# AN2034

# CAP1XXX Touch Key Controller Tuning Guide

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## INTRODUCTION

The tuning guide presented in this application note is divided into two main chapters: basic tuning and advanced tuning. The basic tuning chapter includes sections regarding the sensor control, LED control and operation mode. The advanced tuning chapter consists of chapters about threshold tuning, noise robustness tuning, response time tuning, power consumption tuning and calibration tuning. Additionally, save/load settings and driver integration are included in the document.

## BASIC TUNING

### Overlay

In most cases, the sensor design consists of PCB and overlay.The material type and thickness of the overlay have an impact on the performance. The overlay with higher electrical constant and lower thickness will benefit the sensitivity; otherwise, the sensitivity will be degraded.

### Software and Hardware Tools

To start tuning, the following software and hardware tools are needed:

- CAP1XXX Graphical User Interface (GUI)
- USB I$^2$C Bridge
- Artificial Fingers

#### CAP1XXX GUI

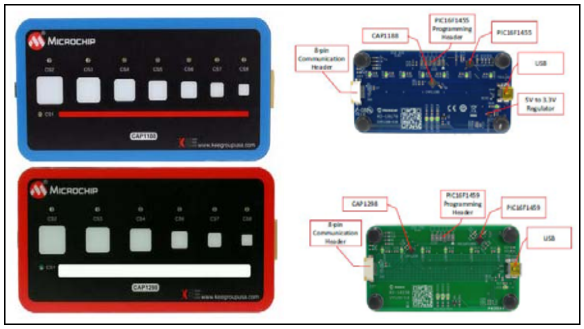
The CAP1XXX GUI is a host emulator that provides several features to allow tuning of the touch key controller and monitoring the signals of the touch keys. The GUI must be installed before beginning the tuning. The GUI enables tuning of a complete touch key system via the I$^2$C communication between the touch key controllers and the PC.

#### USB I$^2$C BRIDGE

USB I$^2$C Bridge is a hardware component connecting the touch key controller to the computer and providing the I$^2$C to USB data communication.

The evaluation boards of CAP1188 and CAP1298 have the communication connector connected to the device. As such, the evaluation board is the USB I$^2$C Bridge for project development. There is some difference regarding the power supply. The CAP1298 EVB supports a maximum of 5.0V, however, the CAP1188 EVB supports a maximum of 3.3V.

**FIGURE 1: EVALUATION BOARD**




#### ARTIFICIAL FINGERS

It is recommended to use standardized metal fingers to measure the signal and sensitivity of the touch key when tuning the performance of the touch key system. In most cases, the size of the metal fingers ranges from 5 mm to 12 mm.

The artificial (fake) finger should represent the electrical model of a user. The JEDEC® JS-001-2012 and MIL-STD-883H standards both recommend using a 1500Ω resistor in series with a 100 pF capacitance. Thus, the fake finger circuit would be Metal Finger, Resistance, Capacitance, and Ground.

The ground reference used should match the user's ground in the final system. If the user and the board share the same ground, the system will behave differently than if the user and the board had isolated grounds.

### Getting Started

The touch key system should be placed in a typical environment with the proper temperature (25°C or room temperature is recommended). All components should be assembled; the sensors must be connected to the touch key controller. The board is connected to the PC via the I$^2$C Bridge. Additionally, no noise should couple from the power or the other components.

## Sensor Control

The CAP1XXX serial touch key controllers support a maximum of 14 touch keys and 11 LEDs, while some of the touch key controllers support the Guard feature. Therefore, the sensors should be assigned according to the schematic and the performance requirements.

### HARDWARE RESOURCES AND FEATURES

The CAP1XXX serial touch key controllers include two families:

- CAP11XX family
- CAP12XX family

Each family has different hardware resources and supports different features.

### CAP11XX Family

The CAP11XX family supports the sensors, the LED drive and the slider. The summary of the hardware features of the CAP11XX family is listed in Table 1.

**TABLE 1: HARDWARE FEATURES OF CAP11XX FAMILY**

| | CAP1133 | CAP1106 | CAP1126 | CAP1128 | CAP1166 | CAP1188 | CAP1114 | CAP1214 |
|---|---|---|---|---|---|---|---|---|
| **Sensor** | 3 | 6 | 6 | 8 | 6 | 8 | 14 | 14 |
| **Slider** | — | — | — | — | — | — | ✓ | ✓ |
| **LED** | 3 | 0 | 2 | 2 | 6 | 8 | 11 | 11 |
| **Proximity** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **VDD** | 3.3V | 3.3V | 3.3V | 3.3V | 3.3V | 3.3V | 3.3V | 3.3V |
| **Interface** | $I^2C$ | $I^2C$ | $I^2C$/SPI | $I^2C$/SPI | $I^2C$/SPI | $I^2C$/SPI | $I^2C$ | $I^2C$ |
| **Package** | 3x3 DFN | 3x3 DFN | 4x4 QFN | 4x4 QFN | 4x4 QFN/ SSOP | 4x4 QFN | 5x5 QFN | 5x5 QFN |
| **Pin#** | 10 | 10 | 16 | 20 | 20/24 | 24 | 32 | 32 |

### CAP12XX Family

The CAP12XX family supports the sensors, the Signal Guard and the Combo mode, but it does not support the LED drive. Therefore, this is the lowest cost option. In addition to the Signal Guard, the CAP12XX family supports the Combo mode, which allows proximity and touch sensor operation together. Detail of the hardware resources and features of the CAP12XX family are listed in Table 2.

**TABLE 2: HARDWARE FEATURES OF CAP12XX FAMILY**

| | CAP1203 | CAP1293 | CAP1206 | CAP1296 | CAP1208 | CAP1298 |
|---|---|---|---|---|---|---|
| **Sensor** | 3 | 3 | 6 | 6 | 8 | 8 |
| **Alert** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Proximity** | — | ✓ | — | ✓ | — | ✓ |
| **Signal Guard** | — | ✓ | — | ✓ | — | ✓ |
| **Combo Mode** | — | ✓ | — | ✓ | — | ✓ |
| **VDD** | 3.3~5.0V | 3.3~5.0V | 3.3~5.0V | 3.3~5.0V | 3.3~5.0V | 3.3~5.0V |
| **Interface** | $I^2C$ | $I^2C$ | $I^2C$ | $I^2C$ | $I^2C$ | $I^2C$ |
| **Package** | 2x3 TDFN-8/ SOIC-8 | 2x3 TDFN-8/ SOIC-8 | 3x3 DFN-10/ SOIC-14 | 3x3 DFN-10/ SOIC-14 | 3x3 QFN-16/ SOIC-14 | 3x3 QFN-16/ SOIC-14 |

### INDIVIDUAL SENSOR SETTING

The individual sensor setting includes Sensor Enable, Sensor Interrupt and Standby Channel, as detailed in Figure 2. Additionally, the CAP129X family can support the Signal Guard feature; Signal Guard Enable is a special item for the CAP129X family, as shown in Figure 3.

**FIGURE 2: SENSOR SETTING OF CAP11XX FAMILY**

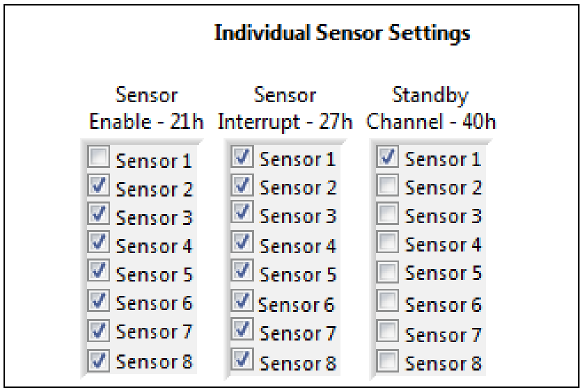
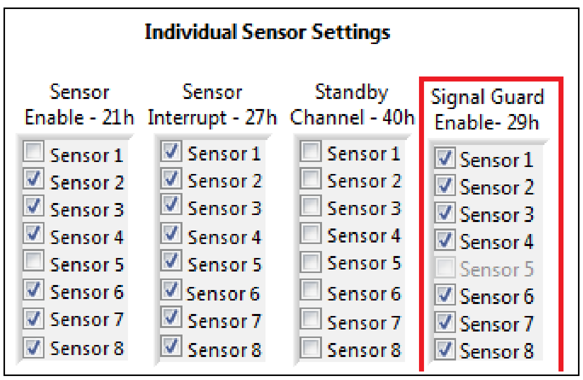


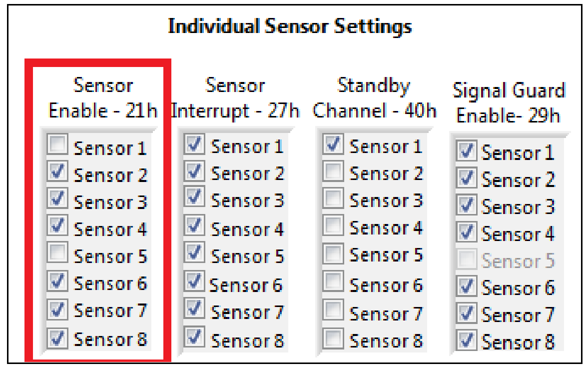

**FIGURE 3: SENSOR SETTING OF CAP12XX FAMILY**




### Sensor Enable

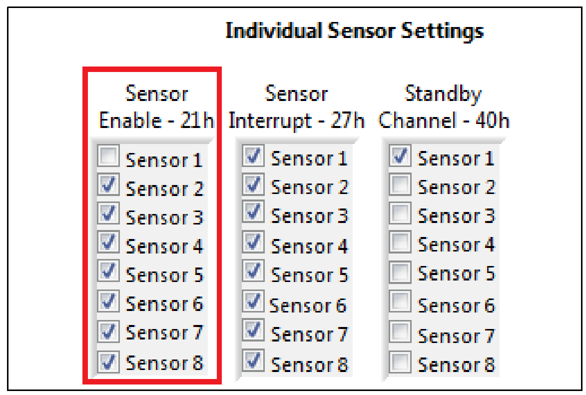
For the CAP12XX family, the specified sensor will be enabled according to the schematic of the design. For example, the CAP1298 touch key controller EVB supports a maximum of eight touch keys. However, based on the schematic, sensor 5 is used as guard to improve the performance, and sensor 1 is assigned as standby sensor. The rest of the sensors are assigned as active sensors. In Active mode the six sensors are touch keys. Details of the sensors' assignment are shown in Figure 4.

