QTouch Library Peripheral Touch Controller

USER GUIDE

Description

Atmel® QTouch® Peripheral Touch Controller (PTC) offers built-in hardware for capacitive touch measurement on sensors that function as buttons, sliders, and wheels. The PTC supports both mutual and self-capacitance measurement without the need for any external component. It offers superb sensitivity and noise tolerance, as well as self-calibration, and minimizes the sensitivity tuning effort by the user.

The PTC is intended for autonomously performing capacitive touch sensor measurements. The external capacitive touch sensor is typically formed on a PCB, and the sensor electrodes are connected to the analog charge integrator of the PTC using the device I/O pins. The PTC supports mutual capacitance sensors organized as capacitive touch matrices in different X-Y configurations, including Indium Tin Oxide (ITO) sensor grids. In mutual capacitance mode, the PTC requires one pin per X-line (drive line) and one pin per Y-line (sense line). In self-capacitance mode, the PTC requires only one pin with a Y-line driver for each self-capacitance sensor.

Features

- Implements low-power, high-sensitivity, environmentally robust capacitive touch buttons, sliders, and wheels
- Supports mutual capacitance and self-capacitance sensing
- Up to 32 buttons in self-capacitance mode
- Up to 256 buttons in mutual capacitance mode
- Supports lumped mode configuration
- One pin per electrode - no external components
- Load compensating charge sensing
- Parasitic capacitance compensation for mutual capacitance mode
- Adjustable gain for superior sensitivity
- Zero drift over the temperature and VDD range
- No need for temperature or VDD compensation
- Hardware noise filtering and noise signal de-synchronization for high conducted immunity
- Atmel provided QTouch Library firmware and QTouch Composer tool

Product Support

For assistance related to QTouch capacitive touch sensing software libraries and related issues, contact your local Atmel sales representative or log on to myAtmel Design Support portal to submit a support request or access a comprehensive knowledge base.

If you do not have a myAtmel account, please visit http://www.atmel.com/design-support/ to create a new account by clicking on **Create Account** in the myAtmel menu at the top of the page.

When logged in, you will be able to access the knowledge base, submit new support cases from the myAtmel page or review status of your ongoing cases.

Table of Contents

1. Development Tools

The following development tools are required for developing QTouch library using PTC:

- Development Environment for GCC Compiler:
  - QTouch Composer 5.9.116 or later versions
  - QTouch Library 5.9.211 or later versions

    Note: The QTouch Library and Composer extensions work only with Atmel Studio 7 which can be downloaded from http://www.atmel.com/
  - Dependent Atmel Studio Extensions
    - Atmel Software Framework 3.30.1 or later versions
    - Atmel Kit Extension 7.0.70 or later versions
- Development Environment for IAR Compiler:
  - IAR Embedded Workbench® for ARM® 7.50.1.10273 or later
  - IAR Embedded Workbench for Atmel AVR® 6.70.1 or later
  - Atmel Software Framework 3.29.0 or later (optional)
  - Atmel QTouch Library 5.9.211 IAR Installer (available at http://www.atmel.com/tools/qtouchlibraryptc.aspx)

2. Device Variants Supported

QTouch Library for SAM and ATmega devices are available for the following device variants:

Series	Variant
SAM D20 J Series	ATSAMD20J18, ATSAMD20J17, ATSAMD20J16, ATSAMD20J15, ATSAMD20J14
SAM D20 G Series	ATSAMD20G18, ATSAMD20G18U, ATSAMD20G17, ATSAMD20G17U, ATSAMD20G16, ATSAMD20G15, ATSAMD20G14
SAM D20 E Series	ATSAMD20E18, ATSAMD20E17, ATSAMD20E16, ATSAMD20E15, ATSAMD20E14
SAM D21 J Series	ATSAMD21J18A, ATSAMD21J17A, ATSAMD21J16A, ATSAMD21J15A, ATSAMD21J16B, ATSAMD21J15B
SAM D21 G Series	ATSAMD21G18A, ATSAMD21G17A, ATSAMD21G16A, ATSAMD21G15A, ATSAMD21G15B, ATSAMD21G16B, ATSAMD21G17AU, ATSAMD21G18AU
SAM D21 E Series	ATSAMD21E18A, ATSAMD21E17A, ATSAMD21E16A, ATSAMD21E15A, ATSAMD21E15B, ATSAMD21E15BU, ATSAMD21E16B, ATSAMD21E16BU
SAM D10 C Series	ATSAMD10C14A
SAM D10 D Series	ATSAMD10D14AM, ATSAMD10D14AS, ATSAMD10D14AU
SAM D11 C Series	ATSAMD11C14A
SAM D11 D Series	ATSAMD11D14AM, ATSAMD11D14AS, ATSAMD11D14AU
SAM L21 E Series	ATSAML21E15B, ATSAML21E16B, ATSAML21E17B, ATSAML21E18B
SAM L21 G Series	ATSAML21G16B, ATSAML21G17B, ATSAML21G18B
SAM L21 J Series	ATSAML21J16B, ATSAML21J17B, ATSAML21J18B
SAM R21 E Series	ATSAMR21E16A, ATSAMR21E17A, ATSAMR21E18A, ATSAMR21E19A
SAM R21 G Series	ATSAMR21G16A, ATSAMR21G17A, ATSAMR21G18A
SAM DA1 E Series	ATSAMDA1E14A, ATSAMDA1E15A, ATSAMDA1E16A
SAM DA1 G Series	ATSAMDA1G14A, ATSAMDA1G15A, ATSAMDA1G16A
SAM DA1 J Series	ATSAMDA1J14A, ATSAMDA1J15A, ATSAMDA1J16A
SAM C21 E Series	ATSAMC21E15A, ATSAMC21E16A, ATSAMC21E17A, ATSAMC21E18A
SAM C21 G Series	ATSAMC21G15A, ATSAMC21G16A. ATSAMC21G17A, ATSAMC21G18A
SAM C21 J Series	ATSAMC21J16A, ATSAMC21J17A, ATSAMC21J18A
SAM C20 E Series	ATSAMC20E15A, ATSAMC20E16A, ATSAMC20E17A, ATSAMC20E18A
SAM C20 G Series	ATSAMC20G15A, ATSAMC20G16A. ATSAMC20G17A, ATSAMC20G18A
SAM C20 J Series	ATSAMC20J16A, ATSAMC20J17A, ATSAMC20J18A
SAM L22 G Series	ATSAML22G16A, ATSAML22G17A, ATSAML22G18A
SAM L22 J Series	ATSAML22J16A, ATSAML22J17A, ATSAML22J18A

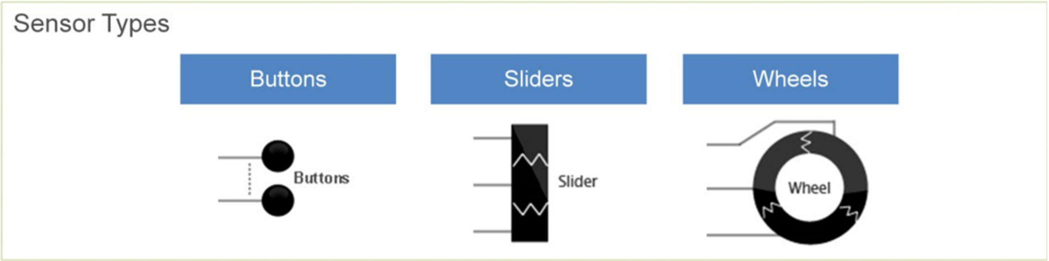
Series	Variant
SAM L22 N Series	ATSAML22N16A, ATSAML22N17A, ATSAML22N18A
ATmega Series	ATmega328PB, ATmega324PB

3. Capacitive Touch Technology

3.1. Capacitive Touch Sensors

Capacitive touch sensors replace conventional mechanical interfaces and operate with no mechanical wear and are closed to the environment. They provide greater flexibility in industrial design and result in differentiating end product design. For more information, refer Capacitive Touch Lumped Sensors and Capacitive Touch Low Power Sensor.

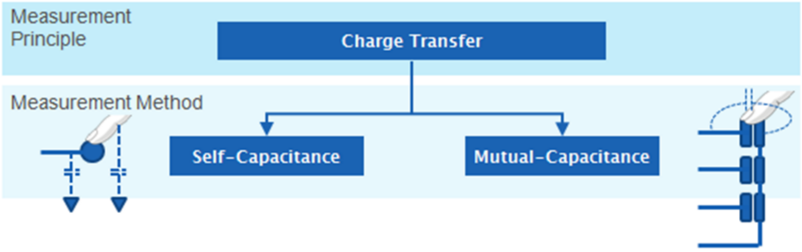
Figure 3-1. Sensor Types



3.2. Capacitance Measurement Methods

Self-capacitance measurement method involves charging a sense electrode of unknown capacitance to a known potential. The resulting charge is transferred into a measurement circuit. By measuring the charge with one or more charge-and transfer cycles, the capacitance of the sense plate can be determined.

Figure 3-2. Capacitance Measurement Principle

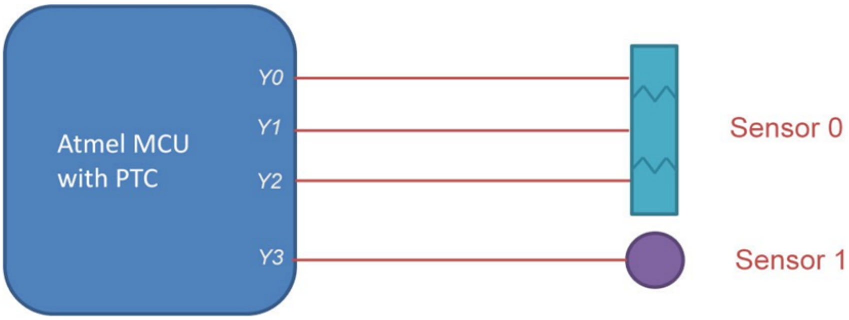


Mutual capacitance measurement method uses a pair of sensing electrodes. One electrode acts as an emitter into which a charge consisting of logic pulses is driven in burst mode. The other electrode acts as a receiver that couples to the emitter using the overlying panel dielectric. When a finger touches the panel, the field coupling is reduced, and touch is detected.

3.3. Self-capacitance Measurement Method

- Uses a single sense electrode (Y-line)
  - Self-capacitance button can be formed using one channel
  - Self-capacitance slider and wheel is formed using 3 channels
- Robust and easy to use, ideal for low sensors count

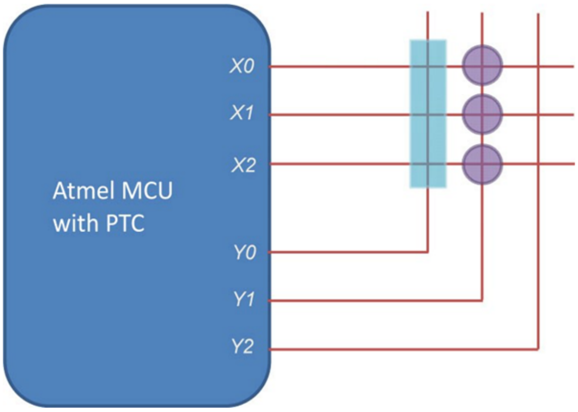
Figure 3-3. Self-capacitance Method



3.4. Mutual Capacitance Measurement Method

- Uses a pair of sense electrodes (X-Y lines)
  - Mutual capacitance buttons use one X-Y channel
  - Mutual capacitance sliders and wheels can be configured to use 3 to 8 X-Y channels, depending on the sensor size
- Suitable for high sensor count
- Better moisture tolerance

Figure 3-4. Mutual Capacitance Method



3.5. Capacitive Touch Lumped Sensors

Lumped sensor configuration is a combination of multiple sense lines (Self-capacitance measurement) or multiple drive and sense lines (Mutual capacitance measurement) to act as one single sensor. Lumped mode acts as a tool for application developers to improve overall system performance.

