specified widgets:

- Zero if no touch is detected in the specified widget or a wrong widgetId is specified
- Non-zero if at least one sensor of the specified widget is active i.e. touch is detected

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_IsSensorActive (uint32 *widgetId*, uint32 *sensorId*)

This function reports if the specified sensor in the widget has detected a touch or not by extracting the information from wdgtStatus registers (CapSense_WDGT_STATUS<X>_VALUE). This function does not process the widget or sensor, but extracts the processed results from the Data Structure.

For Proximity sensors this function returns proximity detection status. To get finger touch status of proximity sensors, use the CapSense_IsProximityTouchActive() function.

Parameters:

widgetId	Specify the ID number of the widget. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID

sensorId	Specify the ID number of the sensor within the widget to get its touch detection status. A macro for the sensor ID within specified widget can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID

Returns:

Returns the touch detection status of the specified sensor / widget:

- Zero if no touch is detected in the specified sensor / widget or a wrong widget ID / sensor ID is specified
- Non-zero if the specified sensor is active i.e. touch is detected. If the specific sensor belongs to a proximity widget, the proximity detection status is returned.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_IsMatrixButtonsActive (uint32 *widgetId*)

This function reports if the specified matrix widget has detected a touch or not by extracting the information from the wdgtStatus registers (CapSense_WDGT_STATUS<X>_VALUE for the CSD widgets and CapSense_SNS_STATUS<WidgetId>_VALUE for CSX widget). In addition, the function provides details of the active sensor including active rows/columns for the CSD widgets. This function should be used only with the matrix button widgets. This function does not process the widget, but extracts the processed results from the Data Structure.

Parameters:

widgetId	Specify the ID number of the matrix button widget to check status of its sensors. A macro for widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID

Returns:

Returns the touch detection status of sensors in the specified matrix buttons widget. Zero indicates that no touch is detected in the specified widget or a wrong widgetId is specified.

1. For the matrix buttons widgets with the CSD sensing mode:
   - Bit [31] if set, indicates that one or more sensors in the widget detected a touch.
   - Bits [30..24] is reserved
   - Bits [23..16] indicates the logical sensor number of the sensor that detected a touch. If more than one sensor detected a touch for the CSD widget, no status is reported as more than one touch is invalid for the CSD matrix buttons widgets.
   - Bits [15..8] indicates a status of each row sensors. Each bit indicates an ON/OFF status of each row sensor.
   - Bits [7..0] indicates a status of each column sensors. Each bit indicates an ON/OFF status of each column sensor.
2. For the matrix buttons widgets with the CSX widgets, each bit (31..0) corresponds to the TX/RX intersection.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_IsProximitySensorActive (uint32 *widgetId*, uint32 *proxId*)

This function reports if the specified proximity sensor has detected a touch or not by extracting the information from the wdgtStatus registers (CapSense_SNS_STATUS<WidgetId>_VALUE). This function should be used only with the proximity sensor widgets. This function does not process the widget but extracts the processed results from the Data Structure.

Parameters:

widgetId	Specify the ID number of the proximity widget. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID
proxId	Specify the ID number of the proximity sensor within the proximity widget to get its touch detection status. A macro for the proximity ID

	within a specified widget can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID

Returns:

Returns the status of the specified sensor of proximity widget. Zero indicates that no touch is detected in the specified sensor / widget or a wrong widgetId / proxId is specified.

- Bits [31..2] is reserved.
- Bit [1] indicates that a touch is detected.
- Bit [0] indicates that a proximity is detected.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_GetCentroidPos (uint32 *widgetId*)

This function reports the centrode value of a specified radial or linear slider widget by extracting the information from the wdgtStatus registers (CapSense_<WidgetName>_POSITION<X>_VALUE). This function should be used only with the radial or linear slider widgets. This function does not process the widget but extracts the processed results from the Data Structure.

Parameters:

widgetId	Specify the ID number of the slider widget to get the centroid of the detected touch. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID

Returns:

Returns the centroid position of a specified slider widget:

- The centroid position if a touch is detected.
- CapSense_SLIDER_NO_TOUCH if no touch is detected or a wrong widgetId is specified.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_GetXYCoordinates (uint32 *widgetId*)

This function reports a touch position (X and Y coordinates) value of a specified touchpad widget by extracting the information from the wdgtStatus registers (CapSense_<WidgetName>_POS_Y_VALUE). This function should be used only with the touchpad widgets. This function does not process the widget, but extracts the processed results from the Data Structure.

Parameters:

widgetId	Specify the ID number of the touchpad widget to get the X/Y position of a detected touch. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.

Returns:

Returns the touch position of a specified touchpad widget:

1. If a touch is detected:
   - Bits [31..16] indicates the Y coordinate.
   - Bits [15..0] indicates the X coordinate.
2. If no touch is detected or a wrong widgetId is specified:
   - CapSense_TOUCHPAD_NO_TOUCH.

Go to the top of the CapSense High Level APIs section.

uint32 CapSense_RunTuner (void)

This function is used to establish synchronized communication between the CapSense component and Tuner application (or other host controllers). This function should be called periodically in the application program loop

to serve the Tuner application (or host controller) requests and commands. In most cases, the best place to call this function is after processing and before next scanning.

If this function is absent in the application program, then communication is asynchronous and the following disadvantages are applicable:

- The raw counts displayed in the tuner may be filtered and/or unfiltered firmware and as a result, noise and SNR measurements will not be accurate.
- The Tuner may read the sensor data such as raw counts from a scan multiple times, as a result, noise and SNR measurement will not be accurate.
- The Tuner and host controller should not change the component parameters via the tuner interface. Changing the component parameters via the tuner interface in the async mode will result in abnormal behavior from the component.

Note that calling this function is not mandatory for the application, but required only to synchronize the communication with the host controller or tuner application.

Returns:

In some cases, the application program may need to know if the component was re-initialized. The return indicates if a restart command was executed or not:

- CapSense_STATUS_RESTART_DONE based on a received command, the component was restarted.
- CapSense_STATUS_RESTART_NONE, no restart was executed by this function.

Go to the top of the CapSense High Level APIs section.

CapSense Low Level APIs

Description

The low-level APIs represent the lower layer of abstraction in support of high-level APIs. These APIs also enable implementation of special case designs requiring performance optimization and non-typical functionalities.

The functions which contain CSD or CSX in the name are specified for CSD or CSX sensing method appropriately and should be used only with dedicated CSD or CSX widgets. All rest functions are not specific to CSD or CSX sensing methods, some of the APIs detects the sensing method used by the widget and executes tasks as appropriately.

Functions

- cystatus CapSense_ProcessWidgetExt(uint32 widgetId, uint32 mode)
  Performs customized data processing on the selected widget.
- cystatus CapSense_ProcessSensorExt(uint32 widgetId, uint32 sensorId, uint32 mode)
  Performs customized data processing on the selected widget's sensor.
- cystatus CapSense_UpdateAllBaselines(void)
  Updates the baseline for all sensors in all widgets.
- cystatus CapSense_UpdateWidgetBaseline(uint32 widgetId)
  Updates the baseline for all sensors in a widget specified by input parameter.
- cystatus CapSense_UpdateSensorBaseline(uint32 widgetId, uint32 sensorId)
  Updates the baseline for a sensor in a widget specified by input parameters.
- void CapSense_InitializeAllBaselines(void)
  Initializes (or re-initialize) the baseline of all sensors of all widgets.
- void CapSense_InitializeWidgetBaseline(uint32 widgetId)
  Initializes (or re-initialize) the baseline of all sensors in a widget specified by input parameter.
- void CapSense_InitializeSensorBaseline(uint32 widgetId, uint32 sensorId)

Initializes (or re-initialize) the baseline of a sensor in a widget specified by input parameters.

- void CapSense_SetPinState(uint32 wdgtIndex, uint32 snsIndex, uint32 state)
  Sets the state (drive mode and output state) of port pin used by a sensor. The possible states are GND, Shield, High-Z, Tx or Rx, sensor. If the sensor specified in the input parameter is a ganged sensor, then state of all pins associated with ganged sensor is updated.
- cystatus CapSense_CalibrateWidget(uint32 wdgtIndex)
  Calibrates the IDACs for all sensors in the specified widget to default target (85%) value, this function detects sensing method used by the widget prior to calibration.
- cystatus CapSense_CalibrateAllWidgets(void)
  Calibrates the IDACs for all widgets in the component to default target (85%) value, this function detects sensing method used by the widgets prior to calibration.
- void CapSense_CSDSetupWidget(uint32 wdgtIndex)
  Performs hardware and firmware initialization required for scanning sensors in a specific widget using the CSD sensing method. The CapSense_CSDScan() function should be used to start scanning when using this function.
- void CapSense_CSDSetupWidgetExt(uint32 wdgtIndex, uint32 snsIndex)
  Performs extended initialization for the CSD widget and also performs initialization required for a specific sensor in the widget. The CapSense_CSXScanExt() function should be called to initiate a scan when using this function.
- void CapSense_CSDScan(void)
  This function initiates the scan for sensors of the widget initialized by the CapSense_CSDSetupWidget() function.
- void CapSense_CSDScanExt(void)
  Starts the CSD conversion on the preconfigured sensor. CapSense_CSXSetupWidgetExt() function should be used to setup the widget when using this function.
- cystatus CapSense_CSDCalibrateWidget(uint32 wdgtIndex, uint32 target)
  Executes IDAC calibration for all sensors in the widget specified in an input.
- void CapSense_CSDConnectSns (CapSense_FLASH_IO_STRUCTconst *snsAddrPtr)
  Connects a port-pin used by the sensor to AMUX bus of CapSense block.
- void CapSense_CSDDisconnectSns (CapSense_FLASH_IO_STRUCTconst *snsAddrPtr)
  Disconnects a sensor port-pin from the CapSense block and AMUX bus. Sets the default state of the un-scanned sensor.
- void CapSense_CSXSetupWidget(uint32 widgetIndex)
  Performs hardware and firmware initialization required for scanning sensors in a specific widget using the CSX sensing method. The CapSense_CSDScan() function should be used to start scanning when using this function.
- void CapSense_CSXSetupWidgetExt(uint32 widgetIndex, uint32 snsIndex)
  Performs extended initialization for the CSX widget and also performs initialization required for a specific sensor in the widget. The CapSense_CSXScan() function should be called to initiate the scan when using this function.
- void CapSense_CSXScan(void)
  This function initiates the scan for sensors of the widget initialized by the CapSense_CSXSetupWidget() function.
- void CapSense_CSXScanExt(void)
  Starts the CSX conversion on the preconfigured sensor. The CapSense_CSXSetupWidgetExt() function should be used to setup a widget when using this function.
- void CapSense_CSXCalibrateWidget(uint32 widgetIndex, uint16 target)
  Calibrates the raw count values of all sensors/nodes in a CSX widget.
- void CapSense_CSXConnectTx (CapSense_FLASH_IO_STRUCTconst *txPtr)
  Connects a TX electrode to the CSX scanning hardware.
- void CapSense_CSXConnectRx (CapSense_FLASH_IO_STRUCTconst *rxPtr)
  Connects an RX electrode to the CSX scanning hardware.

- void CapSense_CSXDisconnectTx (CapSense_FLASH_IO_STRUCTconst *txPtr)
  Disconnects a TX electrode from the CSX scanning hardware.
- void CapSense_CSXDisconnectRx (CapSense_FLASH_IO_STRUCTconst *rxPtr)
  Disconnects an RX electrode from the CSX scanning hardware.
- cystatus CapSense_GetParam(uint32 paramId, uint32 *value)
  Gets the specified parameter value from the Data Structure.
- cystatus CapSense_SetParam(uint32 paramId, uint32 value)
  Sets a new value for the specified parameter in the Data Structure.

Function Documentation

cystatus CapSense_ProcessWidgetExt (uint32 *widgetId*, uint32 *mode*)

This function performs data processes for the specified widget specified by the mode parameter. The execution order of the requested operations is from LSB to MSB of the mode parameter. If a different order is needed, this API can be called multiple times with the required mode parameter.

This function can be used with any of the available scan functions. This function should be called only after all sensors in the specified widget are scanned. Calling this function multiple times with the same mode without sensor scanning causes unexpected behavior. This function ignores the value of the wdgtEnable register.

The CapSense_PROCESS_CALC_NOISE and CapSense_PROCESS_THRESHOLDS flags are supported by the CSD sensing method only when the auto-tuning mode is enabled.

The pipeline scan method (i.e. during scanning of a widget perform processing of a previously scanned widget) can be implemented using this function and it may reduce the total scan/process time, increase the refresh rate and decrease the power consumption.

Parameters:

widgetId	Specify the ID number of the widget to be processed. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.
mode	Specify the type of widget processing that needs to be executed for the specified widget: 1. Bits [31..6] - Reserved 2. Bits [5..0] - CapSense_PROCESS_ALL - Execute all tasks 3. Bit [5] - CapSense_PROCESS_STATUS - Update Status (on/off, centroid position) 4. Bit [4] - CapSense_PROCESS_THRESHOLDS - Update Thresholds (only in CSD auto-tuning mode) 5. Bit [3] - CapSense_PROCESS_CALC_NOISE - Calculate Noise (only in CSD auto-tuning mode) 6. Bit [2] - CapSense_PROCESS_DIFFCOUNTS - Update Difference Counts 7. Bit [1] - CapSense_PROCESS_BASELINE - Update Baselines 8. Bit [0] - CapSense_PROCESS_FILTER - Run Firmware Filter

Returns:

Returns the status of the widget processing operation:

- CYRET_SUCCESS if processing is successfully performed.
- CYRET_BAD_PARAM if the input parameter is invalid.

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_ProcessSensorExt (uint32 *widgetId*, uint32 *sensorId*, uint32 *mode*)

This function performs data processes for the specified sensor specified by the mode parameter. The execution order of the requested operations is from LSB to MSB of the mode parameter. If a different order is needed, this function can be called multiple times with the required mode parameter.

This function can be used with any of the available scan functions. This function should be called only after a specified sensor in the widget is scanned. Calling this function multiple times with the same mode without sensor scanning causes unexpected behavior. This function ignores the value of the wdgtEnable register.

The CapSense_PROCESS_CALC_NOISE and CapSense_PROCESS_THRESHOLDS flags are supported by the CSD sensing method only when the auto-tuning mode is enabled.

The pipeline scan method (i.e. during scanning of a sensor perform processing of a previously scanned sensor) can be implemented using this function and it may reduce the total scan/process time, increase the refresh rate and decrease the power consumption.

Parameters:

widgetId	Specify the ID number of the widget to process one of its sensors. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID
sensorId	Specify the ID number of the sensor within the widget to process it. A macro for the sensor ID within a specified widget can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID
mode	Specify the type of the sensor processing that needs to be executed for the specified sensor: 1. Bits [31..5] - Reserved 2. Bits [4..0] - CapSense_PROCESS_ALL - Executes all tasks 3. Bit [4] - CapSense_PROCESS_THRESHOLDS - Updates Thresholds (only in auto-tuning mode) 4. Bit [3] - CapSense_PROCESS_CALC_NOISE - Calculates Noise (only in auto-tuning mode) 5. Bit [2] - CapSense_PROCESS_DIFFCOUNTS - Updates Difference Count 6. Bit [1] - CapSense_PROCESS_BASELINE - Updates Baseline 7. Bit [0] - CapSense_PROCESS_FILTER - Runs Firmware Filter

Returns:

Returns the status of the sensor process operation:

- CYRET_SUCCESS if processing is successfully performed.
- CYRET_BAD_PARAM if the input parameter is invalid.

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_UpdateAllBaselines (void)

Updates the baseline for all sensors in all widgets. Baseline updating is a part of data processing performed by the process functions. So, no need to call this function except a specific process flow is implemented.

This function ignores the value of the wdgtEnable register. Multiple calling of this function (or any other function with a baseline updating task) without scanning leads to unexpected behavior.

Returns:

Returns the status of the update baseline operation of all widgets:

- CYRET_SUCCESS if operation was successfully completed

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_UpdateWidgetBaseline (uint32 *widgetId*)

This function performs exactly the same tasks as CapSense_UpdateAllBaselines(), but only for a specified widget.

This function ignores the value of the wdgtEnable register. Multiple calling of this function (or any other function with a baseline updating task) without scanning leads to unexpected behavior.

Parameters:

widgetId	Specify the ID number of the widget to update the baseline of all sensors in the widget. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID Specifies the ID of the widget.

Returns:

Returns the status of the specified widget update baseline operation:

- CYRET_SUCCESS if operation was successfully completed

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_UpdateSensorBaseline (uint32 *widgetId*, uint32 *sensorId*)

This function performs exactly the same tasks as CapSense_UpdateAllBaselines() and CapSense_UpdateWidgetBaseline() but only for a specified sensor.

This function ignores the value of the wdgtEnable register. Multiple calling of this function (or any other function with a baseline updating task) without scanning leads to unexpected behavior.

Parameters:

widgetId	Specify the ID number of the widget to update the baseline of the sensor specified by the sensorId parameter. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID Specifies the ID of the widget.
sensorId	Specify the ID number of the sensor within the widget to update its baseline. A macro for the sensor ID within a specified widget can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID

Returns:

Returns the status of the specified sensor update baseline operation:

- CYRET_SUCCESS if operation was successfully completed

Go to the top of the CapSense Low Level APIs section.

void CapSense_InitializeAllBaselines (void)

Initializes the baseline for all sensors of all widgets. Also, this function can be used to re-initialize baselines. CapSense_Start() calls this API as part of CapSense operation initialization.

Go to the top of the CapSense Low Level APIs section.

void CapSense_InitializeWidgetBaseline (uint32 *widgetId*)

Initializes (or re-initializes) the baseline for all sensors of the specified widget.

Parameters:

widgetId	Specify the ID number of a widget to initialize the baseline of all sensors in the widget. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID Specifies the ID of the widget.

