CSA Software Filters with EzI2Cs Slave on CY8C20x34

CE63795

Code Example Name: Example_CSA_EzI^{2}Cs_Filters_20x34
Programming Language: C
Associated Part Families: CY8C20x34
Software Version: PSoC® Designer™ 5.1 SP2 build 2306
Related Hardware: CY3280-20x34 UCC CY3280-SLM Module, CY3240-I2USB Bridge or MiniProg3
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Objective

CE63795 describes how to scan one CapSense® button and a five-segment slider regularly and send the data to the master using I^{2}C protocol. This code example also describes how to apply software filters such as average, IIR, and median on raw count and the jitter filter on the slider centroid position.

Overview

This code example incorporates the CapSense successive approximation (CSA) and EzI2Cs modules to send CapSense data to the I^{2}C master. The CapSense module scans all the buttons and 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 data to the master when 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
CSA	CapSense and comparator
EzI2Cs	I^{2}C/SPI block

User Module Parameter Settings

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

CSA		
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 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 algorithm continues.
Settling Time	80	The settling time parameter controls the duration of the capacitance to the voltage conversion phase. The parameter setting controls a software delay that enables the voltage on the Cmod and Cbus capacitance to stabilize and is dependent on the clock setting.
IDAC Setting	50	This parameter declares the amount of current that the source is going to pump in the second phase of CSA, that is, during the period Cmod tries to reach Vref from Vstart.
ExternalCap	P0[3]	Cmod is connected to the specified pin.
Hysteresis	10	This takes care of false ON and OFF situations whenever 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	10	If the raw count is below baseline and the difference count is more than this threshold, the baseline does not update.

CSA		
Parameter	**Value**	**Comments**
Low BaseLine Reset	50	If the raw count is below baseline and the difference count is more than negative noise threshold for the number of samples given by this parameter, the baseline resets to the new raw count.
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.
High Level API	Enabled	Setting this parameter to Enabled includes the high-level APIs provided by the user module. Disabling this parameter saves RAM and ROM by excluding high-level APIs.
Clock	IMO	Normally, this parameter is left at the default IMO setting. Setting a larger divider of IMO increases the effective resistance of sensor, compensating for the high capacitance.

Note

The parameters for CSA 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 CSA Calibration on page 10 to set these CSA parameters.

EzI^{2}Cs		
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 the firmware at any time.
ROM Registers	Disable	If this is set to Enable, use the RAM area as one slave and the ROM area as another slave with the addresses differing by only a most significant bit (MSB) of a 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.
I^{2}C Clock	100 k Standard	It decides the maximum clock speed that the slave can operate at.
I^{2}C Pin	P1[0]-P1[1]	This indicates which pins are going to be used as serial data (SDA) and serial clock (SCL) lines of I^{2}C.

Note

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

Global Resources

Important Global Resources		
Parameter	**Value**	**Comments**
Power Setting [Vcc / SysClk freq]	5.0 V/12 MHz	Selects 5-V operation and 12 MHz SysClk
CPU_Clock	SysClk/1	Selects 12 MHz as CPU clock.