Improved Power Efficiency

When multiple sensors are lumped together and treated as one single sensor the time taken to perform scans is reduced. For battery powered applications using multiple buttons, a group of touch sensors can be lumped to form a single lumped sensor and this sensor alone can be scanned, thereby resulting in reduced power consumption. Upon user presence detection on the lumped sensor all configured sensors in the system can then be scanned individually.

Improved Response Time

In high key-count applications, there can be a significant latency between touching a sensor and the detection of a touch contact. This is due to the time taken to sequentially measure the capacitance of each key on each measurement cycle.With a Lumped mode implementation this latency can be reduced by arranging the sensors into groups. When one of those lumped groups shows touch detection, only the keys within that group are individually measured to determine which is touched.

E.g. A keyboard consisting 64 keys may be divided into 8 lumped groups of 8.

Thus, each measurement cycle is reduced to measure only the 8 lumped sensors. When a touch contact is applied, first the lump sensor shows touch delta, then the 8 component keys are scanned and the location is resolved. Only 16 measurements are required to resolve the touch status of all keys, compared to 64 measurements in the traditional sequential scan of all keys.

It offers an additional edge during low power acquisition as a group of keys [in lumped configuration] can be scanned thus reducing the power consumed drastically. Each sensor has its own pre-scaled clock and series resistor for improved noise immunity.

Figure 3-5. Self-capacitance Sensors connected to PTC

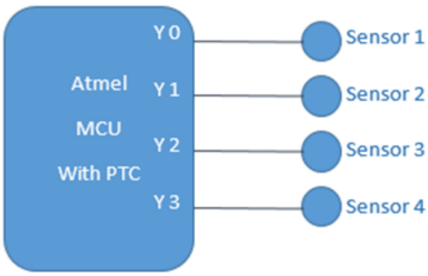
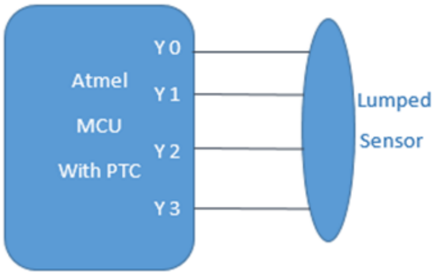


Figure 3-6. Lumped Self-capacitance Sensors connected to PTC



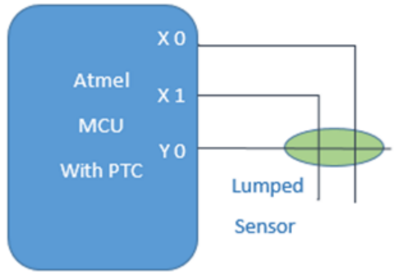
In the preceeding figures, individual buttons are shown along with the lumped equivalent for self-capacitance arrangement.

Lumped Mode Pin and Sensor Configuration for Self-capacitance Method:

```
#define DEF_SELFCAP_LINES Y(5), Y(4), Y(11), Y(10), Y(13), Y(7), Y(12), Y(6), LUMP_Y(5,4)

touch_ret = touch_selfcap_sensor_config(SENSOR_TYPE_LUMP, CHANNEL_8, CHANNEL_8, NO_AKS_GROUP,
40u, HYST_6_25, RES_8_BIT, &sensor_id);
```

Figure 3-7. Lumped Sense Lines Mutual Capacitance Sensors connected to PTC



In the preceeding figure, mutual capacitance lumped sensor configuration is presented.

Lumped Mode Pin and Sensor Configuration for Mutual Capacitance Method:

```
#define DEF_MUTLCAP_NODES X(8), Y(10), X(9), Y(10), X(2), Y(12), X(3), Y(12), \X(8), Y(12),
X(9), Y(12), X(2), Y(13), X(3), Y(13), \X(8), Y(13), X(9), Y(13), LUMP_X(2,3,8,9),
LUMP_Y(10,13)

touch_ret = touch_mutlcap_sensor_config(SENSOR_TYPE_LUMP, CHANNEL_10, CHANNEL_10,
NO_AKS_GROUP, 20u, HYST_6_25, RES_8_BIT, 0, &sensor_id);
```

Limitations of Use

Lumped sensor capacitive load should not exceed the maximum sensor load for individual sensors in either mutual or self-capacitance modes. Lumped mode treats the larger sensors as one single sensor therefore the maximum lumped sensor load should also observe this specification, else this will result in calibration error.

In mutual capacitance measurement mode the capacitive load of each sensor is normally much lower than that of the self-capacitance method. It is therefore possible as a general rule to use more mutual sensors together as a single lumped sensor.

The user can ensure that the lumped sensor does not result in a calibration error (value of 0x80) using

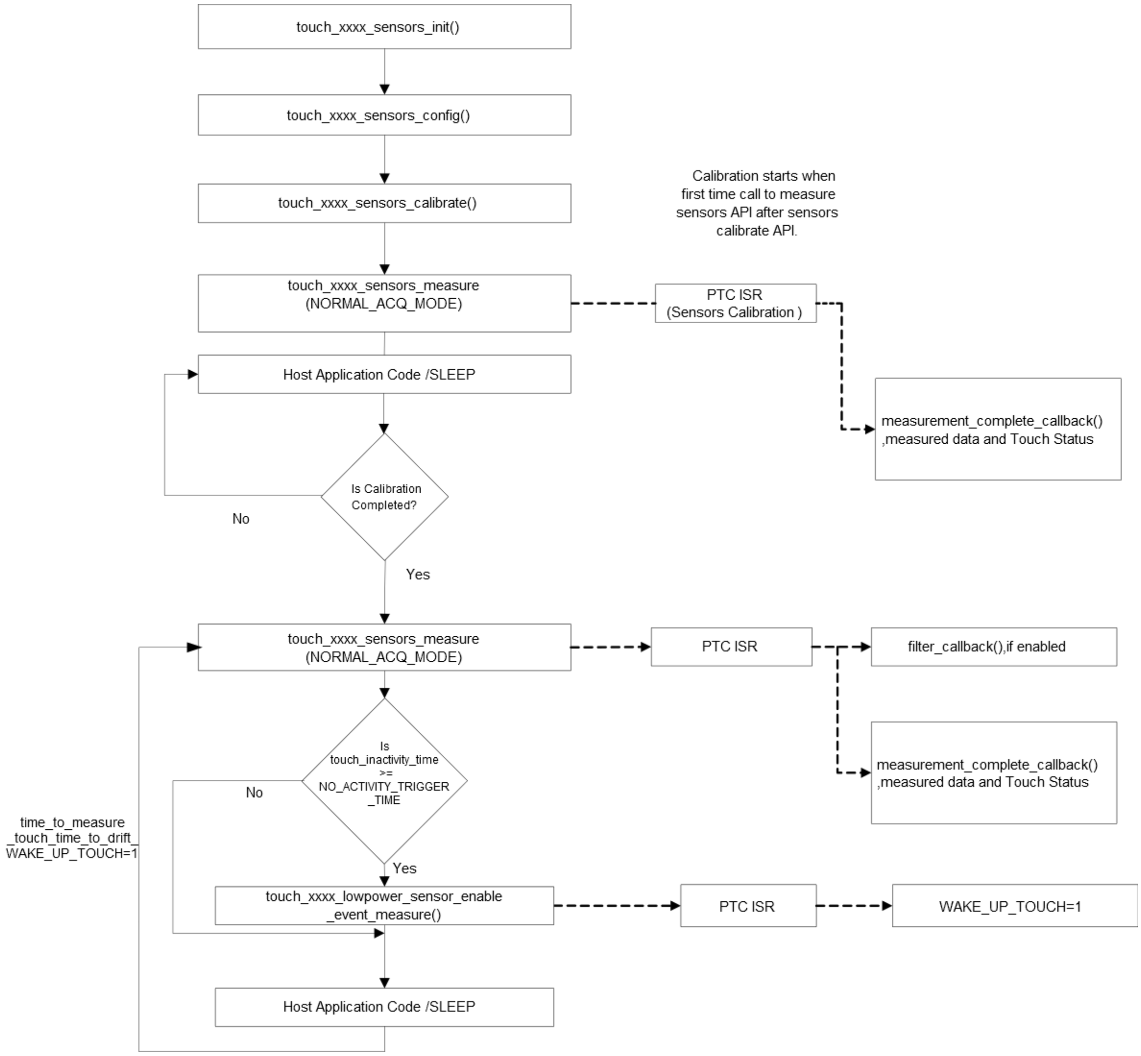
```
p_xxxxcap_measure_data->p_sensors[<SENSOR>].state variable.
```

3.6. Capacitive Touch Low Power Sensor

The QTouch Library may be configured to operate PTC touch sensing autonomously using the Event System. In this mode, a single sensor is designated as the ‘Low Power’ key and may be periodically measured for touch detection without any CPU action. The CPU may be held in deep sleep mode throughout the operation, minimizing power consumption.

The low power key may be a discrete electrode with one Y (Sense) line for Self-capacitance or One X (Drive) plus one Y (Sense) for mutual capacitance, or it may be a combination of multiple Drive and/or Sense lines as a Lumped mode sensor.

Figure 3-8. Low Power Flow



Active Measurement Mode

In the active measurement mode all configured sensors are measured at `DEF_TOUCH_MEASUREMENT_PERIOD_MS` millisecond scan interval.

The user application arrangement could be designed such that when no touch activity is detected on any of the configured sensors for `NO_ACTIVITY_TRIGGER_TIME` milliseconds, then the application switches to low power measurement mode.

Low Power Measurement Mode

In the low power measurement mode, a designated sensor or a lumped sensor can be scanned as a single sensor. In this mode, the system is in standby sleep mode, the CPU and other peripherals are in sleep, excepting for the event system, the RTC and the PTC module / WDT and PTC module in SAM / Mega devices. A user touch on the designated low power sensor will cause the CPU to wake up and perform active measurement in order to resolve the touch. To keep reference tracking of the designated low power sensor, the RTC/WDT is configured to periodically wake up the CPU every `DEF_LOWPOWER_SENSOR_DRIFT_PERIODICITY_MS` millisecond to perform one active measurement.

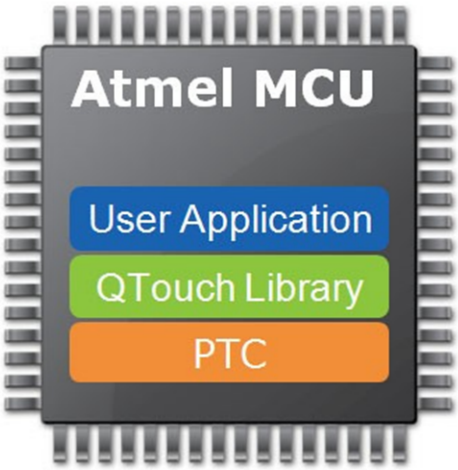
Switching between Active Mode and Low Power Mode

When switching from active to low power mode, all sensors except the lumped sensor are disabled. So, no reference tracking is performed on these sensors during the low power mode. When a touch is detected on the lumped sensor, all disabled sensors shall now be re-enabled and measurement is initiated on the sensors. If the device is in sleep for a very long time, then it is recommended to force calibration on the re-enabled sensors to ensure proper reference values on these sensors.

