CSD Software Filters with EzI2Cs Slave on CY8C24x94

CE63792

Code Example Name: Example_CSD_EzI2Cs_Filters_24x94
Programming Language: C
Associated Part Families: CY8C24x94
Software Version: PSoC® Designer™ 5.1 SP 2 Build 2306
Related Hardware: CY3280-24x94 UCC, CY3280-SLM, CY3240-I2USB Bridge or MiniProg3
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Objective

CE63792 describes how to scan one CapSense® button and a five-segment slider regularly and send the data to the master using I^2C protocol. This code example also describes how to apply software filters such as average, IIR, and median filters on raw count and the jitter filter on slider centroid position.

Overview

This code example incorporates the CapSense sigma delta (CSD) module and EzI2Cs module to send CapSense data to the I^2C master. The CapSense module scans all the buttons, slider segments, and applies filters as enabled and continuously stores the raw count, difference count, baseline, sensor status and slider centroid details in a structure defined by MyI2CRegs. This structure is used by the EzI2Cs module to send the data to master whenever required.

User Module List and Placement

The following table lists user modules used in this code example and the hardware resources occupied by each user module.

User Module	Placement
CSD	ACB01, DBB00, DBB01, DCB02
EzI2Cs	No blocks occupied (uses dedicated hardware)

User Module Parameter Settings

The following tables show the user module parameter settings for each of the user modules used in the code example.

CSD		
Parameter	**Value**	**Comments**
Finger Threshold	100	After the difference count crosses finger threshold plus hysteresis, the button is said to be in On condition.
Noise Threshold	40	If the difference count is less than this, it is treated as noise and the baseline update algorithm takes care of this by putting it in the update bucket.
Baseline Update Threshold	100	As the noise increases, the update bucket is filled and every time it crosses this threshold, baseline is incremented by '1' and the algorithm continues.
Sensors Autoreset	Disabled	When the parameter is set to `disabled', the baseline is updated only when raw count and baseline difference is below the noise threshold parameter.
Hysteresis	10	This takes care of false On and Off situations whenever the button is pressed. Set it equal to the noise threshold.
Debounce	3	If the difference count is more than finger threshold for less than 'Debounce' number of samples, it is not taken as a button press.
Negative Noise Threshold	20	If the raw count is below baseline and the difference count is more than this threshold, the baseline does not update.
Low BaseLine Reset	50	If the raw count is below baseline and the difference count is more than negative noise threshold for number of samples given by this parameter, the baseline resets to the new raw count.

CSD		
Parameter	**Value**	**Comments**
Scanning Speed	Normal	Decides the speed of scanning process
Resolution	12	Higher the resolution, higher is the sensitivity
Modulator Capacitor Pin	P0[5]	Indicates to which pin Cmod is connected
Feedback Resistor Pin	P3[1]	Indicates to which pin Rb is connected
Ref Value	4	This parameter sets the comparator reference value.
ShieldElectrodeOut	None	Shield electrode is not used in this code example.

Note

The parameters for CSD given in the table User Module Parameter Settings on page 1 are set to work without overlay on the CapSense buttons. If you have overlay on CapSense buttons in the board, use the flowchart in CSD Calibration on page 10 to set these CSD parameters.

EzI2Cs		
Parameter	**Value**	**Comments**
Slave Address	10	This parameter decides the address that is assigned to the slave. Value assigned can be any value from 0 to 127 (decimal)
Address_Type	Static	If this parameter is set to dynamic, the address can be changed in firmware at any time.
ROM Registers	Disable	If this parameter is set to Enable, you can use RAM area as one slave and ROM area as another slave with the addresses differing by only a most significant bit (MSB) of 7-bit address. Hence, enabling ROM registers limits the address declaration from 0 to 63 (decimal). MSB = 1 → ROM registers addressed MSB = 0 → RAM area addressed
I2C Clock	100 k standard	It decides the maximum clock speed that the slave can operate at.
I2C Pin	P1[0]-P1[1]	This indicates which pins are going to be used as SDA and SCL lines of I^2C.

Note

P1[0]-P1[1] are also used to program the device; if you have difficulty in using these pins as I^2C lines, update the MiniProg version.

Global Resources

Important Global Resources		
Parameter	**Value**	**Comments**
Power setting [V_{CC} / SysClk frequency]	5.0 V/24 MHz	Selects 5 V operation and 24 MHz SysClk
CPU_Clock	SysClk/2	Selects 12 MHz as CPU clock.