Go to the top of the CapSense Low Level APIs section.

void CapSense_InitializeSensorBaseline (uint32 *widgetId*, uint32 *sensorId*)

Initializes (or re-initializes) the baseline for a specified sensor within a specified widget.

Parameters:

widgetId	Specify the ID number of a widget to initialize the baseline of all sensors in the widget. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID Specifies the ID of the widget.
sensorId	Specify the ID number of the sensor within the widget to initialize its baseline. A macro for the sensor ID within a specified widget can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID

Go to the top of the CapSense Low Level APIs section.

void CapSense_SetPinState (uint32 *wdgtIndex*, uint32 *snsIndex*, uint32 *state*)

This function sets a specified state to the specified sensor pin. If the sensor is a ganged sensor, then the specified state is also set for all ganged pins of this sensor. Scanning should be completed before calling this API.

The CapSense_SHIELD and CapSense_SENSOR states are not allowed if there is no CSD widget configured in the user's project. The CapSense_TX_PIN and CapSense_RX_PIN states are not allowed if there is no CSX widget configured in the user's project.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases. Functions that perform a setup and scan of the sensor/widget automatically set needed pin states. They do not take into account changes in the design made by the CapSense_SetPinState() function.

Parameters:

wdgtIndex	Specify the ID number of the widget to change the pin state of the specified sensor. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID Specifies the ID of the widget.
snsIndex	Specify the ID number of the sensor within the widget to change its pin state. A macro for the sensor ID within a specified widget can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID
state	Specify the state of the sensor that needs to be set: 1. CapSense_GROUND - The pin is connected to ground. 2. CapSense_HIGHZ - The drive mode of the pin is set to High-Z Analog. 3. CapSense_SHIELD - The shield signal is routed to the pin (only in CSD sensing method when shield electrode is enabled). 4. CapSense_SENSOR – The pin is connected to the scanning bus (only in CSD sensing method). 5. CapSense_TX_PIN – The TX signal is routed to the sensor (only in CSX sensing method). 6. CapSense_RX_PIN – The pin is connected to the scanning bus (only in CSX sensing method).

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_CalibrateWidget (uint32 *wdgtIndex*)

This function performs exactly the same tasks as CapSense_CalibrateAllWidgets, but only for a specified widget. This function detects the sensing method used by the widgets and takes into account the Enable compensation IDAC parameter.

This function is available when the CSD and/or CSX Enable IDAC auto-calibration parameter is enabled.

Parameters:

wdgtIndex	Specify the ID number of the widget to calibrate its raw count. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.

Returns:

Returns the status of the specified widget calibration:

- CYRET_SUCCESS if operation is successfully completed.
- CYRET_BAD_PARAM if the input parameter is invalid.
- CYRET_BAD_DATA if the calibration failed and the component may not operate as expected.

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_CalibrateAllWidgets (void)

Calibrates the IDACs for all widgets in the component to the default target (85% of maximum possible raw count) value. This function detects the sensing method used by the widgets and takes into account the Enable compensation IDAC parameter.

This function is available when the CSD and/or CSX Enable IDAC auto-calibration parameter is enabled.

Returns:

Returns the status of the calibration process:

- CYRET_SUCCESS if the operation is successfully completed.
- CYRET_BAD_DATA if the calibration failed and the component may not operate as expected.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSDSetupWidget (uint32 *wdgtIndex*)

This function initializes the specific widget common parameters to perform the CSD scanning. The initialization includes setting up a Modulator and Sense clock frequency and scanning resolution.

This function does not connect any specific sensors to the scanning hardware and also does not start a scanning process. The CapSense_CSDScan() API must be called after initializing the widget to start scanning.

This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status.

This function is called by the CapSense_SetupWidget() API if the given widget uses the CSD sensing method.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example).

Parameters:

wdgtIndex	Specify the ID number of the widget to perform hardware and firmware initialization required for scanning sensors in the specific widget. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSDSetupWidgetExt (uint32 *wdgtIndex*, uint32 *snsIndex*)

This function does the same as CapSense_CSDSetupWidget() and also the following tasks:

1. Connects the first sensor of the widget.
2. Configures the IDAC value.
3. Initializes an interrupt callback function to initialize a scan of the next sensors in a widget.

Once this function is called to initialize a widget and a sensor, the CapSense_CSDScanExt() function should be called to scan the sensor.

This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example).

Parameters:

wdgtIndex	Specify the ID number of the widget to perform hardware and firmware initialization required for scanning the specific sensor in the specific widget. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.
snsIndex	Specify the ID number of the sensor within the widget to perform hardware and firmware initialization required for scanning a specific sensor in a specific widget. A macro for the sensor ID within a specified widget can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSDScan (void)

This function performs scanning of all sensors in the widget configured by the CapSense_CSDSetupWidget() function. It does the following tasks:

1. Connects the first sensor of the widget.
2. Configures the IDAC value.
3. Initializes the interrupt callback function to initialize a scan of the next sensors in a widget.
4. Starts scanning for the first sensor in the widget.

This function is called by the CapSense_Scan() API if the given widget uses the CSD sensing method.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example).

This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status. The widget must be preconfigured by the CapSense_CSDSetupWidget() function if other widget was previously scanned or other type of scan functions were used.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSDScanExt (void)

This function performs single scanning of one sensor in the widget configured by the CapSense_CSDSetupWidgetExt() function. It does the following tasks:

1. Sets the busy flag in the CapSense_dsRam structure.
2. Performs the clock-phase alignment of the sense and modulator clocks.
3. Performs Cmod pre-charging.
4. Starts single scanning.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example). This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status.

The sensor must be preconfigured by using the CapSense_CSDSetupWidgetExt() API prior to calling this function. The sensor remains ready for the next scan if a previous scan was triggered by using the CapSense_CSDScanExt() function. In this case, calling CapSense_CSDSetupWidgetExt() is not required every time before the CapSense_CSDScanExt() function. If a previous scan was triggered in any other way: CapSense_Scan(), CapSense_ScanAllWidgets() or CapSense_RunTuner() (see the CapSense_RunTuner() function description for more details), the sensor must be preconfigured again by using the CapSense_CSDSetupWidgetExt() API prior to calling the CapSense_CSDScanExt() function.

If disconnection of the sensors is required after calling CapSense_CSDScanExt(), the CapSense_CSDDisconnectSns() function can be used.

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_CSDCalibrateWidget (uint32 *wdgtIndex*, uint32 *target*)

Performs a successive approximation search algorithm to find appropriate IDAC values for sensors in the specified widget that provides the raw count to the level specified by the target parameter.

Calibration is always performed in the single IDAC mode and if the dual IDAC mode (Enable compensation IDAC is enabled) is configured, the IDAC values are re-calculated to match the raw count target. If a widget consists of two or more elements (buttons, slider segments, etc.), then calibration is performed by the element with the highest sensor capacitance.

Calibration fails if the achieved raw count is outside of the +/-10% range of the target.

This function is available when the CSD Enable IDAC auto-calibration parameter is enabled or the SmartSense auto-tuning mode is configured.

Parameters:

wdgtIndex	Specify the ID number of the CSD widget to calibrate its raw count. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.
target	Specify the calibration target in percentages of the maximum raw count.

Returns:

Returns the status of the specified widget calibration:

- CYRET_SUCCESS if the operation is successfully completed.
- CYRET_BAD_PARAM if the input parameter is invalid.
- CYRET_BAD_DATA if the calibration failed and the component may not operate as expected.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSDConnectSns (CapSense_FLASH_IO_STRUCTconst * *snsAddrPtr*)

Connects a port-pin used by the sensor to the AMUX bus of the CapSense block while a sensor is being scanned. The function does not take into account if the sensor is a ganged sensor and connects only a specified pin.

Scanning should be completed before calling this API.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases. Functions that perform a setup and scan of sensor/widget automatically set the needed pin states and perform the sensor connection. They do not take into account changes in the design made by the CapSense_CSDConnectSns() function.

Parameters:

snsAddrPtr	Specify the pointer to the FLASH_IO_STRUCT object belonging to a sensor which should be connected to the CapSense block.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSDDisconnectSns (CapSense_FLASH_IO_STRUCTconst * *snsAddrPtr*)

This function works identically to CapSense_CSDConnectSns() except it disconnects the specified port-pin used by the sensor.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases. Functions that perform a setup and scan of sensor/widget automatically set the needed pin states and perform the sensor connection. They do not take into account changes in the design made by the CapSense_CSDDisconnectSns() function.

Parameters:

snsAddrPtr	Specify the pointer to the FLASH_IO_STRUCT object belonging to a sensor which should be disconnected from the CapSense block.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXSetupWidget (uint32 *widgetIndex*)

This function initializes the widgets specific common parameters to perform the CSX scanning. The initialization includes the following:

1. The CSD_CONFIG register.
2. The IDAC register.
3. The Sense clock frequency
4. The phase alignment of the sense and modulator clocks.

This function does not connect any specific sensors to the scanning hardware and also does not start a scanning process. The CapSense_CSXScan() function must be called after initializing the widget to start scanning.

This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns anon-busy status.

This function is called by the CapSense_SetupWidget() API if the given widget uses the CSX sensing method.

It is not recommended to call this function directly from the application . layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example).

Parameters:

widgetId	Specify the ID number of the widget to perform hardware and firmware initialization required for scanning sensors in the specific widget. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXSetupWidgetExt (uint32 *widgetIndex*, uint32 *snsIndex*)

This function does the same tasks as CapSense_CSXSetupWidget() and also connects a sensor in the widget for scanning. Once this function is called to initialize a widget and a sensor, the CapSense_CSXScanExt() function should be called to scan the sensor.

This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example).

Parameters:

widgetId	Specify the ID number of the widget to perform hardware and firmware initialization required for scanning a specific sensor in a specific widget. A macro for the widget ID can be found in CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.
SnsId	Specify the ID number of the sensor within the widget to perform hardware and firmware initialization required for scanning a specific sensor in a specific widget. A macro for the sensor ID within a specified widget can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_SNS<SensorNumber>_ID

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXScan (void)

This function performs scanning of all sensors in the widget configured by the CapSense_CSXSetupWidget() function. It does the following tasks:

1. Connects the first sensor of the widget.
2. Initializes an interrupt callback function to initialize a scan of the next sensors in a widget.
3. Starts scanning for the first sensor in the widget.

This function is called by the CapSense_Scan() API if the given widget uses the CSX sensing method.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example).

This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status. The widget must be preconfigured by the CapSense_CSXSetupWidget() function if other widget was previously scanned or other type of scan functions were used.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXScanExt (void)

This function performs single scanning of one sensor in the widget configured by CapSense_CSXSetupWidgetExt() function. It does the following tasks:

1. Sets a busy flag in the CapSense_dsRam structure.
2. Configures the Tx clock frequency.
3. Configures the Modulator clock frequency.
4. Configures the IDAC value.
5. Starts single scanning.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time or pipeline scanning for example). This function should be called when no scanning in progress. I.e. CapSense_IsBusy() returns a non-busy status.

The sensor must be preconfigured by using the CapSense_CSXSetupWidgetExt() API prior to calling this function. The sensor remains ready for the next scan if a previous scan was triggered by using the CapSense_CSXScanExt() function. In this case, calling CapSense_CSXSetupWidgetExt() is not required every time before the CapSense_CSXScanExt() function. If a previous scan was triggered in any other way: CapSense_Scan(), CapSense_ScanAllWidgets() or CapSense_RunTuner() (see the CapSense_RunTuner() function description for more details), the sensor must be preconfigured again by using the CapSense_CSXSetupWidgetExt() API prior to calling the CapSense_CSXScanExt() function.

If disconnection of the sensors is required after calling CapSense_CSXScanExt(), the CapSense_CSXDisconnectTx() and CapSense_CSXDisconnectRx() APIs can be used.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXCalibrateWidget (uint32 *widgetIndex*, uint16 *target*)

Performs a successive approximation search algorithm to find appropriate IDAC values for sensors in the specified widget that provides a raw count to the level specified by the target parameter.

This function is available when the CSX Enable IDAC auto-calibration parameter is enabled.

Parameters:

widgetIndex	Specify the ID number of the CSX widget to calibrate its raw count. A macro for the widget ID can be found in the CapSense_Configuration.h file defined as CapSense_<WidgetName>_WDGT_ID.
target	Specify the calibration target in percentages of the maximum raw count.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXConnectTx (CapSense_FLASH_IO_STRUCTconst * *txPtr*)

This function connects a port pin (Tx electrode) to the CSD_SENSE signal. It is assumed that the drive mode of the port pin is already set to STRONG in the HSIOM_PORT_SELx register.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time when there is only one port pin for an electrode for example).

Parameters:

txPtr	Specify the pointer to the FLASH_IO_STRUCT object belonging to a sensor which should be connected to the CapSense block as Tx pin.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXConnectRx (CapSense_FLASH_IO_STRUCTconst * *rxPtr*)

This function connects a port pin (Rx electrode)to AMUXBUS-A and sets the drive mode of the port pin to HIgh-Z in the GPIO_PRT_PCx register.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time when there is only one port pin for an electrode for example).

Parameters:

rxPtr	Specify the pointer to the FLASH_IO_STRUCT object belonging to a sensor which should be connected to the CapSense block as Rx pin.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXDisconnectTx (CapSense_FLASH_IO_STRUCTconst * *txPtr*)

This function disconnects a port pin (Tx electrode) from the CSD_SENSE signal and configures the port pin to the strong drive mode. It is assumed that the data register (GPIO_PRTx_DR) of the port pin is already 0.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time when there is only one port pin for an electrode for example).

Parameters:

txPtr	Specify the pointer to the FLASH_IO_STRUCT object belonging to a Tx pin sensor which should be disconnected from the CapSense block.

Go to the top of the CapSense Low Level APIs section.

void CapSense_CSXDisconnectRx (CapSense_FLASH_IO_STRUCTconst * *rxPtr*)

This function disconnects a port pin (Rx electrode) from AMUXBUS_A and configures the port pin to the strong drive mode. It is assumed that the data register (GPIO_PRTx_DR) of the port pin is already 0.

It is not recommended to call this function directly from the application layer. This function should be used to implement only the user's specific use cases (for faster execution time when there is only one port pin for an electrode for example).

Parameters:

rxPtr	Specify the pointer to the FLASH_IO_STRUCT object belonging to a Rx pin sensor which should be disconnected from the CapSense block.

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_GetParam (uint32 *paramId*, uint32 * *value*)

This function gets the value of the specified parameter by the paramId argument. The paramId for each register is available in the CapSense_RegisterMap.h file as CapSense_<ParameterName>_PARAM_ID. The paramId is a special enumerated value generated by the customizer. The format of paramId is as follows:

1. [byte 3 byte 2 byte 1 byte 0]
2. [TTWFCCCC UIIIIIII MMMMMMMM LLLLLLLL]
3. T - encodes the parameter type:
   - 01b: uint8
   - 10b: uint16
   - 11b: uint32
4. W - indicates whether the parameter is writeable:
   - 0: ReadOnly
   - 1: Read/Write
5. C - 4 bit CRC (X^3 + 1) of the whole paramId word, the C bits are filled with 0s when the CRC is calculated.
6. U - indicates if the parameter affects the RAM Widget Object CRC.
7. I - specifies that the widgetID parameter belongs to
8. M,L - the parameter offset MSB and LSB accordingly in:

- Flash Data Structure if W bit is 0.
- RAM Data Structure if W bit is 1.

Refer to the Data Structure section for details of the data structure organization and examples of its register access.

Parameters:

paramId	Specify the ID of parameter to get its value. A macro for the parameter ID can be found in CapSense_RegisterMap.h file defined as CapSense_<ParameterName>_PARAM_ID.
value	The pointer to a variable that should be updated with the got value.

Returns:

Returns the status of operation:

- CYRET_SUCCESS if the operation is successfully completed.
- CYRET_BAD_PARAM if the input parameter is invalid.

Go to the top of the CapSense Low Level APIs section.

cystatus CapSense_SetParam (uint32 *paramId*, uint32 *value*)

This function sets the value of the specified parameter by the paramId argument. The paramId for each register is available in the CapSense_RegisterMap.h file as CapSense_<ParameterName>_PARAM_ID. The paramId is a special enumerated value generated by the customizer. The format of paramId is as follows:

1. [byte 3 byte 2 byte 1 byte 0]
2. [TTWFCCCC UIIIIIII MMMMMMMM LLLLLLLL]
3. T - encodes the parameter type:
   - 01b: uint8
   - 10b: uint16
   - 11b: uint32
4. W - indicates whether the parameter is writeable:
   - 0: ReadOnly
   - 1: Read/Write
5. C - 4 bit CRC (X^3 + 1) of the whole paramId word, the C bits are filled with 0s when the CRC is calculated.
6. U - indicates if the parameter affects the RAM Widget Object CRC.
7. I - specifies that the widgetID parameter belongs to
8. M,L - the parameter offset MSB and LSB accordingly in:
   - Flash Data Structure if W bit is 0.
   - RAM Data Structure if W bit is 1.

Refer to the Data Structure section for details of the data structure organization and examples of its register access.

Parameters:

paramId	Specify the ID of parameter to set its value. A macro for the parameter ID can be found in CapSense_RegisterMap.h file defined as CapSense_<ParameterName>_PARAM_ID.
value	Specify the new parameter's value.

Returns:

Returns the status of operation:

- CYRET_SUCCESS if the operation is successfully completed.
- CYRET_BAD_PARAM if the input parameter is invalid.

Go to the top of the CapSense Low Level APIs section.

ADC Application Public Interface

Description

The ADC application public interface represents the abstraction layer of the ADC function. The ADC public interface is exposed to the user to implement the ADC function.