**FIGURE 4: INDIVIDUAL SENSOR SETTING OF CAP12XX FAMILY**




For the CAP11XX family, the sensors are only assigned as active sensors or standby sensors, no Signal Guard feature is supported, as shown in Figure 5.

**FIGURE 5: INDIVIDUAL SENSOR SETTING OF CAP11XX FAMILY**




### Sensor Interrupt

If the Sensor Interrupt is enabled, the interrupt signal will be asserted to inform the host that an effective touch or release is detected. Then the host will read the status of the touch key. Otherwise, no interrupt signal is generated.

If the sensor is marked (set '1'), the INT will be generated when touch is detected in the touch sensor. As shown in Figure 6, all the sensors are enabled with the Interrupt feature.

The INT in the Status and Control panel will be red if the interrupt is asserted, as shown in Figure 7. If the interrupt is not asserted, the INT will be in gray.

It is recommended that the interrupt for the sensors is enabled.

**FIGURE 6: INTERRUPT CONTROL**

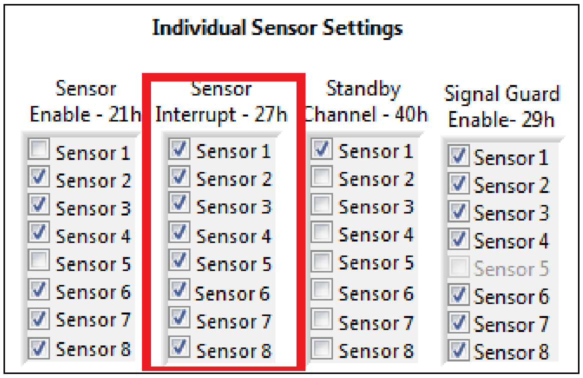
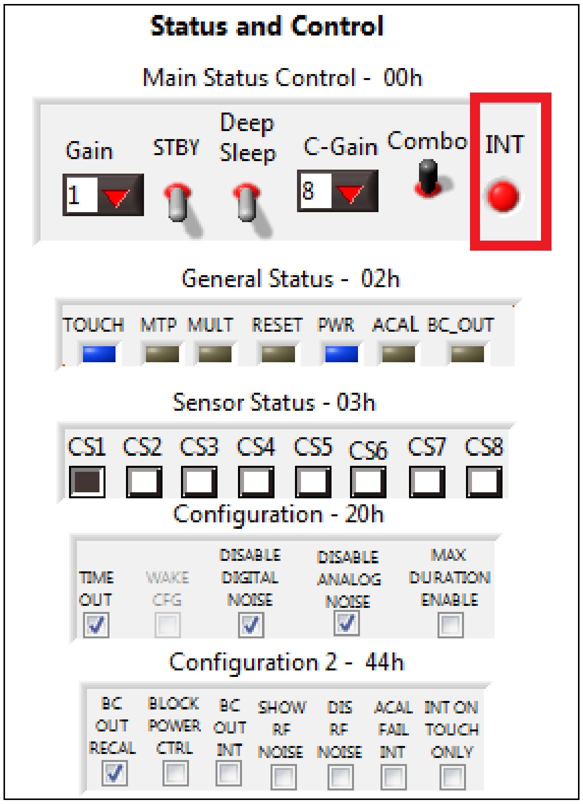


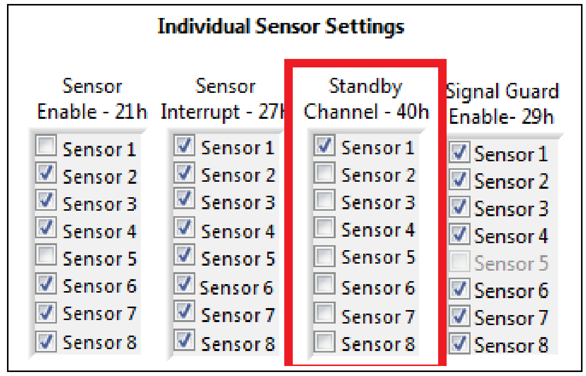

**FIGURE 7: INTERRUPT STATUS WITH INTERRUPT ASSERTED**




## Standby Channel

If the sensor is enabled as a Standby Channel, the sensor will keep scanning in Standby mode. However, the active sensor scanning will stop in Standby mode. For example, in Figure 8 sensor 1 is enabled with Standby Channel, so it keeps scanning in Standby mode, but the other sensors' scanning is stopped. This feature will be helpful for power saving due to the minimum sensor scanning. The typical application is that one sensor with proximity sensitivity is assigned to the Standby Channel, as shown in Figure 8.

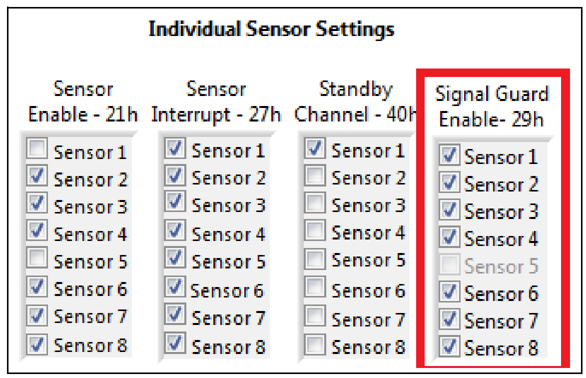
**FIGURE 8: STANDBY SENSOR CONTROL**




## Signal Guard

Signal Guard is the new feature for the CAP129X touch key controllers. According to the schematic and the data sheet, a proper sensor is assigned as the Signal Guard. The performance is improved with the guard design.

**FIGURE 9: SIGNAL GUARD CONTROL**




## POWER BUTTON

In most of the designs, buttons are tuned for quick response to a touch. However, in some applications the button is used as a power button to turn the machine on/off. The power button should not be turned on/off unexpectedly by brushing the button. If the button is assigned as a power button, the interrupt will only be generated when the touch is detected for a configurable period of time.

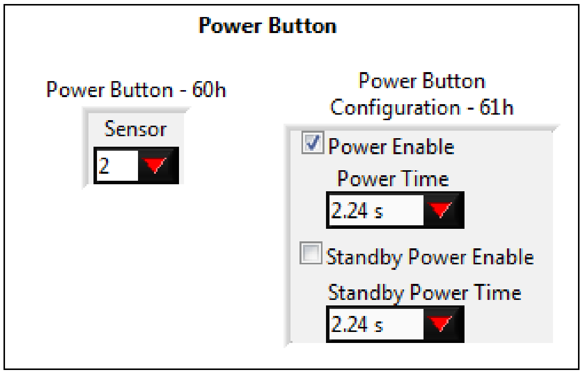
The power button feature can be enabled/disabled for the Active mode and Standby mode separately, as shown in Figure 10.

Figure 10 shows how the power button determines which sensor is assigned as a power button. The power button configuration determines when the power button feature is enabled or disabled and the period for the interrupt generation.

Recommendation for tuning:

- The correct sensor is assigned as a power button according to the schematic and the design requirements.
- The default value for the period is appropriate for most of the designs. However, it can be adjusted according to the requirements of the project.

**FIGURE 10: POWER BUTTON**




## MULTIPLE TOUCH SETTINGS

The Multiple Touch Patterns (MTP) detection circuitry can be used to detect lid closure or other similar events. An event can be flagged based on either a minimum number of sensor inputs or on specific sensor inputs simultaneously exceeding an MTP threshold. When this occurs, an interrupt will be generated if the MTP alert is enabled. During an MTP event, all touches are blocked, as shown in Figure 11, when Multiple Block Enable is marked (set '1').

1. MTP ENABLE

If it is marked (set '1'), the feature will be enabled. Otherwise, disable this feature.

2. MTP THRS

It is the threshold for the MTP feature. It is a percentage of sensor input threshold.

3. MTP ALERT

If it is marked (set '1'), the interrupt will be asserted with the MTP event.

If it is cleared (set '0'), the interrupt will not be asserted with the MTP event.

4. COMP PTRN

It determines whether the MTP detection circuitry will use the Multiple Touch Pattern register as a specific pattern of sensor inputs or as an absolute number of sensor inputs.

If it is marked (set '1'), the MTP detection will use a pattern recognition.

If it is cleared (set '0'), the MTP detection will use the MTP register as an absolute number of sensor inputs that must be triggered at the same time. The number of bits set is the number of sensors that must cross the MTP threshold to trigger then MTP event.

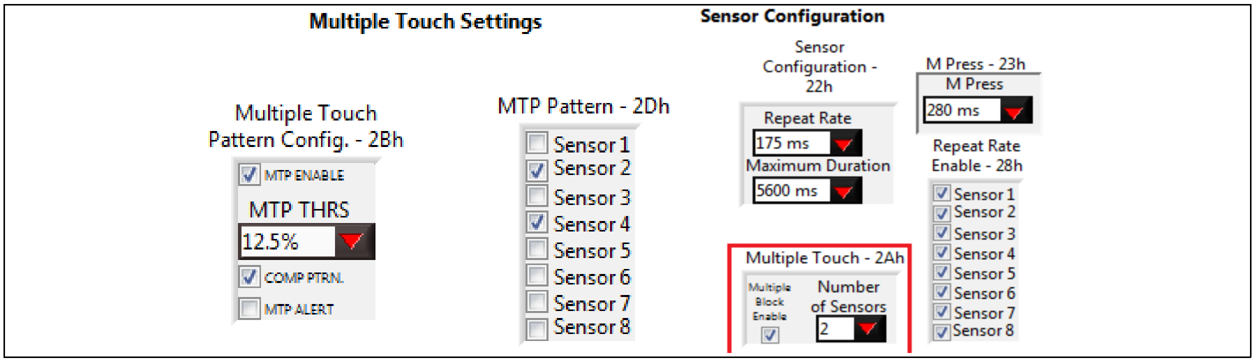
5. MTP Pattern

It is a pattern to identify an expected sensor input profile for an MTP event.