3.7. PTC and its Benefits

- Mixed Hardware + Firmware solution, allows user to define sensor configuration
  - Peripheral Touch Controller + QTouch library
- PTC runs data acquisition autonomously, resulting in low CPU utilization and power consumption
  - User controlled power-performance trade-off
  - CPU can sleep during acquisition to save power
  - Alternatively, CPU can perform other time critical operations during touch acquisition
- Robust noise performance

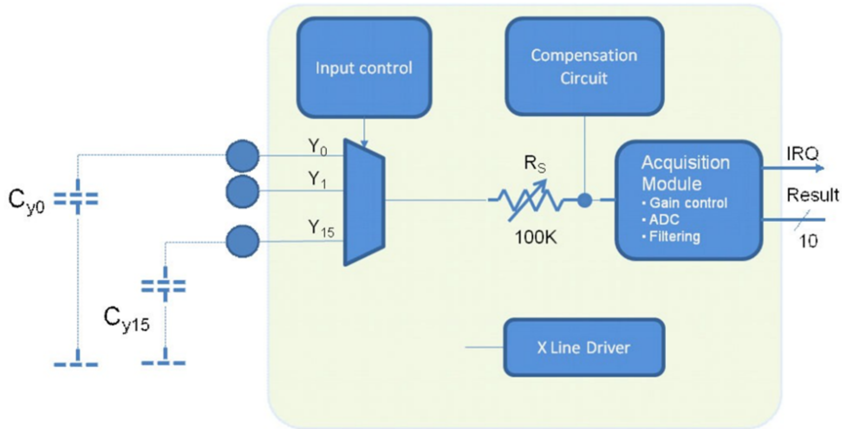
Figure 3-9. User Application with PTC Device



3.8. PTC Block Diagram for Self-capacitance and Mutual Capacitance Method

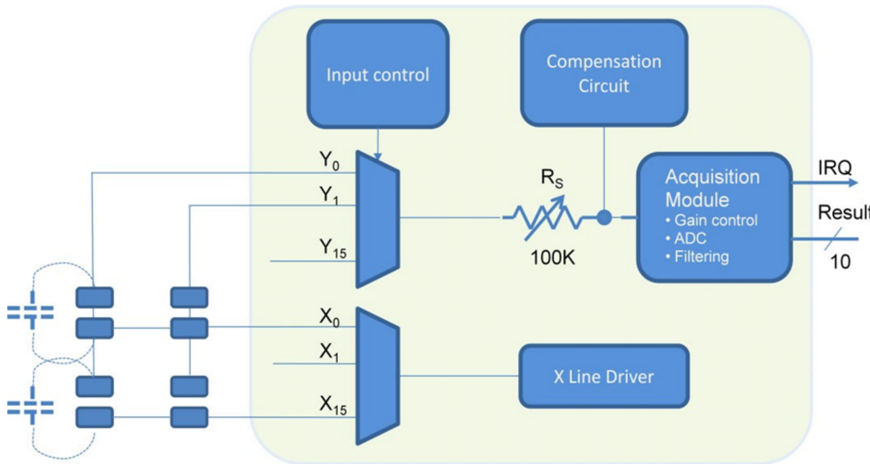
The PTC block diagram for self-capacitance measurement is shown in the following figure. Only Y-lines can be connected to self-capacitance sensors and are selected using the Input control. X-lines remain unused and can be used for any other GPIO functionality. The acquisition module along with the compensation circuit helps in measuring the change in capacitance due to user touch.

Figure 3-10. PTC Self-capacitance Method - Block Diagram



The PTC block diagram for mutual capacitance measurement is as shown in the following figure. Both X-lines and Y-lines should be connected to mutual capacitance sensors and are selected using the Input control.

Figure 3-11. PTC Mutual Capacitance Method - Block Diagram



3.8.1. Compensation Circuit

The PTC has an internal compensation circuit which is used to compensate the sensor capacitance. Both self-capacitance and mutual capacitance sensing modes have the same compensation range. But the mutual capacitance mode can compensate more parasitic capacitance compared to self-capacitance mode.

The `tag_touch_measure_data_t` structure contains the `p_cc_calibration_vals` parameter which represents the current channel's compensation circuit value. For more information, refer Measure Data Type (tag_touch_measure_data_t) .

```
Compensation circuit value used in pF = (p_cc_calibration_vals[channel_no]& 0x0F)*0.00675 +
((p_cc_calibration_vals[channel_no] >> 4) & 0x0F)*0.0675 +
((p_cc_calibration_vals[channel_no] >> 8) & 0x0F)*0.675 + ((p_cc_calibration_vals[channel_no]
>> 12) & 0x3 ) * 6.75
```

Also, the `touch_xxxxcap_sensors_calibrate` function helps the user to calibrate the compensation circuit according to the sensors used. If the routine fails to calibrate the compensation circuit due to saturation, the measurement will return `TOUCH_CC_CALIB_ERROR`. The compensation circuit could have exceeded its limit. The specific sensor that has failed can be determined using `p_xxxxcap_measure_data->p_sensors[<sensor>].state`when it contains the value of `SENSOR_CALIBRATION_ERROR(0x80u)`.

- Typical compensation circuit value for the self-capacitance mode ranges from 10 to 25 pF and for the mutual capacitance mode it is around 2 pF.
- The compensation circuit value is affected by sensor size and the ground surrounding the sensor or trace. The compensation ciruit value ranges from 0.00675 pF to 31.48 pF.
- If the compensation circuit value exceeds the limit, to reduce the value, use a mesh instead of a solid plane in the sensor and ground plane.
- For detailed sensor design, refer http://www.atmel.com/images/doc10752.pdf.

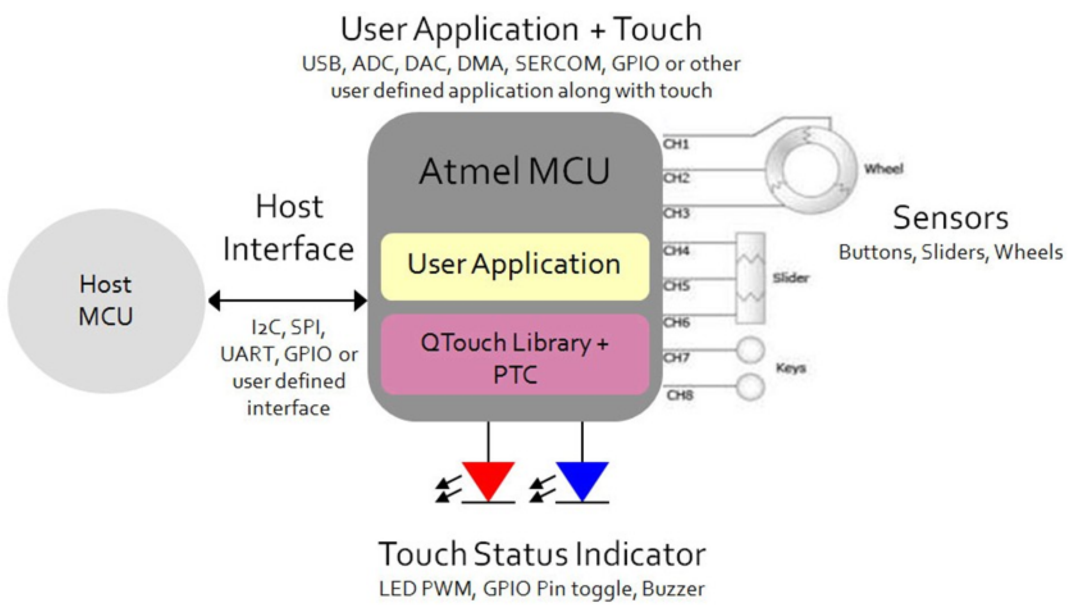
3.9. Design Approach with PTC

Two design approaches are possible when using Atmel MCU along with PTC. The Atmel MCU could be predominantly used as an MCU for touch measurement. Else, the Atmel MCU can function as a Host MCU utilizing peripherals such as the USB, ADC, DAC, SERCOM, DMA and GPIO along with the PTC used for "on-chip" touch functionality.

The design approaches are:

- Atmel MCU with PTC predominantly functioning as a touch MCU
  – Used for touch sensor status and rotor/slider position detection
  – Additionally used to indicate touch status using LED, buzzer etc
  – Sends touch status and rotor/slider position information to a Host MCU
- Atmel MCU functions as a Host MCU with on-chip touch functionality
  – Can be a cost saving design as a single chip solution with on-chip touch functionality
  – Utilizes other on-chip peripheral for a desired user application

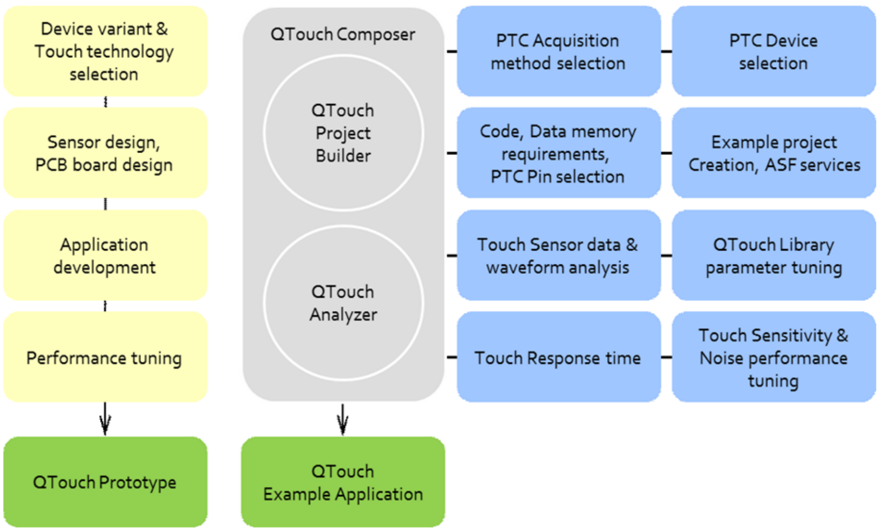
Figure 3-12. PTC Design Approach



3.10. Capacitive Touch Development Cycle

The capacitive touch development cycle involves PCB board design to develop the user interface hardware as well as firmware application development. The QTouch Composer PC software available as part of Atmel Studio extension gallery allows for PTC QTouch Library projects to be generated automatically with a desired user configuration for touch sensors. The QTouch Composer also allows for touch sensor data analysis and performance tuning for sensitivity and noise.