Functions

- cystatus CapSense_AdcStartConvert(uint8 chId)
  Initializes an analog-to-digital conversion on the selected channel.
- uint8 CapSense_AdcIsBusy(void)
  The function returns the status of ADC's operation.
- uint16 CapSense_AdcReadResult_mVolts(uint8 chId)
  The blocking function that starts a conversion and waits for the result; returning it.
- uint16 CapSense_AdcGetResult_mVolts(uint8 chId)
  Returns the last valid result for the given channel.
- cystatus CapSense_AdcCalibrate(void)
  Performs built-in calibration.
- void CapSense_AdcStop(void)
  Disables the CSD sub-blocks that are in use while in the ADC mode, and frees the routing.
- void CapSense_AdcResume(void)
  Resumes the ADC Component after a Stop call.

Function Documentation

cystatus CapSense_AdcStartConvert (uint8 *chId*)

Initializes an analog-to-digital conversion on the selected channel.

Parameters:

chId	The ID of the channel to be converted.

Returns:

The function returns cystatus of its operation.

- CYRET_LOCKED - The CSD hardware is in-use by CapSense. No conversion started.
- CYRET_BAD_PARAM - The chId was out of bounds. No conversion started.
- CYRET_STARTED - The ADC is already converting. No conversion started.
- CYRET_SUCCESS - A conversion has started. No conversion started.

Go to the top of the ADC Application Public Interface section.

uint8 CapSense_AdcIsBusy (void)

The function returns the status of ADC's operation.

Returns:

The function returns status of the ADC's operation.

- CapSense_AdcSTATUS_IDLE - The ADC is not in use.
- CapSense_AdcSTATUS_CONVERTING - A conversion is in progress.
- CapSense_AdcSTATUS_CALIBPH1 - The ADC is in the first phase (of 2) of calibration.
- CapSense_AdcSTATUS_CALIBPH2 - The ADC is in the second phase (of 2) of calibration.
- CapSense_AdcSTATUS_OVERFLOW - The most recent measurement caused an overflow.

Go to the top of the ADC Application Public Interface section.

uint16 CapSense_AdcReadResult_mVolts (uint8 *chId*)

The blocking function that starts a conversion and waits for the result; returning it.

Parameters:

chId	The ID of the channel to be measured

Returns:

The function returns voltage in millivolts or CapSense_AdcVALUE_BADCHANID if chId is invalid.

Go to the top of the ADC Application Public Interface section.

uint16 CapSense_AdcGetResult_mVolts (uint8 *chId*)

Returns the last valid result for the given channel.

Parameters:

chId	The ID of the channel to be measured

Returns:

The function returns voltage in mV or CapSense_AdcVALUE_BADCHANID if chId is invalid.

Go to the top of the ADC Application Public Interface section.

cystatus CapSense_AdcCalibrate (void)

Performs built-in calibration.

Returns:

The function returns cystatus of its operation.

- CYRET_LOCKED - The CSD hardware is in-use by CapSense, and could not be released.
- CYRET_SUCCESS - The block is configured for ADC use.
- CYRET_STARTED - Another ADC operation is in progress; this one was not completed.

Go to the top of the ADC Application Public Interface section.

void CapSense_AdcStop (void)

Disables the CSD sub-blocks that are in use while in the ADC mode, and frees the routing.

Go to the top of the ADC Application Public Interface section.

void CapSense_AdcResume (void)

Resumes the ADC Component after a Stop call.

Go to the top of the ADC Application Public Interface section.

Interrupt Service Routine

Description

The CapSense component uses an interrupt that triggers after the end of each sensor scan.

After scanning is complete, the ISR copies the measured sensor raw data to the Data Structure. If the scanning queue is not empty, the ISR starts the next sensor scanning.

Component implementation avoids using critical sections in the code. In an unavoidable situation, the critical section is used and the code is optimized for the shortest execution time.

The CapSense component does not alter or affect the priority of other interrupts in the system.

These API should not be used in the application layer.

Functions

- CY_ISR(CapSense_AdcIntrHandler)
  This is an internal ISR function for ADC implementation.
- CY_ISR(CapSense_CSDPostSingleScan)
  This is an internal ISR function for single-sensor scanning implementation.
- CY_ISR(CapSense_CSDPostMultiScan)
  This is an internal ISR function for multiple sensor-scanning implementation.
- CY_ISR(CapSense_CSDPostMultiScanGanged)
  This is an internal ISR function for multiple sensor scanning implementation for ganged sensors.

Function Documentation

CY_ISR (CapSense_AdcIntrHandler)

This ISR is triggered after a measurement completes or during calibration phases.

To use the entry or exit callbacks, define CapSense_ADC_[ENTRY|EXIT]_CALLBACK and define the corresponding function, CapSense_Adc[Entry|Exit]Callback().

Go to the top of the Interrupt Service Routine section.

CY_ISR (CapSense_CSDPostSingleScan)

This ISR handler is triggered when the user calls the CapSense_CSDScanExt() function.

The following tasks are performed for CSDv1 HW IP block:

1. Disable the CSD interrupt
2. Read the Counter register and update the data structure with raw data
3. Connect the Vref buffer to the AMUX bus
4. Update the Scan Counter
5. Reset the BUSY flag
6. Enable the CSD interrupt.

The following tasks are performed for CSDv2 HW IP block:

1. Check if the raw data is not noisy
2. Read the Counter register and update the data structure with raw data
3. Configure and start the scan for the next frequency if the multi-frequency is enabled
4. Update the Scan Counter
5. Reset the BUSY flag
6. Enable the CSD interrupt.

The ISR handler changes IMO and initializes scanning for the next frequency channels when multi-frequency scanning is enabled.

This function has two Macro Callbacks that allow calling the user code from macros specified in a component's generated code. Refer to the Macro Callbacks section of PSoC Creator User Guide for details.

Go to the top of the Interrupt Service Routine section.

CY_ISR (CapSense_CSDPostMultiScan)

This ISR handler is triggered when the user calls the CapSense_Scan() or CapSense_ScanAllWidgets() APIs.

The following tasks are performed:

1. Disable the CSD interrupt
2. Read the Counter register and update the data structure with raw data
3. Connect the Vref buffer to the AMUX bus
4. Disable the CSD block (after the widget has been scanned)
5. Update Scan Counter
6. Reset the BUSY flag

7. Enable the CSD interrupt.

The ISR handler initializes scanning for the previous sensor when the widget has more than one sensor. The ISR handler initializes scanning for the next widget when the CapSense_ScanAllWidgets() APIs are called and the project has more than one widget. The ISR handler changes the IMO and initializes scanning for the next frequency channels when multi-frequency scanning is enabled.

This function has two Macro Callbacks that allow calling the user code from macros specified in a component's generated code. Refer to the Macro Callbacks section of PSoC Creator User Guide for details.

Go to the top of the Interrupt Service Routine section.

CY_ISR (CapSense_CSDPostMultiScanGanged)

This ISR handler is triggered when the user calls the CapSense_Scan() API for a ganged sensor or the CapSense_ScanAllWidgets() API in the project with ganged sensors.

The following tasks are performed:

1. Disable the CSD interrupt
2. Read the Counter register and update the data structure with raw data
3. Connect the Vref buffer to the AMUX bus
4. Disable the CSD block (after the widget has been scanned)
5. Update Scan Counter
6. Reset the BUSY flag
7. Enable the CSD interrupt.

The ISR handler initializes scanning for the previous sensor when the widget has more than one sensor. The ISR handler initializes scanning for the next widget when the CapSense_ScanAllWidgets() APIs are called and the project has more than one widget. The ISR handler changes the IMO and initializes scanning for the next frequency channels when multi-frequency scanning is enabled.

This function has two Macro Callbacks that allow calling the user code from macros specified in a component's generated code. Refer to the Macro Callbacks section of PSoC Creator User Guide for details.

Go to the top of the Interrupt Service Routine section.

Macro Callbacks

Macro callbacks allow the user to execute code from the API files automatically generated by PSoC Creator. Refer to the PSoC Creator Help and Component Author Guide for the more details.

In order to add code to the macro callback present in the component's generated source files, perform the following:

- Define a macro to signal the presence of a callback (in cyapicallbacks.h). This will "uncomment" the function call from the component's source code.
- Write the function declaration using provided in the table name (in cyapicallbacks.h). This will make this function visible by all the project files.
- Write the function implementation (in any user file).

CapSense Macro Callbacks

Macro Callback Function Name	Associated Macro	Description
CapSense_EntryCallback	CapSense_ENTRY_CALLBACK	Used at the beginning of the CapSense interrupt handler to perform additional application-specific actions
CapSense_ExitCallback	CapSense_EXIT_CALLBACK	Used at the end of the CapSense interrupt handler to perform additional application-specific actions

ADC Macro Callbacks

Macro Callback Function Name	Associated Macro	Description
CapSense_AdcEntryCallback	CapSense_ADC_ENTRY_CALLBACK	Used at the beginning of the ADC interrupt handler to perform additional application-specific actions
CapSense_AdcExitCallback	CapSense_ADC_EXIT_CALLBACK	Used at the end of the ADC interrupt handler to perform additional application-specific actions

Global Variables

Description

The section documents the CapSense component related global Variables.

The CapSense component stores the component configuration and scanning data in the data structure. Refer to the Data Structure section for details of organization of the data structure.

Variables

- CapSense_RAM_STRUCT CapSense_dsRam

Variable Documentation

CapSense_RAM_STRUCT CapSense_dsRam

Variable that contains CapSense configuration, settings and scanning results. CapSense_dsRam represents RAM Data Structure.

API Constants

Description

The section documents the CapSense component related API Constants.

Variables

- const CapSense_FLASH_STRUCT CapSense_dsFlash
- const CapSense_FLASH_IO_STRUCT CapSense_ioList[CapSense_TOTAL_ELECTRODES]
- const CapSense_SHIELD_IO_STRUCT CapSense_shieldIoList[CapSense_CSD_TOTAL_SHIELD_COUNT]
- const CapSense_FLASH_IO_STRUCT CapSense_adcIoList[CapSense_ADC_TOTAL_CHANNELS]

Variable Documentation

const CapSense_FLASH_STRUCT CapSense_dsFlash

Constant for the FLASH Data Structure

const CapSense_FLASH_IO_STRUCT CapSense_ioList[CapSense_TOTAL_ELECTRODES]

Array of pointers to the electrode specific register

const CapSense_SHIELD_IO_STRUCT CapSense_shieldIoList[CapSense_CSD_TOTAL_SHIELD_COUNT]

Array of pointers to the shield electrode specific register

const CapSense_FLASH_IO_STRUCT CapSense_adcIoList[CapSense_ADC_TOTAL_CHANNELS]

Array of pointers to the ADC input channels specific register

Data Structure

Description

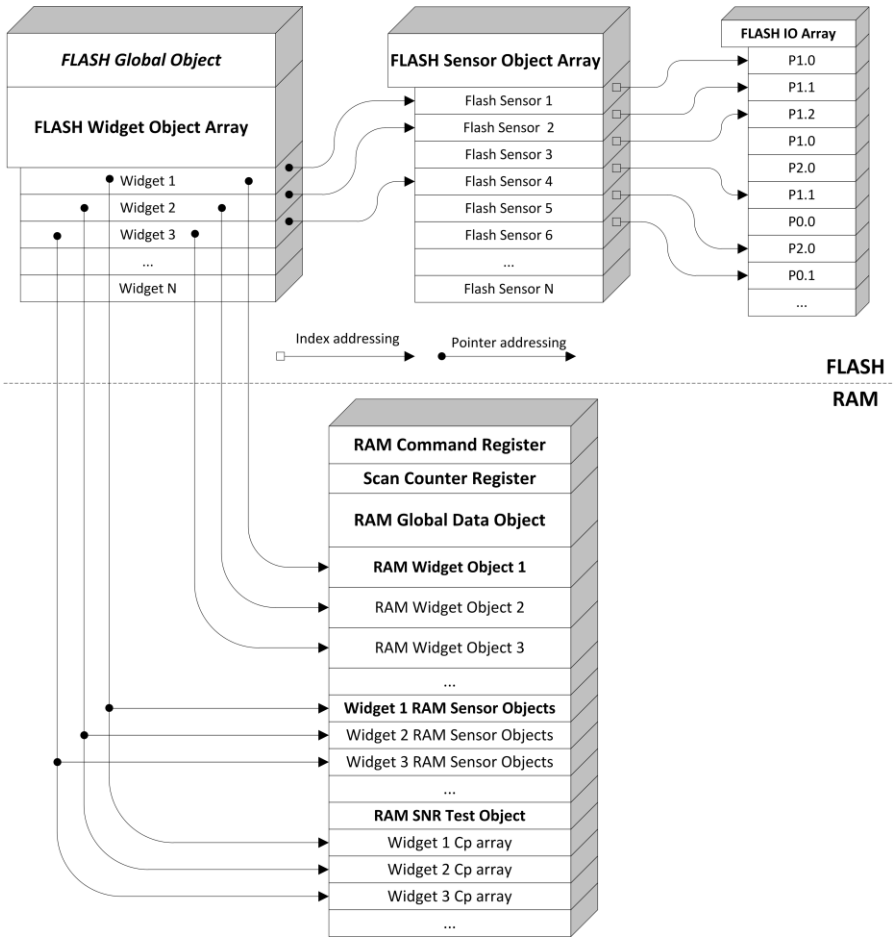
This section provides the list of structures/registers available in the component.

The key responsibilities of Data Structure are as follows:

- The Data Structure is the only data container in the component.
- It serves as storage for the configuration and the output data.
- All other component FW part as well as an application layer and Tuner SW use the data structure for the communication and data exchange.

The CapSense Data Structure organizes configuration parameters, input and output data shared among different FW IP modules within the component. It also organizes input and output data presented at the Tuner interface (the tuner register map) into a globally accessible data structure. CapSense Data Structure is only a data container.

The Data Structure is a composite of several smaller structures (for global data, widget data, sensor data, and pin data). Furthermore, the data is split between RAM and Flash to achieve a reasonable balance between resources consumption and configuration / tuning flexibility at runtime and compile time. A graphical representation of CapSense Data Structure is shown below:



Note that figure above shows a sample representation and documents the high level design of the data structure, it may not include all the parameters and elements in each object.

CapSense Data Structure does not perform error checking on the data written to CapSense Data Structure. It is the responsibility of application layer to ensure register map rule are not violated while modifying the value of data field in CapSense Data Structure.

The CapSense Data Structure parameter fields and their offset address is specific to an application, and it is based on component configuration used for the project. A user readable representation of the Data Structure specific to the component configuration is the component register map. The Register map file available from the Customizer GUI and it describes offsets and data/bit fields for each static (Flash) and dynamic (RAM) parameters of the component.

The embedded CapSense_RegisterMap.h file list all registers of data structure with the following:

```
#define CapSense_<RegisterName>_VALUE       (<Direct Register Access Macro>)
#define CapSense_<RegisterName>_OFFSET      (<Register Offset Within Data Structure (RAM or Flash)>)
#define CapSense_<RegisterName>_SIZE        (<Register Size in Bytes>)
#define CapSense_<RegisterName>_PARAM_ID    (<ParamId for Getter/Setter functions>)
```

To access CapSense Data Structure registers you have the following options:

1. Direct Access

The access to registers is performed through the Data Structure variable CapSense_dsRam and constants CapSense_dsFlash from application program.

Example of access to the Raw Count register of third sensor of Button0 widget:

```
rawCount = CapSense_dsRam.snsList.button0[CapSense_BUTTON0_SNS2_ID].raw[0];
```

Corresponding macro to access register value is defined in the CapSense_RegisterMap.h file:

```
rawCount = CapSense_BUTTON0_SNS2_RAW0_VALUE;
```

2. Getter/Setter Access

The access to registers from application program is performed by using two functions:

```
cystatus CapSense_GetParam(uint32 paramId, uint32 *value)
cystatus CapSense_SetParam(uint32 paramId, uint32 value)
```

The value of paramId argument for each register can be found in CapSense_RegisterMap.h file.
Example of access to the Raw Count register of third sensor of Button0 widget:

```
CapSense_GetParam(CapSense_BUTTON0_SNS2_RAW0_PARAM_ID, &rawCount);
```

You can also write to a register if it is writable (writing new finger threshold value to Button0 widget):

```
CapSense_SetParam(CapSense_BUTTON0_FINGER_TH_PARAM_ID, fingerThreshold);
```

3. Offset Access

The access to registers is performed by host through the I2C communication by reading / writing registers based on their offset.

Example of access to the Raw Count register of third sensor of Button0 widget: Setting up communication data buffer to CapSense data structure to be exposed to I2C master at primary slave address request once at initialization an application program:

```
EZI2C_Start();
EZI2C_EzI2CSetBuffer1(sizeof(CapSense_dsRam), sizeof(CapSense_dsRam),
                      (uint8 *)&CapSense_dsRam);
```

Now host can read (write) whole CapSense Data Structure and get the specified register value by register offset macro available in CapSense_RegisterMap.h file:

```
rawCount = *(uint16 *)(I2C_buffer1Ptr + CapSense_BUTTON0_SNS2_RAW0_OFFSET);
```

The current example is applicable to 2-byte registers only. Depends on register size defined CapSense_RegisterMap.h file by corresponding macros (CapSense_BUTTON0_SNS2_RAW0_SIZE) specific logic should be added to read 4-byte, 2-byte and 1-byte registers.

Data Structures

- struct CapSense_RAM_WD_BASE_STRUCT
  Declare common widget RAM parameters.
- struct CapSense_RAM_WD_BUTTON_STRUCT
  Declare RAM parameters for the CSD Button.
- struct CapSense_RAM_WD_SLIDER_STRUCT
  Declare RAM parameters for the Slider.
- struct CapSense_RAM_WD_CSD_MATRIX_STRUCT
  Declare RAM parameters for the CSD Matrix Buttons.
- struct CapSense_RAM_WD_CSD_TOUCHPAD_STRUCT
  Declare RAM parameters for the CSD Touchpad.
- struct CapSense_RAM_WD_PROXIMITY_STRUCT
  Declare RAM parameters for the Proximity.
- struct CapSense_RAM_WD_CSX_MATRIX_STRUCT
  Declare RAM parameters for the CSX Matrix Buttons.
- struct CapSense_RAM_WD_LIST_STRUCT
  Declare RAM structure with all defined widgets.