If the sensor is marked (set '1'), the sensor input is used as part of the MTP pattern.

If the sensor is cleared (set '0'), the sensor input is not used as part of the MTP pattern.

**FIGURE 11: MTP CONFIGURATION**



Tuning process for the Multiple Touch

1. Mark the Multiple Block Enable to enable the feature to block the touch report.
2. Set the number of the sensors according to the requirements of the project; for example, the number is set to 2 in Figure 11.
3. Mark the MTP ENABLE to enable the MTP feature.
4. Mark COMP PTRN.
5. Clear MTP ALERT to disable the INT for the MTP event.
6. Mark the sensors to set the MTP pattern, as shown in Figure 11: Sensor 2 and Sensor 4 are enabled. If Sensor 2 and Sensor 4 are pressed simultaneously, the touch will be blocked. However, all other combinations of sensor presses will be allowed. For example, Sensor 2 and Sensor 3 can be pressed at the same time.

## LED Control

The CAP11XX family supports the LED control feature. The LED control tuning includes LED control and LED behavior tuning.

### ALL LED CONTROL

LED control includes the following items:

1. LED Output Type

The LED output type controls the type of the output for the LED pins. If it is cleared (set '0') the corresponding LED pin will be an open-drain output, if it is marked (set '1'), the LED pin will be push-pull output. For example, as is shown in Figure 12, the LED 7 pin is set as push-pull output and the rest of the LED pins are set as open-drain output.

2. LED Sensor Linking

The LED sensor linking controls whether a capacitive touch sensor is linked to a LED output. If it is marked (set '1'), the corresponding LED output is related to the touch sensor input, the LED will be active with sensor touch. If it is cleared (set '0'), the LED output will not be related to the LED output. As shown in Figure 12, LED1~LED7 are linked to the touch sensors. The LED 8 is not linked to the touch Sensor 8. This configuration option is used when the host wants to manually control the LED output through the CAP1XXX communications.

3. LED Polarity

The LED polarity controls the logical polarity of the LED output.

If it is cleared (set '0'), the LED output is inverted. For example, setting '1' for the LED output control register will result in output logic '0' on the LED pin. If it is marked (set '1'), the LED output is non-inverted. For example, setting '1' for the LED output control register will result in the logic '1' on the LED pin.

4. LED Output Control

The LED output control register controls the output of the LED pins that are not linked to sensor inputs. The output of the LED is not related to the sensor input, but to the state of the LED output register.

If it is cleared (set '0'), the LED output is driven at the minimum duty cycle or not actuated.

If it is marked (set '1'), the LED output is driven at the maximum duty cycle or is actuated.

As shown in Figure 12, the LED 8 is not related to the sensor input, and the state of the LED is determined by the LED output control.

5. LED Linked Transition

The LED Linked Transition Registers controls the LED drive when the LED is linked to the touch sensor input.

If it is cleared (set '0'), the LED output control bit is '1'. When LED is linked to the touch sensor and no touch is detected, the LED will change states.

If it is marked (set '1'), the INV_LINK_TRAN bit is '1', when the LED output control bit is '1', and when the sensor is linked to the LED and no touch is detected, the LED will not change states. However, the LED will change with detected touch on the sensor.

6. LED Mirror

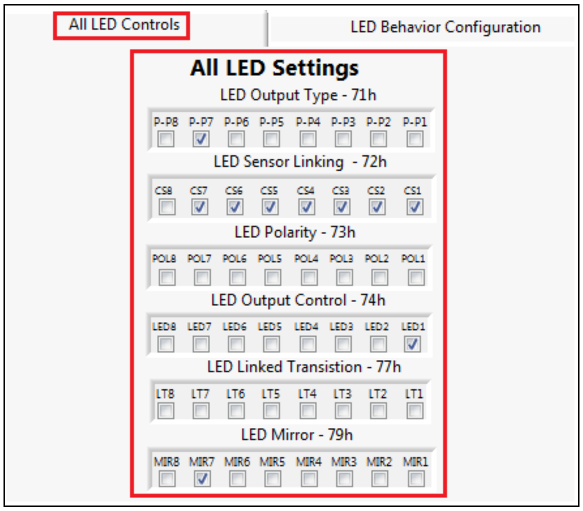
The LED Mirror control register determines the meaning of duty cycle settings when polarity is non-inverted for each LED channel. When the polarity is set to non-inverted, to obtain correct steps for LED behavior, the minimum and maximum duty cycles need to be relative to 100%, instead of default 0%.

If it is cleared (set '0'), the duty cycle settings are determined relative to 0% and directly by the settings.

If it is marked (set '1'), the duty cycle settings are determined relative to 100%.

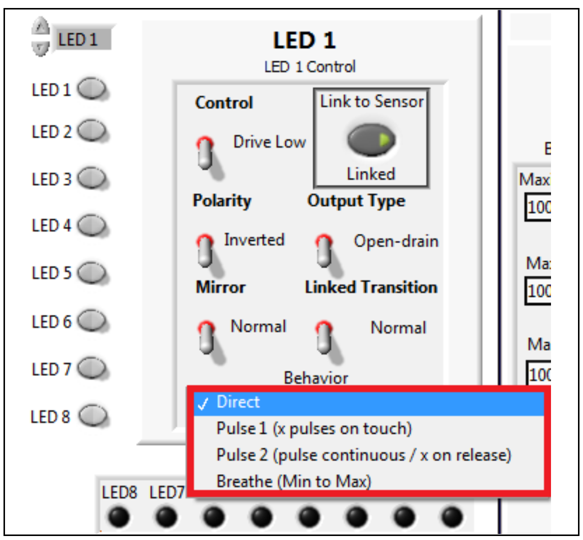
**FIGURE 12: ALL LED SETTINGS**




## LED BEHAVIOR CONFIGURATION

The LED Behavior Configuration can support four behaviors: Direct, Pulse 1, Pulse 2 and Breathe, as shown in Figure 13.

**FIGURE 13: LED BEHAVIOR CONFIGURATION**




Direct

If the LED is linked to the specified touch sensor, the LED will be ON or OFF according to the state of the touch sensor and the LED will be driven to the programmed state.

The configuration of the direct behavior includes the minimum and maximum LED output, rise rate, off delay and fall rate. For example, the configuration for direct behavior is shown in Figure 14, and the profile of the drive pulse is shown in Figure 15.

| | |
|---|---|
| **Note:** | For tuning, the default value is appropriate for most of the designs. However, the settings can be adjusted based on the requirement of the project. |

**FIGURE 14: CONFIGURATION FOR DIRECT**

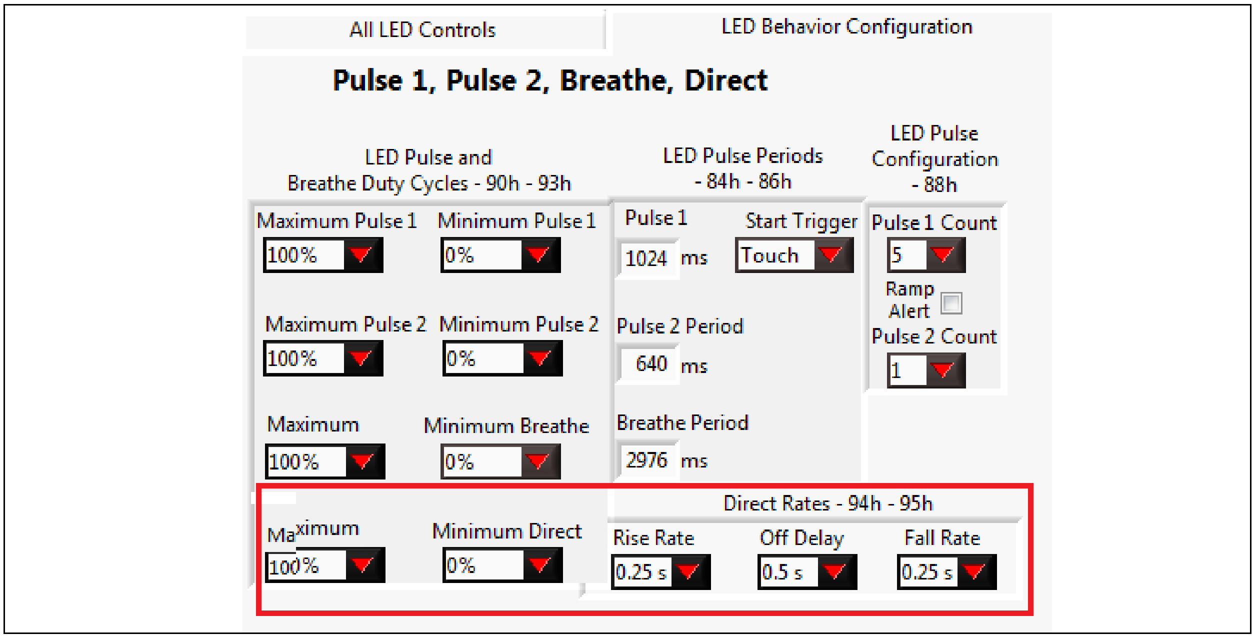
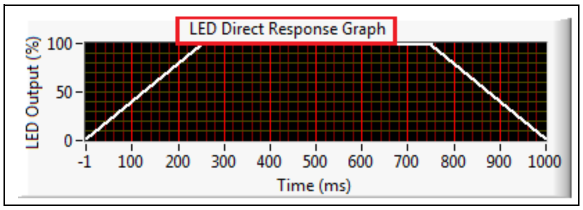



**FIGURE 15: PROFILE OF THE DIRECT PULSE**




Pulse 1 and Pulse 2

If the LED is linked to a touch sensor and it is configured as a Pulse 1 or Pulse 2, the LED will be ON/OFF according to the state of the touch sensor. The brightness of the LED is controlled by the programmed pulse. The LED will “pulse” a programmed number of times. During each pulse the LED will breathe up to the maximum brightness and back down to the minimum brightness, so that the total pulse period matches the programmed value.