Figure 3-13. Capacitive Touch Development Cycle



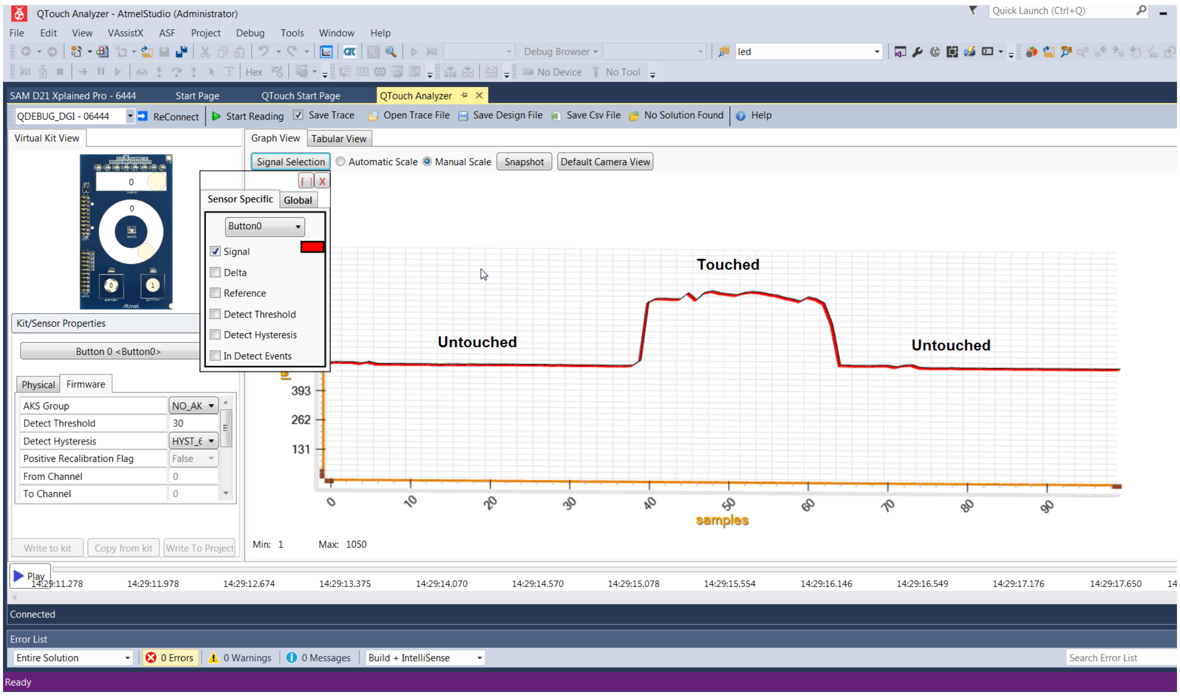
4. Touch Sensor Debug and Status Information

The touch sensor debug information necessary for tuning of the sensors are signal, reference, delta, and compensation capacitance. While the signal, reference and delta help in sensitivity and noise tuning the sensor parameters, the compensation capacitance is an indicator for extreme sensor design. The sensor status and position information are parameters that must be judged by the user application to initate the relevant touch action.

4.1. Signal

Signal value is the raw measurement data on a given touch channel. The value increases upon touch.

Figure 4-1. Channel Signal



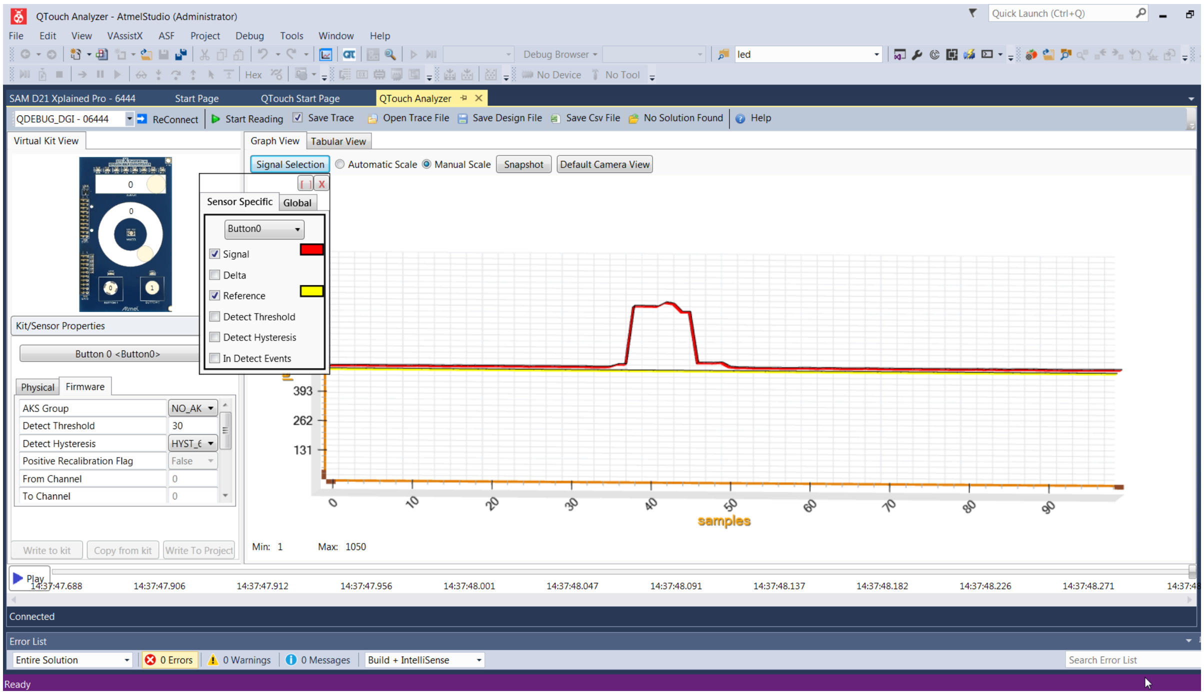
4.2. Reference

Reference value of a touch channel is the long term average measurement on a specific channel.

It represents:

- Resting signal when there is no touch
- Initial value obtained during the calibration process
- Reference is adapted by Drift Compensation algorithm

Figure 4-2. Channel Reference

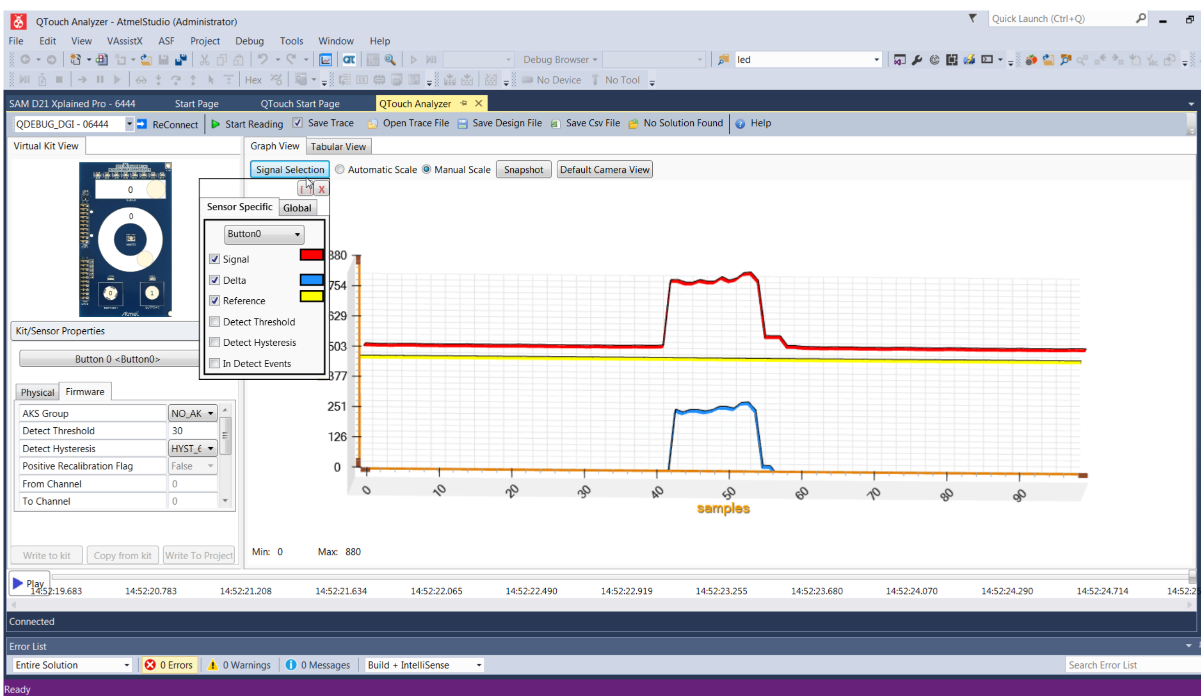


4.3. Delta

Delta value of a touch channel represents touch strength.

- Delta = (signal - reference)
- Deltas increase with touch

Figure 4-3. Sensor Delta



4.4. Touch Status & Slider/Wheel Position

The sensor touch status is the primary touch sensor information utilized by a user application. The sensor state can either be ON or OFF. For sliders and wheel, additionally the touch position is of interest. For an 8-bit resolution, the touch position ranges from 0 to 255 end-to-end. It is possible to configure with a lower resolution by configuring setting in the touch library. The sensor touch status and slider/wheel position must always be used once the library completes the measurements.

The touch sensor state for mutual capacitance or self-capacitance sensor can be obtained by reading the following boolean variables.

```
bool sensor_state_self = GET_SELFCAP_SENSOR_STATE(SENSOR_NUMBER);
bool sensor_state_mutl = GET_MUTLCAP_SENSOR_STATE(SENSOR_NUMBER);
```

The touch sensor rotor or slider position information for mutual capacitance or self-capacitance sensor can be obtained using the following parameters.

```
uint8_t rotor_slider_position_self = GET_SELFCAP_ROTOR_SLIDER_POSITION(ROTOR_SLIDER_NUMBER);
uint8_t rotor_slider_position_mutl = GET_MUTLCAP_ROTOR_SLIDER_POSITION(ROTOR_SLIDER_NUMBER);
```

The touch sensor noise status for mutual capacitance or self-capacitance sensor can be obtained using the following parameters.

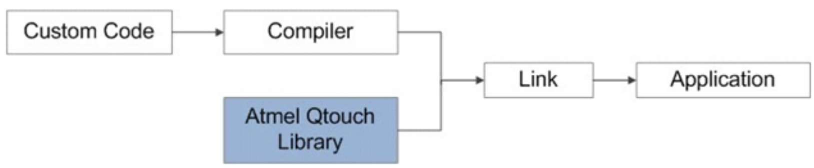
```
bool sensor_noise_state_self = GET_SELFCAP_SENSOR_NOISE_STATUS(SENSOR_NUMBER);
bool sensor_noise_state_mutl = GET_MUTLCAP_SENSOR_NOISE_STATUS(SENSOR_NUMBER);
```

5. QTouch Library

Atmel QTouch Library makes it simple for developers to embed capacitive touch button, slider, wheel functionality into general purpose Atmel SMART | ARM and AVR® microcontroller applications. The royalty- free QTouch Library provides several library files for each device and supports different numbers of touch channels, enabling both flexibility and efficiency in touch applications.

QTouch Library can be used to develop single-chip solutions for many control applications, or to reduce chip count in more complex applications. Developers have the latitude to implement buttons, sliders, and wheels in a variety of combinations on a single interface.

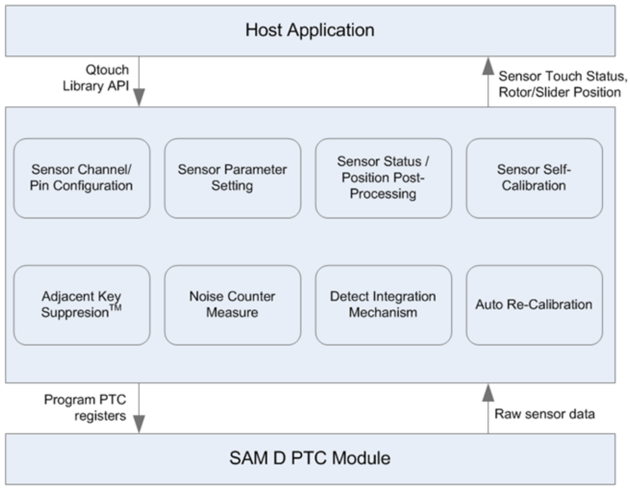
Figure 5-1. QTouch Library



5.1. Overview

QTouch Library API for PTC can be used for touch sensor pin configuration, acquisition parameter setting as well as periodic sensor data capture and status update operations. The QTouch Library in turn interfaces with the PTC module to perform the necessary action. The PTC module interfaces with the external capacitive touch sensors and is capable of performing self and mutual capacitance method measurements. The library features low power and lumped mode configuration.