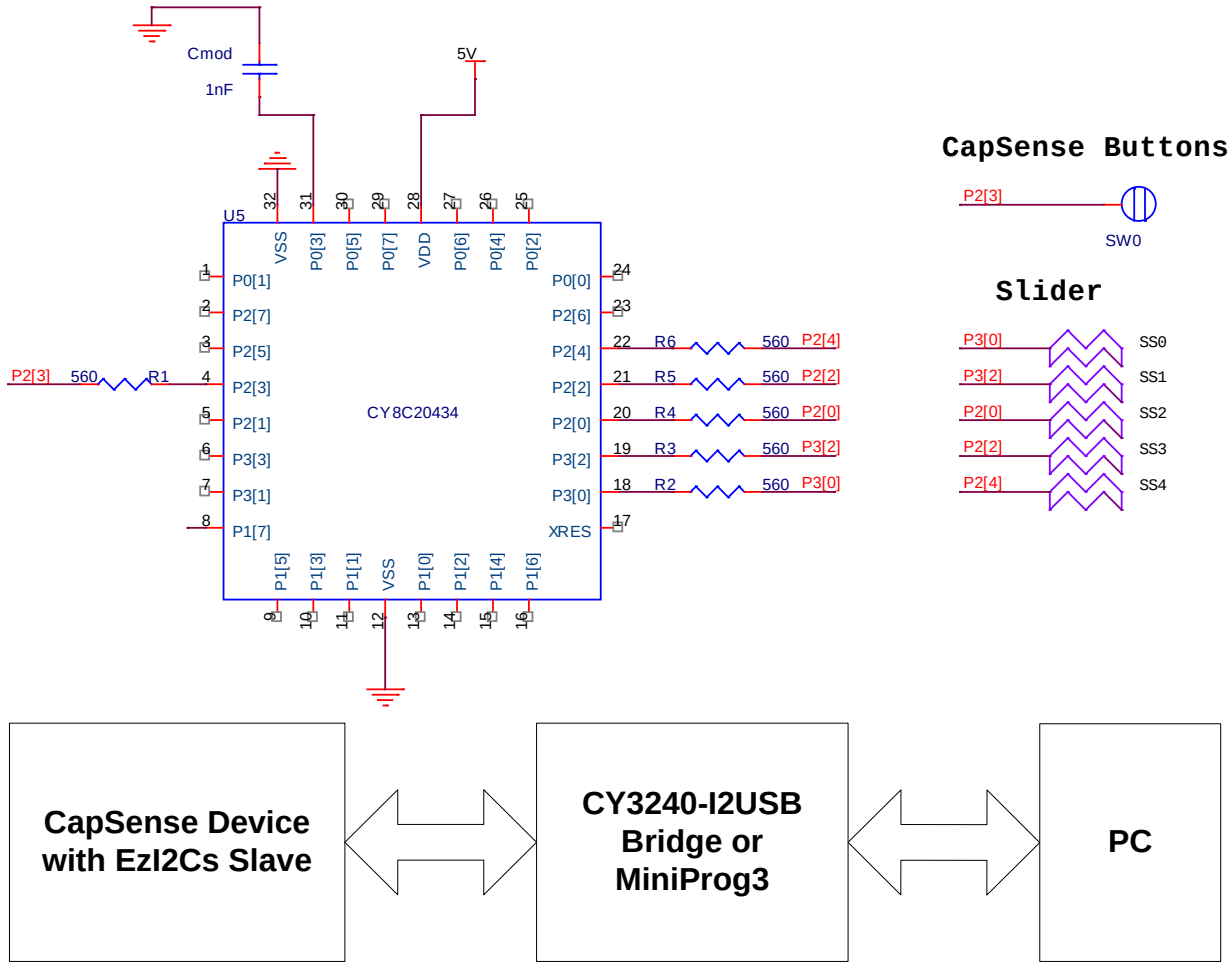
Note

Other parameters are left at their default value.

Hardware Connections

The code example's schematic diagram follows.

Figure 1. Schematic Diagram



Cmod is connected to P0[3]. The 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 itself. You can use the CY3240-I2USB Bridge or MiniProg3 program 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 firmware performs the following operations:

- 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 CSA User Module starts, finger thresholds for buttons are set, and baselines are initialized.
- The EzI2Cs User Module is started and “sI2CRegs” is set as the I^2C buffer.
- The IIR filter history is initialized if the IIR filter is enabled
- The following functions are performed 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 slider centroid position is applied, if enabled
  - 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 the 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 CSA Calibration on page 10. 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