The configuration of the pulse includes maximum/minimum of the LED output, the period of the pulse, the number of the pulse and the trigger condition.

1. Maximum/Minimum of LED Drive

The maximum and minimum of the LED drive determine the highest and lowest of the drive level, respectively. The default value is appropriate for most of the designs.

2. The Pulse Period

This parameter defines the period of a single pulse. As shown in Figure 16, the period of Pulse 1 and Pulse 2 is 1024 ms and 640 ms, respectively. The corresponding profiles of the Pulse 1 and Pulse 2 are shown in Figure 17. The default is proper for most of the designs. However, the parameter can be adjusted according to the requirements of the project.

3. Pulse Count

This parameter determines the number of the single pulse in one event. As shown in Figure 16, the number of the pulse is 2 and 1, respectively. The corresponding profile of the Pulse 1 and Pulse 2 are shown in Figure 17. The default is proper for most of the designs. However, the parameter can be adjusted based on the requirement of the project.

4. Start Trigger

Start Trigger determines how to trigger the LED pulse behavior. It includes Touch and Release functions.

If the Start Trigger is Touch, then the LED will pulse when the touch is detected or the drive bit is set.

If the Start Trigger is Release, the LED will pulse when the touch release or the drive bit is cleared.

The default is appropriate for most of the designs. However, it can be adjusted based on the requirement of the project.

**FIGURE 16: CONFIGURATION FOR PULSE1 AND PULSE2**

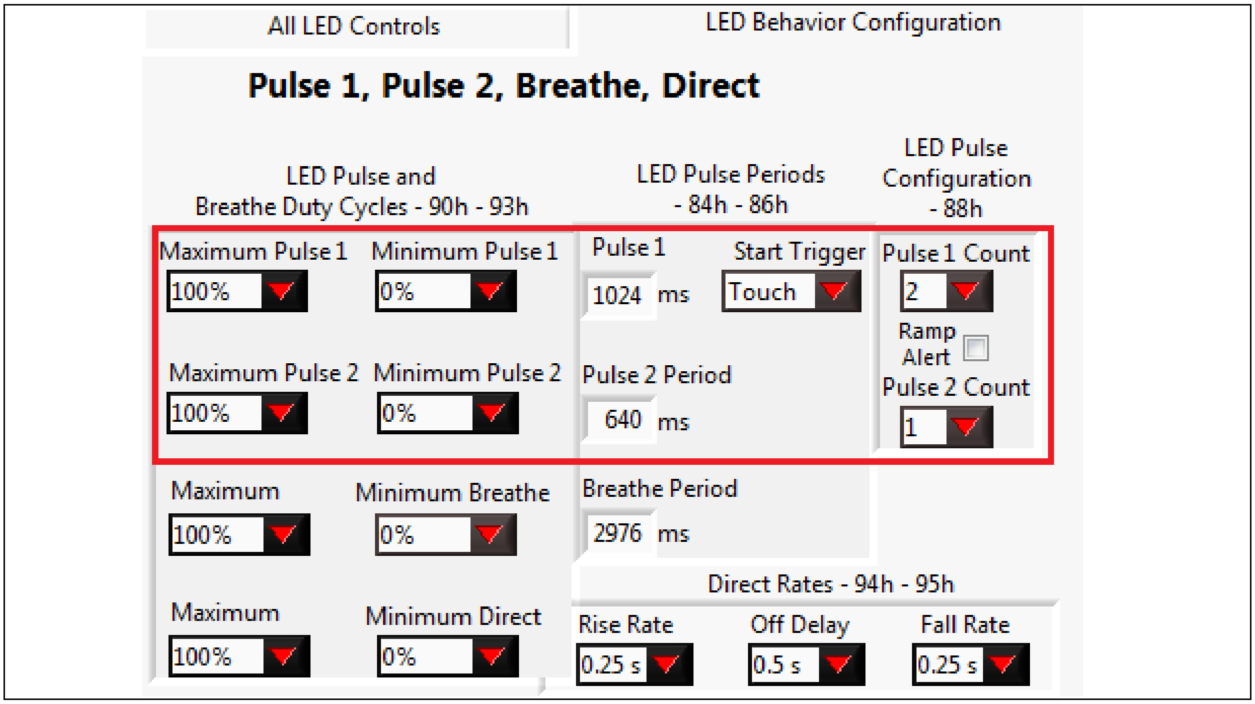
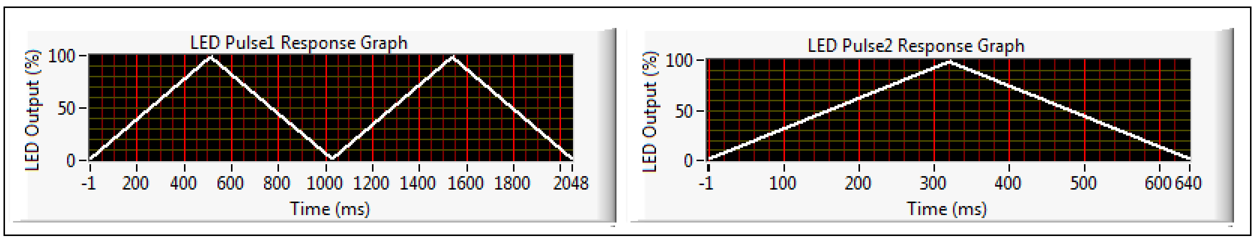



**FIGURE 17: PROFILE OF THE PULSE**



### Breathe

If the LED is configured to Breathe mode, the LED driver will output a duty cycle that ramps up from the minimum to the maximum and then back down again. Each ramp takes up half of the period.

The configuration of the Breathe mode includes maximum/minimum and the period.

1. Maximum/Minimum

This parameter determines the maximum and the minimum of the duty cycle of the pulse, which is used to drive the LED.

The default value is proper for most of the designs. However, it can be adjusted according to the requirement of the project.

2. Breathe Period

This parameter determines the total period of each "breath".

The default value is proper for most of the designs. However, it can be adjusted according to the requirement of the project. As shown in Figure 18, the period is set to 2976 ms. The profile of the pulse is shown in Figure 19.

**FIGURE 18: CONFIGURATION OF BREATHE**

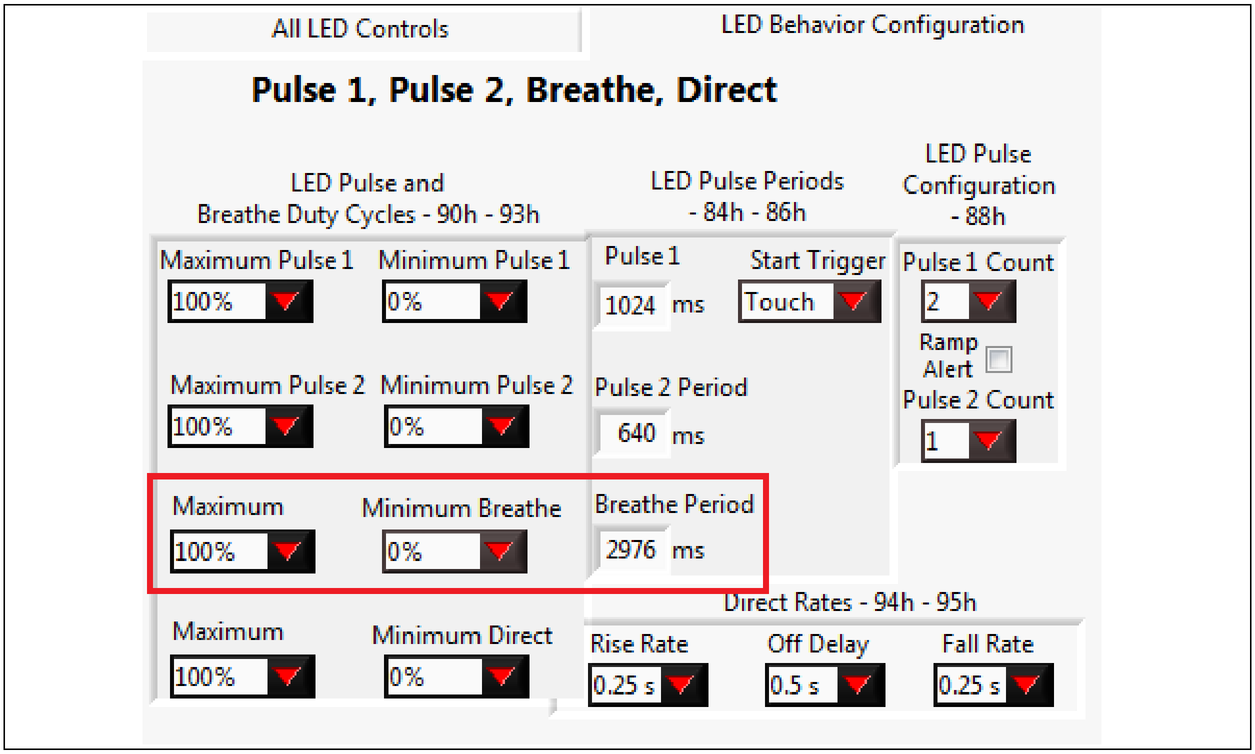
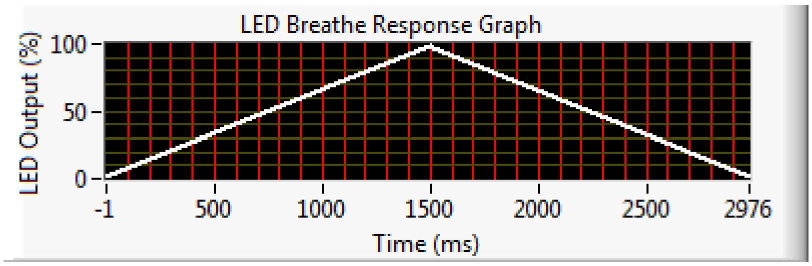



**FIGURE 19: PROFILE OF THE PULSE**



INDIVIDUAL LED CONTROL

If the parameters are changed in all LED control, the corresponding parameters in individual LED control will be updated automatically.