Figure 5-2. QTouch Library Overview



The QTouch Library API is arranged such that the user application can use standalone self-capacitance or mutual capacitance method or both methods, simultaneously. The following table captures the APIs available for each method. For normal operation, it is sufficient to use the set of Regular APIs for each method. The Helper APIs provides additional flexibility to the user application.

Method	Regular API	Helper API
Mutual capacitance	touch_mutlcap_sensors_init touch_mutlcap_sensor_config touch_mutlcap_sensors_calibrate touch_mutlcap_sensors_measure touch_mutlcap_sensors_deinit touch_mutlcap_lowpower_sensor_enable_event_measure	touch_mutlcap_sensor_get_delta touch_mutlcap_sensor_update_config touch_mutlcap_sensor_get_config touch_mutlcap_update_global_param touch_mutlcap_get_global_param touch_mutlcap_update_acq_config touch_mutlcap_get_acq_config touch_mutlcap_sensor_disable touch_mutlcap_sensor_reenable touch_multcap_mois_tolrnce_enable touch_multcap_mois_tolrnce_disable touch_mutlcap_cnfg_mois_threshold touch_mutlcap_cnfg_mois_mltchgrp touch_mutlcap_mois_tolrnce_quick_reburst_enable touch_mutlcap_mois_tolrnce_quick_reburst_disable touch_mutlcap_get_libinfo touch_library_get_version_info touch_resume_ptc touch_suspend_ptc
Self-capacitance	touch_selfcap_sensors_init touch_selfcap_sensor_config touch_selfcap_sensors_calibrate touch_selfcap_sensors_measure touch_selfcap_sensors_deinit touch_selfcap_lowpower_sensor_enable_event_measure	touch_selfcap_sensor_get_delta touch_selfcap_sensor_update_config touch_selfcap_sensor_get_config touch_selfcap_update_global_param touch_selfcap_get_global_param touch_selfcap_update_acq_config touch_selfcap_get_acq_config touch_selfcap_sensor_disable touch_selfcap_sensor_reenable touch_selfcap_mois_tolrnce_enable touch_selfcap_mois_tolrnce_disable touch_selfcap_cnfg_mois_threshold touch_selfcap_cnfg_mois_mltchgrp touch_selfcap_mois_tolrnce_quick_reburst_enable touch_selfcap_mois_tolrnce_quick_reburst_disable touch_selfcap_get_libinfo touch_library_get_version_info touch_suspend_ptc touch_resume_ptc

5.2. Library Parameters

The QTouch Library configuration parameters are listed in the following table:

Configuration	Mutual capacitance	Self-capacitance
Pin Configuration	DEF_MUTLCAP_NODES	DEF_SELFCAP_LINES
Sensor Configuration	DEF_MUTLCAP_NUM_CHANNELS DEF_MUTLCAP_NUM_SENSORS DEF_MUTLCAP_NUM_ROTORS_SLIDERS DEF_MUTLCAP_PTC_GPIO_STATE DEF_MUTLCAP_QUICK_REBURST_ENABLE	DEF_SELFCAP_NUM_CHANNELS DEF_SELFCAP_NUM_SENSORS DEF_SELFCAP_NUM_ROTORS_SLIDERS DEF_SELFCAP_PTC_GPIO_STATE DEF_SELFCAP_QUICK_REBURST_ENABLE
Sensor Individual Parameters	Detect Threshold Detect Hysteresis Position Resolution Position Hysteresis AKS group	Detect Threshold Detect Hysteresis Position Resolution AKS group
Sensor Global Parameters	DEF_MUTLCAP_DI DEF_MUTLCAP_TCH_DRIFT_RATE DEF_MUTLCAP_ATCH_DRIFT_RATE DEF_MUTLCAP_MAX_ON_DURATION DEF_MUTLCAP_DRIFT_HOLD_TIME DEF_MUTLCAP_ATCH_RECAL_DELAY DEF_MUTLCAP_ATCH_RECAL_THRESHOLD DEF_MUTLCAP_TOUCH_POSTPROCESS_MODE DEF_MUTLCAP_AKS_ENABLE DEF_MUTLCAP_CSD DEF_MUTLCAP_AUTO_OS_SIGNAL_STABILITY_LIMIT	DEF_SELFCAP_DI DEF_SELFCAP_TCH_DRIFT_RATE DEF_SELFCAP_ATCH_DRIFT_RATE DEF_SELFCAP_MAX_ON_DURATION DEF_SELFCAP_DRIFT_HOLD_TIME DEF_SELFCAP_ATCH_RECAL_DELAY DEF_SELFCAP_ATCH_RECAL_THRESHOLD DEF_SELFCAP_TOUCH_POSTPROCESS_MODE DEF_SELFCAP_AKS_ENABLE DEF_SELFCAP_CSD DEF_SELFCAP_AUTO_OS_SIGNAL_STABILITY_ LIMIT

Configuration	Mutual capacitance	Self-capacitance
Sensor Acquisition Parameters	DEF_MUTLCAP_FILTER_LEVEL_PER_NODE DEF_MUTLCAP_AUTO_OS_PER_NODE DEF_MUTLCAP_GAIN_PER_NODE DEF_MUTLCAP_FREQ_MODE DEF_MUTLCAP_HOP_FREQS DEF_MUTLCAP_CLK_PRESCALE_PER_NODE DEF_MUTLCAP_SENSE_RESISTOR_PER_NODE	DEF_SELFCAP_FILTER_LEVEL_PER_NODE DEF_SELFCAP_AUTO_OS_PER_NODE DEF_SELFCAP_GAIN_PER_NODE DEF_SELFCAP_FREQ_MODE DEF_SELFCAP_HOP_FREQS DEF_SELFCAP_CLK_PRESCALE_PER_NODE DEF_SELFCAP_SENSE_RESISTOR_PER_NODE
Sensor Calibration Auto Tune Setting	AUTO_TUNE_PRSC, AUTO_TUNE_RSEL, AUTO_TUNE_NONE	AUTO_TUNE_PRSC, AUTO_TUNE_RSEL, AUTO_TUNE_NONE
Sensor Noise measurement and Lockout Parameters	DEF_MUTLCAP_NOISE_MEAS_ENABLE DEF_MUTLCAP_NOISE_MEAS_SIGNAL_STABILITY_LIMIT DEF_MUTLCAP_NOISE_LIMIT DEF_MUTLCAP_NOISE_MEAS_BUFFER_CNT DEF_MUTLCAP_LOCKOUT_SEL DEF_MUTLCAP_LOCKOUT_CNTDOWN	DEF_SELFCAP_NOISE_MEAS_ENABLE DEF_SELFCAP_NOISE_MEAS_SIGNAL_STABILITY_LIMIT DEF_SELFCAP_NOISE_LIMIT DEF_SELFCAP_NOISE_MEAS_BUFFER_CNT DEF_SELFCAP_LOCKOUT_SEL DEF_SELFCAP_LOCKOUT_CNTDOWN
Sensor Acquisition Frequency Auto-tuning Parameters	DEF_MUTLCAP_FREQ_AUTO_TUNE_ENABLE DEF_MUTLCAP_FREQ_AUTO_TUNE_SIGNAL_STABILITY_LIMIT DEF_MUTLCAP_FREQ_AUTO_TUNE_IN_CNT	DEF_SELFCAP_FREQ_AUTO_TUNE_ENABLE DEF_SELFCAP_FREQ_AUTO_TUNE_SIGNAL_STABILITY_LIMIT DEF_SELFCAP_FREQ_AUTO_TUNE_IN_CNT
Common Parameters	DEF_TOUCH_MEASUREMENT_PERIOD_MS, DEF_TOUCH_PTC_ISR_LVL	
Low Power Paramaters	DEF_LOWPOWER_SENSOR_EVENT_PERIODICITY, DEF_LOWPOWER_SENSOR_DRIFT_PERIODICITY_MS, DEF_LOWPOWER_SENSOR_ID	
Moisture Parameters	DEF_MUTLCAP_MOIS_TOLERANCE_ENABLE DEF_MUTLCAP_NUM_MOIS_GROUPS DEF_MUTLCAP_MOIS_QUICK_REBURST_ENABLE	DEF_SELFCAP_MOIS_TOLERANCE_ENABLE DEF_SELFCAP_NUM_MOIS_GROUPS DEF_SELFCAP_MOIS_QUICK_REBURST_ENABLE

5.2.1. Pin, Channel, and Sensor Parameters

Mutual capacitance method uses a pair of sensing electrodes for each touch channel. These electrodes are denoted as X and Y lines. Capacitance measurement is performed sequentially in the order in which touch (X-Y) nodes are specified in the `DEF_MUTLCAP_NODES` configuration parameter. A mutual capacitance touch button sensor is formed using a single X-Y channel, while a touch rotor or slider sensor is formed using three to eight X-Y channels.

Mutual Capacitance Channel (X-Y Sense Node)

- SAM D20J and SAM D21J (64 pins): up to 256 touch channels, 16 X and 16 Y-lines
- SAM D20G and SAM D21G (48 pins): up to 120 touch channels, 12 X and 10 Y-lines
- SAM D20E and SAM D21E (32 pins): up to 60 touch channels, 10 X and 6 Y-lines
- SAM R21E(32 pins): up to 12 touch channels, 6 X and 2 Y-lines
- SAM R21G(48 pins) up to 48 touch channels, 8 X and 6 Y-lines
- SAM DA1J (64 pins): up to 256 touch channels, 16 X and 16 Y-lines
- SAM DA1G (48 pins): up to 120 touch channels, 12 X and 10 Y-lines
- SAM DA1E (32 pins): up to 60 touch channels, 10 X and 6 Y-lines
- SAM D21G17AU and SAM D21G18AU (45 pins): up to 132 touch channels, 12 X and 11 Y-lines
- SAM D21E15BU and SAM D21E16BU (35 pins): up to 60 touch channels, 10 X and 6 Y-lines

The following devices have X and Y multiplexing option.

- SAM D10C14A and SAM D11C14A (14 pins): up to 12 touch channels, 4 X and 3 Y-lines
- SAM D10D14 AS/AU and SAM D11D14 AS/AU (20 pins): up to 42 touch channels, 7 X and 6 Y-lines
- SAM D10D14AM and SAM D11D14AM (24 pins): up to 72 touch channels, 9 X and 8 Y-lines
- SAM L21E (32 pins): up to 42 touch channels, 7 X and 6 Y-lines
- SAM L21G (48 pins): up to 81 touch channels, 9 X and 9 Y-lines
- SAM L21J (64 pins): up to 169 touch channels, 13 X and 13 Y-lines

- SAM L22G (48 pins): up to 132 touch channels, 11 X and 12 Y-lines
- SAM L22J (64 pins): up to 182 touch channels, 13 X and 14 Y-lines
- SAM L22N (100 pins): up to 256 touch channels, 16 X and 16 Y-lines
- SAM C21E and SAM C20E(32 pins): up to 60 touch channels,10 X and 6 Y-lines
- SAM C21G and SAM C20G(48 pins): up to 120 touch channels,12 X and 10-Y lines
- SAM C21J and SAM C20J(64 pins): up to 256 touch channels,16 X and 16 Y-lines
- ATmega328PB (32 pins): up to 144 touch channels, 12 X and 12 Y-lines
- ATmega324PB (44 pins): up to 256 touch channels, 16 X and 16 Y-lines

A few pins can be used either as X-line or Y-line. The datasheets of individual devices provide more information about this multiplexing option.