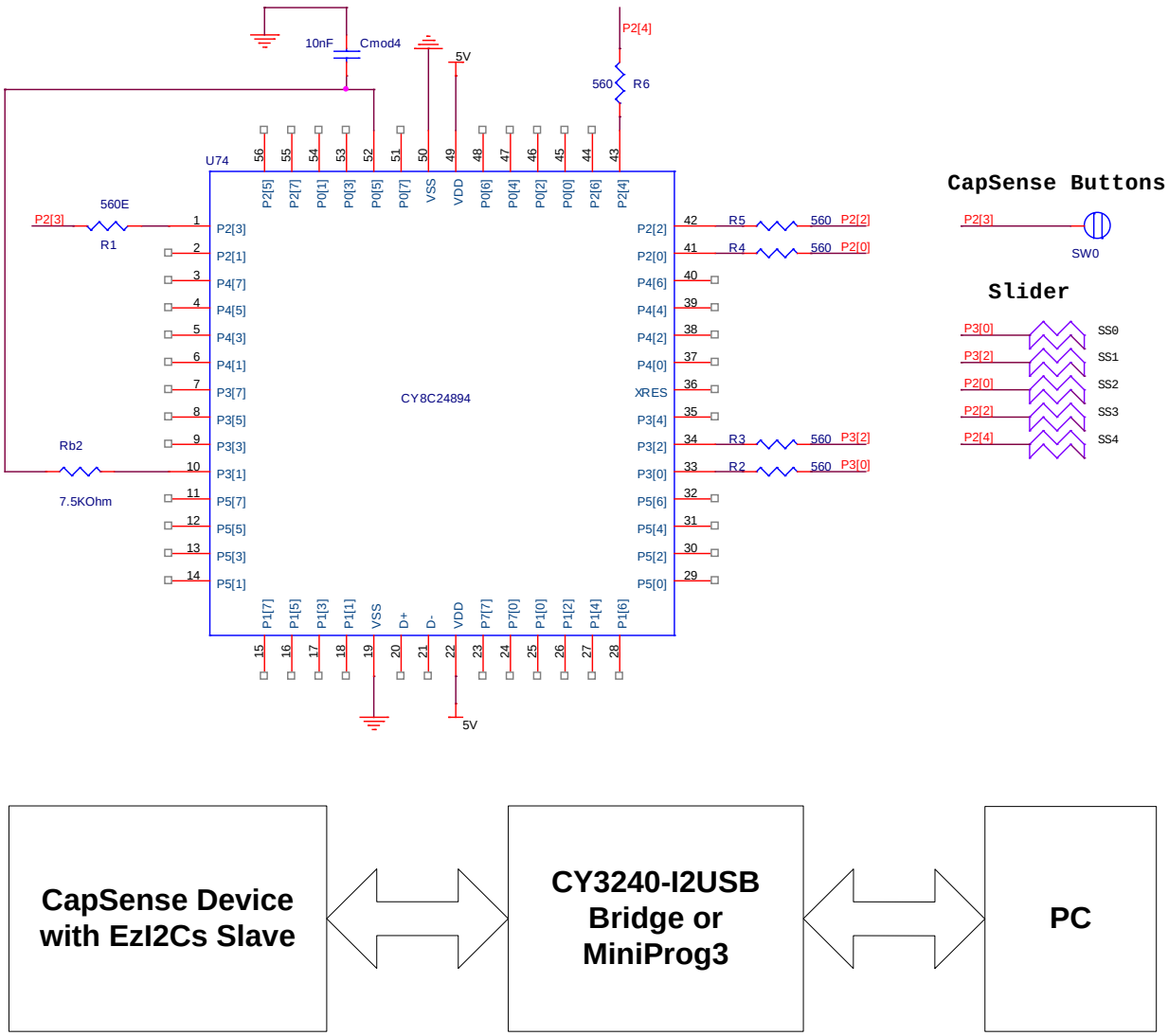
Note

Other parameters are left at their default value.

Hardware Connections

The schematic diagram for the code example follows.

Figure 1. Schematic Diagram



The CY3214-PSoC Evaluation Board is suitable for this code example. Cmod is connected to P0[5] and Rb is connected to P1[5]. CY3240-I2USB Bridge or MiniProg3 can be used as I^2C master to get the CapSense data from slave device. Because P1[0] and P1[1] are used as I^2C lines, the CY3240-I2USB Bridge or MiniProg3 can be connected to the ISSP header. The CY3240-I2USB Bridge or MiniProg3 program can be used to monitor the CapSense data. A 560-ohm resistor is connected in series with each CapSense button to reduce RF interference.

The pin assignment for CapSense buttons used in this code example is as follows:

Button 0 – P2[3]

Slider Segment 0 – P3[0]

Slider Segment 0 – P3[2]

Slider Segment 0 – P2[0]

Slider Segment 0 – P2[2]

Slider Segment 0 – P2[4]

Operation

On reset, all hardware settings from the device configuration are loaded into the device and *main.c* is executed.

The following operations are performed by the firmware.

- A structure (sI2CRegs) is defined to store the button number, raw count, difference count, baseline, status of the CapSense button, and slider centroid position.
- Global interrupt is enabled and the CSD user module is started, finger thresholds for buttons are set, and baselines are initialized.
- EzI2Cs user module is started and "sI2CRegs" is set as the I^2C buffer.
- IIR filter history is initialized if IIR filter is enabled
- In an infinite while loop, all the CapSense buttons are scanned, filters are applied on raw counts if enabled, all baselines are updated, slider centroid position is calculated, jitter filter on the slider centroid position is applied if enabled and sI2CRegs is updated with the raw count, difference count, baseline, and status of the requested CapSense button.
- I^2C master can request CapSense data of a particular button by writing the button number into first byte of the I^2C buffer of slave.