- struct CapSense_RAM_SNS_STRUCT
  Declare RAM structure for sensors.
- struct CapSense_RAM_SNS_LIST_STRUCT
  Declare RAM structure with all defined sensors.
- struct CapSense_RAM_STRUCT
  Declares the top-level RAM Data Structure.
- struct CapSense_FLASH_IO_STRUCT
  Declares the Flash IO object.
- struct CapSense_FLASH_SNS_STRUCT
  Declares the Flash Electrode object.
- struct CapSense_FLASH_SNS_LIST_STRUCT
  Declares the structure with all Flash electrode objects.
- struct CapSense_FLASH_WD_STRUCT
  Declare Flash widget object.
- struct CapSense_FLASH_STRUCT
  Declares top-level Flash Data Structure.
- struct CapSense_SHIELD_IO_STRUCT
  Declares the Flash IO structure for Shield electrodes.

Data Structure Documentation

struct CapSense_RAM_WD_BASE_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.
uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.
CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.
uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)
uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the

		modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.

struct CapSense_RAM_WD_BUTTON_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.
uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.
CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.
uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)
uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the

		modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.

struct CapSense_RAM_WD_SLIDER_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.
uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.
CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.
uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)
uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the

		modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.
uint16	position[CapSense_NUM_CENTROIDS]	Reports the widget position.

struct CapSense_RAM_WD_CSD_MATRIX_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.
uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.
CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.
uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)

uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.
uint8	posCol	The active column sensor. From 0 to ColNumber - 1.
uint8	posRow	The active row sensor. From 0 to RowNumber - 1.
uint8	posSnsId	The active button ID. From 0 to RowNumber*ColNumber - 1.

struct CapSense_RAM_WD_CSD_TOUCHPAD_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.
uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.
CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.

uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)
uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.
uint16	posX	The X coordinate.
uint16	posY	The Y coordinate.

struct CapSense_RAM_WD_PROXIMITY_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.
uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.

CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.
uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)
uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.
CapSense_THRESHOLD_TYPE	proxTouchTh	The proximity touch threshold.

struct CapSense_RAM_WD_CSX_MATRIX_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	resolution	Provides scan resolution for the CSD Widgets. Provides number of the sub-conversions for the CSX Widgets.
CapSense_THRESHOLD_TYPE	fingerTh	Widget Finger Threshold.
uint8	noiseTh	Widget Noise Threshold.
uint8	nNoiseTh	Widget Negative Noise Threshold.

uint8	hysteresis	Widget Hysteresis for the signal crossing finger threshold.
uint8	onDebounce	Widget Debounce for the signal above the finger threshold. OFF to ON.
CapSense_LOW_BSLN_RST_TYPE	lowBslnRst	The widget low baseline reset count. Specifies the number of samples the sensor has to be below the Negative Noise Threshold to trigger a baseline reset.
uint16	posBslnRst	Sensor auto reset count. Specifies the number of samples the sensor has to be higher than the Noise Threshold to trigger a baseline reset.
uint8	bslnCoeff	The widget baseline filter coefficient N (for IIR 2 to 8) or baseline update threshold (for bucket method 1 to 255)
uint8	idacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the CSD widgets. For the CSD Touchpad and Matrix Button widgets sets the current of the modulation IDAC for the column sensors. Not used for the CSX widgets.
uint8	rowIdacMod[CapSense_NUM_SCAN_FREQS]	Sets the current of the modulation IDAC for the row sensors for the CSD Touchpad and Matrix Button widgets. Not used for the CSX widgets.
uint8	snsClk	Specifies the sense clock divider. Present only if individual clock dividers are enabled. Specifies the sense clock divider for the Column sensors for the Matrix Buttons and Touchpad widgets. Sets Tx clock divider for the CSX Widgets.
uint8	rowSnsClk	For the Matrix Buttons and Touchpad widgets specifies the sense clock divider for the row sensors. Present only if individual clock dividers are enabled.
uint8	snsClkSource	Register for internal use
uint8	rowSnsClkSource	Register for internal use
uint16	fingerCap	Widget Finger capacitance parameter. Available only if the SmartSense is enabled. Not used for the CSX Widgets.
uint16	sigPFC	The 75% of signal per user-defined finger capacitance
uint8	offDebounce	The Widget Debounce for a lift-off event. ON to OFF.

struct CapSense_RAM_WD_LIST_STRUCT

Go to the top of the Data Structures section.

Data Fields:

CapSense_RAM_WD_BUTTON_STRUCT	button0	Button0 widget RAM structure
CapSense_RAM_WD_SLIDER_STRUCT	linearslider0	LinearSlider0 widget RAM structure

CapSense_RAM_WD_SLIDER_STRUCT	radialslider0	RadialSlider0 widget RAM structure
CapSense_RAM_WD_CSD_MATRIX_STRUCT	matrixbuttons0	MatrixButtons0 widget RAM structure
CapSense_RAM_WD_CSD_TOUCHPAD_STRUCT	touchpad0	Touchpad0 widget RAM structure
CapSense_RAM_WD_PROXIMITY_STRUCT	proximity0	Proximity0 widget RAM structure
CapSense_RAM_WD_BUTTON_STRUCT	button1	Button1 widget RAM structure
CapSense_RAM_WD_CSX_MATRIX_STRUCT	matrixbuttons1	MatrixButtons1 widget RAM structure

struct CapSense_RAM_SNS_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	raw[CapSense_NUM_SCAN_FREQS]	The sensor raw counts.
uint16	bsln[CapSense_NUM_SCAN_FREQS]	The sensor baseline.
uint8	bslnExt[CapSense_NUM_SCAN_FREQS]	For the bucket baseline algorithm holds the bucket state, For the IIR baseline keeps LSB of the baseline value.
uint8	idacComp[CapSense_NUM_SCAN_FREQS]	CSD Widgets: The compensation IDAC value. CSX Widgets: The balancing IDAC value.
CapSense_THRESHOLD_TYPE	diff	Sensor differences.
CapSense_LOW_BSLN_RST_TYPE	negBslnRstCnt[CapSense_NUM_SCAN_FREQS]	The baseline reset counter for the low baseline reset function.
uint16	posBslnRstCnt[CapSense_NUM_SCAN_FREQS]	The baseline reset counter for the sensor auto reset function.

struct CapSense_RAM_SNS_LIST_STRUCT

Go to the top of the Data Structures section.

Data Fields:

CapSense_RAM_SNS_STRUCT	button0[CapSense_BUTTON0_NUM_SENSORS]	Button0 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	linearslider0[CapSense_LINEARSLIDER0_NUM_SENSORS]	LinearSlider0 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	radialslider0[CapSense_RADIALSLIDER0_NUM_SENSORS]	RadialSlider0 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	matrixbuttons0[CapSense_MATRIXBUTTONS0_NUM_COLS+CapSense_MATRIXBUTTONS0_NUM_ROWS]	MatrixButtons0 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	touchpad0[CapSense_TOUCHPAD0_NUM_COLS+CapSense_TOUCHPAD0_NUM_ROWS]	Touchpad0 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	proximity0[CapSense_PROXIMITY0_NUM_SENSORS]	Proximity0 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	button1[CapSense_BUTTON1_NUM_SENSORS]	Button1 sensors RAM structures array
CapSense_RAM_SNS_STRUCT	matrixbuttons1[(CapSense_MATRIXBUTTONS1_NUM_RX)*(CapSense_MATRIXBUTTONS1_NUM_TX)]	MatrixButtons1 sensors RAM structures array

struct CapSense_RAM_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	configId	16-bit CRC calculated by the customizer for the component configuration. Used by the Tuner application to identify if the FW corresponds to the specific user configuration.
uint16	deviceId	Used by the Tuner application to identify device-specific configuration.
uint16	tunerCmd	Tuner Command Register. Used for the communication between te Tuner GUI and the component.
uint16	scanCounter	This counter gets incremented after each scan.
uint32	status	Status information: Current Widget, Scan active, Error code.
uint32	wdgtEnable[CapSense_WDGT_STATUS_WORDS]	The bitmask that sets which Widgets are enabled and scanned, each bit corresponds to one widget.

uint32	wdgtStatus[CapSense_WDGT_STATUS_WORDS]	The bitmask that reports activated Widgets (widgets that detect a touch signal above the threshold), each bit corresponds to one widget.
CapSense_SNS_STS_TYPE	snsStatus[CapSense_TOTAL_WIDGETS]	For Buttons, Sliders, Matrix Buttons and CSD Touchpad each bit reports status of the individual sensor of the widget: 1 - active (above the finger threshold); 0 - inactive; For the CSD Touchpad and CSD Matrix Buttons, the column sensors occupy the least significant bits. For the Proximity widget, each sensor uses two bits with the following meaning: 00 - Not active; 01 - Proximity detected (signal above finger threshold); 11 - A finger touch detected (signal above the touch threshold); For the CSX Touchpad Widget, this register provides a number of the detected touches. The array size is equal to the total number of widgets. The size of the array element depends on the max number of sensors per widget used in the current design. It could be 1, 2 or 4 bytes.
uint16	adcResult[CapSense_ADC_TOTAL_CHANNELS]	Stores the latest ADC result for the channel. The array size is equal to the number of ADC channels used in the project.
uint8	adcStatus	Stores the status of ADC.
uint16	csd0Config	The configuration register for global parameters of the CSD0 block.
uint16	csd1Config	The configuration register for global parameters of the CSD1 block.
uint8	modCsdClk	The modulator clock divider for the CSD widgets.
uint8	modCsxClk	The modulator clock divider for the CSX widgets.
uint8	snsCsdClk	The global sense clock divider for the CSD widgets.
uint8	snsCsxClk	Global sense clock divider for the CSX widgets.
uint8	adcResolution	Stores the ADC resolution.
uint8	adcIdac	ADC IDAC
uint8	adcAzTime	Stores the AZ time used for ADC conversion.
CapSense_RAM_WD_LIST_STRUCT	wdgtList	RAM Widget Objects.
CapSense_RAM_SNS_LIST_STRUCT	snsList	RAM Sensor Objects.
uint8	snrTestWidgetId	The selected widget ID.
uint8	snrTestSensorId	The selected sensor ID.
uint16	snrTestScanCounter	The scan counter.

uint16	snrTestRawCount[CapSense_NUM_SCAN_FREQS]	The sensor raw counts.

struct CapSense_FLASH_IO_STRUCT

Go to the top of the Data Structures section.

Data Fields:

reg32 *	hsiomPtr	Pointer to the HSIOM configuration register of the IO.
reg32 *	pcPtr	Pointer to the port configuration register of the IO.
reg32 *	drPtr	Pointer to the port data register of the IO.
reg32 *	psPtr	Pointer to the pin state data register of the IO.
uint32	hsiomMask	IO mask in the HSIOM configuration register.
uint32	mask	IO mask in the DR and PS registers.
uint8	hsiomShift	Position of the IO configuration bits in the HSIOM register.
uint8	drShift	Position of the IO configuration bits in the DR and PS registers.
uint8	shift	Position of the IO configuration bits in the PC register.

struct CapSense_FLASH_SNS_STRUCT

Go to the top of the Data Structures section.

Data Fields:

uint16	firstPinId	Index of the first IO in the Flash IO Object Array.
uint8	numPins	Total number of IOs in this sensor.
uint8	type	Sensor type: • ELTD_TYPE_SELF_E - CSD sensor; • ELTD_TYPE_MUT_TX_E - CSX Tx sensor; • ELTD_TYPE_MUT_RX_E - CSX Rx sensor;

struct CapSense_FLASH_SNS_LIST_STRUCT

Go to the top of the Data Structures section.

Data Fields:

CapSense_FLASH_SNS_STRUCT	button0[CapSense_BUTTON0_NUM_SENSORS]	Button0 FLASH electrodes array

struct CapSense_FLASH_WD_STRUCT

Go to the top of the Data Structures section.

Data Fields:

void const *	ptr2SnsFlash	Points to the array of the FLASH Sensor Objects or FLASH IO Objects that belong to this widget. Sensing block uses this pointer to

		access and configure IOs for the scanning. Bit #2 in WD_STATIC_CONFIG field indicates the type of array: 1 - Sensor Object; 0 - IO Object.
void *	ptr2WdgtRam	Points to the Widget Object in RAM. Sensing block uses it to access scan parameters. Processing uses it to access threshold and widget specific data.
CapSense_RAM_SNS_STRUCT*	ptr2SnsRam	Points to the array of Sensor Objects in RAM. The sensing and processing blocks use it to access the scan data.
void *	ptr2FltrHistory	Points to the array of the Filter History Objects in RAM that belongs to this widget.
uint8 *	ptr2DebounceArr	Points to the array of the debounce counters. The size of the debounce counter is 8 bits. These arrays are not part of the data structure.
uint16	staticConfig	Miscellaneous configuration flags.
uint16	totalNumSns	The total number of sensors. For CSD widgets: WD_NUM_ROWS + WD_NUM_COLS For CSX widgets: WD_NUM_ROWS * WD_NUM_COLS
uint8	wdgtType	Specifies one of the following widget types: WD_BUTTON_E, WD_LINEAR_SLIDER_E, WD_RADIAL_SLIDER_E, WD_MATRIX_BUTTON_E, WD_TOUCHPAD_E, WD_PROXIMITY_E
uint8	csdblk	Specifies the CSD block to use on the capable devices. Available only if CSD2x or CSX2x is enabled.
uint16	slotIndex	Slot index occupied by the first sensor in the widget
uint8	senseMethod	Specifies the widget sensing method that could be either WD_CSD_SENSE_METHOD or WD_CSX_SENSE_METHOD
uint8	numCols	For CSD Button and Proximity Widgets, the number of sensors. For CSD Slider Widget, the number of segments. For CSD Touchpad and Matrix Button, the number of the column sensors. For CSX Button, Touchpad and Matrix Button, the number of the Rx electrodes.
uint8	numRows	For CSD Touchpad and Matrix Buttons, the number of the row sensors. For the CSX Button, the number of the Tx electrodes (constant 1u). For CSX Touchpad and Matrix Button, the number of the Rx electrodes.
uint16	xResolution	Sliders: The Linear/Angular resolution. Touchpad: The X-Axis resolution.
uint16	yResolution	Touchpad: The Y-Axis resolution.
uint16	xCentroidMultiplier	The pre-calculated X resolution centroid multiplier used for the X-axis position calculation. Calculated as follows: RADIAL: (WD_X_RESOLUTION * 256) / WD_NUM_COLS; LINEAR: (WD_X_RESOLUTION * 256) /

		(WD_NUM_COLS - 1); TOUCHPAD: the same as LINEAR
uint16	yCentroidMultiplier	The pre-calculated Y resolution centroid multiplier used for the Y-axis position calculation. Calculated as follows: (WD_X_RESOLUTION * 256) / (WD_NUM_ROWS - 1);
SMARTSENSE_CSD_NOISE_ENVELOPE_STRUCT*	ptr2NoiseEnvlp	The pointer to the array with the sensor noise envelope data. Set to the valid value only for the CSD widgets. For the CSX widgets this pointer is set to NULL. The pointed array is not part of the data structure.
const uint8 *	ptr2DiplexTable	The pointer to the Flash Diplex table that is used by the slider centroid algorithm.
void *	ptr2PosHistory	The pointer to the RAM position history object. This parameter is used for the Sliders and CSD touchpads that have enabled the median position filter.

struct CapSense_FLASH_STRUCT

Go to the top of the Data Structures section.

Data Fields:

CapSense_FLASH_WD_STRUCT	wdgtArray[CapSense_TOTAL_WIDGETS]	Array of flash widget objects
CapSense_FLASH_SNS_LIST_STRUCT	eltdList	Structure with all Ganged Flash electrode objects

struct CapSense_SHIELD_IO_STRUCT

Go to the top of the Data Structures section.

Data Fields:

reg32 *	hsiomPtr	Pointer to the HSIOM configuration register of the IO.
reg32 *	pcPtr	Pointer to the port configuration register of the IO.
reg32 *	drPtr	Pointer to the port data register of the IO.
uint32	hsiomMask	IO mask in the HSIOM configuration register.
uint8	hsiomShift	Position of the IO configuration bits in the HSIOM register.
uint8	drShift	Position of the IO configuration bits in the DR and PS registers.
uint8	shift	Position of the IO configuration bits in the PC register.

Memory Usage

The component Flash and RAM memory usage varies significantly depending on the compiler, device, number of APIs called by the application program and component configuration. The table below provides the total memory usage of firmware for given component configuration.

The measurements have been done with an associated compiler configured in Release mode with optimization set for Size. For a specific design, the map file generated by the compiler can be analyzed to determine the memory usage.

PSoC 4 (GCC)

The following component configuration is used to represent the memory usage:

Configuration	Memory Consumption	
	Flash	SRAM
CSX Matrix Button: One widget with 4 Rx and 8 Tx. ADC (disabled): The *Number of input channels* = 0.	<4800	<500
CSD Buttons: Three widgets with 4, 3 and 3 sensors in each widget, and in Manual tuning mode. ADC (disabled): The *Number of input channels* = 0.	<5500	<300
CSD Buttons: Three widgets with 4, 3 and 3 sensors in each widget, and in Manual tuning mode and all firmware raw count filters enabled. The following parameters are used to enable the filters: Enable IIR filter (First order), Enable average filter (4-sample) and Enable median filter (3-sample). ADC (disabled): The *Number of input channels* = 0.	<6100	<400
CSD Buttons: Three widgets with 4, 3 and 3 sensors in each widget, and in *SmartSense (Full Auto-Tune)* mode. ADC (disabled): The *Number of input channels* = 0.	<6600	<400
CSD Buttons: Three widgets with 4, 3 and 3 sensors in each widget, and in Manual tuning mode. ADC (enabled): *Resolution (bits)* = 10-bit / *Number of input channels* = 10.	<7600	<300

Note Configurations consist of the default customizer configuration except where noted. The default customizer configuration includes:

- All filters disabled. The *Enable IIR filter (First order)*, *Enable average filter (4-sample)* and *Enable median filter (3-sample)* parameters are disabled.
- The *Enable compensation IDAC* parameter is enabled.
- The *Enable IDAC auto-calibration* parameter is enabled.