Figure 5-3. Mutual Capacitance Sensor Arrangement

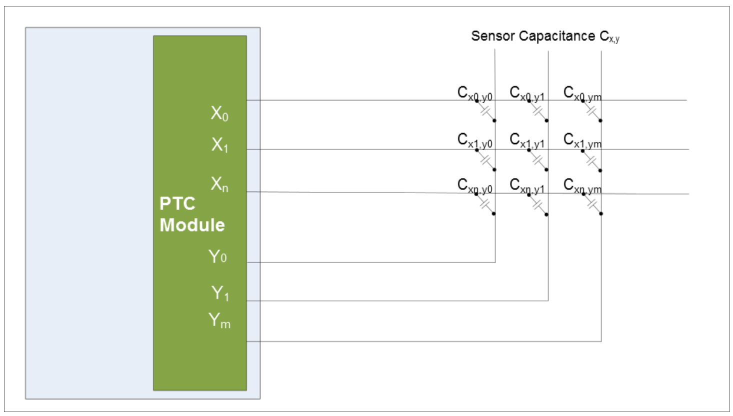
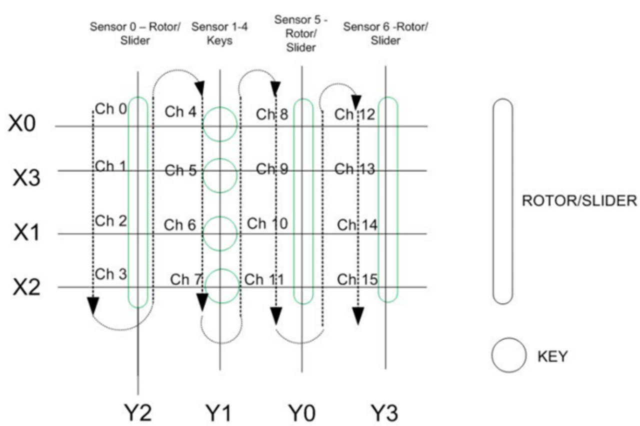


Figure 5-4. Mutual Capacitance - Channel to Sensor Mapping



X-Y node pair can be specified using the configuration parameter `DEF_MUTLCAP_NODES` in a non-sequential order. The channel numbering is done in the same order as the X-Y node pair specified in the configuration parameter `DEF_MUTLCAP_NODES`.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Mutual Cap Touch Channel Nodes	DEF_MUTLCAP_NODES	uint16_t array	None	1 X-Y node pair	256 X-Y nodepair	-
Mutual Cap Number of Channels	DEF_MUTLCAP_NUM_CHANNELS	uint16_t	None	1	256 X-Y nodepair	-
Mutual Cap Number of Sensors	DEF_MUTLCAP_NUM_SENSORS	uint16_t	None	1	256 X-Y nodepair	-
Mutual Cap Number of Rotors and Sliders	DEF_MUTLCAP_NUM_ROTORS_SLIDERS	uint8_t	None	0	85 node pair	-

Self-capacitance method uses a single sense electrode, denoted by a Y-line. Capacitance measurement is performed sequentially in the order in which Y-lines are specified in the DEF_SELFCAP_LINES configuration parameter. Self-capacitance touch button sensor is formed using a single - line channel, while a touch rotor or slider sensor can be formed using three Y-line channels.

Self-capacitance Channel (Y-sense line)

- SAM D20J and SAM D21J (64 pins): up to 16 channels
- SAM D20G and SAM D21G (48 pins): up to 10 channels
- SAM D20E and SAM D21E (32 pins): up to 6 channels
- SAM D10C14A and SAMD 11C14A (14 pins): up to 7 touch channels
- SAM D10D14 AS/AU and SAMD 11D14 AS/AU (20 pins): up to 13 touch channels
- SAM D10D14AM and SAMD 11D14AM (24 pins): up to 16 touch channels
- SAM L21E (32 pins): up to 7 touch channels
- SAM L21G (48 pins): up to 10 touch channels
- SAM L21J (64 pins): up to 16 touch channels
- SAMR21E (32 pins): up to 2 touch channels
- SAMR21G (48 pins): up to 6 touch channels
- SAM DA1J (64 pins): up to 16 channels
- SAM DA1G (48 pins): up to 10 channels
- SAM DA1E (32 pins): up to 6 channels
- SAM C21E and SAM C20E (32 pins): up to 16 touch channels
- SAM C21G and SAM C20G (48 pins): up to 22 touch channels
- SAM C21J and SAM C20J (64 pins): up to 32 touch channels
- SAM L22G (48 pins): up to 15 touch channels
- SAM L22J (64 pins): up to 19 touch channels
- SAM L22N (100 pins): up to 24 touch channels
- ATmega328PB (32 pins): up to 24 touch channels

- ATmega324PB (44 pins): up to 32 touch channels

Figure 5-5. Self-capacitance Sensor Arrangement

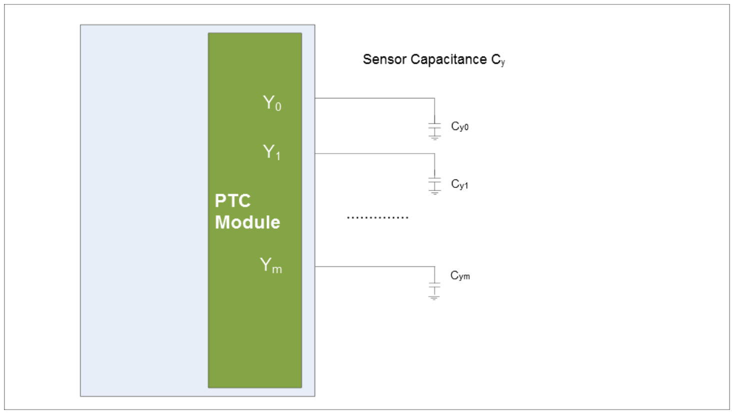
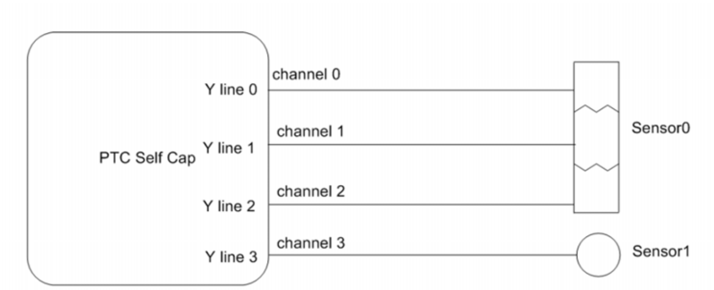


Figure 5-6. Self-capacitance Channel to Sensor Mapping



Y sense line can be specified using the configuration parameter `DEF_SELFCAP_LINES` in non-sequential order. The channel numbering is done in the same order as the Y sense line specified in the configuration parameter `DEF_SELFCAP_LINES`.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Self Cap touch channel nodes	`DEF_SELFCAP_NODES`	`uint16_t array`	None	1 Y-line	32 Y-line	-
Self Cap number of channels	`DEF_SELFCAP_NUM_CHANNELS`	`uint16_t`	None	1 Y-line	32 Y-line	-
Self Cap number of Sensors	`DEF_SELFCAP_NUM_SENSORS`	`uint16_t`	None	1 Y-line	32 Y-line	-
Self Cap number of Rotors and Sliders	`DEF_SELFCAP_NUM_ROTORS_SLIDERS`	`uint8_t`	None	0 Y-line	10 Y-line	-

The touch sensors must be enabled in the sequential order of the channels specified using the `touch_xx_sensor_config()` API. For improved EMC performance, a series resistor with value of 1 Kilo-ohm must be used on X and Y lines. For more information about designing the touch sensor, refer to Buttons, Sliders and Wheels Touch Sensor Design Guide available at www.atmel.com.

5.2.2. Sensor Individual Parameters

This section explains the settings that are specific to the individual sensor.

Detect Threshold

A sensor's detect threshold defines how much its signal must increase above its reference level to qualify as a potential touch detect. However, the final detection confirmation must satisfy the Detect Integrator (DI) limit. Larger threshold values desensitize sensors since the signal must change more (i.e. requires larger touch) to exceed the threshold level. Conversely, lower threshold levels make sensors more sensitive.

Threshold setting depends on the amount of signal swing when a sensor is touched. Usually, thicker front panels or smaller electrodes have smaller signal swing on touch, thus require lower threshold levels. Typically, detect threshold isset to 50% of touch delta. Desired touch delta for a buttons is ~30 to 80 counts and for wheels or sliders is ~50 to 120 counts.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Threshold	`detect_threshold`	`threshold_t`	Counts	3	255	20-50(For buttons) 30-80(For sliders and wheels

Detect Hysteresis

This setting is sensor detection hysteresis value. It is expressed as a percentage of the sensor detection threshold setting. Once a sensor goes into detect its threshold level is reduced (by the hysteresis value) in order to avoid the sensor dither in and out of detect if the signal level is close to original threshold level.

- Setting of 0 = 50% of detect threshold value (`HYST_50`)
- Setting of 1 = 25% of detect threshold value (`HYST_25`)
- Setting of 2 = 12.5% of detect threshold value (`HYST_12_5`)
- Setting of 3 = 6.25% of detect threshold value (`HYST_6_25`)

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Hysteresis	`detect_threshold`	`uint8_t` (2bits)	Enum	`HYST_6_25`	`HYST_50`	`HYST_6_25`

Position Resolution

The rotor or slider needs the position resolution (angle resolution in case of rotor and linear resolution in case of slider)to be set. Resolution is the number of bits needed to report the position of rotor or slider. It can have values from 2 bits to 8 bits.

Setting	Configuration Name	Data Type	Unit	Min	Reported Position	Max	Reported Position	Typical
Position Resolution	`position_resolution`	`uint8_t` (3bits)	None	2bits	0-3	8bits	0-255	8

Position Hysteresis

In case of Mutual Cap, the rotor or slider needs the position hysteresis (angle hysteresis in case of rotor and linear hysteresis in case of slider) to be set. It is the number of positions the user has to move back, before touch position is reported when the direction of scrolling is changed and during the first scrolling after user press.

Hysteresis can range from 0 (1 position) to 7 (8 positions). The hysteresis is carried out at 8 bits resolution internally and scaled to desired resolution; therefore at resolutions lower than 8 bits there might be a difference of 1 reported position from the hysteresis setting, depending on where the touch is detected. At lower resolutions, where skipping of the reported positions is observed, hysteresis can be set to 0 (1 position). At Higher resolutions (6 to 8bits), it would be recommended to have a hysteresis of at least 2 positions or more.

Note: It is not valid to have a hysteresis value more than the available bit positions in the resolution. For instance, a hysteresis value of 5 positions with a resolution of 2 bits (4 positions) is invalid. Position hysteresis is invalid (unused) in case of self-capacitance method sensors.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Position Hysteresis	`position_hysteresis`	`uint8_t` (3bits)	-	0	7	8

Adjacent Key Suppression (AKS®)

In designs where the sensors are close together or configured for high sensitivity, multiple sensors might report a detect simultaneously. To allow applications to determine the intended single touch, the touch library provides the user the ability to configure a certain number of sensors in an AKS group.

When a group of sensors are in the same AKS group, only the first strongest sensor will report detection. The sensor reporting detection will continue to report detection even if another sensor's delta becomes stronger. The sensor stays indetect until its delta falls lower than its detection threshold. If any more sensors in the AKS group are still in detect onlythe strongest will report detection. At a given time point, only one sensor from each AKS group is reported to be indetect.

AKS feature can be enabled or disabled using a macro `DEF_XXXXCAP_AKS_ENABLE`

- 1u = AKS grouping functionality is enabled
- 0u = AKS grouping functionality is disabled

The library provides the ability to configure a sensor to belong to one of the Adjacent Key Suppression Groups (AKS Group).