Using Filters in the Code example

- First disable all the filters and tune the CapSense system using the flowchart in CSD Calibration. To disable all the filters set the macros to the following values:
  - AVERAGE_FILTER_ENABLED – 0x00
  - IIR_FILTER_ENABLED – 0x00
  - MEDIAN_FILTER_ENABLED – 0x00
  - JITTER_FILTER_RAWCOUNT_ENABLED – 0x00
  - JITTER_FILTER_SLIDER_ENABLED – 0x00
  - FILTER_ORDER_AVERAGE – 0x00
  - FILTER_ORDER_IIR – 0x00
  - FILTER_ORDER_MEDIAN – 0x00
- Monitor the raw count using the CY3240-I2USB Bridge or MiniProg3 (refer to How to Use Bridge Control Panel to Monitor CapSense Data on page 5 on how to monitor raw counts) and measure the noise on raw counts (Noise on raw count = Max raw count – Min raw count when the finger is not present on button). Apply a filter if the noise is more on raw counts.
- To enable filters on raw counts set the following macros
  - Enable average filter → AVERAGE_FILTER_ENABLED – 0x01
  - Enable IIR filter → IIR_FILTER_ENABLED – 0x01
  - Enable median filter → MEDIAN_FILTER_ENABLED – 0x01
  - Enable jitter Filter → JITTER_FILTER_RAWCOUNT_ENABLED – 0x01

Note: If the average, IIR, and median filters are enabled, the filter is also applied to the raw counts of slider segments.

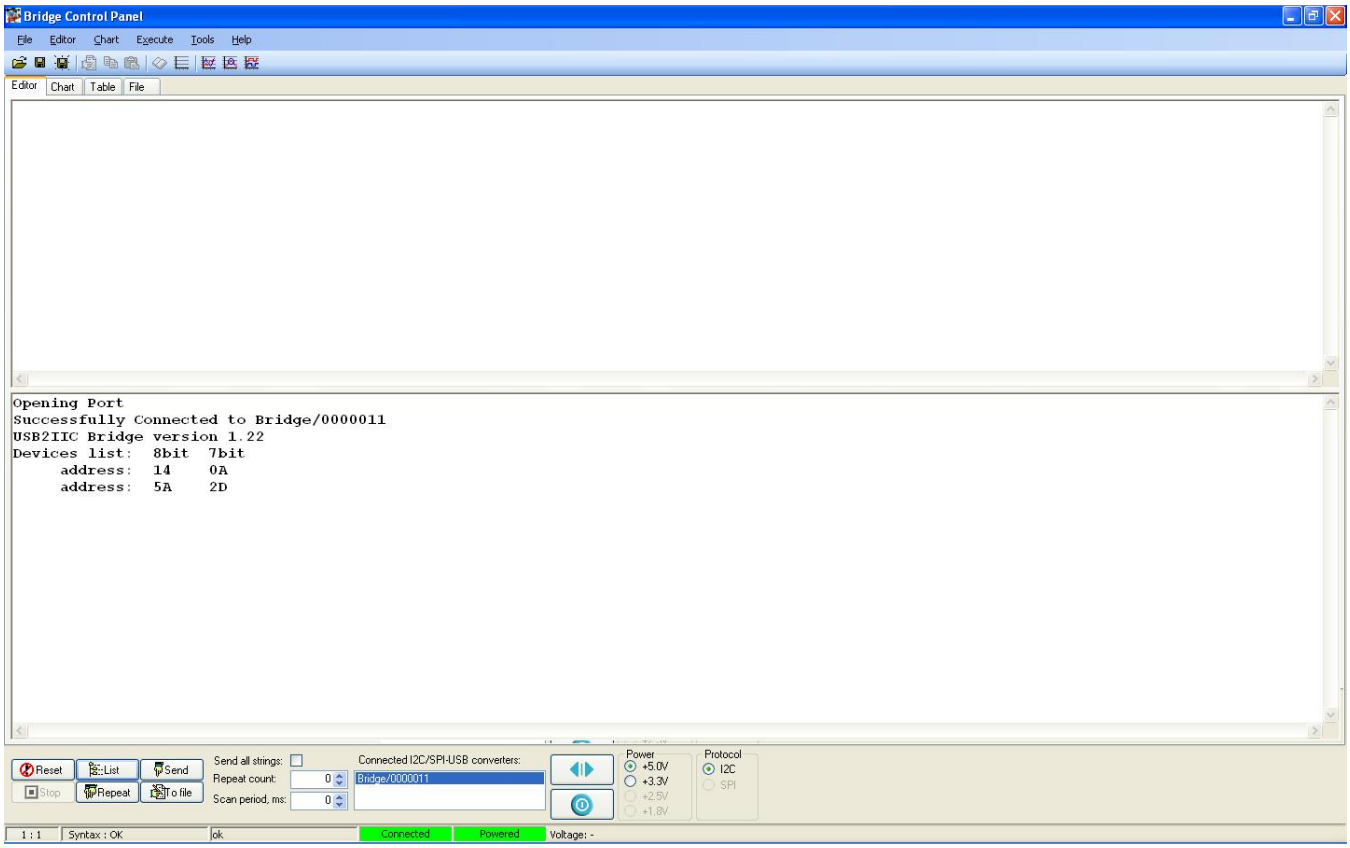
- Set the order of the filter. Use the macros mentioned to set the order of the filter. The valid filter orders for different filters is as follows:
  - Average filter → FILTER_ORDER_AVERAGE → Valid Order 2-8
  - IIR filter → FILTER_ORDER_IIR → Valid Order 1,2
  - Median filter → FILTER_ORDER_MEDIAN → Valid Order 3,5

- You can enable different filters and use the filter that reduces noise in the code example. Some general recommendations are given below:
  - Medium noise in the system – Average filter order 2,4 and IIR filter of order-1
  - High noise in the system – Average filter order 8 and IIR filter order-2
  - Spikes in the raw counts – Median filter of order 3, 5
- When slider is touched and finger is not moved on slider the slider Centroid position should be constant but due to noise in system the Centroid position may vary continuously by +/-1 count. To avoid noise on slider Centroid position enables the Jitter filter. To enable jitter filter set the following macros:
  - JITTER_FILTER_ENABLED – 0x01
- When the slider is touched and the finger does not move on the slider, the slider centroid position should be constant but due to noise in the system, the centroid position may vary continuously by one or two counts. To avoid noise on the slider centroid position, enable the jitter filter. To enable the jitter filter, set the following macros:
  - JITTER_FILTER_ENABLED – 0x01