CapSense Tuner

The CapSense component provides a graphical-based Tuner application for debugging and tuning the CapSense system. To open the tuner application, right click on the component symbol and select the **Launch Tuner** option.

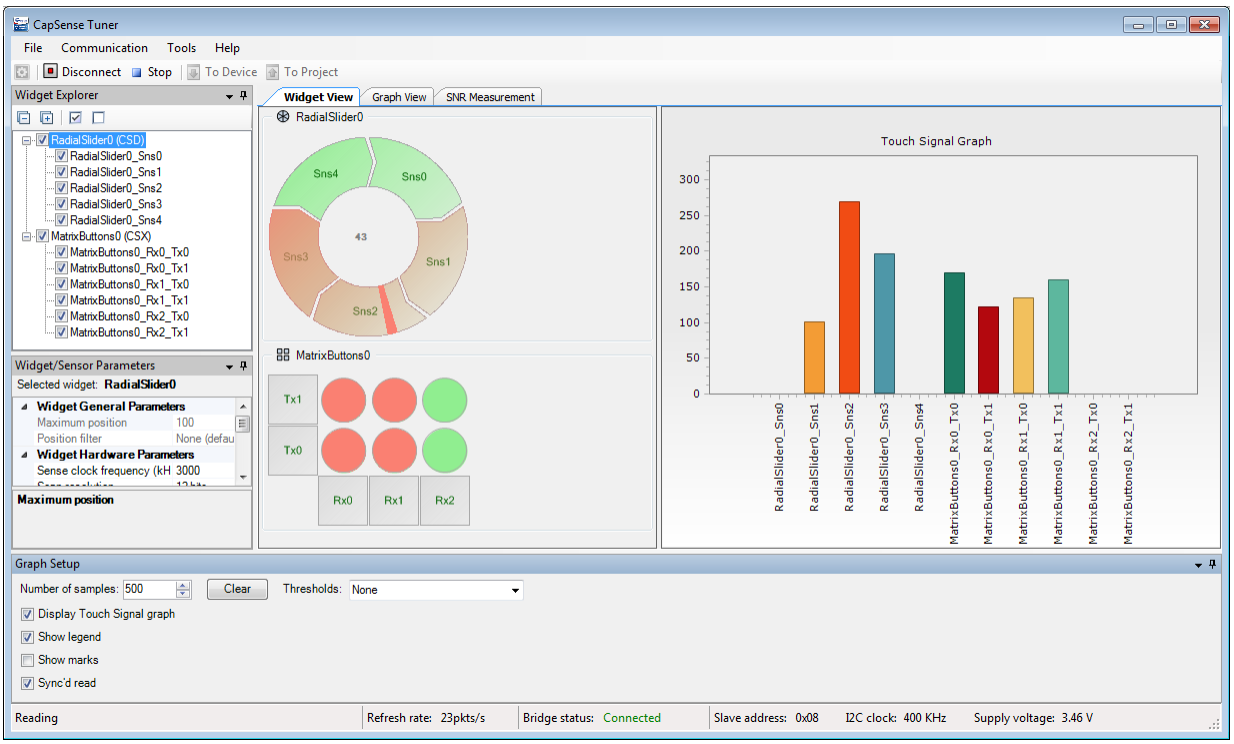
Note The CapSense Tuner does not support the ADC functionality. This feature will be added in a future component version.

To make the tuner application work, an SCB component should be added to the project and the component register map should be exposed to the tuner application.

The user has the read and write access for all parameters when using the *The CSX sensing method* or when using *Manual* tuning for *CSD tuning mode* in the *Basic Tab* tab. When *SmartSense (Hardware parameters only)* is selected for *CSD tuning mode*, the user has the read and write access to all *Widget Threshold Parameters* and the read only access to *Widget Hardware Parameters*. When *SmartSense (Full Auto-Tune)* is selected for the *CSD tuning mode*, the user has the read only access parameters.

This section describes the parameters used in the Tuner UI interface. For details of the tuning and system design guidelines, refer to *PSoC® 4 CapSense® Design Guide*.

General Interface



The application consists of the following tabs:

- *Widget View* – Displays widgets, their touch status, and the touch signal bar graph.

- *Graph View* – Displays the sensor data charts.
- *SNR Measurement* – Provides the SNR measurement functionality.

Menus

The main menu provides the following commands to help control and navigate the Tuner:

- **File > Apply to Device (Ctrl + D)** – Commits the current values of the widget/sensor parameters to the device. This menu item becomes active if a value of any configuration parameter is changed from the Tuner UI (i.e. if the parameter values in the Tuner and the device are different). This is an indication that the changed parameter values need to be applied to the device.
- **File > Apply to Project (Ctrl + S)** – Commits the current values of widget/sensor parameters to the CapSense component instance. The changes are applied after the Tuner is closed. Note, when SmartSense is enabled for CSD widgets, auto-tuned widget parameters are also committed to the project. Similarly, when IDAC auto-calibration is enabled, IDAC values calibrated by the component firmware are applied to the project. There values can be later used as a starting point for manual calibration or tuning.
- **File >** Save **Graph… (Ctrl+Shift+S)** – Opens the dialog to save the current graph as a PNG image. The saved graph depends on the currently selected view: it is *Touch Signal Graph* for *Widget View* (only when shown), a combined graph with Sensor Data, Sensor Signal and Status for Graph View, and SNR Raw counts graph for SNR Measurement View.
- **File > Exit (Alt+F4)** – Asks to save changes if there are any and closes the Tuner. Changes are saved to the PSoC Creator project (merged back by the customizer).
- **Communication > Connect (F4)** – Connects to the device via a communication channel selected in the Tuner Communication Setup dialog. When the channel was not previously selected, the Tuner communication dialog is shown.
- **Communication > Disconnect (Shift+F4)** – Closes the communication channel with the connected device.
- **Communication > Start (F5)** – Starts reading data from the device.
- **Communication > Stop (Shift+F5)** – Stops reading data from the device.
- **Tools > Tuner Communication Setup… (F10)** – Opens the configuration dialog to set up a communication channel with the device.
- **Tools > Options** – Opens the configuration dialog to set up different tuner preferences.
- **Help > Help Contents (F1)** – Opens the CapSense component datasheet.

Toolbar

Contains frequently used buttons that duplicate the main menu items:

-  - Duplicates the **Tools > Tuner Communication Setup** menu item.
-  - Duplicates the **Communication > Connect** menu item.
-  - Duplicates the **Communication > Disconnect** menu item.
-  - Duplicates the **Communication > Start** menu item.
-  - Duplicates the **File > Apply to Device** menu item.
-  - Duplicates the **File > Apply to Project** menu item.

Status bar

The status bar displays various information related to the communication state between the Tuner and the device. This includes:

- **Current operation mode of tuner**: Either **Reading** (when tuner is reading from the device), **Writing** (when the write operation is in progress), or empty (idle – no operation performed).
- **Refresh rate**: Count of read samples performed per second. The count depends on multiple factors: the selected communication channel, communication speed, and amount of time needed to perform a single scan.
- **Bridge status**: Either **Connected**, when the communication channel is active, or **Disconnected** otherwise.
- **Slave address** [I2C specific]: The address of the I2C slave configured for the current communication channel.
- **I2C clock** [I2C specific]: The data rate used by the I2C communication channel.
- **Supply voltage**: The supply voltage.

Widget Explorer Pane

The Widget explorer pane contains a tree of widgets and sensors used in the CapSense project. The Widget nodes can be expanded/collapsed to show/hide widget's sensor nodes. It is possible to check/uncheck individual widgets and sensors. The Widget checked status affects its visibility on the *Widget View*, while the sensor checked status controls the visibility of the sensor raw count / baseline / signal / status graph series on the Graph View and signals on the *Touch Signal Graph* on the *Widget View*.

Selection of widget or sensor in the *Widget Explorer Pane* updates the selection in the *Widget/Sensor Parameters Pane.* It is possible to select multiple widget or sensor nodes to edit multiple parameters at once. For example, you can edit the Finger Threshold parameter for all widgets at once.

Note For CSX widgets, the sensor tree displays individual nodes (Rx0_Tx0, Rx0_Tx1 …) as contrary to the customizer where the CSX electrodes are displayed (Rx0, Rx1 … Tx0, Tx1 ...).

The toolbar at the top of the widget explorer provides easy access to commonly used functions: buttons  can be used to expand/collapse all sensor nodes at once, and  to check/ uncheck all widgets and sensors.

Widget/Sensor Parameters Pane

The Widget/Sensor parameters pane displays the parameters of the widget or sensor selected in the Widget Explorer tree. The grid is similar to the grid on the *Widget Details* tab in the CapSense customizer. The main difference is that some parameters are available for modification in the customizer, but not in the tuner. This includes:

- **Widget General Parameters:** Cannot be modified from the Tuner because corresponding parameter values reside in the Flash widget structures that cannot be modified at runtime.
- **Widget Hardware Parameters:** Cannot be modified for the CSD widgets when *CSD tuning mode* is set to *SmartSense (Full Auto-Tune)* or *SmartSense (Hardware parameters only)* in the CapSense customizer. In the *Manual* tuning mode (for both CSD and CSX widgets), any change to *Widget Hardware Parameters* requires hardware re-initialization which can be performed only if the Tuner communicates with the device in Synchronized mode.
- **Widget Threshold Parameters:** Cannot be modified for the CSD widgets when the *CSD tuning mode* is set to *SmartSense (Full Auto-Tune)* in the customizer. In the *Manual* tuning mode (for both CSD and CSX widgets), the threshold parameters are always writeable (synchronized mode is not required). The exception is the *ON debounce* parameter that also requires a component restart (in the same way as the hardware parameters).
- **Sensor Parameters:** Sensors-specific parameters. The Tuner application displays only *IDAC Values* or/and *Compensation IDAC value*. The parameter is not present for the CSD widget when *Enable compensation IDAC* is disabled on the customizer *CSD Settings* tab. When CSD *Enable IDAC auto-calibration* or/and CSX *Enable IDAC auto-calibration* is enabled, the parameter is read-only and displays the IDAC value as calibrated by the component firmware. When auto-calibration is disabled, the IDAC value entered in the customizer is shown. If the Tuner operates in the *Sync'd read*, it is possible to edit the value and apply to the device.

Graph Setup Pane

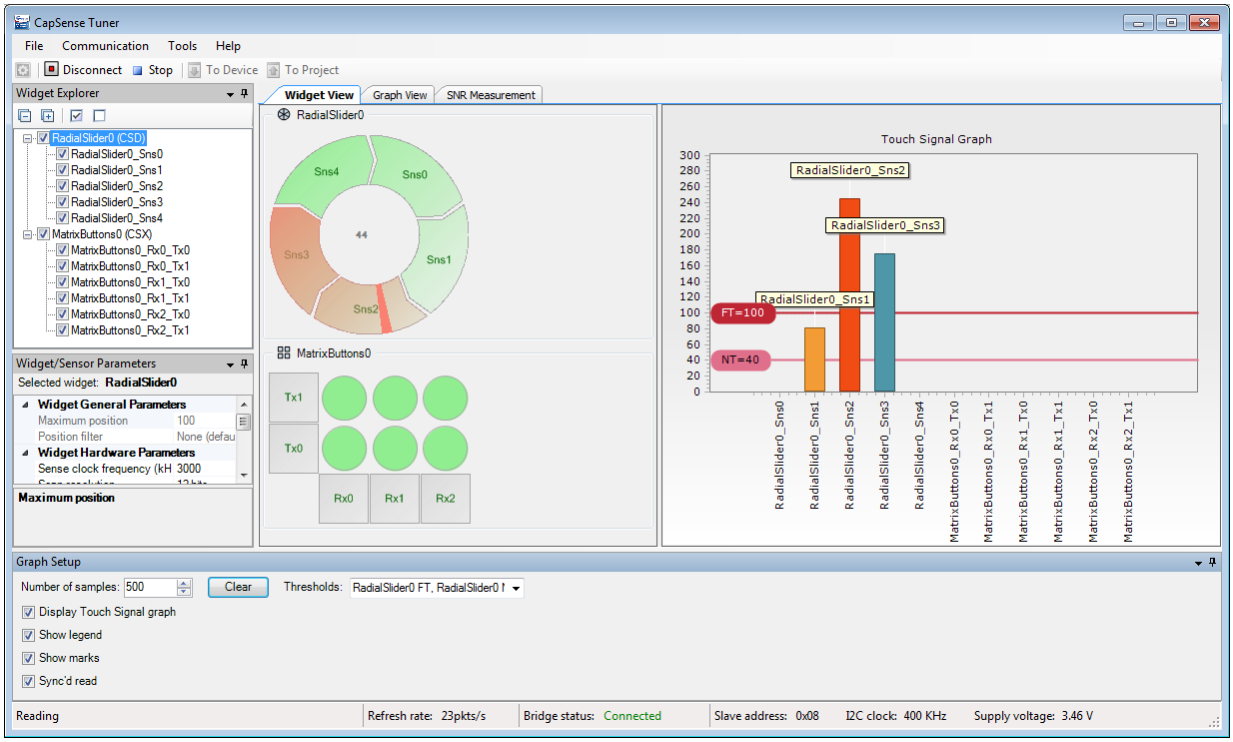
The Graph Setup pane provides quick access to different Tuner configuration options that affect the Tuner graphs display.

- **Number of samples:** Defines the total amount of data samples shown on a single graph.
- **Show legend:** Displays the sensor series descriptions (with names and colors) on graphs when checked (Sensor Data/Sensor Signal/Status graphs on a *Graph View* and *Touch Signal Graph* on a *Widget View*).
- **Show marks:** When checked, the sensor names are shown as marks over the signal bars on *Touch Signal Graph*.
- **Sync'd read;** Controls the communication mode of the Tuner. The Sync'd read mode is available when a FW loop periodically calls a corresponding Tuner API.

  When unchecked, the Tuner reads data asynchronously to sensor scanning. Because reading data by CapSense Tuner and data processing happen asynchronously, it is possible that CapSense Tuner will read the updated data only partially. For example, the device updates only the first sensor data and the second sensor is not updated yet. At this moment, the CapSense Tuner reads the data. As a result, the second sensor data is not processed.

  When the synchronized read mode is enabled, the CapSense Tuner manages an execution flow by suspending scanning during read operation. Before starting data reading, the Tuner sends a **Suspend** command to the device. The device hangs the FW flow until a **Resume** command is received. The Tuner reads all the needed data and sends a **Resume** command. The device restores operation by executing the next scan.

Widget View



Provides a visual representation of all widgets that are selected in the *Widget Explorer Pane*. If a widget is composed of more than one sensor, individual sensors may be selected to be highlighted in the *Widget Explorer Pane* and *Widget/Sensor Parameters Pane.*

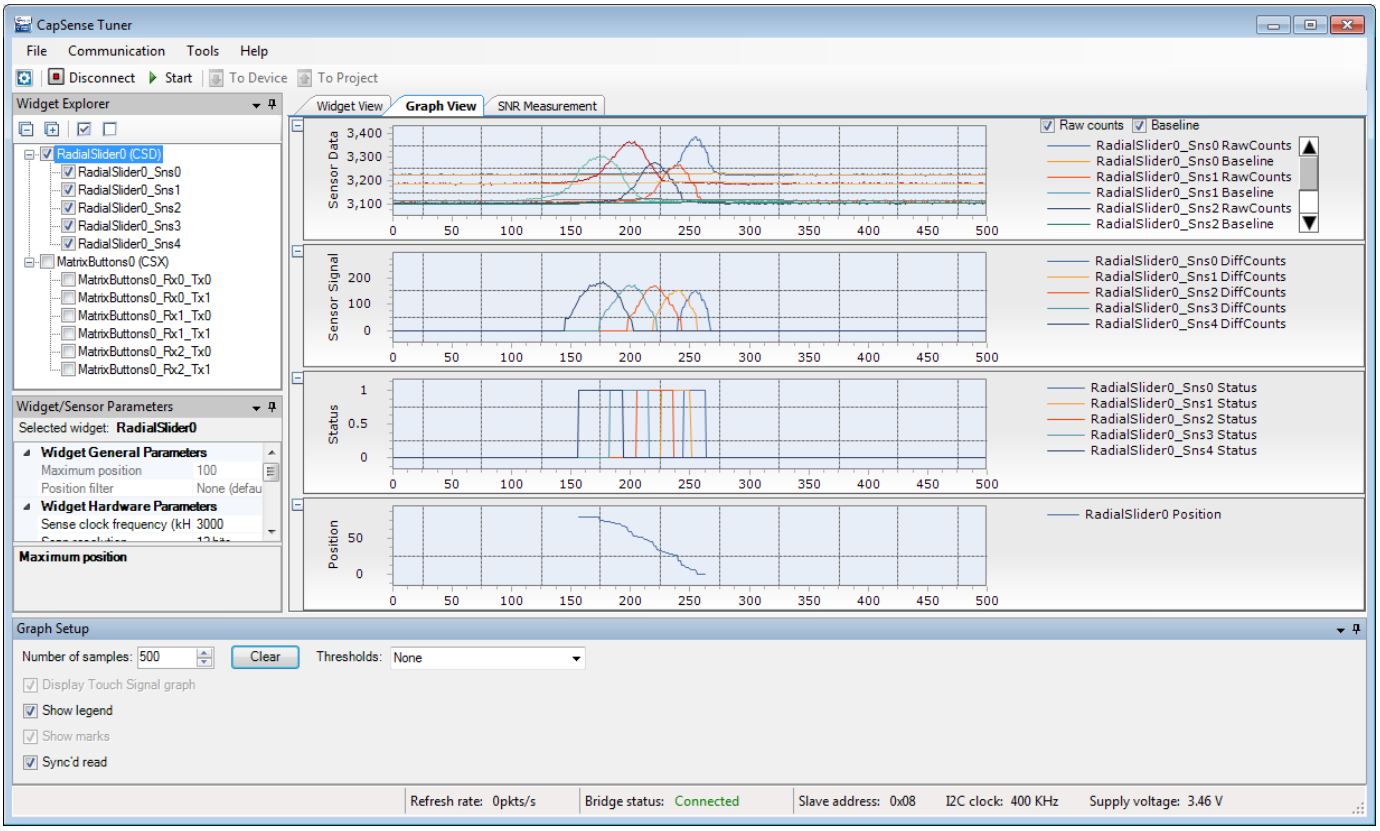
The Widget sensors are highlighted red when the device reports their touch status as active.