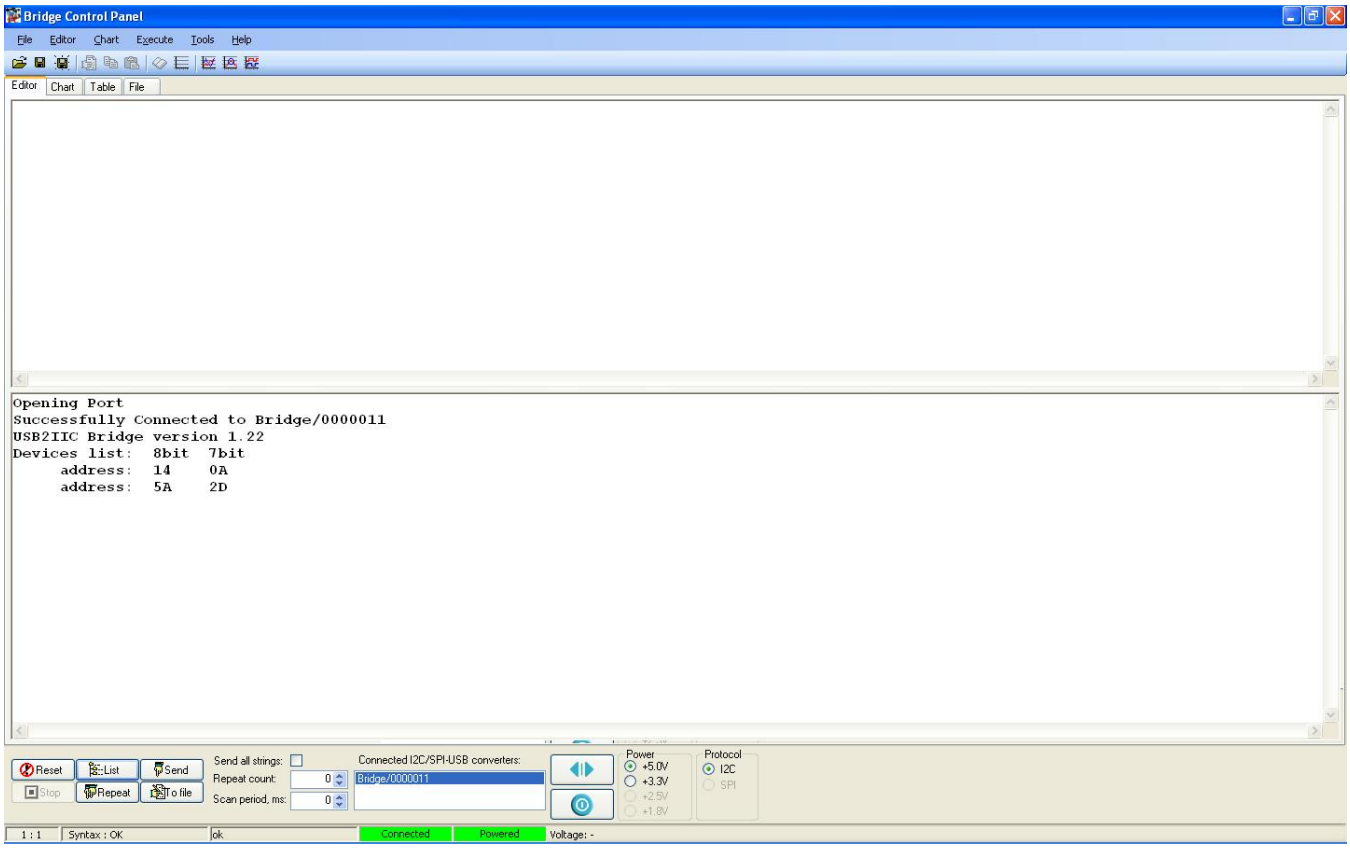
Note: If the average, IIR, and median filters are enabled, the filter is also applied to the raw counts of slider segments.

- Set the order of the filter. Use the macros mentioned to set the filter order. The valid filter orders for different filters are 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. Here are some general recommendations:
  - 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 the slider is touched and the finger is not moved on the 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 the slider centroid position, enable the Jitter filter. To enable 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 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 **List**. This lists all the slave device addresses. In this case, the device address is 10 (0x0A) and it is displayed in the status window, as shown in the following figure.