How to Use Bridge Control Panel to Monitor CapSense Data

1. Open the bridge control panel software and connect the CY3240-I2USB Bridge or MiniProg3 Bridge to USB port.
2. Click on **Tools** and select **Protocol Configuration**. Select **IIC Speed** as 100 KHz.
3. At the right bottom corner, click the **+5 V** radio button. This powers the target device with 5 V.
4. At the left bottom corner, click the **List** button. This lists all the slave device addresses. In this case, device address is 10 (0x0A) and it is displayed in the status window, as shown in the following figure.

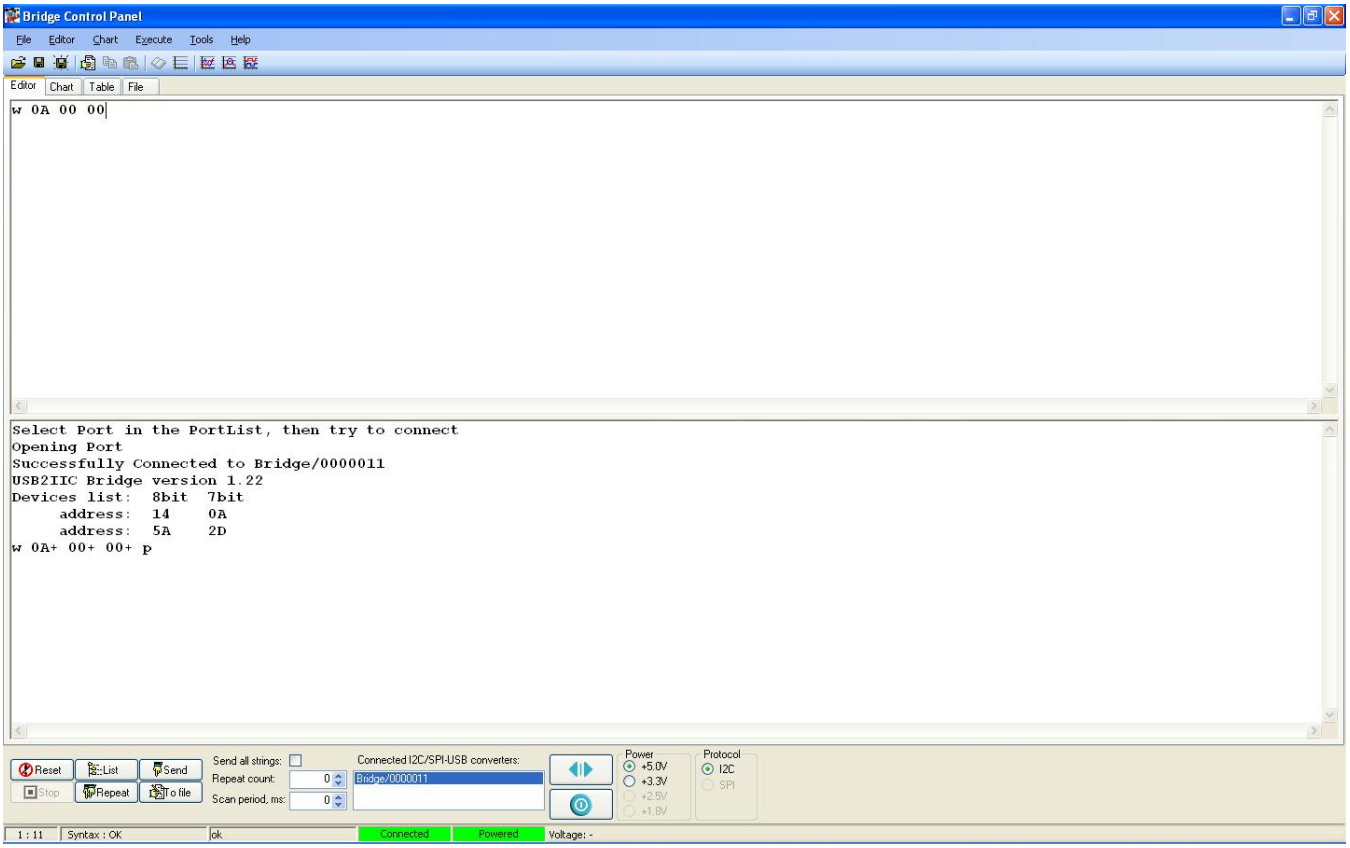
Figure 2. Display of Slave Address in Status Window