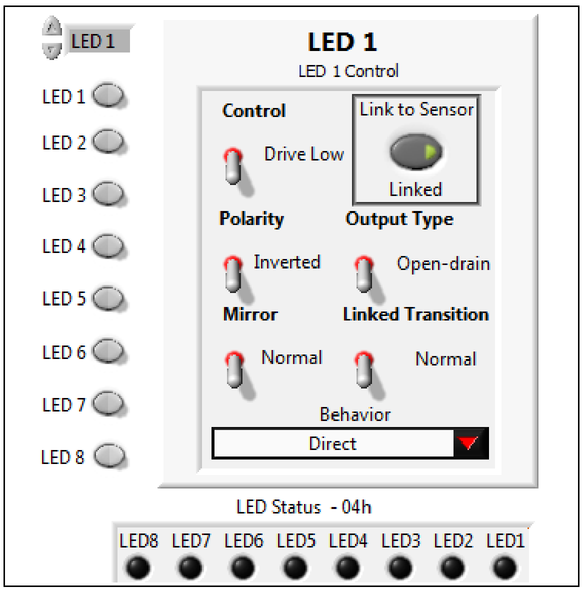
For the parameters, refer to the **Section "All LED Control"**.

The behavior of the LEDs can be configured separately.

The tuning process follows the steps below:

1. Click the respective LED button on the left side of the control panel.
2. When the control panel displays the selected LED, click the "Link to Sensor" button.
3. When Linked is displayed on the panel, the LED is linked to the touch sensor successfully. As shown in Figure 20, LED 1 is linked to the touch sensor 1.
4. After the LED is linked to the touch sensor, the LED can be configured. All parameters are the same as those in **Section "All LED Control"**.
5. Click "Behavior" to set the LED behavior according to the requirements. The behavior tuning is in **Section "LED Behavior Configuration"**.

**FIGURE 20: INDIVIDUAL LED SETTINGS**




## Operation Mode

The CAP1XXX has four or three operation modes depending on the hardware resource of the device. Refer to the data sheet of the appropriate CAP1XXX device for more details.

- Active mode

In Active mode, all features are enabled.

- Standby mode

Compared to the Active mode, the separate settings such as sensitivity and threshold are implemented, and specified sensors are scanned.

- Deep Sleep mode

In Deep Sleep mode, the sensor scanning and LED drive are stopped.

- Combo mode

In Combo mode, active and standby sensors are scanned at the same time with the separate settings.

As shown in Figure 21 and Figure 22, the mode can be changed by clicking the switch buttons with the CAP1XXX GUI easily.

If the host controls the device, the host can set or clear the corresponding bit to enable or disable the mode.

**FIGURE 21: OPERATION MODE FOR CAP129X FAMILY**

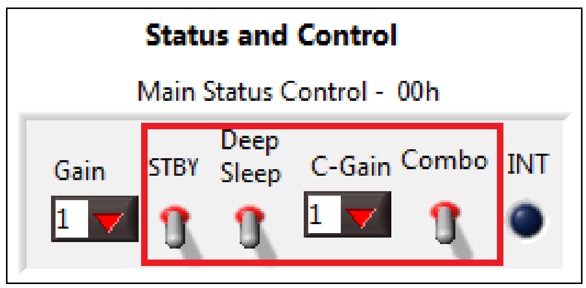
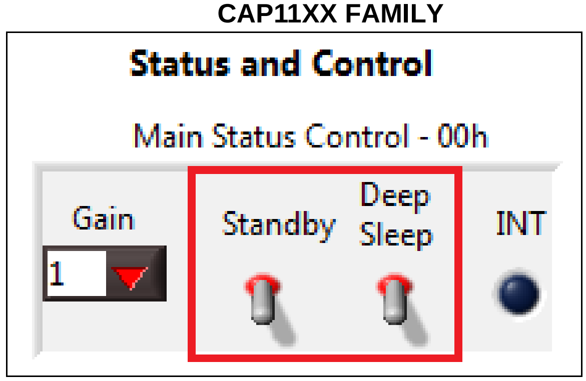



**FIGURE 22: OPERATION MODE FOR CAP11XX FAMILY**



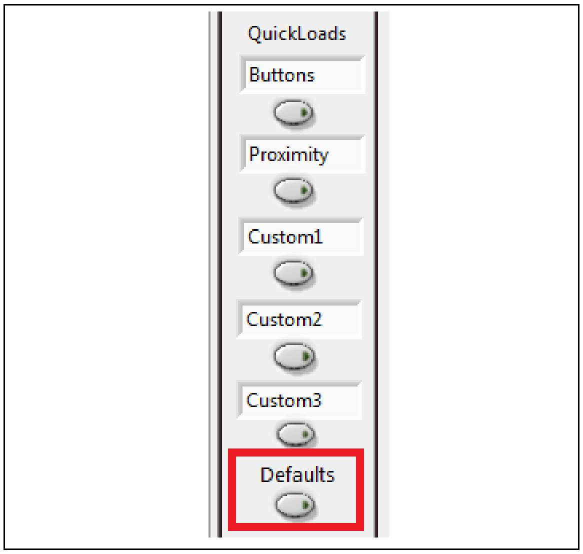
## ADVANCED TUNING

Once the basic tuning is completed, advanced tuning can be started. The advanced tuning includes sensitivity, gain, threshold, response time, calibration and power consumption tuning to achieve the acceptable performance for all touch keys.

### Scanning and Response Time

1. Start with the default values by clicking the button "Defaults", as shown in Figure 23. The touch key controller will run with all default values.

**FIGURE 23: DEFAULT VALUE SETTING**




2. Calibrate the touch key system. After setting the default values, click the "Calibration Activate" button to calibrate the system, as shown in Figure 24. If the calibration is done, the delta count of the sensors is around zero, as shown in Figure 25.

**FIGURE 24: CALIBRATION OF THE TOUCH KEY SYSTEM**

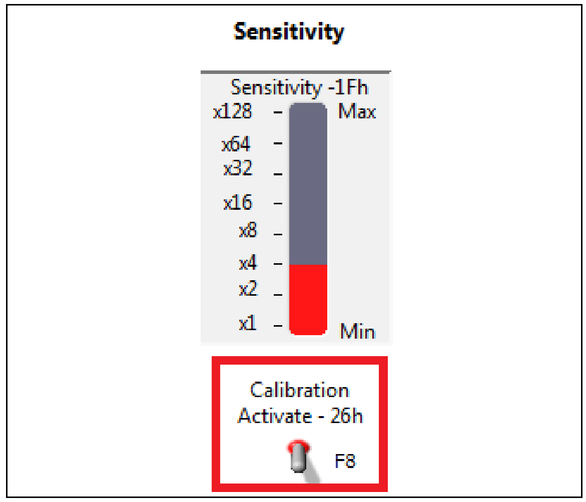
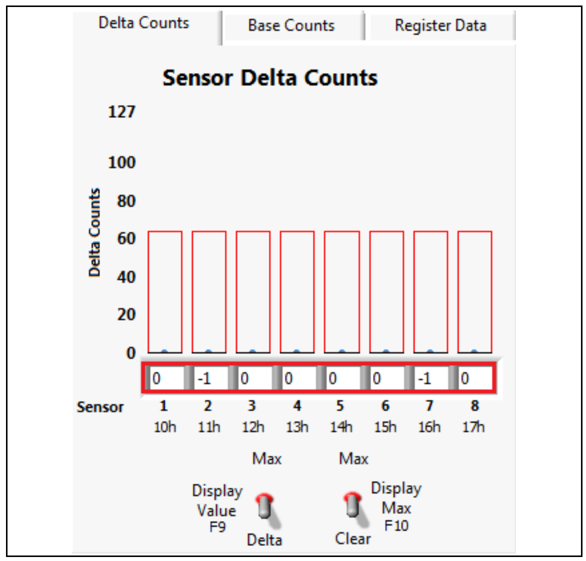
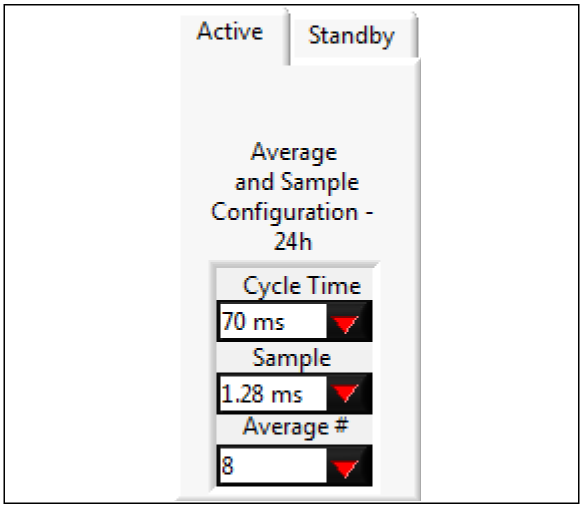



**FIGURE 25: SENSOR DELTA COUNT AFTER CALIBRATION**



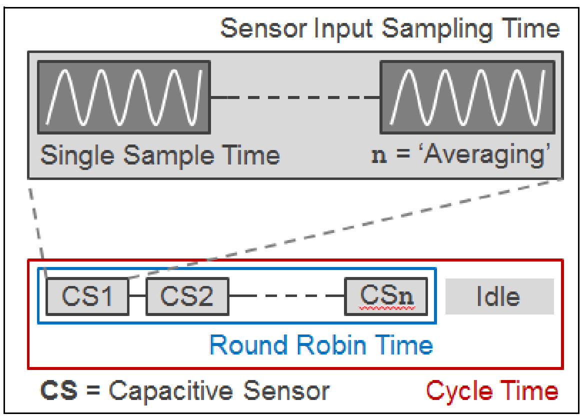

If the number of the live sensors is fixed, the response time is related to the following parameters: cycle time, single sample time and number of sample for average, as shown in Figure 26.

**FIGURE 26: SCANNING CONFIGURATION WITH DEFAULT VALUE**




| **Note:** | The Average could affect the noise immunity. |
|---|---|

**FIGURE 27: SCANNING AND RESPONSE TIME**




Based on Figure 27, the total scanning time is shown in Equation 1.