Some additional features are available depending on the widget type:

Touch Signal Graph

The Widget view also displays Touch Signal Graph when the “Display Touch Signal graph” checkbox is checked in the *Graph Setup Pane*. This graph contains a touch signal level for each sensor that is selected in the *Widget Explorer Pane*.

Graph View



Displays graphs for selected sensors in the *Widget Explorer Pane*. Three charts are available:

Sensor Data graph: Displays raw counts and baseline.

It is possible to select which series should be displayed with the checkboxes on the right:

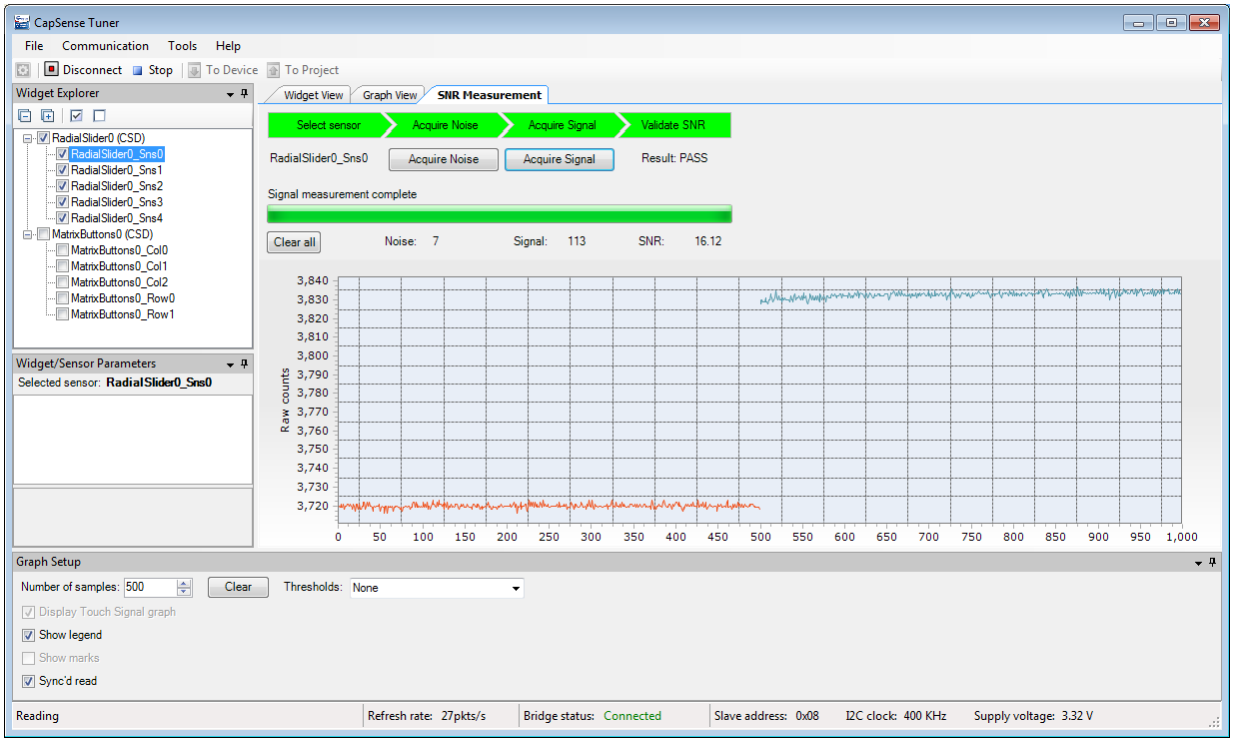
- Raw counts and baseline series
- Raw counts only
- Baseline only

Sensor Signal graph: Displays a signal difference.

Status graph: Displays the sensor status (Touch/No Touch). For proximity sensors, it also shows the proximity status (at 50% of the status axis) along with the touch status (at 100% of the axis).

Position graph: Displays touch positions for the *Linear Slider*, *Radial Slider* and *Touchpad* widgets.

SNR Measurement



The **SNR Measurement** tab allows measuring a SNR (Signal-to-Noise Ratio) for individual sensors.

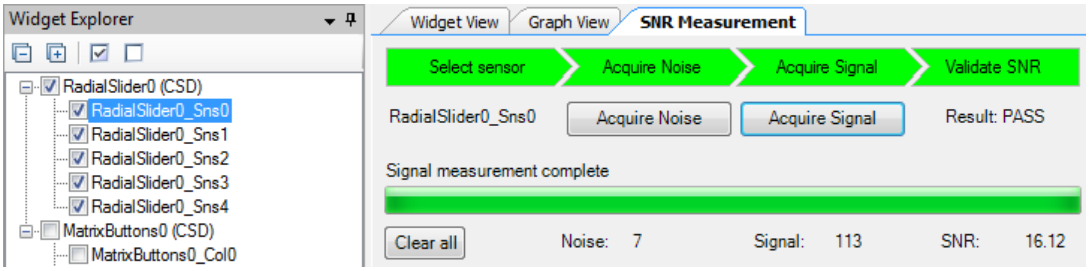
The tab provides UI to acquire noise and signal samples separately and then calculates a SNR based on the captured data. The obtained value is then validated by a comparison with the required minimum (5 by default, can be configured in the Tuner Configuration Options).

Typical flow of SNR measurement

1. Connect to the device and start communication (by pressing the **Connect**, then **Start** buttons on the toolbar).
2. Switch to the **SNR Measurement** tab.
3. Select a sensor in the *Widget Explorer Pane* located at the left of the **SNR Measurement** tab.
4. Make sure no touch is present on the selected sensor.
5. Press the **Acquire Noise** button and wait for the required count of noise samples to be collected.
6. Observe the Noise label is updated with the calculated noise average value.
7. Put a finger on the selected sensor.
8. Press the **Acquire Signal** button and wait for required count of signal samples to be collected.
9. Observe the Signal label is updated with the calculated signal average value

10. Observe the SNR label is updated with the signal to noise ratio.

Description of SNR measurement GUI



At the top of the **SNR measurement** tab, there is a bar with the status labels. Each label status is defined by its background color:

- **Select sensor** is green when there is a sensor selected; gray otherwise.
- **Acquire noise** is green when noise samples are already collected for the selected sensor; gray otherwise.
- **Acquire signal** is green when signal samples are already collected for the selected sensor; gray otherwise.
- **Validate SNR** is green when both noise and signal samples are collected, and the SNR is above the valid limit; red when the SNR is below the valid limit, and gray when either noise or signal are not yet collected.
- Below the top bar, there are the following controls:
- **Sensor name** label selected in the *Widget Explorer Pane* or None (if no sensor selected).
- **Acquire Noise** button is disabled when the sensor is not selected or communication is not started. When acquiring noise is in progress, the button can be used to abort the operation.
- **Acquire Signal** button is disabled when the sensor is not selected, communication is not started, or noise samples are not yet collected for the selected sensor. When acquiring signal is in progress, the button can be used to abort the operation.
- **Result** label shows either “N/A” (when the SNR cannot be calculated due to noise/signal samples not yet collected), “PASS” (when SNR is above the required limit), or “FAIL” (when the SNR is below the required limit).

Below, there is a status label displaying the current status message and progress bar displaying the progress of the current operation.

At the bottom of the control area, there are the following controls:

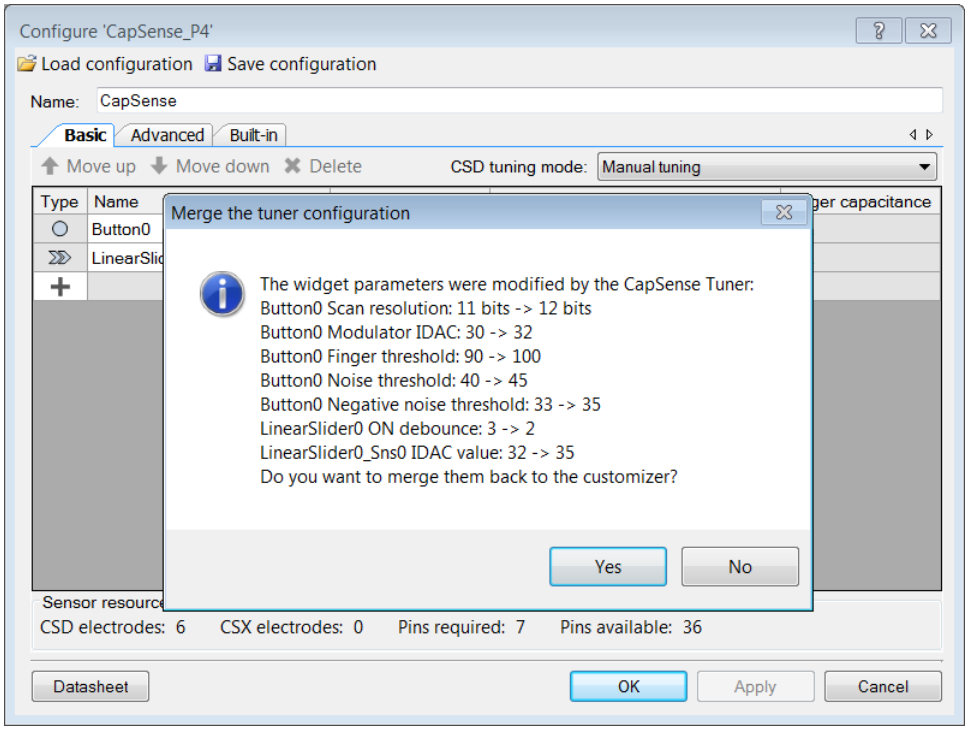
- **Clear all** button allows clearing all measured data. When data acquisition is in progress, the operation is restarted (i.e. all samples collected so far are discarded, and measurement is started from scratch).
- **Noise** label shows the noise average value calculated during the last noise measurement for the selected sensor, or “N/A” if no noise measurement is performed yet.
- **Signal** label shows the signal average value calculated during the last signal measurement for the selected sensor, or “N/A” if no signal measurement was performed yet.
- **SNR** label shows a calculated SNR value. This is the result of Signal/Noise division rounded up to 2 decimal points. When a SNR cannot be calculated, “N/A” is displayed instead.

Tuner Parameter Saving Flow

Changes to widget/sensor parameters made during the tuning session are not automatically applied to the PSoC Creator project. Follow these steps to merge parameters modified by the tuner back to the component instance:

1. Close the tuner application.
2. Whenever there are some changes not yet saved to the project (with the “Apply to Project” button), the dialog “Do you want to save the updated CapSense parameters?” appears. Accept the dialog.
3. Open the component customizer GUI.

The following dialog asks to merge tuner configuration updates back to the customizer:

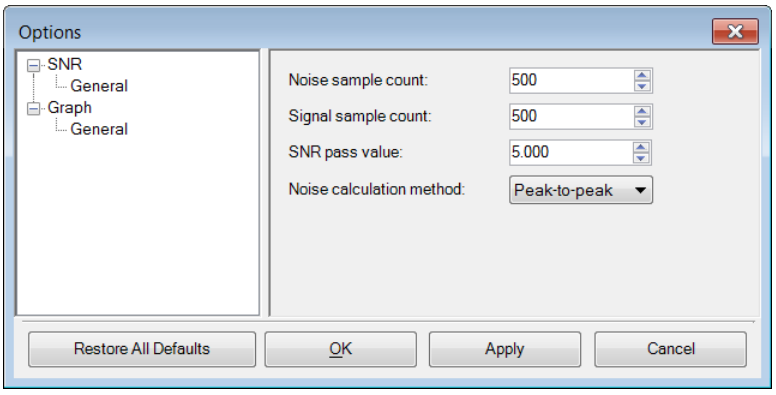


4. Click **OK**; then build and program the project to the device.

Tuner Configuration Options

The Tuner application allows setting different configuration options with the Options dialog. Settings are applied on a project basis and divided into groups:

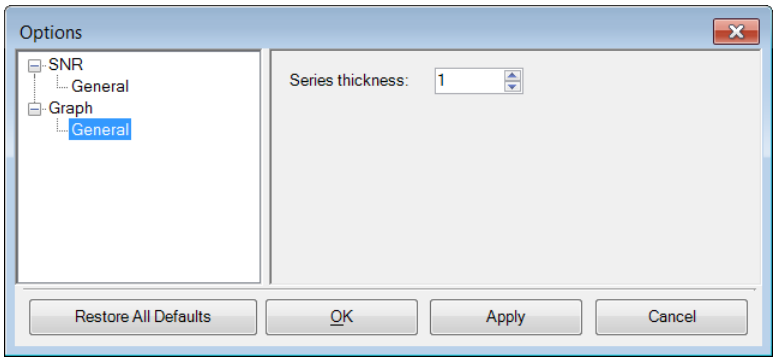
SNR Options



- **Noise sample count:** Count of samples to acquire during the noise measurement operation.

- **Signal sample count:** Count of samples to acquire during the signal measurement operation.
- **SNR pass value:** The minimal acceptable value of the SNR.
- **Noise calculation method:** Allows selecting the method to calculate the noise average. Two methods are available for selection:
  - **Peak-to-peak** (by default): Calculates noise as a difference between the maximum and minimum value collected during the noise measurement.
  - **RMS:** Calculates noise as a root mean-square of all samples collected during the noise measurement.

Graph options



- **Series thickness** allows specifying the thickness of lines drawn on the graphs.

MISRA Compliance Report

This section describes the MISRA-C: 2004 compliance and deviations for the component. There are two types of deviations defined:

- Project deviations – applicable for all PSoC Creator components
- Specific deviations –applicable only for this component

This section provides information on the component-specific deviations. The project deviations are described in the “MISRA Compliance” section of the *System Reference Guide* along with information on the MISRA compliance verification environment.

The CapSense_P4 component has the following specific deviations:

MISRA-C:2004 Rule	Rule Class (Required/ Advisory)	Rule Description	Description of Deviation(s)
8.8	R	An external object or function shall be declared in only one file.	Some arrays are generated based on the component configuration and these arrays are declared locally in the .c source files where they are used instead of in .h include files.
12.13	A	The increment (++) and decrement (--) operators should not be mixed with other operators in an expression.	These violations are reported for the GCC ARM optimized form of the “for” loop that have the following syntax: for(index = COUNT; index --> 0u;) It is used to improve performance.
14.2	R	All non-null statements shall either have at least one side effect however executed, or cause the control flow to change.	These violations are caused by expressions suppressing the C-compiler warnings about the unused function parameters. The CapSense component has manydifferent configurations. Some of them do not use specific function parameters. To avoid the complier's warning, the following code is used: (void)paramName.
16.7	A	A pointer parameter in a function prototype should be declared as the pointer to const if the pointer is not used to modify the addressed object.	Mostly all data processing for variety configuration, widgets and data types is required to pass the pointers as an argument. The architecture and design are intended for this casting.
18.4	R	Unions shall not be used.	There are two general cases in the code where this rule is violated. 1. CapSense_PTR_FILTER_VARIANT definition and usage. This union is used to simplify the pointer arithmetic with the Filter History Objects. Widgets may have two kinds of Filter History: Regular History Object and Proximity History Object. The mentioned union defines three different pointers: void, RegularObjPtr, and ProximityObjPtr. 2. APIs use unions to simplify operation with pointers on the parameters. The union defines four pointers: void*, uint8*, uint16*, and uint32*. In all cases, the pointers are verified for proper alignment before usage.

Component Debug Window

PSoC Creator allows you to view debug information about components in your design. Each component window lists the memory and registers for the instance. For detailed hardware registers descriptions, refer to the appropriate device technical reference manual.

To open the Component Debug window:

1. Make sure the debugger is running or in the break mode.
2. Choose Windows > Components… from the Debug menu.
3. In the Component Window Selector dialog, select the component instances to view and click OK.

The selected Component Debug window(s) will open within the debugger framework. Refer to the "Component Debug Window" topic in the PSoC Creator Help for more information.

Resources

The CapSense component always consumes one CSD (CapSense Sigma-Delta) block, one Analog Mux bus, and one port pin for each sensors, Tx and Rx electrodes configured to use a dedicated pin in the *Widget Details* tab.

Additionally,

- An additional analog mux bus is consumed with a shield electrode enabled in the *CSD Settings* tab.
- One 7-bit IDAC in the CSD block is not consumed (and available for general purpose use) when the Enable compensation IDAC is unselected in the **CSD Settings** tab.
- Two analog buses and two 7-bit IDACs are used always when ADC Number of input channels is non-zero.