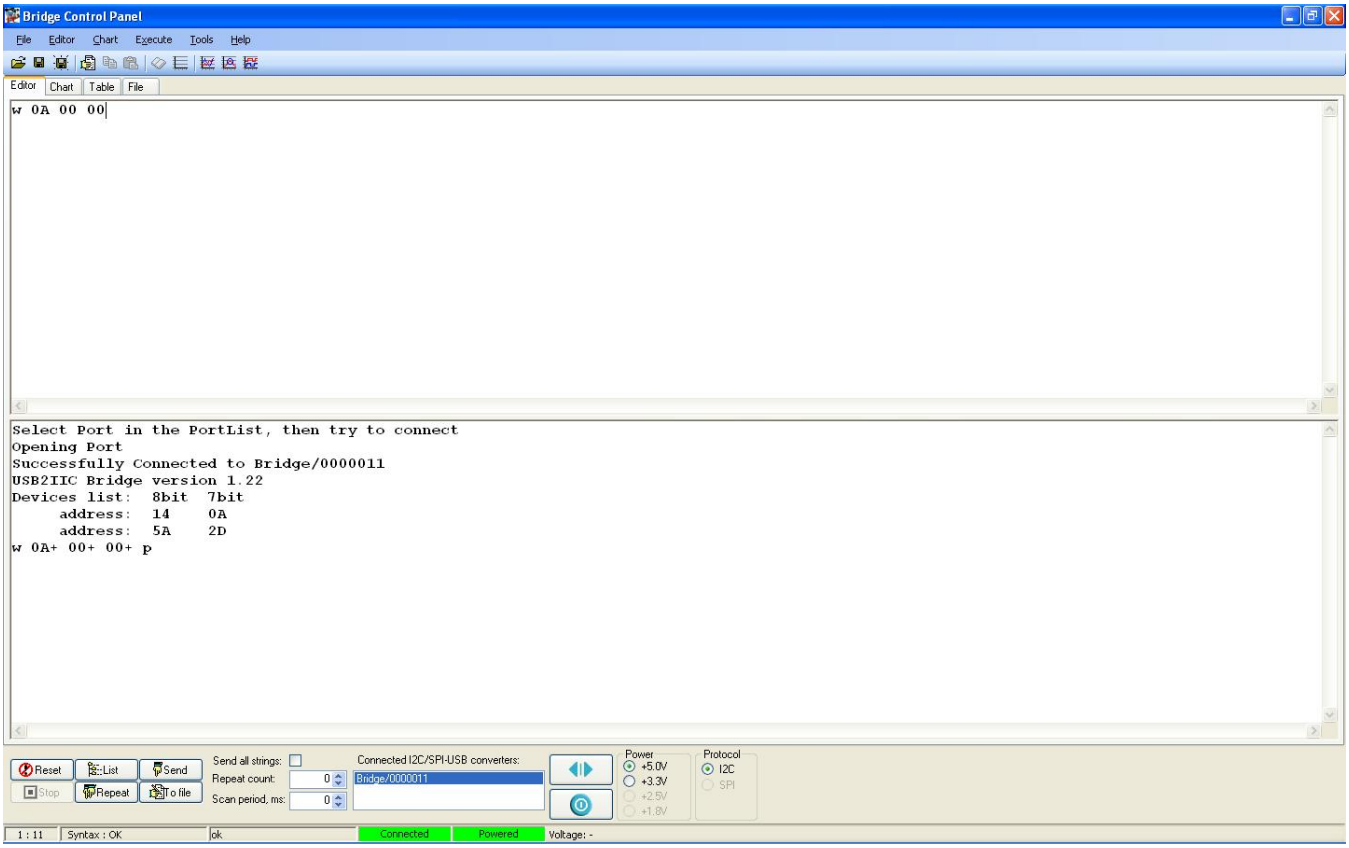
Figure 2. Display of Slave Address in Status Window