5.2.3. Sensor Global Parameters

This section explains the settings that are common all sensors. For instance, if recalibration threshold (one of the global settings) of mutual cap sensors is set as `RECAL_100`, all mutual capacitance sensors will be configured for a recalibration threshold of 100%.These sensor global parameter settings can be independently set to self-capacitance and mutual capacitance sensors.

Detect Integration

The QTouch Library features a detect integration mechanism, which confirm detection in a robust environment. The detect integrator (DI) acts as a simple signal filter to suppress false detections caused by spurious events such as electrical noise.

A counter is incremented each time the sensor delta has exceeded its threshold and stayed there for a specific numberof acquisitions, without going below the threshold levels. When this counter reaches a preset limit (the DI value) the sensor is finally declared to be touched. If on any acquisition the delta is below the threshold level, the counter is cleared and the process has to start from the beginning. The DI process is applicable to a 'release' (going out of detect) event as well.

For example, if the DI value is 10, the device has to exceed its threshold and stay there for (10 + 2) successive acquisitions without going below the threshold level, before the sensor is declared to be touched.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
DI	`DEF_MUTLCAP_DI`, `DEF_SELFCAP_DI`	`uint8_t`	Cycles	0	255	4

Max-ON Duration

If an object unintentionally contacts a sensor resulting in a touch detection for a prolonged interval it is usually desirable to recalibrate the sensor in order to restore its function, after a time delay of a few seconds.

The Maximum ON duration timer monitors such detections; if detection exceeds the timer's settings, the sensor is automatically recalibrated. After a recalibration has taken place, the affected sensor once again functions normally even if it still in contact with the foreign object.

Max-ON duration can be disabled by setting it to zero (infinite timeout) in which case the channel never recalibrates during a continuous detection (but the host could still command it).

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Maximum ON Duration	`DEF_MUTLCAP_MAX_ON_DURATION`, `DEF_SELFCAP_MAX_ON_DURATION`	`uint8_t`	200ms	0	255	30(6s)

Away from Touch and Towards Touch Drift Rate

Drift in a general sense means adjusting reference level (of a sensor) to allow compensation for temperature (or other factor) effect on physical sensor characteristics. Decreasing reference level for such compensation is called Negative drift & increasing reference level is called Positive drift. Specifically, the drift compensation should be set to compensate faster for increasing signals than for decreasing signals.

Signals can drift because of changes in physical sensor characteristics over time and temperature. It is crucial that such drift be compensated for; otherwise false detections and sensitivity shifts can occur.

Drift compensation occurs only while there is no detection in effect. Once a finger is sensed, the drift compensation mechanism ceases since the signal is legitimately detecting an object. Drift compensation works only when the signal inquestion has not crossed the 'Detect threshold' level.

The drift compensation mechanism can be asymmetric. It can be made to occur in one direction faster than it does in the other simply by changing the appropriate setup parameters.

Signal values of a sensor tend to increase when an object (touch) is approaching it or a characteristic change of sensor over time and temperature. Increasing signals should not be compensated quickly, as an approaching finger could be compensated for partially or entirely before even touching the channel (towards touch drift).

However, an object over the channel which does not cause detection, and for which the sensor has already made full allowance (over some period of time), could suddenly be removed leaving the sensor with an artificially suppressed reference level and thus become insensitive to touch. In the latter case, the sensor should compensate for the object's removal by raising the reference level relatively quickly (away from touch drift).

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Towards touch Drift	`DEF_MUTLCAP_TCH_DRIFT_RATE`, `DEF_SELFCAP_TCH_DRIFT_RATE`	`uint8_t`	200ms	0	127	20(4s)
Away from touch Drift	`DEF_MUTLCAP_ATCH_DRIFT_RATE`, `DEF_SELFCAP_ATCH_DRIFT_RATE`	`uint8_t`	200ms	0	127	5(1s)

Drift Hold Time

Drift Hold Time (DHT) is used to restrict drift on all sensors while one or more sensors are activated. It defines the length of time the drift is halted after a key detection.This feature is useful in cases of high density keypads where touching a key or floating a finger over the keypad would cause untouched keys to drift, and therefore create a sensitivity shift, and ultimately inhibit any touch detection.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Drift Hold Time	`DEF_MUTLCAP_DRIFT_HOLD_TIME`, `DEF_SELFCAP_DRIFT_HOLD_TIME`	`uint8_t`	200ms	0	255	20(4s)

Away From Touch Recalibration Threshold

Recalibration threshold is the level beyond which automatic recalibration occurs. Recalibration threshold is expressed as a percentage of the detection threshold setting.

This setting is an enumerated value and its settings are as follows:

- Setting of 0 = 100% of detect threshold (`RECAL_100`)
- Setting of 1 = 50% of detect threshold (`RECAL_50`)
- Setting of 2 = 25% of detect threshold (`RECAL_25`)
- Setting of 3 = 12.5% of detect threshold (`RECAL_12_5`)
- Setting of 4 = 6.25% of detect threshold (`RECAL_6_25`)

However, an absolute value of 4 is the hard limit for this setting. For example, if the detection threshold is, 40 and the Recalibration threshold value is set to 4.

Although this implies an absolute value of 2 (40 * 6.25% = 2.5), it is hard limited to 4.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Recalibration threshold	`DEF_MUTLCAP_ATCH_RECAL_THRESHOLD`, `DEF_SELFCAP_ATCH_RECAL_THRESHOLD`	`uint8_t`	Enum	`RECAL_6_25`	Detect threshold	`RECAL_100`

Away From Touch Recalibration Delay

If any key is found to have a significant negative delta, it is deemed to be an error condition. If this condition persists for more than the away from touch recalibration delay, i.e., `qt_pos_recal_delay period`, then an automatic recalibration is carried out.

A counter is incremented each time the sensor delta is equal to the away from touch recalibration threshold and stayed there for a specific number of acquisitions. When this counter reaches a preset limit (the PRD value) the sensor is finally recalibrated. If on any acquisition the delta is seen to be greater than the away from touch recalibration threshold level, the counter is cleared and the away from touch drifting is performed.

For example, if the away from touch recalibration delay setting is 10, then the delta has to drop below the recalibration threshold and stay there for 10 acquisitions in succession without going below the threshold level, before the sensor is declared to be recalibrated. Away from touch recalibration can be disabled with a setting of 0.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Away from touch Recalibration Delay	`DEF_MUTLCAP_ATCH_RECAL_DELAY`, `DEF_SELFCAP_ATCH_RECAL_DELAY`	`uint8_t`	Cycles	0	255	10

Sensor Post-Processing Mode

When `TOUCH_LIBRARY_DRIVEN` mode is selected, the library self-initiates repeated touch measurements to resolve touch press, release and calibration. This mode is suited for best response time.

When `TOUCH_APPLN_DRIVEN` mode is selected, the library does not initiate repeated touch measurement to resolve touch press, release and calibration. This mode suits deterministic PTC interrupt execution time for applications requiring stringent CPU time requirements. As repeated touch measurements are delayed due to other critical application code being executed. This mode can potentially affect the touch response time.

In order to improve the touch response time with the `TOUCH_APPLN_DRIVEN` mode, the `touch_xxxcap_sensors_measure` API call should be modified as below to initiate touch measurements periodically or when the burst again acquisition status flag has been set.

```
if ((touch_time.time_to_measure_touch == 1u) ||(p_mutlcap_measure_data->acq_status &
TOUCH_BURST_AGAIN)
                    {
                        /* Start a touch sensors measurement process. */
                        touch_ret =
touch_mutlcap_sensors_measure(touch_time.current_time_ms,NORMAL_ACQ_MODE,touch_mutlcap_measure
```

```
_complete_callback);
                 }
```

Setting	Configuration Name	Data Type	Options	Typical
Sensor post-processing mode	`DEF_MUTLCAP_TOUCH_POSTPROCESS_MODE`, `DEF_SELFCAP_TOUCH_POSTPROCESS_MODE`	`uint16_t`	`TOUCH_LIBRARY_DRIVEN`, `TOUCH_APPLN_DRIVEN`	`TOUCH_LIBRARY_DRIVEN`

Charge Share Delay

Charge share delay indicates the number of additional charge cycles that are inserted within a capacitance measurement cycle to ensure that the touch sensor is fully charged. The CSD value is dependent on the sensor capacitance along with the series resistor on the Y line.
Note: Any increase in the charge share delay also increases the measurement time for a specific configuration.

When manual tuning is performed, the CSD value for the sensor with largest combination of capacitance along with series resistance should be considered.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
CSD (Charge Share Delay)	`DEF_MUTL_CAP_CSD_VALUE`, `DEF_SELF_CAP_CSD_VALUE`	`uint8_t`	PTC cycles	0	250	0

How to tune the CSD setting manually?

1. Initially, use an arbitrarily large value such as 64 and note the signal value. A large value ensures that the charge time is enough for full charge transfer
2. Reduce the CSD and verify the signal value drop, until signal is approximately 97-98% of the value used initially. This ensures a good charge transfer without any major loss in the signal.
3. Continue the same procedure [Step 1 and 2] for all the sensors available in the system. Use the largest value of the CSD used in the system for the global setting.

Note: For the same CSD setting, Mutual capacitance has a lower burst time than self-capacitance. A unit increase in mutual capacitance CSD consumes around 12 PTC cycles. Whereas for the self-capacitance an increase in CSD consumes approximately twice the mutual capacitance CSD time with the same setting.

Auto-OS Signal Stability Limit

The parameter `DEF_XXXXCAP_AUTO_OS_SIGNAL_STABILITY_LIMIT` defines the stability limit of the signals for performing over-samples. Stability limit is the variance in sensor signal value under noisy environment. A high level of stability limit is set to auto trigger oversamples on large noise presence. It is recommended to keep this setting close to the lowest sensor detect threshold of the system and tune it further based on the noise.

Range: 1 to 1000

5.2.4. Sensor Acquisition Parameters

Filter Level

The filter level setting controls the number of samples taken to resolve each acquisition. A higher filter level setting provides improved signal to noise ratio under noisy conditions, while increasing the total time for measurement resulting in increased power consumption and response time. This setting is available on per channel basis, allowing easy tuning.

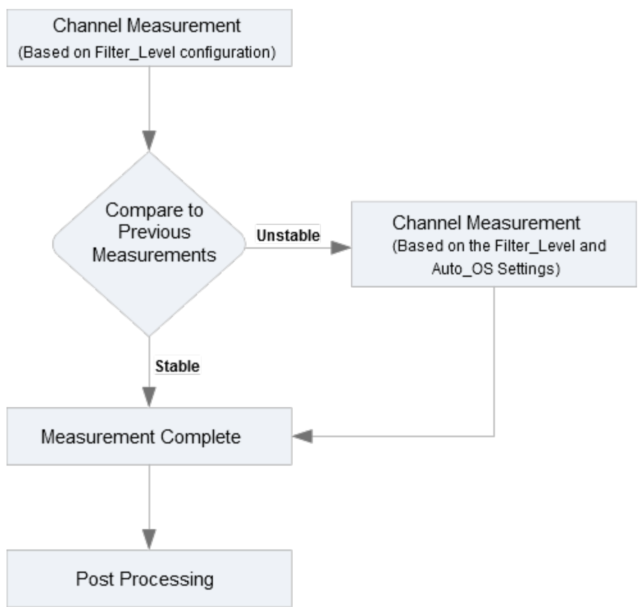
Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Filter level	`DEF_MUTLCAP_FILTER_LEVEL_PER_NODE`, `DEF_SELFCAP_FILTER_LEVEL_PER_NODE`	`filter_level_t`	Number of samples	1	64	16

Auto Oversamples

Auto oversample controls the automatic oversampling of sensor channels when unstable signals are detected with the default setting of 'Filter level'. Enabling Auto oversample results in 'Filter level' x 'Auto Oversample' number of samples taken on the corresponding sensor channel when an unstable signal is observed. In a case where 'Filter level' is set to `FILTER_LEVEL_4` and 'Auto Oversample' is set to `AUTO_OS_4`, 4 oversamples are taken with stable signal values and 16 oversamples are taken when unstable signal is detected. This setting is available on per channel basis, allowing easy tuning.