References

General References

- *Cypress Semiconductor web site*
- *PSoC 4 Device datasheets*

Application Notes

Cypress provides a number of application notes describing how PSoC can be integrated into your design. You can access them at the *Cypress Application Notes web page*. Examples that relate to CapSense include:

- *AN64846* - Getting Started with CapSense®
- *AN72362* - Reducing Radiated Emissions in Automotive CapSense® Applications
- *AN85951* - PSoC® 4 CapSense® Design Guide
- *AN92239* - Proximity Sensing with CapSense®

Code Examples

PSoC Creator provides access to code examples in the Code Example dialog. For component-specific examples, open the dialog from the Component Catalog or an instance of the component in a schematic. For general examples, open the dialog from the Start Page or **File** menu. As needed, use the **Filter Options** in the dialog to narrow the list of projects available to select.

Refer to the "Code Example" topic in the PSoC Creator Help for more information.

There are also numerous code examples that include schematics and code examples available online at the *Cypress Code Examples web page*. The examples that use this component include:

- *CE210289 - PSoC®4 CapSense® Linear Slider*
- *CE210291 - PSoC® 4 CapSense® One Button*
- *CE210290 - PSoC® 4 CapSense® Low-Power Ganged Sensor*
- *CE210311 - CapSense® ADC Sequential*

Development Kit Boards

Cypress provides a number of development kits. You can access them at the *Cypress Development Kit web page*. Mentioned Code Examples uses the following development kits:

- *CY8CKIT-040 PSoC® 4000 Pioneer Kit*
- *CY8CKIT-042-BLE Bluetooth® Low Energy Pioneer Kit*
- *CY8CKIT-042 PSoC® 4 Pioneer Kit*
- *CY8CKIT-044 PSoC® 4 M-Series Pioneer Kit*
- *CY8CKIT-046 PSoC® 4 L-Series Pioneer Kit*

- *CY8CKIT-041 PSoC® 4 S-Series Pioneer Kit*

Electrical Characteristics

Specifications are valid for +25° C, VDD 3.3v, Cmod = 2.2nF, Csh = 10nF, and CintA = CintB = 470 pF except where noted.

Note Final characterization data for PSoC 4000S, PSoC 4100S and PSoC Analog Coprocessor devices is not available at this time. Once the data is available, the component datasheet will be updated on the Cypress web site.

CapSense Performance Characteristics (Preliminary)

Parameter	Condition	Typical	Units
Sensor Calibration level (Applicable for sensor with highest Cp within a Widget)	Cp = 5 to 45pF (Single IDAC mode)	85% of full scale ±5 %	-
	Cp = 5 to 10pF (Dual IDAC mode)	70% of full scale ±10 %	-
Touch signal accuracy The touch signal is the difference in the measured raw counts with and without a finger present on a sensor (difference count).		Not less than 10% of sensor sensitivity	-
Supported Sensor Cp range		Min: 5. Max: 45	pF
SNR (Noise Floor) The simple ratio of (Signal/Noise) is called the CapSense SNR. It is usually simplified to [(Finger Signal/Noise): 1]	Cp < 35 pF	> 5:1	-
	Cp < 45 pF	> 4:1	-
Supply (VDD) ripple	V_{DD} > 3.3V, Finger capacitance = 0.1 pF, V_{DD} ripple +/-50mV	< 30% of noise	
	V_{DD} < 2V, internally regulated mode, Finger capacitance = 0.4 pF, V_{DD} ripple +/-50mV	< 30% of noise	
	V_{DD} < 2v, externally regulated mode, Finger capacitance = 0.4 pF, V_{DD} ripple +/-25mV	< 30% of noise	
GPIO Sink Current	10 mA per GPIO on multiple pin to sink max current. Device max = 80mA for PSoC 4000. Device max = 40mA for all other PSoCs	< 30% of noise	
Finger-Conducted AC Noise	50/60Hz, noise Vpp = 20V	< 30%	-

Parameter	Condition	Typical	Units
Finger-Conducted AC Noise is the change in sensor raw count when AC noise is applied on sensor (injected into the system)	10 kHz to 1 MHz, noise Vpp = 20V, Cp < 10pF	< 60%	-
Interrupt immunity Excessive raw counts noise at asynchronous interrupts is used.	SNR > 5:1	< 30%	-
Current Consumption	1 CSD Button Widget (Ganged Sensor, 4 electrodes). Resolution = 9 bits. Each electrode Cp < 10pF. Shield Electrode = Disabled. SYSCLK = 16MHz. No I2C traffic (I2C block ON). Report Rate >= 8Hz. Chip state = DeepSleep (LFT).	< 6 (PSoC 4000)	µA
		< 7 (PSoC 4000S)	µA
	1 CSD Button Widget, 8 Sensors. Resolution = 9-bits. Each electrode Cp < 10pF. Shield Electrode = Disabled. SYSCLK = 16MHz. No I2C traffic (I2C block ON). Report Rate >= 8Hz Chip state = DeepSleep (LFT).	< 18 (PSoC 4000)	µA
		< 22 (PSoC 4000S)	µA
	1 CSX Button Widget (1 x 1 electrodes). Num of sub-conversions = 25. SYSCLK = 16MHz. Overlay >= 1mm plastic. Button Size <= 10mm. No I2C traffic (I2C block ON). Report Rate >= 8Hz. Chip state = DeepSleep (LFT).	< 6 (PSoC 4000)	µA
		< 6 (PSoC 4000S)	µA
	1 CSX Touchpad Widget 32 nodes (9 x 4 electrodes).	< 150 (PSoC 4000)	µA

Parameter	Condition	Typical	Units
	Num of sub-conversions = 25. SYSCLK = 16MHz. Overlay => 1mm plastic. 4.8 x 4.8 mm diamond sensors. 9mm metal finger. 1 Touch only. Report Rate >= 8Hz. Chip state = DeepSleep (LFT).	< 200 (PSoC 4000)	µA

ADC Performance Characteristics (Preliminary)

Parameter	Min	Typ	Max	Units	Details/ Conditions
Resolution	-	-	10	bits	Auto-zeroing is required every millisecond
Number of channels - single ended	-	-	16		Defined by AMUX Bus
Monotonicity	-	-	-	Yes	Yes
Gain error	-	-	±2	%	In V_{REF} (2.4 V) mode with V_{DDA} bypass capacitance of 10 µF
Input offset voltage	-	-	3	mV	In V_{REF} (2.4 V) mode with V_{DDA} bypass capacitance of 10 µF
Current consumption	-	-	0.25	mA	
Input voltage range - single ended	V_{SSA}	-	V_{DDA}	V	
Input resistance	-	2.2	-	KΩ	
Input capacitance	-	20	-	pF	
Power supply rejection ratio	-	60	-	dB	In V_{REF} (2.4 V) mode with V_{DDA} bypass capacitance of 10 µF
Sample acquisition time	-	1	-	µs	
Conversion time for 8-bit resolution at conversion rate = Fhclk/(2^(N+2)). Clock frequency = 48 MHz.	-	-	21.3	µs	Does not include acquisition time. Equivalent to 44.8 ksps including acquisition time.

Parameter	Min	Typ	Max	Units	Details/ Conditions
Conversion time for 10-bit resolution at conversion rate = Fhclk/(2^(N+2)). Clock frequency = 48 MHz.	-	-	85.3	µs	Does not include acquisition time. Equivalent to 11.6 ksps including acquisition time.
Signal-to-noise and Distortion ratio (SINAD)	61	-	-	dB	With 10Hz input sine wave, external 2.4V reference, V_{REF} (2.4 V) mode
Input bandwidth without aliasing	-	-	22.4	KHz	8-bit resolution
Integral Non Linearity. 1 KSPS	-	-	2	LSB	V_{REF} = 2.4 V or greater
Differential Non Linearity. 1 KSPS	-	-	1	LSB	

DC/AC Specifications

Refer to devices specific datasheet *PSoC 4 Device datasheets* for more details.

Component Errata

This section lists known problems with the CapSense P4 ADC component.

Cypress ID	Component Version	Problem	Workaround
240777	3.0	**CSD (Self-cap) Sensing mode:** When "Auto" is selected for *Sense clock source* under CSD Settings, the correct clock source is not selected when *Scan resolution* under Widget Details is greater than 11-bit and *Sense clock frequency* under Widget Details is less than 300 kHz. **CSX (Mutual-cap) Sensing mode:** When "Auto" is selected for *Tx clock source* under CSX Settings, the correct clock source is not selected when *Tx clock frequency* under Widget Details is less than 300 kHz. This errata applies to PSoC 4000S, PSoC 4100S and PSoC Analog Coprocessor device families.	Use one of the following workarounds for the widgets that use CSD sensing mode: ▪ Set the *Sense Clock frequency* to 300 kHz or higher. ▪ Set the *Scan resolution* to 11-bit or less and set when Sense clock frequency is less than 300 kHz. ▪ Set the *Modulator clock frequency* under CSD Settings to 48 MHz. ▪ Select the *Sense clock source* other than "Auto" by following the recommendation from the *CapSense Design Guide*. Use one of the following workarounds for the widgets that use CSX sensing mode: ▪ Set the *Tx Clock frequency* to 300 kHz or higher. ▪ Set the *Modulator clock frequency* under CSX Settings to 48 MHz. ▪ Select the *Tx clock source* other than "Auto" by following the recommendation from the *CapSense Design Guide*.

Component Changes

This section lists the major changes in the component from the previous version.

Version	Description of Changes	Reason for Changes / Impact
3.0.c	Edited datasheet.	Revised to correct omission of the APIs.
3.0.b	Edited datasheet.	Added Component Errata section to document potential issue with Auto mode.
3.0.a	Removed empty CapSense_SaveConfig() and CapSense_RestoreConfig() APIs	No usage of these API is expected in future.
	Renamed CapSense_IsProximityTouchActive() to CapSense_IsProximitySensorActive() without functionality change	Providing a meaningful name and being consistent with other APIs

Version	Description of Changes	Reason for Changes / Impact
	Changed Sensitivity parameter to Finger Capacitance	Providing a meaningful parameter with intuitive usage
	Added IDAC sensing configuration parameter with IDAC sinking mode	Expanded functionality
	Edited datasheet.	Final characterization data for PSoC 4000S, PSoC 4100S and PSoC Analog Coprocessor devices is not available at this time. Once the data is available, the component datasheet will be updated on the Cypress web site.
3.0 (Early Access Release)	The initial version of new component implementation. This version is not backward compatible with the previous versions. See *Migration Guide* for more information.	Improved implementation of the CapSense component with PSoC 4 devices.

Migration Guide

CapSense P4 v3.0 is not backward compatible with CapSense CSD P4 v2.40, and design that uses version 2.40 requires manual migration to version v3.0 to take advantage of the new version.

It is highly recommended that all the new design must start with CapSense P4 v3.0, and the design that requires features of CapSense P4 v3.0 such as mutual-cap sensing or low power needs to be manually migrated. The existing designs in production or minor revisions of the existing product may use version 2.40, however, no further enhancements are planned on that version.

This section provides the guidelines migration to CapSense P4 v3.0. In general migration requires the following steps to be performed:

- *Step-1: Add Widget / Sensor*
- *Step-2: Parameters: Enable firmware filters*
- *Step-3: Parameters: CSD Settings*
- *Step-4: Parameters: Widgets Details*
- *Step-5: Scan Order*
- *Step-6: Pinout*
- *Step-7: API Transferring*

Differences in supported features

The table below shows the difference in the features supported by v2.40 and v3.0 components.

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
Gesture	Planned for future version of the component.	Contact Cypress customer support in case your design requires this feature to provide ф solution.
Built-in self-test	Planned for future version of the component.	It сфт be implemented on the application level
Generic widget type	Planned for future version of the component.	Use the Button widget as ф replacement.
Guard Sensor	Replaced with the Button widget.	Use the Button widget type to create a guard sensor in the design.
Jitter filter for Raw Counts	Not supported	The Jitter filter is supported only for slider/touchpad positions; this filter is not very effective for noise suppression in raw counts, so use IIR, Median or average filters instead.
Widget Resolution (8-bit)	Not supported	Only 16-bit widget resolution is supported.
Modulator clock frequency for each sensor	Not supported	The modulator clock frequency is set for the whole component for optimized performance.
IDAC Sink mode	Not supported	The IDAC Sink or Source mode is not selectable in the new component. The mode is fixed to IDAC sourcing mode because it provides superior performance in all use cases compared to the IDAC sink mode.
IDAC range (8x)	Not supported	CapSense designs does not require the 8x mode, in order to make tuning simple, the 8x mode is removed.

Note In case of devices with more than one HW CSD block, CapSense CSD P4 v2.40 or earlier versions should not be used in conjunction with CapSense P4 v3.0 or later (i.e. do not place v2.40 in HW CSD block1 and v3.0 in HW CSD block2), such configuration is not guaranteed to be functional.

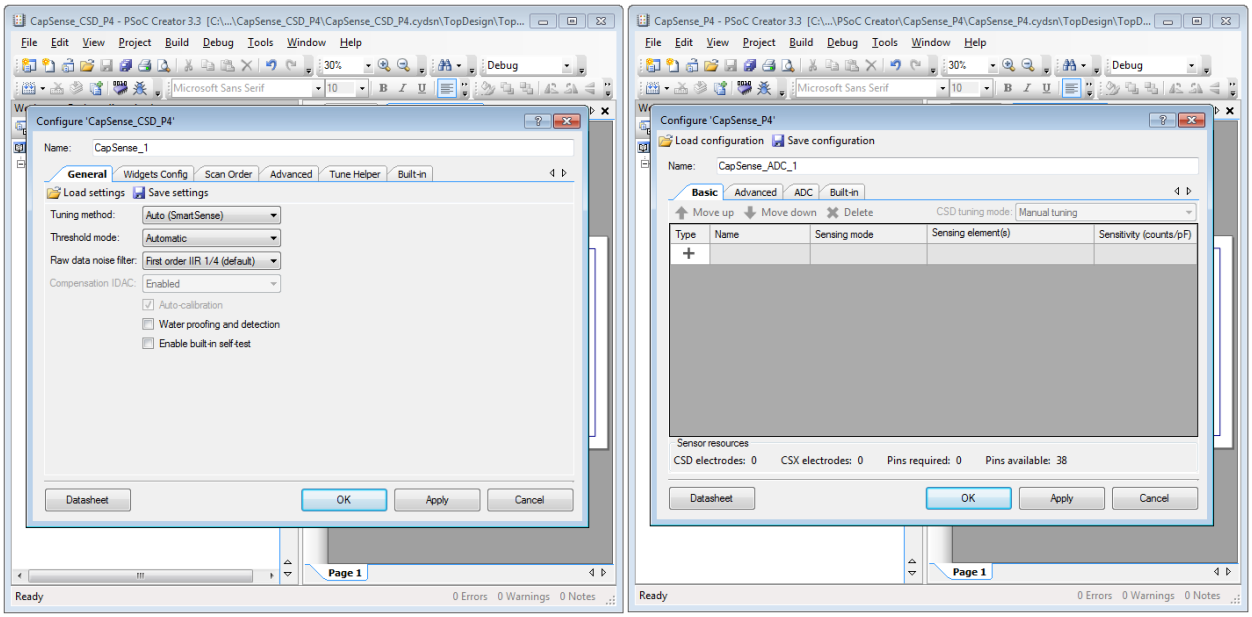
Step-1: Add Widget / Sensor

a. In v2.40, the **Widget Config** tab is used to create and configure the widgets, and *Basic Tab* is used to create widgets and *Widget Details* sub-tab under *Advanced Tab* is used to configure the widgets parameters in the v3.0 component.

   Behavior of all widgets is the same between both versions, except for the Button and Generic widgets. In CapSense v3.0, up to 32 sensors can be created under one *Button* widget, configure and scan all those sensors as a group of sensors called “widget”. If the design is based on v2.40 had multiple button sensors, consider creating several widgets and multiple sensors in the widgets for optimized performance.

Add the widgets in the *Basic Tab*, select a number of sensors or segments of those widgets.

b. Select *The CSD sensing method* for all widgets for *Sensing Mode*.



c. Tuning mode selection in the new component is updated.

Note that there is only one selection in the new component for the tuning mode instead two parameters (“Tuning method” and “Threshold mode”) in the old component. Table below shows equivalent tuning modes in CapSense v3.0.

CapSense CSD P4 (v2.40)		CapSense P4 (v3.0)	Comments
Tuning Method	**Threshold Mode**	***CSD tuning mode***	
Auto (SmartSense)	Automatic	*SmartSense (Full Auto-Tune)*	Both *Widget Hardware Parameters* and *Widget Threshold Parameters* are auto-tuned. SmartSense in CapSense CSD P4 v2.40 enables compensation IDAC automatically. SmartSense in CapSense P4 v3.0 is more flexible and allows operating with disabled Compensation IDAC. To properly migrate enable the *Enable compensation IDAC* parameter (enabled by default).
Auto (SmartSense)	Flexible	*SmartSense (Hardware parameters only)*	*Widget Hardware Parameters* are auto-tuned and *Widget Threshold Parameters* can be set by users in the customizer.
Manual with run-time tuning	N/A	*Manual*	Set both *Widget Hardware Parameters* and *Widget Threshold*

CapSense CSD P4 (v2.40)		CapSense P4 (v3.0)	Comments
Tuning Method	**Threshold Mode**	***CSD tuning mode***	
Manual	N/A		*Parameters* manually in the customizer.

d. If *SmartSense Auto-tuning* was not used, skip below step.

The new component has enhanced flexibility for *Finger capacitance* selection (Sensitivity in v.240 component) compared to only 10 selections in the v2.40 component:

- from 0.1pF to 1pF in steps of 0.02pF in *SmartSense (Full Auto-Tune)* mode
- from 0.02pF to 20.48pF on the exponential scale in *SmartSense (Hardware parameters only)* mode.

The table below shows equivalent settings in the v3.0 component for 10 selections in the v2.40 component. It is also acceptable to select different user-set value for this parameter to take advantage of CapSense v3.0 performance.