**EQUATION 1: TOTAL SCANNING TIME**

$$T_{scan} = T_{sample} \cdot N_{sample} \cdot N_{sensor}$$

$T_{scan}$ = Total scanning time

$T_{sample}$ = Single sample time

$N_{sample}$ = Number of the single sample for average

$N_{sensor}$ = Number of the live sensors

The interval of the update time is shown in Equation 2.

**EQUATION 2: CYCLE TIME**

$$T_{cycle} = T_{scan} + T_{idle}$$

**Note:** $T_{cyle}$ = Cycle time

$T_{idle}$ = Idle time

The response time tuning follows the steps below:

1. Set the three parameters to the default value.
2. Touch the key with the standard metal finger to measure the response performance.
3. If the performance cannot meet the requirements, switch to a short cycle time, for example 35 ms.
4. Repeat step 2 to measure the response time.
5. If the response time cannot meet the requirements, switch to a short single sample time, such as 640 us.
6. Measure the response time with finger touch.
7. If the response performance cannot meet the requirements, decrease the number of single sample for average; for example, choose 4 or less samples for average.
8. Adjust the three parameters – cycle time, single sample and average – to get the acceptable response performance.
9. The calculated cycle time should not exceed the configured cycle time.

## Sensitivity and Threshold Tuning

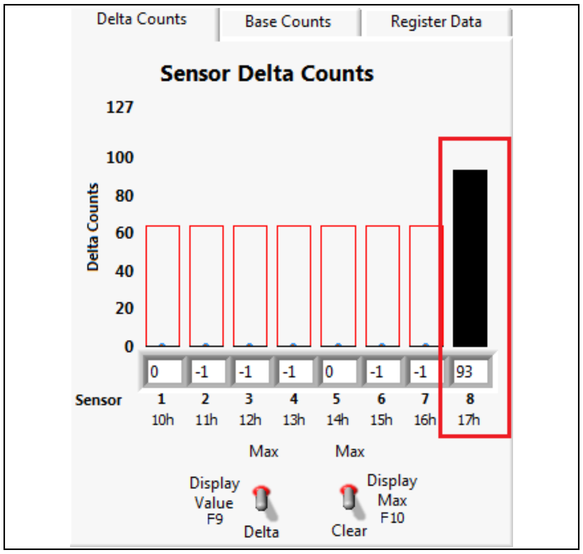
After the scanning and the response tuning is completed, the sensitivity and threshold tuning can start. The sensitivity and threshold is different in Active mode and Standby mode. Thus, the tuning is divided into two parts: Active mode and Standby mode.

### ACTIVE MODE

In Active mode the tuning process follows these steps:

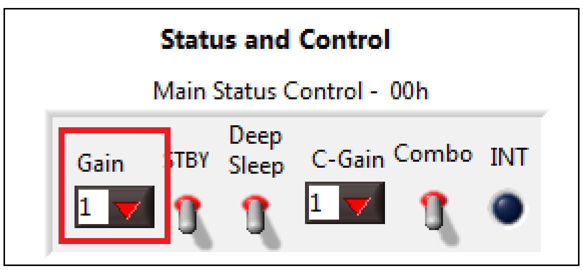
1. Switch to Active mode by clicking the switch buttons.
2. Measure the sensor delta count with the specified metal finger on the touch key. The sensitivity is based on the customer's requirements. In most cases, the typical finger size is 9 mm. Keep the delta count within 60~110.
3. If the sensor delta count is not within 60~110, adjust the sensitivity to make sure that the delta count is within proper range, as shown in Figure 28.

**FIGURE 28: DELTA COUNT WITH FINGER TOUCH**




4. Adjust the gain. If the maximum and minimum sensitivity values cannot meet the requirements, adjust the gain value by one count, as indicated in Figure 29.

**FIGURE 29: GAIN VALUE ADJUSTMENT**



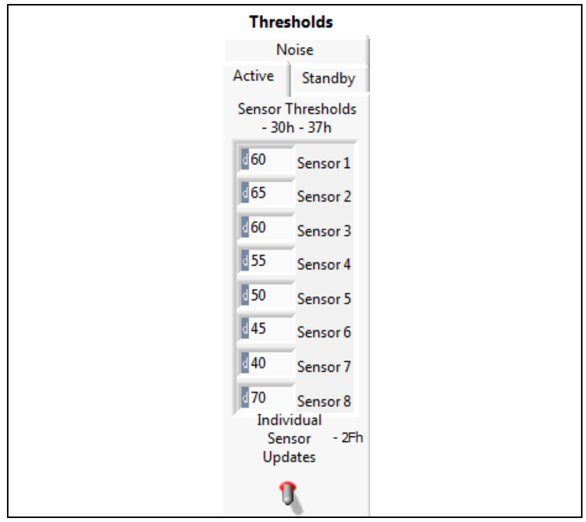

5. After adjusting the gain, repeat steps 3 to 5, until the delta count meets the requirements.
6. Set the proper threshold. It is recommended that the threshold be around 75% of the touch delta count. For example, the delta count of Sensor 8 is 93, so the threshold of Sensor 8 will be as shown in Equation 3.

**EQUATION 3: THRESHOLD OF SENSOR 8**

$$93 \times 75\% = 70$$

This rule can be applied to set the threshold for all touch keys, as shown in Figure 30.

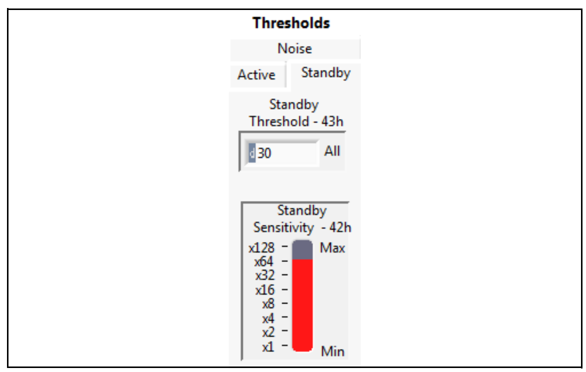
**FIGURE 30: THRESHOLD FOR ACTIVE MODE**




## STANDBY MODE

In Standby mode all the sensors share one threshold. The sensors assigned to the Standby Channel will share the same threshold in Standby mode, as shown in Figure 31.

**FIGURE 31: SENSITIVITY AND THRESHOLD FOR STANDBY MODE**




After the tuning for the Active mode is done, switch to the Standby mode tuning by clicking the "STBY" switch on the Status and Control panel.

### Buttons

In the Standby mode the touch keys can be used as buttons or proximity. If the touch keys are used as buttons, the tuning process is the same as in the Active mode, which is described in **Section "Active Mode"** steps 3 to 5.

### Proximity

If the touch keys are used as proximity, follow the proximity tuning process.

Take CAP1298 EVB as an example; sensor 1 is assigned as standby sensor.

1. Disable the “Max Duration Enable” to avoid recalibration due to the expiration of the maximum duration.
2. Disable the “Digital Noise Threshold” to use the noise threshold.
3. Set the noise threshold to the default value.
4. Set the standby sensitivity to x8.
5. Place the palm above the proximity sensor and keep the distance of 10 cm.
6. If the sensor delta count is not within 60~110, set a higher standby sensitivity, such as x16.
7. Increase the standby sensitivity till the sensor delta is within the proper range.
8. If the maximum standby sensitivity cannot meet the requirements, increase the gain and then repeat steps 5 to 7.
9. Adjust the parameter until the performance meets the requirements.

## Power Consumption Tuning

Power consumption depends on the number of sensor inputs enabled, as well as on the averaging, sampling time and cycle time.

If the number of the sensors is fixed in Active or Standby mode, the power consumption is dependent on the scanning configuration, as shown in Figure 26.

The power consumption is inversely proportional to the cycle time: the longer the cycle time, the lower the power consumption is achieved.

If the cycle time is fixed, the power consumption is proportional to the total scanning time, as indicated in Figure 27.

The power consumption tuning follows these steps:

1. Set the scanning parameters to the default value.
2. Measure the power consumption.
3. If the performance cannot meet the requirements, switch to a longer cycle time, such as 105 ms.
4. Measure the power consumption.
5. If the performance cannot meet the requirements, set smaller number of samples for average, such as 4.
6. Measure the power consumption.
7. If the performance cannot meet the requirements, set a shorter single sample time, such as 640 us.
8. Repeat steps 2 to 7 and adjust the three parameters until the power consumption is acceptable.

This tuning will undo the settings of response time tuning.

## Noise Robustness Tuning

Noise immunity is the important feature for the capacitive sensing system. The CAP1XXX serial touch key controllers support analog and digital filters to suppress noise.

The noise robustness is related to the filters and the scanning configuration.

### FILTERS TUNING

The filters include digital filters and analog filters.

### Analog Noise

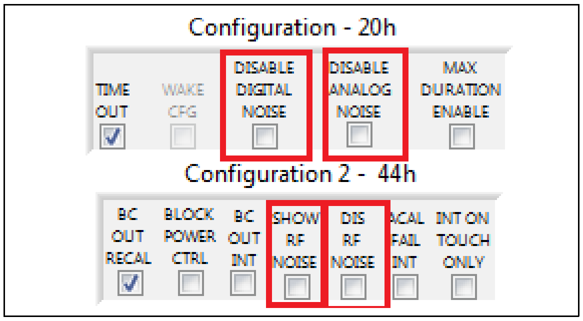
1. Low-Frequency Noise Detection

Detectors are placed on all sensor channels. If the low-frequency noise is injected into the sensor channels and results in corrupted sampling data, the touch key controller will discard the corrupted data.

If low-frequency noise is detected by the detector, the delta count on the corresponding channel will be reset to zero.

Disabling the “Disable Analog Noise” function will enable this feature. It is recommend that this feature is enabled for better noise robustness, as shown in Figure 32.

**FIGURE 32: FILTERS’ TUNING**




2. RF Noise Detection

If RF noise is detected by the analog block, the delta count on the corresponding channel is reset to zero, which will avoid the false touch and improve the noise robustness.

Figure 32 shows how disabling the “DIS RF NOISE” will enable this feature. It is recommended that this feature is enabled.