5. To monitor the CapSense data of button 0, write the following command in the command window and press <enter>.

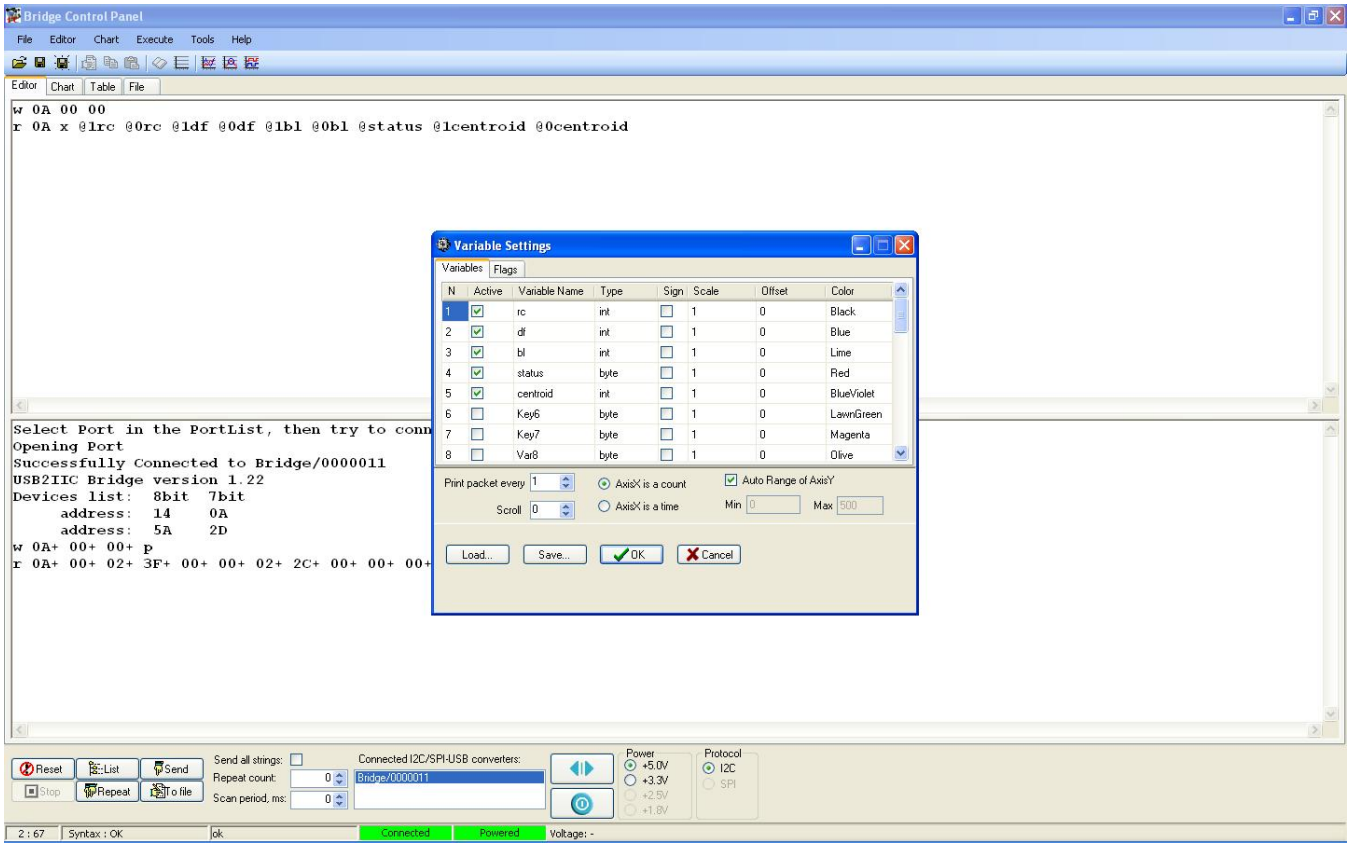
```
W 0A 00 00
```

Figure 3. Write Command Execution



6. To view CapSense data as a graph, click **Chart** and select **Variable Settings**.
7. The **Variables Settings** window appears. In the **Variables** tab, in the **Active** column check the first five check boxes.
8. In the **Variable Name** column enter the first five names as rc (RawCounts), df (difference counts), bl (baseline), status (button ON/OFF status) and centroid (slider centroid position).
9. In the **Type** column, select int for rc, df, bl, and centroid. Select byte for status. Click **OK**.