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

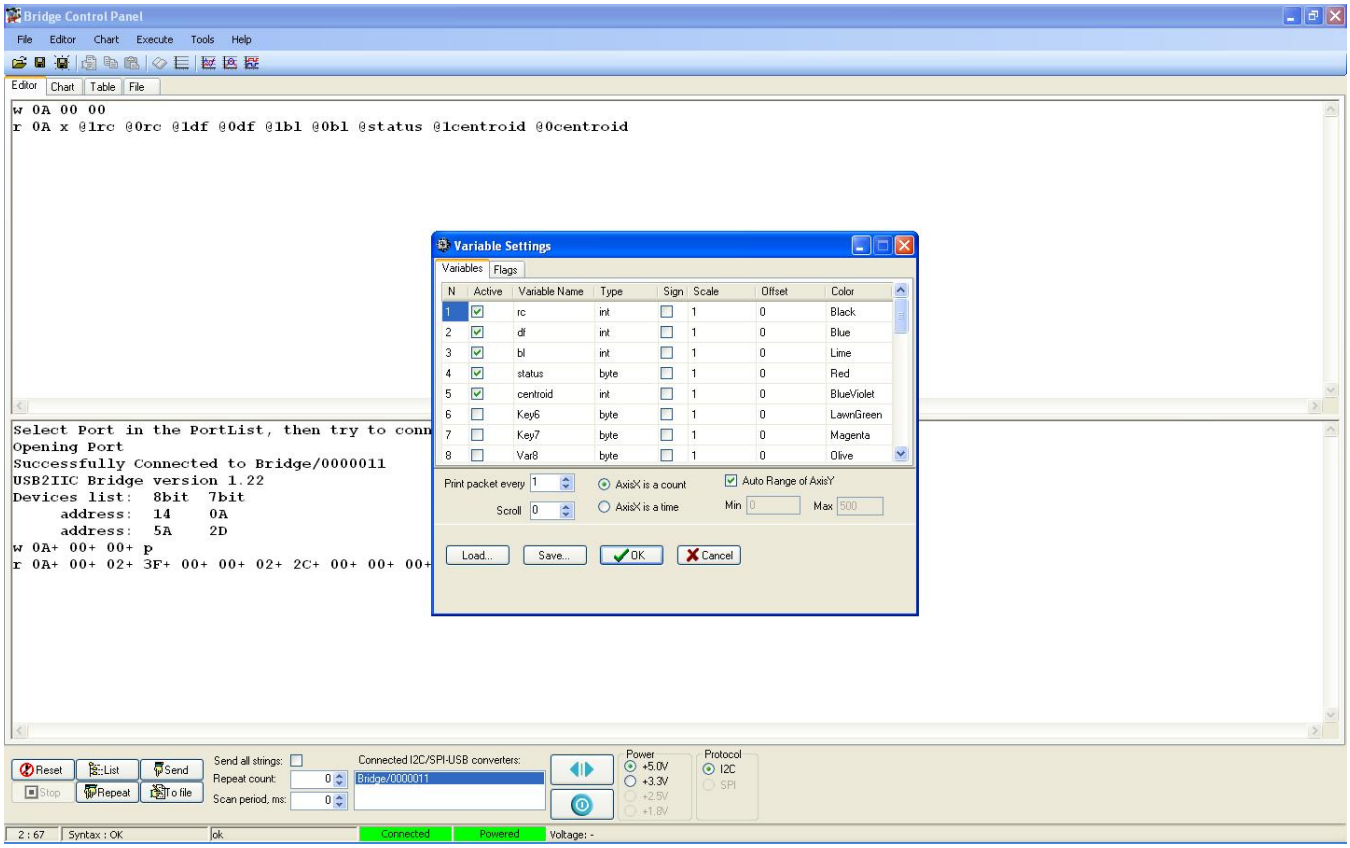
```
W 0A 00 00
```

Figure 3. Write Command Execution



6. To view CapSense data as a graph, click **Chart** and select **Variable Settings**.
7. The **Variable 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**.