Digital Noise

If a capacitive touch sensor input exceeds the sensor noise threshold, but does not exceed the touch threshold in the Active state or sensor standby threshold, it is determined to be caused by a noise spike. The samples will be discarded so they are not used in the automatic recalibration routine.

Figure 32 shows how disabling the “Disable Digital Noise” function will enable this feature. It is recommended that this feature is enabled for better noise robustness. Additionally, the sensor noise threshold should be set properly according to the actual noise level.

SCANNING CONFIGURATION TUNING

The proper scanning configuration can be helpful for noise suppression. In Active mode or Standby mode the output of the channel is the average of a serial of results of the single sample, therefore, the average of the samples is a low-pass filter which can suppress spike noise.

The more single samples are used for average, the more powerful noise immunity will be.

It is recommended using the default number of single sample for average. If obvious noise is detected on the sensor delta count, switch to the bigger value to suppress the noise, such as x16 or even bigger x32.

However, this tuning will have impact on the response time and on the power consumption. This is a trade off between the response time, power consumption and the noise robustness.

## Calibration and Recalibration

CAP1XXX serial touch key controllers support two types of calibration: analog calibration and digital calibration. Calibration is very important for touch sensitivity.

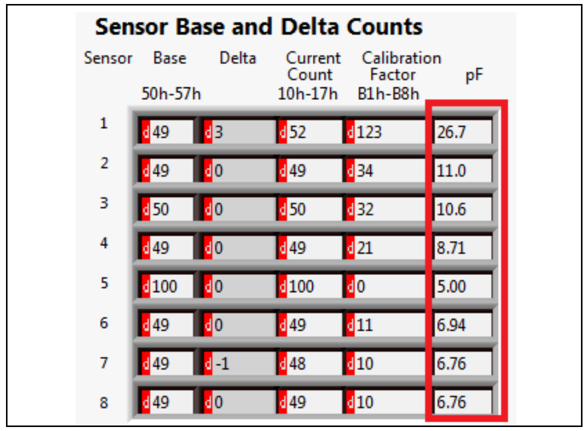
ANALOG CALIBRATION

Analog calibration occurs automatically after a Power-on Reset, mode change or a request from the host.

During analog calibration, the analog sensing circuits are tuned to the capacitance of the untouched pad and then the base count is established. After the successful calibration, the sensor counts without touches are all zero.

As the maximum external capacitance that the CAP1XXX serial touch key controller can support is 50 pF, the analog calibration will fail when the external capacitance is higher than 50 pF. A successful analog calibration is shown in Figure 33, where the capacitance of each channel is within 50 pF.

**FIGURE 33: CALIBRATION RESULT**

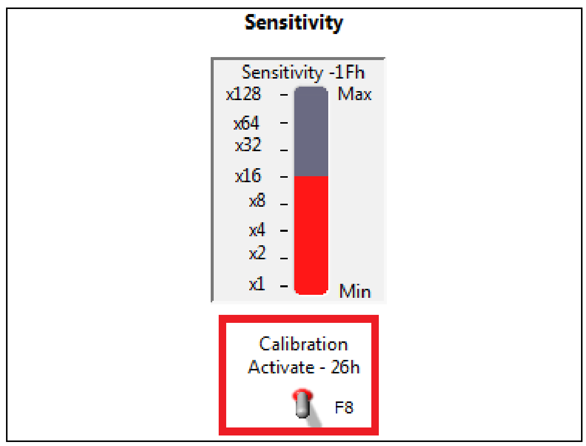



Triggering the Analog Calibration

The analog calibration can be triggered by one of the following steps:

- The touch key controller is power-on.
- The mode is changed. For example, the touch controller switches to Active mode from the previous Standby mode.
- The host sends a command to force calibration. With CAP1XXX GUI, the user can click the “Calibration Active” switch to trigger a forced calibration, as shown in Figure 34.

**FIGURE 34: FORCE CALIBRATION**




DIGITAL CALIBRATION

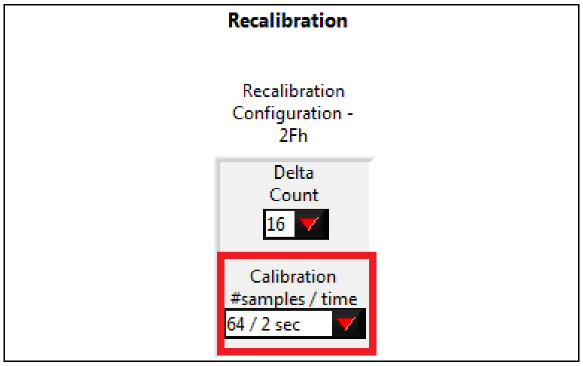
Digital calibration is triggered in the following situations:

- after a successful analog calibration
- regular calibration during no touch
- timeout of the maximum duration touch
- successive negative delta count

### Automatic Regular Recalibration

Each sensor input is regularly recalibrated at a specified rate. The recalibration routine stores the average of previous measurements and periodically updates the base of “not touched” settings for the capacitive touch sensor input. Automatic regular recalibration only works when the delta count is below the active sensor input threshold and no touch is detected. The number of the previous measurement for average is specified by the user, as indicated in Figure 35.

**FIGURE 35: SAMPLES FOR REGULAR CALIBRATION**

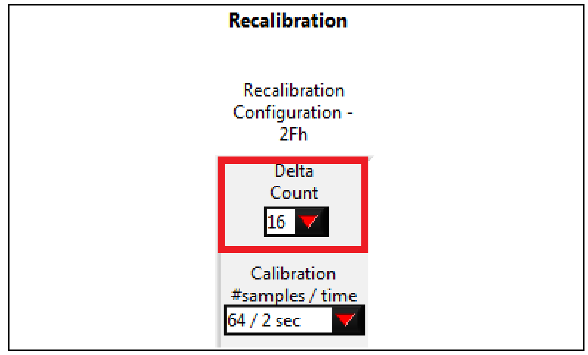



In most cases, the default value is the right one. Fewer samples will trigger the calibration more frequently and reduce the impact from environment, such as the temperature change, and improve the system robustness.

### Negative Delta Count Recalibration

Sometimes the touch key does not respond to any touch. This is due to the result of a noisy environment recalibration when the pad is touched, but delta counts do not exceed the threshold, or to other environmental changes. When this occurs, the base untouched sensor input may generate negative delta count values. After a specified number of consecutive negative delta readings, the force calibration will be triggered. After calibration, the negative delta count and the sensitivity will recover after the touch release. Figure 36 shows the tuning for the negative delta count recalibration. In most cases, the default value is appropriate for the project’s requirements. However, the setting should be adjusted according to the actual negative delta count.

**FIGURE 36: NEGATIVE DELTA COUNT FOR RECALIBRATION**




### Timeout Recalibration

Sometimes a “stuck button” occurs when something is placed on a button which causes a touch to be detected for a longer period. Recalibration can be triggered when a touch is held on a button for longer than the specified duration. Timeout recalibration only works when the delta count is above the active sensor input threshold.

The tuning process for timeout calibration is as follows:

- Enable this feature as shown in Figure 37.
- Set the maximum duration as shown in Figure 38.

**FIGURE 37: ENABLE THE TIMEOUT RECALIBRATION**

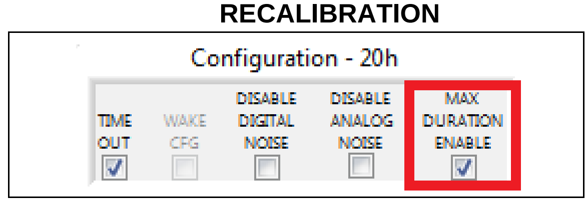
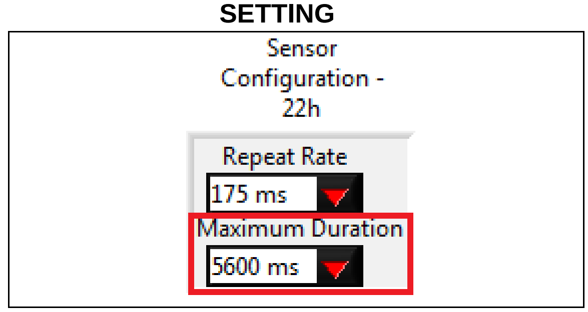


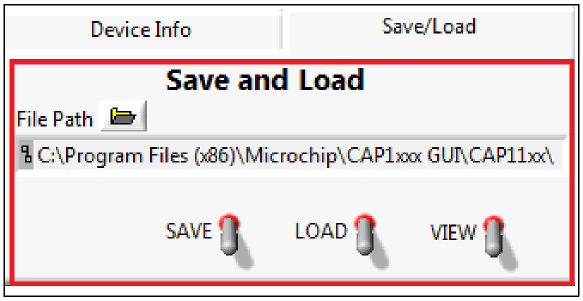

**FIGURE 38: MAXIMUM DURATION SETTING**




## SAVE AND LOAD SETTINGS

After the tuning is finished, all the settings configured for the device should be saved. So the settings can configure the device quickly or be integrated into the driver. Figure 39 shows the tools for save and load.

**FIGURE 39: SAVE AND LOAD SETTINGS**




## How to save the settings

To save the device configuration settings follow these steps:

1. Select the **Save** and **Load** tab.
2. Tap a path or click the folder icon to browse a new location.
3. Click the 'Save' switch to save the settings into the file, which is named with the extension `.txt`.

## How to load the settings

To load the device settings follow the steps below:

1. Select the **Save** and **Load** tab.
2. Click the folder icon to browse to the location of the file, where the settings are saved.
3. Click the 'Load' switch to load the settings in the file.

Details are shown in Figure 39.

## Quick Load

The "Quick Load" function allows the user to load the configuration file quickly, as shown in Figure 41.

The "Quick Load" button is linked to a `.txt` file in your installation directory that has the file name listed above the button. For example, the directory is C:\Program Files (x86)\Microchip\CAP1XXX GUI\CAP11xx.

In the directory you can find the files whose names are the same as the buttons, as shown in Figure 40.