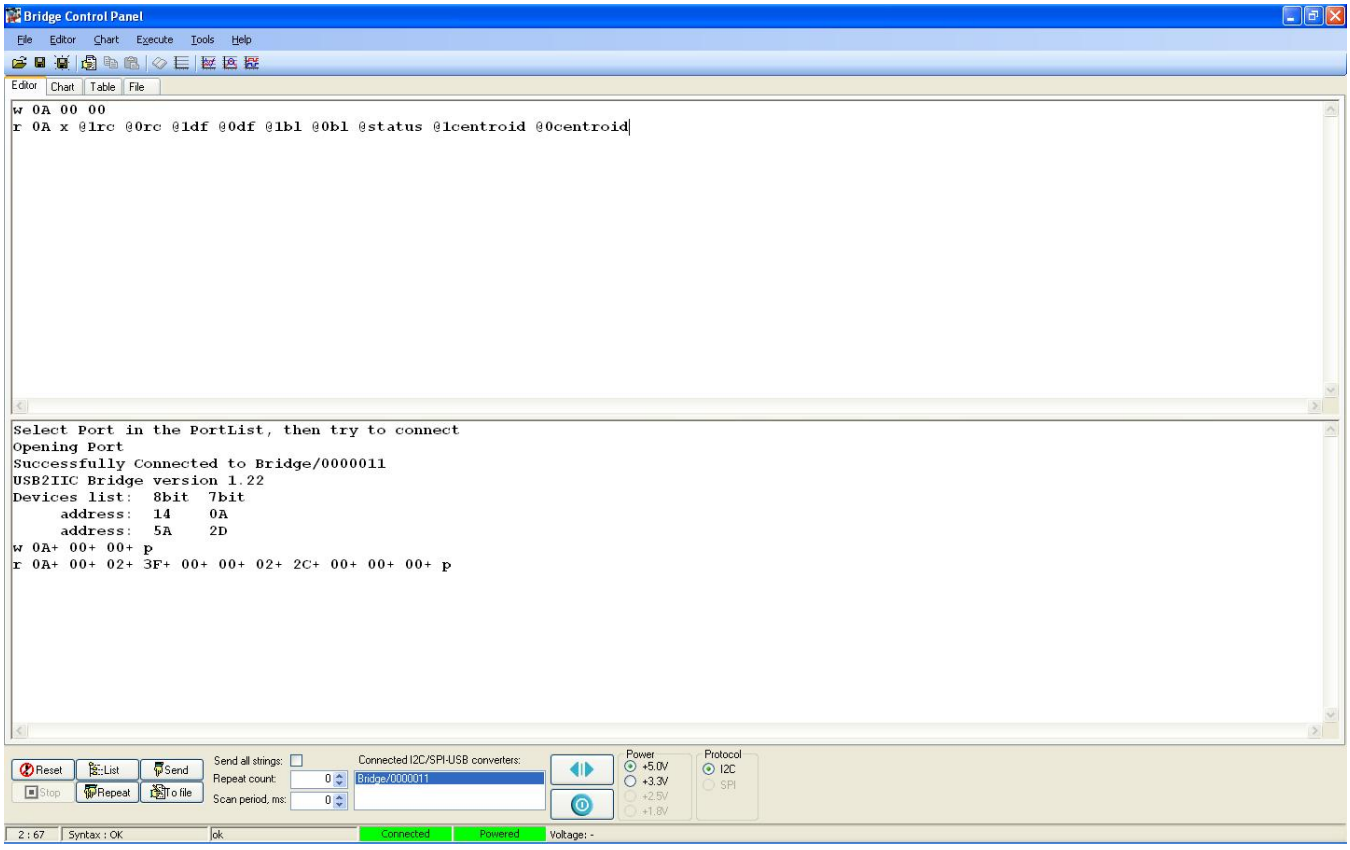
Figure 4. Variable Settings Window



10. Press <**Ctrl**> + <**Enter**> buttons to move the cursor to next line.
11. Write the following command in the command window.

    r 0A x @1rc @0rc @1df @0df @1bl @0bl @status @1centroid @0centroid

Figure 5. Read Command Execution



12. Click the **Chart** tab and then click **Repeat** button. Now, CapSense data is seen.
13. To monitor only RawCounts, uncheck df, bl, status and centroid. This is shown in the following figure. Repeat the same procedure to monitor other CapSense raw data.