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	
Sensitivity	***Finger capacitance***	**Signal Representation**
1	0.1	50 Counts/0.1pF
2	0.2	50 Counts/0.2pF
3	0.3	50 Counts/0.3pF
4	0.4	50 Counts/0.4pF
5	0.5	50 Counts/0.5pF
6	0.6	50 Counts/0.6pF
7	0.7	50 Counts/0.7pF
8	0.8	50 Counts/0.8pF
9	0.9	50 Counts/0.9pF
10	1.0	50 Counts/1.0pF

e. Compensation IDAC in v2.40: If the compensation IDAC is enabled in the basic tab of the v2.40 component, enable the same (*Enable compensation IDAC*) in *CSD Settings* sub-tab of v3.0.

f. Raw data filter in v2.40: If the Raw data noise filter is used in the v2.40 component, enable the same (*Regular widget raw count filter type*) in *General* sub-tab of the new component as described in *Step-2*.

g. Enable Built-in self-test in v2.40: Enable built-in test is not supported in v3.0 and is expected to support in a future version.

h. Water proofing and detection: If water proofing and detection is enabled, enable the shield electrodes (*Enable shield electrode*) in *CSD Settings* sub-tab as described in *Step-3*, create a Button widget instead of guard sensors, and discard the status reported by widgets/sensors when the guard sensor is active in the application program.

Step-2: Parameters: Enable firmware filters

If the design based on the v2.40 component met the following conditions, migration of the component configuration is complete and go to the *Step-7* application programming interface section to continue:

- Used Auto SmartSense tuning mode
- Used Automatic threshold mode
- All firmware filters were disabled
- Water proofing and detection in v2.40 was disabled.
- Sensor auto-reset was disabled.

The firmware filter feature in v2.40 allows using only one filter in a design and all widget types must use common filter settings. In the CapSense P4 v3.0 component, the filter feature is enhanced by:

- Allowing coexistence of multiple filters simultaneously in a project.
- Both baseline filter and raw count filter coefficients having more configurable options.
- Both baseline and raw count filter for proximity and non-proximity sensors can be configured separately. Proximity filters often require different filter configuration as proximity sensors are usually more affected by noise.

Raw count filters

The table below shows equivalent configurations between the v2.40 and v3.0 components, enable the filters and select coefficients based on the information in table below:

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
Raw data noise filter	***Regular widget raw count filter type***	
None	No check box selected	
Median	Select *Enable median filter (3-sample)*	
Averaging	Select *Enable average filter (4-sample)*	Note that v3.0 implements averaging of 4 samples compared to 3 samples in v2.40.

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
Raw data noise filter	***Regular widget raw count filter type***	
First order IIR 1/2	Select *Enable IIR filter (First order)* and set *IIR filter raw count coefficient* to 128	Note that v3.0 implements more flexibility to set a filter coefficient from 1 to 128 in steps on 1. This table shows coefficients equivalent to the configuration in previous component.
First order IIR 1/4 (default)	Select *Enable IIR filter (First order)* and set *IIR filter raw count coefficient* to 64	
First order IIR 1/8	Select *Enable IIR filter (First order)* and set *IIR filter raw count coefficient* to 32	
First order IIR 1/16	Select *Enable IIR filter (First order)* and set *IIR filter raw count coefficient* to 16	
Jitter	Not supported.	The Jitter filter is supported only for the centroid positions with sliders and touchpad as these filters don't provide a significant benefit on the sensor raw counter filtering.

Make the same for *Proximity widget raw count filter type*.

Baseline filters:

Set the filter coefficients as listed below for equivalent performance of v2.40 from CapSens3 v3.0 component:

- *Regular widgetbaseline coefficient* = 1
- *Proximity widget baseline coefficient* = 1

Enable sensor auto-reset

- Select *Enable sensor auto-reset* if it was enabled in the previous component.

Step-3: Parameters: CSD Settings

The *CSD Settings* sub-tab contains the parameter common to all CSD widgets available in the **Advanced** tab of the v2.40 component. Follow the guidelines in the table below to set the parameters in the table below.

Note The parameters requiring selection of a "frequency" are dependent on the HFCLK settings in cydwr. If HFCLK is changed in cydwr, these parameters may need to be set again.

Parameter in v2.40	Parameter in v3.0 (***CSD Settings*** sub-tab)	Comment
Current source	NA	Not configurable and set to the IDAC source mode in v3.0 as IDAC source mode provides superior performance in all use case.

Parameter in v2.40	Parameter in v3.0 (*CSD Settings* sub-tab)	Comment
IDAC range	NA	Not configurable and set to 4x in v3.0 as all designs can work with a 4x range.
Analog Switch drive source	*Sense clock source*	The same selection options are available in both versions of the component, use the same configuration from the previous component.
Individual frequency settings	*Enable common Sense clock*	If individual frequency setting was enabled in v2.40, unselect the Enable common clock in the v3.0 component.
Sense clock divider	*Sense clock frequency*	v3.0 sets a clock in terms of a “frequency” instead of divider value. If *Enable common Sense clock* is selected, set *Sense clock frequency* in the *CSD Settings* tab, if not then set *Sense clock frequency* under *Widget Details* for each widget.
Modulator clock divider	*Modulator clock frequency*	V3.0 sets a clock in terms of a “frequency” instead of divider value. Set the same modulator clock in the new component.
Sensor auto-reset	*Enable sensor auto-reset* (In *General* tab)	No change in the functionality between the component versions.
Widget resolution	NA	The Widget resolution is not configurable and set to 16-bits in v3.0 of the component. If the previous design used 16-bits, no change is required. If previous design used the 8-bits, it is automatically moved to 16-bits in v3.0.
Negative Noise threshold	*Negative noise threshold* (In *Widget Details* tab)	No change in the functionality between the component versions. However, v3.0 sets these parameters separately for each widget.
Low baseline reset	*Low baseline reset* (In *Widget Details* tab)	
Shield	*Enable shield electrode*	No change in the functionality between the component versions. These parameters are available in v *CSD Settings* tab only when *Enable shield electrode* is selected.
Shield signal delay	*Shield electrode delay*	
Shield tank capacitor	*Enable shield tank (Csh) capacitor*	
Pre-charge settings (shield tank capacitor)	*Csh initialization source*	
Inactive sensor connection	*Inactive sensor connection*	No change in the functionality between the component versions.
Compensation IDAC (General tab)	*Enable compensation IDAC*	
Auto-calibration (General tab)	*Enable IDAC auto-calibration*	

Parameter in v2.40	Parameter in v3.0 (*CSD Settings* sub-tab)	Comment
Guard sensor	NA	As mentioned in *Step-1*, use the button sensor instead of the guard sensor.
NA	*Number of shield electrodes*	The number of dedicated shield electrodes was fixed to 1 in v2.40. But, v3.0 allows using more than one dedicated shield electrode.

Step-4: Parameters: Widgets Details

Parameter in v2.40	Parameter in v3.0 (*Widget Details* sub-tab)	Comment
Diplexing	Diplexing	No change in the feature.
API resolution	Maximum position	The parameter renamed, no change in the feature.
Row API resolution	Maximum X-axis position	
Column API resolution	Maximum Y-axis position	
Position Filter	*Position filter*	No disables of the filters in both version of the component. The *Median Filter (3 sample)* and *Jitter Filter* functionality has not changed, but the name is updated. For *Average Filter (2 sample)*, v2.40 implemented 3 sample average filter and v3.0 implements 2 sample average filter. v3.0 supports *IIR Filter* (½), instead of IIR filter ½ and ¼ in v2.40.
Sense clock divider (Scan order tab)	*Sense clock frequency*	The v3.0 component allows setting the Sense clock frequency separately for each widget. In case a dedicated Sense clock frequency is required for each sensor, create multiple widgets with one sensor each. In addition, *Matrix Buttons* and *Touchpad* widgets set separate sense clocks for rows and columns.
	Row sense clock frequency	
	Column sense clock frequency	
Scan Resolution	*Scan resolution*	The parameter behavior is the same between v2.40 and v3.0 except the following changes.
Row Scan Resolution		

Parameter in v2.40	Parameter in v3.0 (*Widget Details* sub-tab)	Comment
Column Scan Resolution		The v2.40 component provides one common Scan resolution for all the sensors in a widget. There is no separate scan Resolution for each sensor in a button widget or no separate scan Resolution for rows and columns of the matrix buttons and touchpads. As best practice, sensors with similar electrical properties should be grouped as a widget, so no dedicated scan resolution required for each sensor, row or column. In case a dedicated scan Resolution is required for each sensor, create multiple widgets with one sensor each. Similarly, create two widgets for column and row sensors, but, this is not recommended design.
Modulator IDAC (Scan order tab)	*Modulator IDAC* *Row modulator IDAC* *Column modulator IDAC*	The v3.0 component sets the modulator IDAC separately for each widget. In case a dedicated modulator IDAC is required for each sensor, create multiple widgets with one sensor each. In addition, *Matrix Buttons* and *Touchpad* widgets set separate modulator IDAC for rows and columns.
Finger Threshold Row Finger Threshold Column Finger Threshold	*Finger threshold* (*Proximity threshold* and *Touch threshold* for *Proximity* widget)	The parameter behavior is the same between v2.40 and v3.0 except the following changes. The v2.40 component provides one common finger threshold for all sensors in a widget. There is not a separate finger threshold for each sensor in a button widget or not a separate finger threshold for rows and columns of the matrix buttons and touchpads. As best practice, sensors with similar electrical properties should be grouped as a widget, so no dedicated scan resolution is required for each sensor, row or column. In case a dedicated finger thresholds is required for each sensor, create multiple widgets with one sensor each. Similarly, create two widgets for column and row sensors, but, this is not the recommended design. For *Proximity* widget, the threshold is split into two following thresholds: ▪ *Proximity threshold* to detect an approaching hand or a finger ▪ *Touch threshold* to detect a finger touch on the sensor similarly to other *Widget Type* sensors.
Noise Threshold Row Noise Threshold Column Noise Threshold	*Noise threshold*	The same rule as *Finger Threshold* applies.

Parameter in v2.40	Parameter in v3.0 (*Widget Details* sub-tab)	Comment
Negative Noise Threshold (Advanced Tab)	*Negative noise threshold*	The parameter behavior is the same between v2.40 and v3.0 except the following changes. The v3.0 component setting *Negative noise threshold* separately for each widget, compared to the common value for all widgets in v2.40. Follow the design guide to set values for the negative noise threshold, or set the same value for all widgets for backward compatibility.
Low baseline reset (Advanced Tab)	*Low baseline reset*	The same rule as *Negative Noise Threshold* applies.
Hysteresis	*Hysteresis*	The parameter behavior is the same between v2.40 and v3.0 except the following changes. All widgets have dedicated hysteresis in v3.0, and it is used along with the Finger threshold for finger detection. Follow the design guide to set values for the hysteresis, or set a value to zero for backward compatibility for the *Linear Slider*, *Radial Slider* and *Touchpad* widgets.
Row Hysteresis		
Column Hysteresis		
Debounce	*ON debounce*	The parameter behavior is the same between v2.40 and v3.0 except the following changes. All widgets have a dedicated ON denounce in v3.0, and it is used along with the Finger threshold for detection finger detection. Follow the design guide to set values for the ON debounce, or set a value to zero for backward compatibility for the *Linear Slider*, *Radial Slider* and *Touchpad* widgets.
Compensation IDAC (Scan order tab)	*Compensation IDAC value*	Behavior is the same because the v3.0 component sets the compensation IDAC separately for each sensor.
NA	*Selected pins*	Each sensor in the *Button*, *Matrix Buttons* and *Proximity* widgets use a dedicated port pin for a sensor or reuses one or more pins from the existing sensors. By reusing the port pins from other sensor, ganged sensors, implementation of CSD and CSX sensing methods on the same port pins can be done.

Step-5: Scan Order

The **Scan Order** tab has no editable contents in v3.0, all the parameters available in the **Scan Order** tab of v2.40 are already configured in the other tabs on v3.0 in the steps above.

Step-6: Pinout

Assign the pins in cydwr, this interface is not affected by component update.

Step-7: API Transferring

The following table lists the APIs whose functionality hasn't changed in v3.0 of the component.

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
IsBusy()	IsBusy()	No major functional changes.
Sleep()	Sleep()	
Stop	Stop()	
Wakeup()	Wakeup()	
InitializeAllBaselines()	InitializeAllBaselines()	
InitializeSensorBaseline()	InitializeSensorBaseline()	
ScanEnabledWidgets()	ScanAllWidgets()	
UpdateSensorBaseline()	UpdateSensorBaseline()	
UpdateThresholds()	ProcessSensorExt()	
UpdateWidgetBaseline()	UpdateWidgetBaseline()	

The following table shows list of API in v2.40 and its functional equivalent in v3.0 component.

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
Start()	Start()	Start API in v3.0 also initializes sensor baselines and Tuner interfaces compared to v2.40.
CheckIsAnyWidgetActive()	IsAnyWidgetActive()	Name updated. These APIs return the same output, but note that the APIs in v3.0 do not execute the touch detection algorithm every time an API is called, instead it returns the previously identified status by ProcessWidget() APIs.
CheckIsSensorActive()	IsSensorActive()	
CheckIsWidgetActive()	IsWidgetActive()	
GetCentroidPos()	GetCentroidPos()	
GetRadialCentroidPos()		
GetMatrixButtonPos()	IsMatrixButtonsActive()	
GetTouchCentroidPos()	GetXYCoordinates()	

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
GetBaselineData() GetCompensationIDAC() GetDebounce() GetDiffCountData() GetFingerHysteresis() GetFingerThreshold() GetLowBaseline () GetModulationIDAC() GetScanResolution() GetSenseClkDivider() GetModulatorClkDivider() GetNoiseThreshold() GetSensitivityCoefficient() ReadSensorRaw()	GetParam()	The APIs in v2.40 are used to read the status and output values of the parameter of the component. In v3.0, these parameter values (or value equivalent parameter in v3.0) can be read using common APIs by passing an appropriate register address as an argument. In addition to the parameters that can be read using these APIs, v3.0 provides access to many more other parameters as well as through a register map interface. The register address is defined in the RegisterMap header file. Details of the registers and bit fields of the register will be available in ReusterMap.pdf and ReusterMap.xml files in a future version of the component.
SetBaselineData() SetCompensationIDAC() SetDebounce() SetDiffCountData() SetFingerHysteresis() SetFingerThreshold() SetLowBaselineReset() SetModulationIDAC() SetModulatorClkDivider() SetNegativeNoiseThreshold() SetNoiseThreshold() SetScanResolution() SetSenseClkDivider() SetSensitivity() WriteSensorRaw() SetUnscannedSensorState() EnableWidget() DisableWidget()	SetParam()	The APIs in v2.40 are used to write values to the parameter of the component. In v3.0, these parameter values (or a value-equivalent parameter in v3.0) can be set using common APIs by passing an appropriate register address and value as arguments. In addition to the parameters that can be read using these APIs, v3.0 provides access to many more other parameters as well as through a register map interface. The register address is defined in the RegisterMap header file. The details of registers and bit fields of the register will be available in ReusterMap.pdf and ReusterMap.xml files in a future version of the component.
InitializeEnabledBaselines()	InitializeAllBaselines() InitializeWidgetBaseline() InitializeSensorBaseline()	Baselines are initialized in Start() API, so this API is discontinued. But, the same functionality can be achieved using one of the three APIs available in v3.0.
UpdateBaselineNoThreshold()	ProcessWidgetExt() ProcessSensorExt()	This API is discontinued, but, the same functionality can be implemented using one of the listed APIs from v3.0

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
UpdateEnabledBaselines()	ProcessAllWidgets() ProcessWidget() ProcessWidgetExt() ProcessSensorExt() UpdateSensorBaseline() UpdateAllBaselines() UpdateWidgetBaseline()	This API is discontinued, but, the same functionality can be implemented using one of the listed APIs from v3.0.
DisableRawDataFilters() EnableRawDataFilters()	ProcessWidgetExt() ProcessSensorExt()	These v2.40 APIs are discontinued and the filter is enabled in the firmware if it is enabled in the customizer and executed part of the Process Widget APIs. If required to avoid execution of the filter even if it is enabled in the customizer, use the one of the listed API from v3.0.
ScanSensor()	CSDSetupWidgetExt() CSDScanExt()	This v2.40 API is discounted, but, the same functionality can be achieved using two APIs in v3.0 (both APIs are needed to implement the functionality). Refer to the code examples, design guides (*References*) or API description (Application Programming Interface) to learn how to optimize the system performance using these APIs.
ScanWidget()	CSDSetupWidget() CSDScan()	
DisableSensor()	CSDDisconnectSns()	Both APIs disconnect the sensor port pin and are set to an inactive state.
EnableSensor()	CSDConnectSns()	Both APIs connect a sensor port pin AMUX and the sensor is ready for scan.
ClearSensors()	CSDDisconnectSns()	v2.40 API disconnects all sensors. Call the v3.0 API in a loop to disconnect all sensors for functional equivalence.
Enable()	NA	The component is enabled and the tuner and the component is initialized by the Start API, so this API is discontinued without functional impact.
Init()		
TunerStart()		
SetScanSlotSettings()	CSDSetupWidget()	The v2.40 API loads settings for scanning a sensor. v3.0 API loads the common parameters for all sensors in the widget.

The following table shows the list of discontinued APIs and feature related these APIs are not available in the component.

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
DecodeAllGestures()	NA	Not supported

CapSense CSD P4 (v2.40)	CapSense P4 (v3.0)	Comments
GetDiffDoubleCentroidPos()		
GetDoubleTouchCentroidPos()		
GetScrollCnt()		
GetWidgetNumber()		
GetNormalizedDiffCountData()		
GetNoiseEnvelope()		
ReadCurrentScanningSensor()		
GetIDACRange()		
SetIDACRange()		
SetDriveModeAllPins()		
RestoreDriveModeAllPins()		
SaveConfig()		
RestoreConfig()		
MeasureCmod()		These APIs are discontinued and appropriate features will be introduced in a future version of the component.
MeasureCShield()		
MeasureCShieldTank()		
GetSensorCp()		

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