**FIGURE 40: QUICK LOAD FILES**

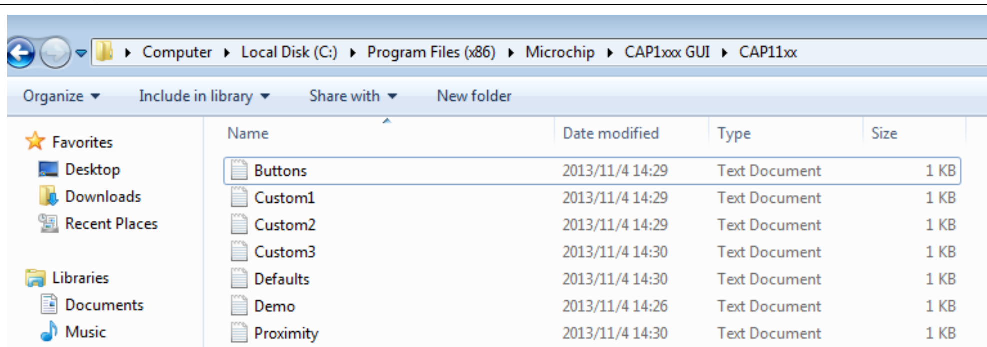
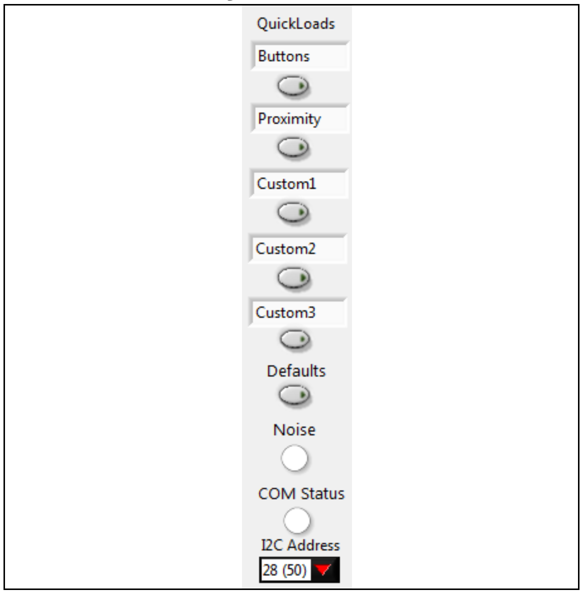


**FIGURE 41: QUICK LOAD SETTINGS**




To use the "Quick Load" to load the device settings, follow these steps:

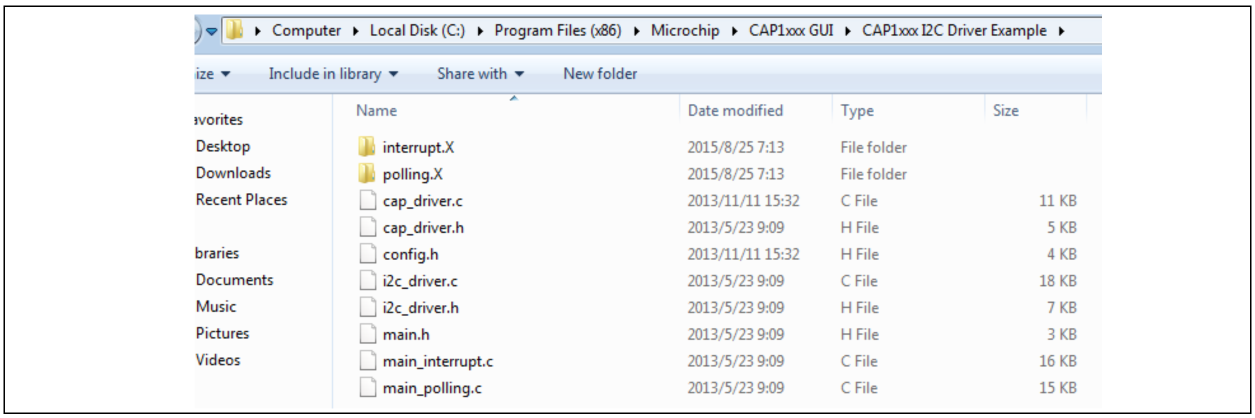
1. After the tuning is completed and the settings of the configuration are saved, name the file "Buttons".
2. Link the "Quick Load" button to the file by typing the file name (without the extension) in the box above the button, then click off the field.
3. Click the button to load the file quickly.

## DRIVER INTEGRATION

After the settings of configuration are saved successfully, the settings can be integrated into the driver.

The example code of the driver is located in the directory: C:\Program Files (x86)\Microchip\CAP1XXX GUI\CAP1XXX I2C Driver Example.

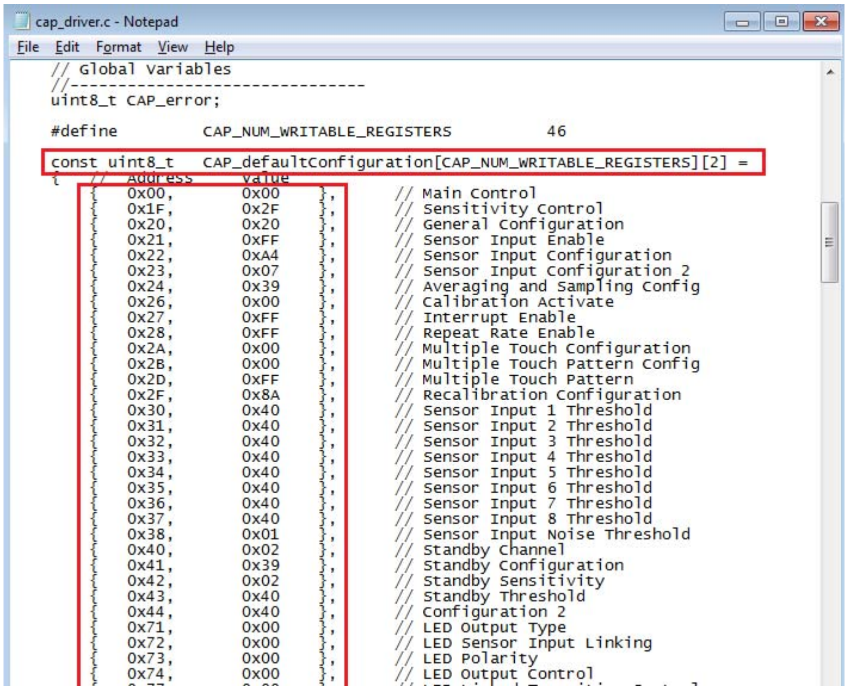
**FIGURE 42: DRIVER LOCATION**




Follow the steps below to integrate the settings into the driver:

1. Replace the content of CAP_defaultConfiguration Array in `cap_driver.c` file with the saved settings, as indicated in Figure 43.
2. Change the parameter CAP_NUM_WRITABLE_REGISTERS according to the actual number of the parameters.

**FIGURE 43: SOURCE CODE DETAILS**



```
cap_driver.c - Notepad
File  Edit  Format  View  Help
// Global variables
//-------------------------------
uint8_t CAP_error;

#define         CAP_NUM_WRITABLE_REGISTERS          46

const uint8_t   CAP_defaultConfiguration[CAP_NUM_WRITABLE_REGISTERS][2] =
{   //  Address     Value
    {   0x00,       0x00    },      // Main Control
    {   0x1F,       0x2F    },      // Sensitivity Control
    {   0x20,       0x20    },      // General Configuration
    {   0x21,       0xFF    },      // Sensor Input Enable
    {   0x22,       0xA4    },      // Sensor Input Configuration
    {   0x23,       0x07    },      // Sensor Input Configuration 2
    {   0x24,       0x39    },      // Averaging and Sampling Config
    {   0x26,       0x00    },      // Calibration Activate
    {   0x27,       0xFF    },      // Interrupt Enable
    {   0x28,       0xFF    },      // Repeat Rate Enable
    {   0x2A,       0x00    },      // Multiple Touch Configuration
    {   0x2B,       0x00    },      // Multiple Touch Pattern Config
    {   0x2D,       0xFF    },      // Multiple Touch Pattern
    {   0x2F,       0x8A    },      // Recalibration Configuration
    {   0x30,       0x40    },      // Sensor Input 1 Threshold
    {   0x31,       0x40    },      // Sensor Input 2 Threshold
    {   0x32,       0x40    },      // Sensor Input 3 Threshold
    {   0x33,       0x40    },      // Sensor Input 4 Threshold
    {   0x34,       0x40    },      // Sensor Input 5 Threshold
    {   0x35,       0x40    },      // Sensor Input 6 Threshold
    {   0x36,       0x40    },      // Sensor Input 7 Threshold
    {   0x37,       0x40    },      // Sensor Input 8 Threshold
    {   0x38,       0x01    },      // Sensor Input Noise Threshold
    {   0x40,       0x02    },      // Standby Channel
    {   0x41,       0x39    },      // Standby Configuration
    {   0x42,       0x02    },      // Standby Sensitivity
    {   0x43,       0x40    },      // Standby Threshold
    {   0x44,       0x40    },      // Configuration 2
    {   0x71,       0x00    },      // LED Output Type
    {   0x72,       0x00    },      // LED Sensor Input Linking
    {   0x73,       0x00    },      // LED Polarity
    {   0x74,       0x00    },      // LED Output Control
```

## APPENDIX A: REFERENCES

Microchip created serial documents to support the design of the touch key controllers. The following list will guide you in identifying the proper documents for your reference.

1. *CAP1XXX User's Guide* (DS50002221)
2. *CAP1XXX Evaluation Board User's Guide* (DS50002221)
3. *CAP1188 Data Sheet* (DS00001620)
4. *CAP1298 Data Sheet* (DS00001571)

## APPENDIX B: UNITS OF MEASURE

This table lists the units of measure used in the application note.

**TABLE 3: UNITS OF MEASURE**

| Symbol | Unit of Measure |
|---|---|
| °C | degrees Celsius |
| µA | micro-amperes |
| µF | micro-farads |
| µs | microseconds |
| µV | microvolts |
| Kbps | kilobits (1024 bits) per second |
| kHz | kilohertz |
| MHz | megahertz |
| MΩ | megaohms |
| mA | milliamperes |
| ms | milliseconds |
| s | second |
| pF | picofarads |

**NOTES:**

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