Figure 6. RawCounts Chart without Button Press

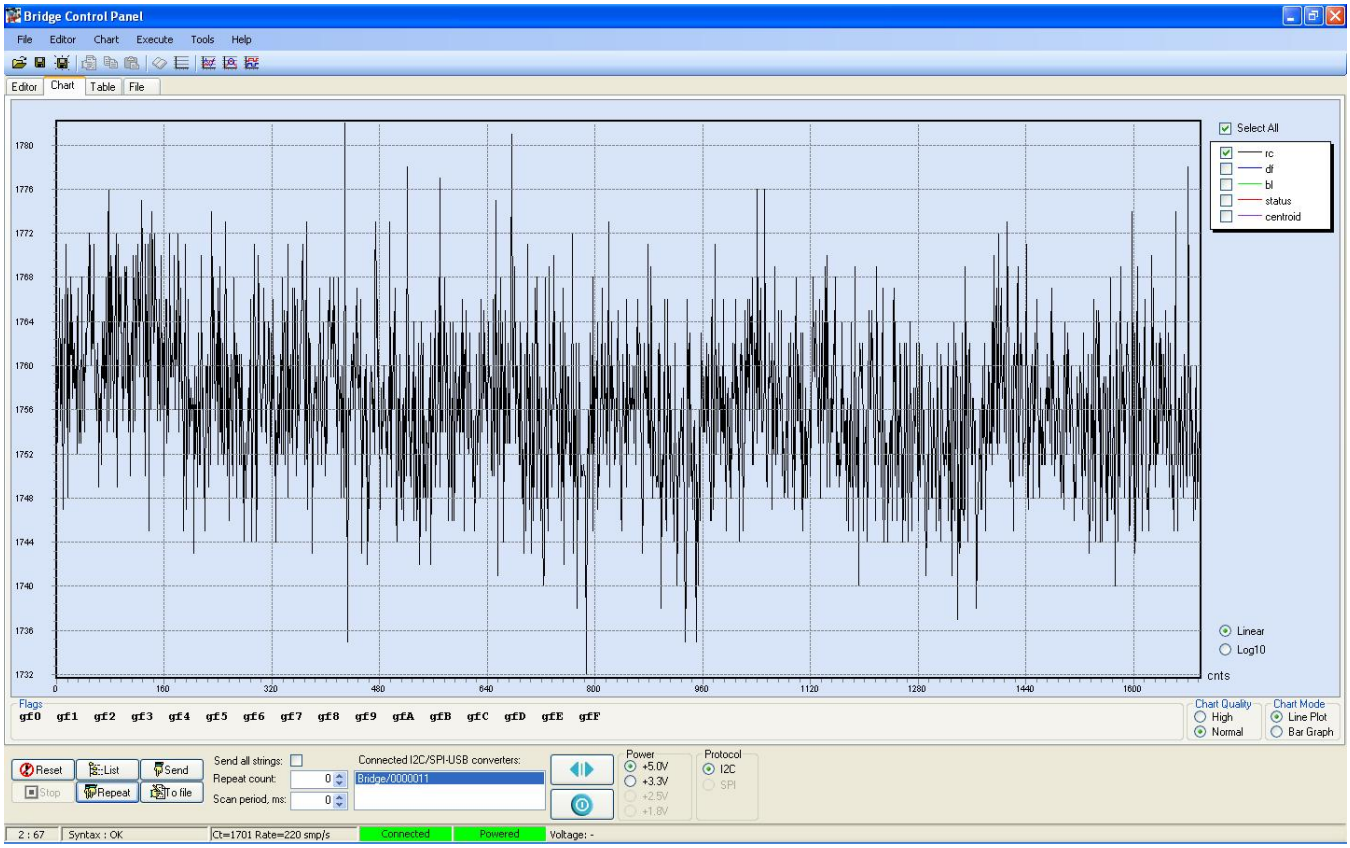
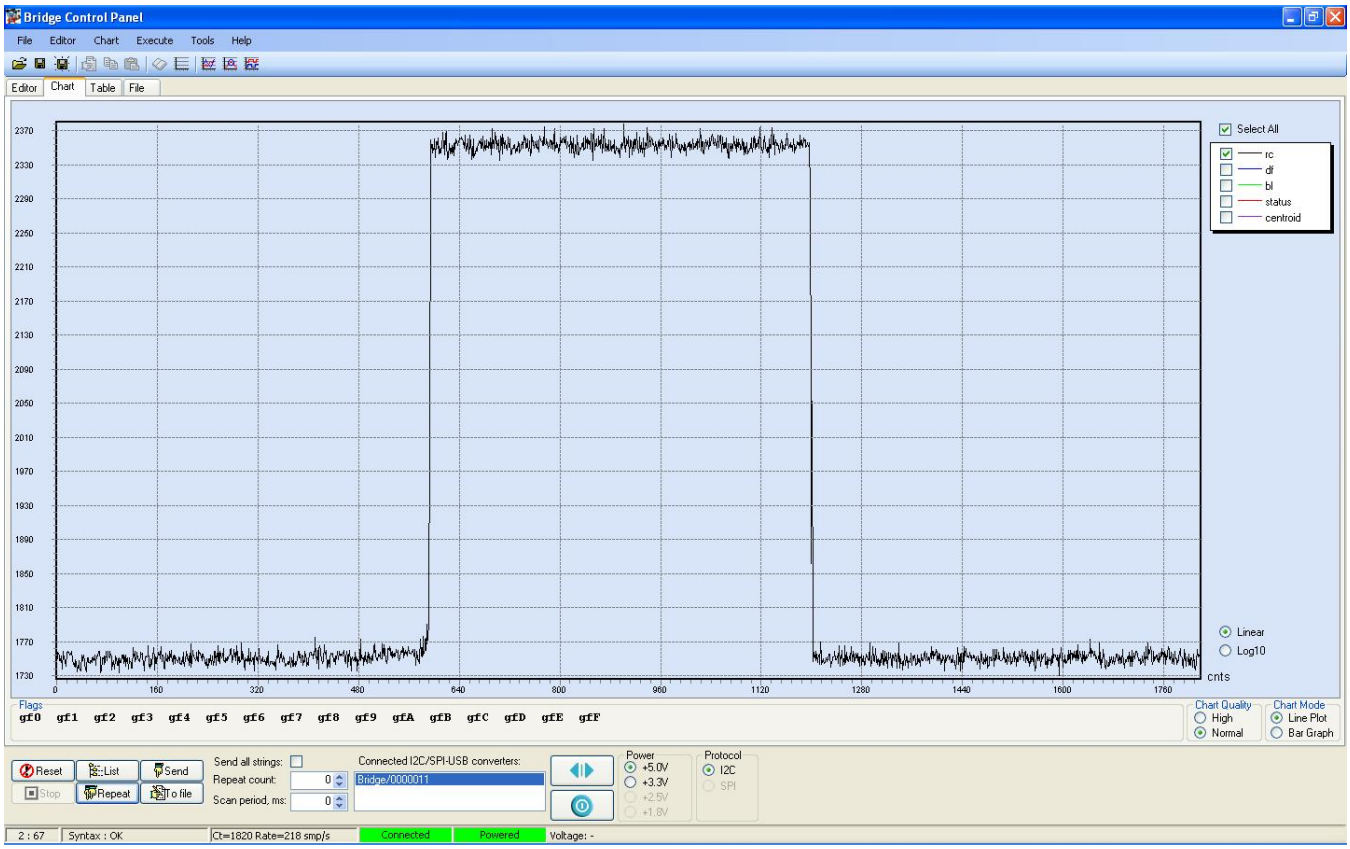