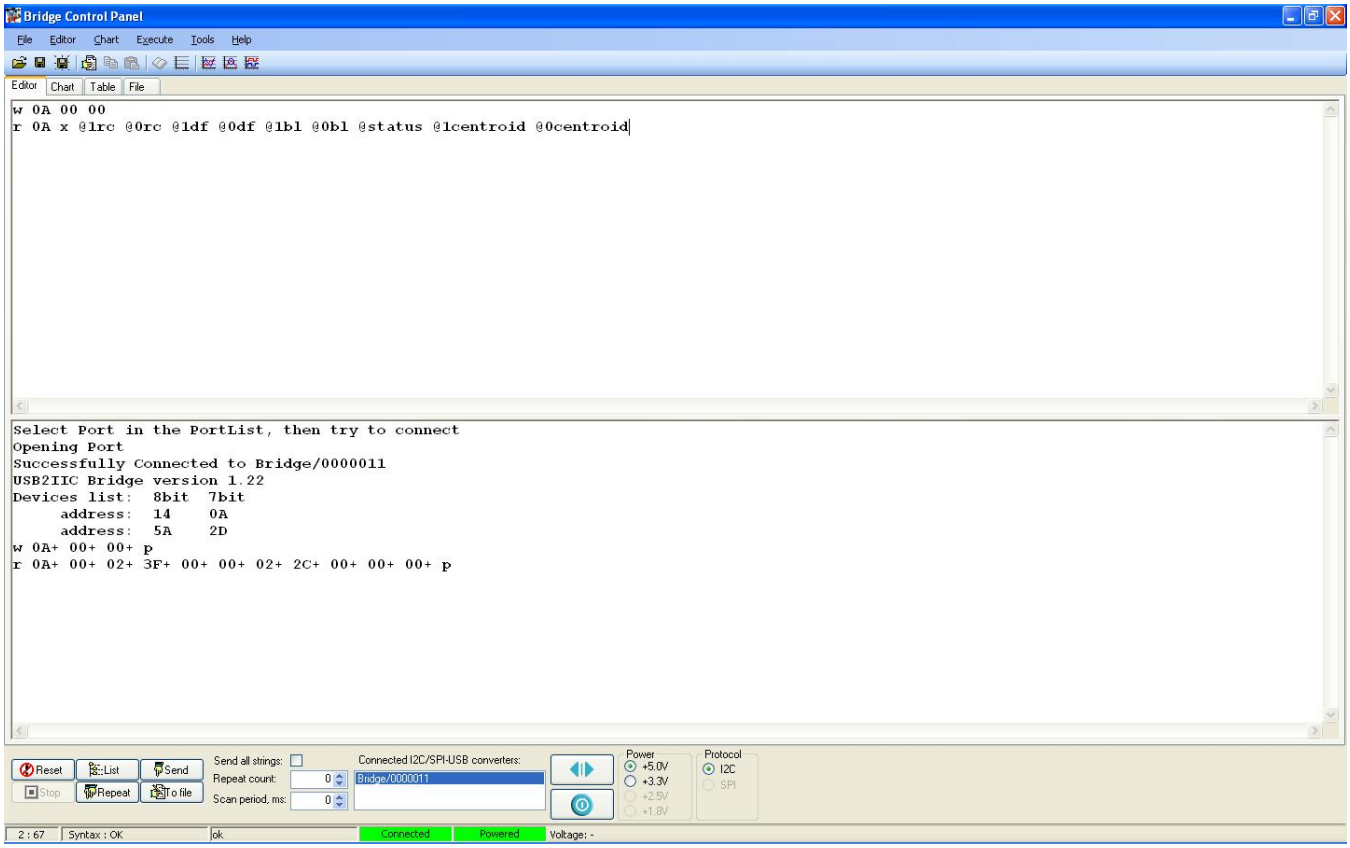
Figure 4. Variable Settings Window



10. Press <**Ctrl**> + <**Enter**> 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**. Now, you can see the CapSense data.
13. To monitor only raw counts, uncheck df, bl, and status (see the following figure).