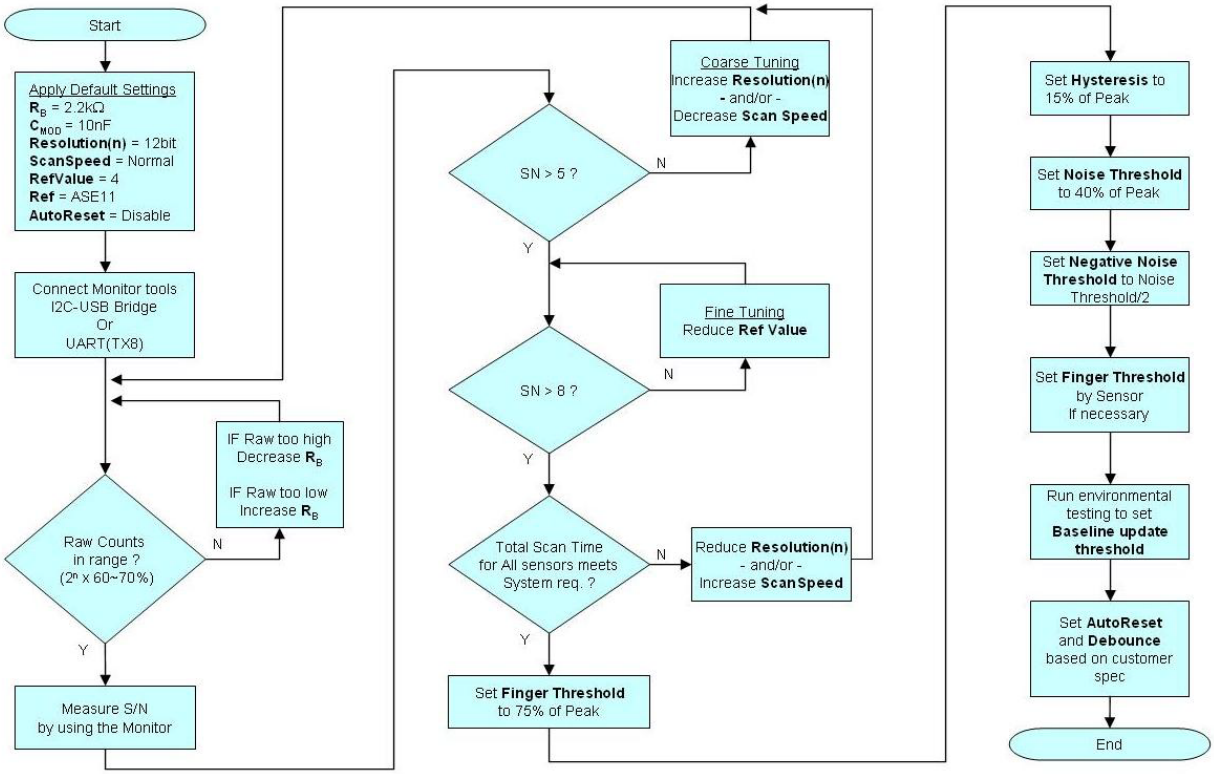
Figure 7. Raw Counts Chart (Button Pressed)



CSD Calibration

For optimum performance, the CSD parameters are tuned with the actual CapSense hardware and overlay. The following flowchart shows the steps to be performed for calibrating CSD.

Figure 8. CSD Calibration Flowchart



1. Start with the default settings of the CSD user module.
2. Using CY3240-I2USB Bridge or MiniProg3 or UART and the actual hardware and overlay, capture the raw counts, baseline, and difference counts for the sensors.
3. **Coarse Tuning**: Check if signal-to-noise ratio (SNR) is greater than 5. If SNR is less than 5, increase SNR using the recommended PCB guidelines, increasing the resolution of the CSD, and reducing the scan speed of the CSD. For PCB guidelines refer to the application note CapSense Best Practices - AN2394. For details on SNR and how to measure SNR, refer to the application note Capacitance Sensing - Signal-to-Noise Ratio Requirement for CapSense Applications - AN2403.
4. **Fine Tuning**: Check if SNR is greater than 8. If it is less than 8, reduce the Ref Value parameter to increase SNR.
5. Check if the total scan time for all the sensors meets requirement. If they do not, reduce resolution and/or increase scan speed. As these parameters also affect SNR, go back to Step 3. With a couple of passes, arrive at the optimum resolution and scan speed parameters that produce the best SNR and the desired scan time.
6. Capture the difference counts when the button is activated. Set the finger threshold parameter to 75 percent of the peak.
7. Set the noise threshold to 40 percent of the peak value.
8. Set the negative noise threshold to half the noise threshold.
9. Set finger thresholds for individual sensors if necessary. This is done by writing to the `CSD_baBtnFThreshold` array in firmware.

10. Set the baseline update threshold according to requirements. The frequency with which the baseline is updated must be determined on a project-to-project basis. The baseline should be a slow moving reference, which helps to reduce the effects of noise and temperature on the capacitive sensor.
    - **Fast update baseline rates**: This can create problems if you move your finger slowly to the button. It is called 'baselining out the finger.'
    - **Slow update baseline rates**: This can leave the buttons vulnerable to temperature fluctuations and potentially lead to 'button lock.'
11. Set AutoReset and Debounce parameters as required. Refer to the CSD user module datasheet for details of these parameters.
12. For any other parameters refer to the user module datasheet.

Document History

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Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	3016346	ARVM	08/25/10	New example project
*A	3329618	UDYG	07/27/11	Updated software version to PSoC® Designer™ 5.1 SP 2 Build 2306. Changed all "example project" to "code example".
*B	4196172	SLAN	11/19/2013	No technical updates. Completing Sunset Review.
*C	4593808	SLAN	12/11/2014	Replaced "I2CtoUSB bridge", "USBtoI2C bridge", "USB-I2C bridge" and "I2C-USB bridge" with "CY3240-I2USB Bridge or MiniProg3" in all instances across the document.

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