Figure 6. RawCounts Chart without Button Press

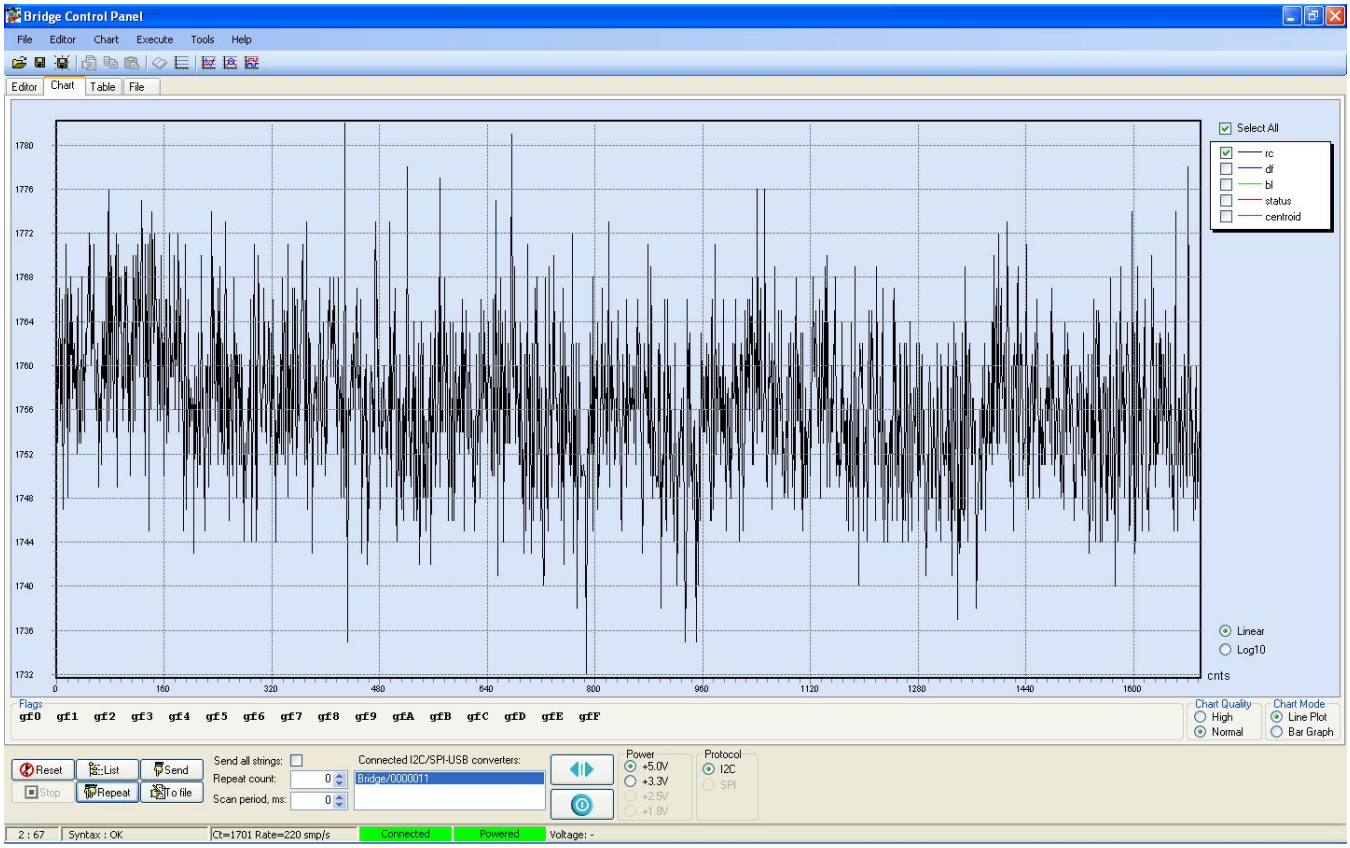
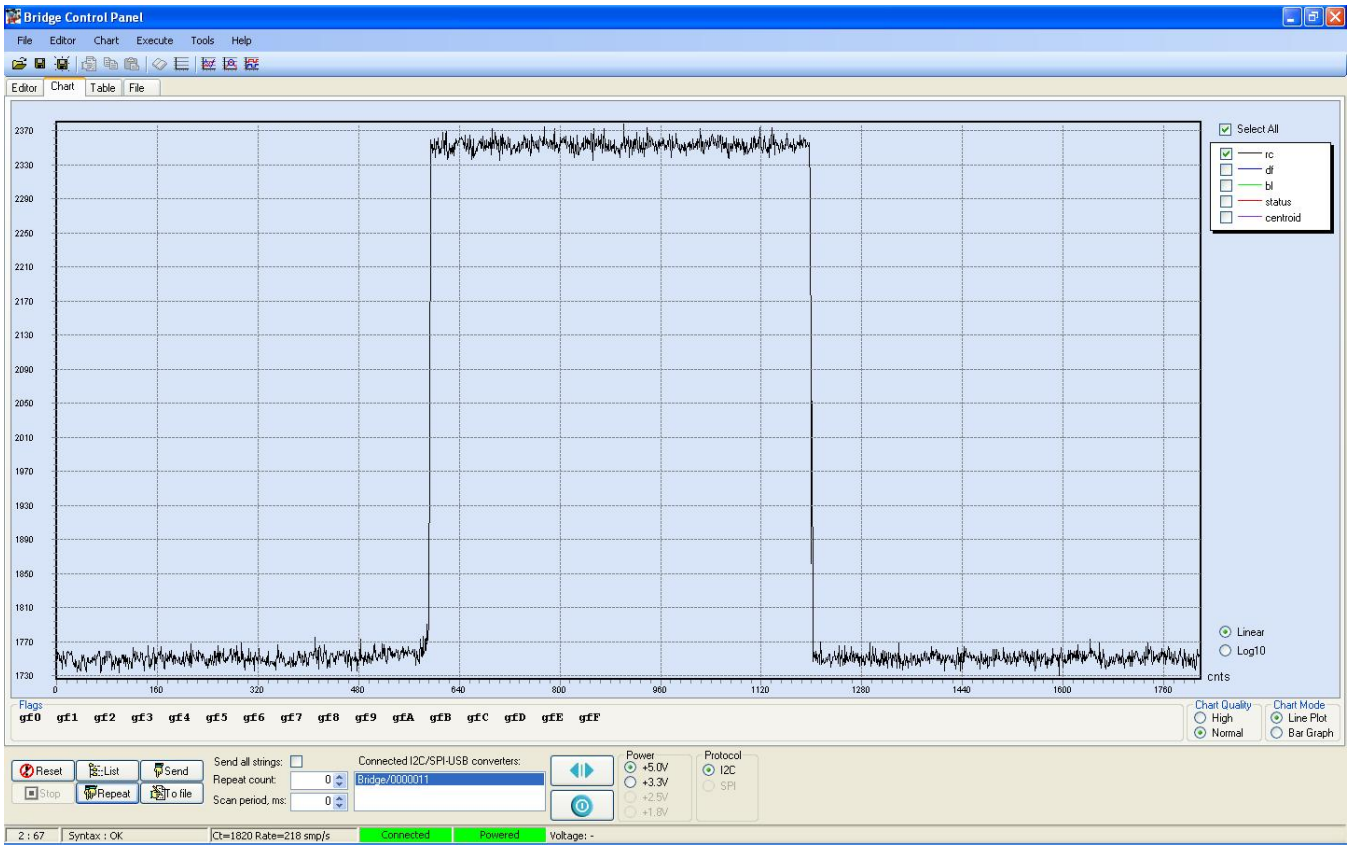


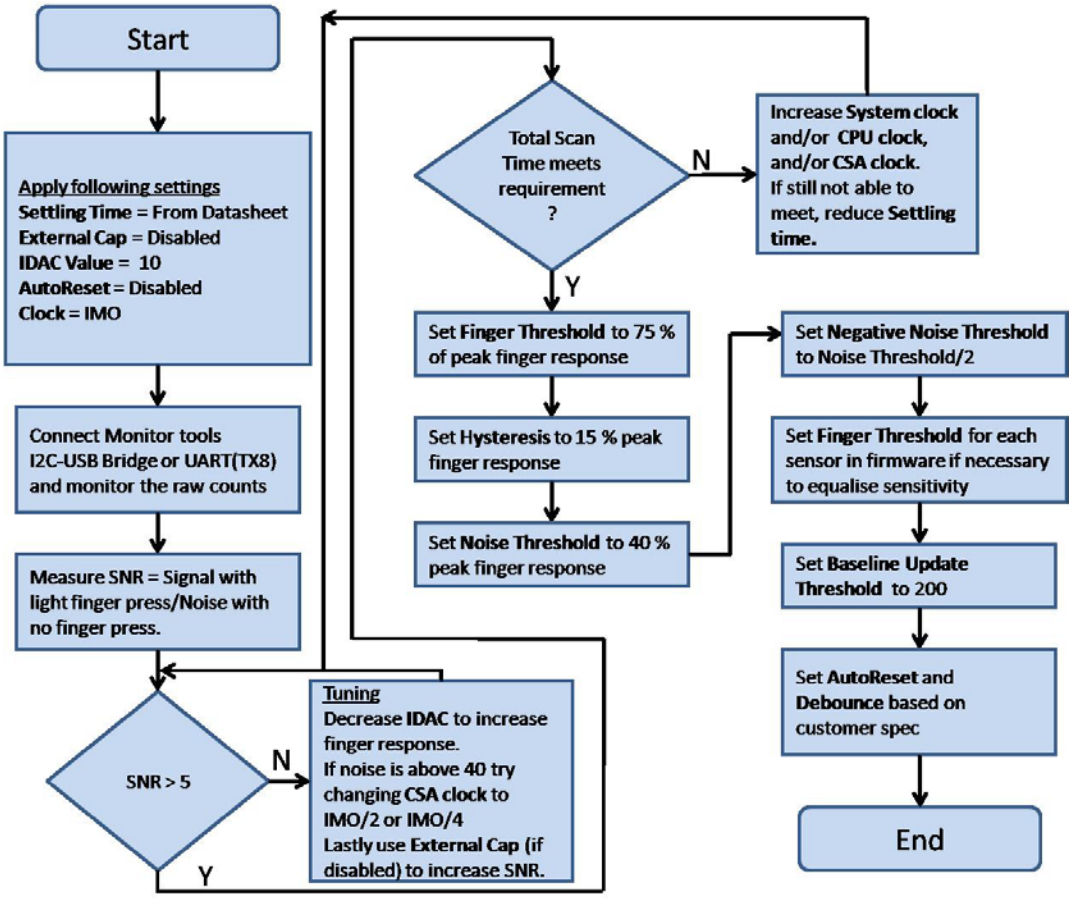
Figure 7. Raw Counts Chart (Button Pressed)



CSA Calibration

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

Figure 8. CSA Calibration Flowchart



1. Start with the default settings of the CSA User Module.
2. Using the 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 the signal-to-noise ratio (SNR) is greater than 5. If SNR is less than 5, increase SNR by following the recommended PCB guidelines, decreasing the IDAC value, changing CSA clock, and using an external capacitor. For PCB guidelines, refer to the Getting Started with CapSense guide.
4. Check if the total scan time for all the sensors meets requirement. If not, increase system clock, CPU clock, and/or CSA clock. Because these parameters also affect SNR, go back to Step 3. With a couple of passes, arrive at the optimum IDAC and CSA clock parameters that produce the best SNR and the desired scan time.
5. Capture the difference counts when the button is activated. Set the finger threshold parameter to 75 percent of the peak finger response.
6. Set the hysteresis parameter to 15 percent of the peak finger response.
7. Set the noise threshold to 40 percent of the peak finger response.
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 `CSA_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. This 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 CSA user module datasheet for details of these parameters.
12. For any other parameters refer to the user module datasheet.

Document History

Document Title: CSA Software Filters with EzI2Cs Slave on CY8C20x34 - CE63795

Document Number: 001-63795

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	3015652	SLAN	08/25/10	New example project.
*A	3329618	UDYG	07/27/11	Updated software version to "PSoC Designer 5.1 SP2 build 2306". Replaced all "project" to "code example".
*B	3638499	ZINE	06/06/2012	Removed reference to the CY3203 CapSense board.
*C	4196214	SLAN	11/19/2013	No technical updates. Completing Sunset Review.
*D	4594867	SLAN	12/12/2014	Replaced "I2CtoUSB bridge", "USBtoI2C bridge" and "USB-I2C bridge" with "CY3240-I2USB Bridge or MiniProg3" in all instances across the document.

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