A higher filter level setting provides improved signal to noise ratio under noisy conditions, while increasing the total time for measurement resulting in increased power consumption and response time.

Figure 5-7. Auto oversamples



Auto oversamples can be disabled to obtain best power consumption.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Auto Oversamples	`DEF_MUTLCAP_AUTO_OS_PER_NODE`, `DEF_SELFCAP_AUTO_OS_PER_NODE`	`auto_os_t`	`Sample multiplier`	2	128	`AUTO_OS_NONE`

Gain Setting

Gain setting is applied on a per-channel basis to allow a scaling-up of the touch delta upon contact. Gain setting depends on the sensor design and touch panel thickness.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Gain	`DEF_MUTLCAP_GAIN_PER_NODE`, `DEF_SELFCAP_GAIN_PER_NODE`	`gain_t`	Gain multiplier	1	32	1 (For self-capacitance) 4 (For mutual capacitance)

The figure shows the expected signal value for a given combination of gain setting and filter level setting. The values provided are only indicative and the actual sensor signal values might be close to the suggested levels.

Figure 5-8. Average Settling Signal Value for FILTER LEVEL and GAIN Combination

S_Gain = Software Gain [Digital Gain] and H_Gain = Hardware Gain [Analog gain]						
Average settling Signal value for FILTER LEVEL and GAIN combination	GAIN_1	GAIN_2	GAIN_4	GAIN_8	GAIN_16	GAIN_32
FILTER_LEVEL_1	512 S_Gain = 0 H_Gain = 0	512 S_Gain = 0 H_Gain = 1	512 S_Gain = 0 H_Gain = 2	512 S_Gain = 0 H_Gain = 3	512 S_Gain = 0 H_Gain = 4	512 S_Gain = 0 H_Gain = 5
FILTER_LEVEL_2	512 S_Gain = 0 H_Gain = 0	1024 S_Gain = 1 H_Gain = 0	1024 S_Gain = 1 H_Gain = 1	1024 S_Gain = 1 H_Gain = 2	1024 S_Gain = 1 H_Gain = 3	1024 S_Gain = 1 H_Gain = 4
FILTER_LEVEL_4	512 S_Gain = 0 H_Gain = 0	1024 S_Gain = 1 H_Gain = 0	2048 S_Gain = 2 H_Gain = 0	2048 S_Gain = 2 H_Gain = 1	2048 S_Gain = 2 H_Gain = 2	2048 S_Gain = 2 H_Gain = 3
FILTER_LEVEL_8	512 S_Gain = 0 H_Gain = 0	1024 S_Gain = 1 H_Gain = 0	2048 S_Gain = 2 H_Gain = 0	4096 S_Gain = 3 H_Gain = 0	4096 S_Gain = 3 H_Gain = 1	4096 S_Gain = 3 H_Gain = 2
FILTER_LEVEL_16	512 S_Gain = 0 H_Gain = 0	1024 S_Gain =1 H_Gain = 0	2048 S_Gain =2 H_Gain = 0	4096 S_Gain =3 H_Gain = 0	8192 S_Gain = 4 H_Gain = 0	8192 S_Gain = 4 H_Gain = 1
FILTER_LEVEL_32	512 S_Gain = 0 H_Gain = 0	1024 S_Gain=1 H_Gain = 0	2048 S_Gain =2 H_Gain = 0	4096 S_Gain =3 H_Gain = 0	8192 S_Gain = 4 H_Gain = 0	16384 S_Gain = 5 H_Gain = 0
FILTER_LEVEL_64	512 S_Gain = 0 H_Gain = 0	1024 S_Gain=1 H_Gain = 0	2048 S_Gain = 2 H_Gain = 0	4096 S_Gain =3 H_Gain = 0	8192 S_Gain = 4 H_Gain = 0	16384 S_Gain = 5 H_Gain = 0
RECOMMENDATIONS	EXCELLENT			GOOD	POOR	

Prescalar Setting

The prescaler parameter denotes the clock divider for the particular channel. It can be set on per channel basis and is independent to each sensor node/channel. This parameter is auto tuned based on the auto tune settings. Tuning this parameter allows for improved noise performance.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Prescalar	`DEF_MUTLCAP_CLK_PRESCALE_PER_NODE,` `DEF_SELFCAP_CLK_PRESCALE_PER_NODE`	`prsc_div_sel_t`	`PRSC_DIV_SEL_1, PRSC_DIV_SEL_2, PRSC_DIV_SEL_4, PRSC_DIV_SEL_8`	`PRSC_DIV_SEL_1`	`PRSC_DIV_SEL_8`	`PRSC_DIV_SEL_1`

Series Resistor Setting

The series resistor denotes the resistor used on the particular channel for the acquisition. The value is tunable and allows both auto and manual tuning options. Tuning this parameter allows for improved noise performance.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Series Resistor	`DEF_MUTLCAP_SENSE_RESISTOR_PER_NODE` `DEF_SELFCAP_SENSE_RESISTOR_PER_NODE`	`rsel_val_t`	`RSEL_VAL_0, RSEL_VAL_20, RSEL_VAL_50, RSEL_VAL_100`	`RSEL_VAL_0`	`RSEL_VAL_100`	`RSEL_VAL_100`

Boot Prescalar Setting

The boot prescaler parameter denotes the clock divider for the particular channel. It can be set on per channel basis and is independent to each sensor node/channel. This setting is used for calibrating the sensors after a power-on. This parameter must be configured as the auto tune is not available.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Boot Prescalar	DEF_MUTLCAP_CC_CAL_CLK_PRESCALE_PER_NODE, DEF_SELFCAP_CC_CAL_CLK_PRESCALE_PER_NODE	prsc_div_sel_t	PRSC_DIV_SEL_1, PRSC_DIV_SEL_2, PRSC_DIV_SEL_4, PRSC_DIV_SEL_8	PRSC_DIV_SEL_1	PRSC_DIV_SEL_8	PRSC_DIV_SEL_1

Boot Series Resistor Setting

The boot series resistor denotes the resistor used on the particular channel on device power-on calibration. This parameter must be configured as the auto tune is not available.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Boot Series Resistor	DEF_MUTLCAP_CC_CAL_SENSE_RESISTOR_PER_NODE DEF_SELFCAP_CC_CAL_SENSE_RESISTOR_PER_NODE	rsel_val_t	RSEL_VAL_0, RSEL_VAL_20, RSEL_VAL_50, RSEL_VAL_100	RSEL_VAL_0	RSEL_VAL_100	RSEL_VAL_100

Frequency Mode

Frequency mode setting allows users to tune the PTC touch acquisition frequency characteristics to counter environment noise.

FREQ_MODE_HOP

When frequency mode hopping option is selected, the PTC runs a frequency hopping cycle with subsequent measurements done using the three PTC acquisition frequency delay settings as specified in `DEF_SELFCAP_HOP_FREQS`. In this case, an additional software median filter is applied to the measured signal values.

FREQ_MODE_SPREAD

When frequency mode spread spectrum option is selected, the PTC runs with spread spectrum enabled for jittered delay based acquisition.

FREQ_MODE_SPREAD_MEDIAN

When frequency mode spread spectrum median option is selected, the PTC runs with spread spectrum enabled. In this case, an additional software median filter is applied to the measured signal values.

FREQ_MODE_NONE

When frequency mode none option is selected, the PTC runs at constant speed. This mode is suited for best power consumption.

Setting	Configuration Name	Data Type	Options	Min	Max	Typical
Frequency mode	DEF_MUTLCAP_FREQ_MODE , DEF_SELFCAP_FREQ_MODE	freq_mode_sel_t	FREQ_MODE_NONE, FREQ_MODE_HOP, FREQ_MODE_SPREAD, FREQ_MODE_SPREAD_MEDIAN	FREQ_MODE_NONE	FREQ_MODE_SPREAD_MEDIAN	FREQ_MODE_NONE

Frequency Hop Delay

The frequency hop delay setting is used when the Frequency mode is set to `FREQ_MODE_HOP`. A set of three frequency hop delay settings should be specified. This delay setting inserts n PTC clock cycles between consecutive measurements on a given sensor, thereby changing the PTC acquisition frequency. `FREQ_HOP_SEL_1` setting inserts 0 PTC clock cycle between consecutive measurements. `FREQ_HOP_SEL_16` setting inserts 15 PTC clock cycles. Hence, higher delay setting will increase the total time taken for capacitance measurement on a given sensor as compared to a lower delay setting. A desired setting can be used to avoid noise around the same frequency as the acquisition frequency.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Frequency hop delay	DEF_MUTLCAP_HOP_FREQS, DEF_SELFCAP_HOP_FREQS	freq_hop_sel_t	nPTC_clock_cycles	FREQ_HOP_SEL_1	FREQ_HOP_SEL_16	FREQ_HOP_SEL_1, FREQ_HOP_SEL_2, FREQ_HOP_SEL_3

5.2.5. Sensor Calibration Auto Tune Setting

Auto tune parameter setting is passed to the `touch_xx_sensors_calibrate` API in order to allow users to tune the PTC module for power consumption or noise performance.

AUTO_TUNE_PRSC

When Auto tuning of pre-scaler is selected, the PTC uses the user defined internal series resistor setting (`DEF_XXXXCAP_SENSE_RESISTOR_PER_NODE`) and the pre-scaler is adjusted to slow down the PTC operation to ensure full charge transfer. Auto tuning of pre-scaler with `RSEL_VAL_100` as the series resistor results in least power consumption while resulting in increased power consumption and touch response time.

AUTO_TUNE_RSEL

When Auto tuning of the series resistor is selected, the PTC runs at user defined pre-scaler setting speed (`DEF_XXXXCAP_CLK_PRESCALE_PER_NODE`) and the internal series resistor is tuned automatically to the optimum value to allow for full charge transfer. Auto tuning of series resistor with `PRSC_DIV_SEL_1` as the PTC pre-scale results in best case power consumption.

AUTO_TUNE_NONE

When manual tuning option is selected, the user defined values of PTC pre-scaler and series resistor is used for PTC operation as given in `DEF_XXXXCAP_CLK_PRESCALE_PER_NODE` and `DEF_XXXXCAP_SENSE_RESISTOR_PER_NODE`

Setting	Configuration Name	Data Type	Unit	Values	Typical
Auto tune	Provided to `touch_xxcap_sensors_calibrate` API input	auto_tune_type_t	None	AUTO_TUNE_NONE, AUTO_TUNE_PRSC,AUTO_TUNE_RSEL	AUTO_TUNE_NONE

5.2.6. Sensor Noise Measurement and Lockout Parameters

Noise is measured on a per-channel basis after each channel acquisition, using historical data on a rolling window of successive measurements. Reported noise to exclude the instance of an applied or removed touch contact, but the noise indication must react sufficiently fast that false touch detection before noise lockout is prevented.

Signal change from sample to sample during the window buffer is compared to the stability limit. Noise is reported only when two changes occur within the window period and both of which exceed the `DEF_XXXXCAP_NOISE_MEAS_SIGNAL_STABILITY_LIMIT` limit.

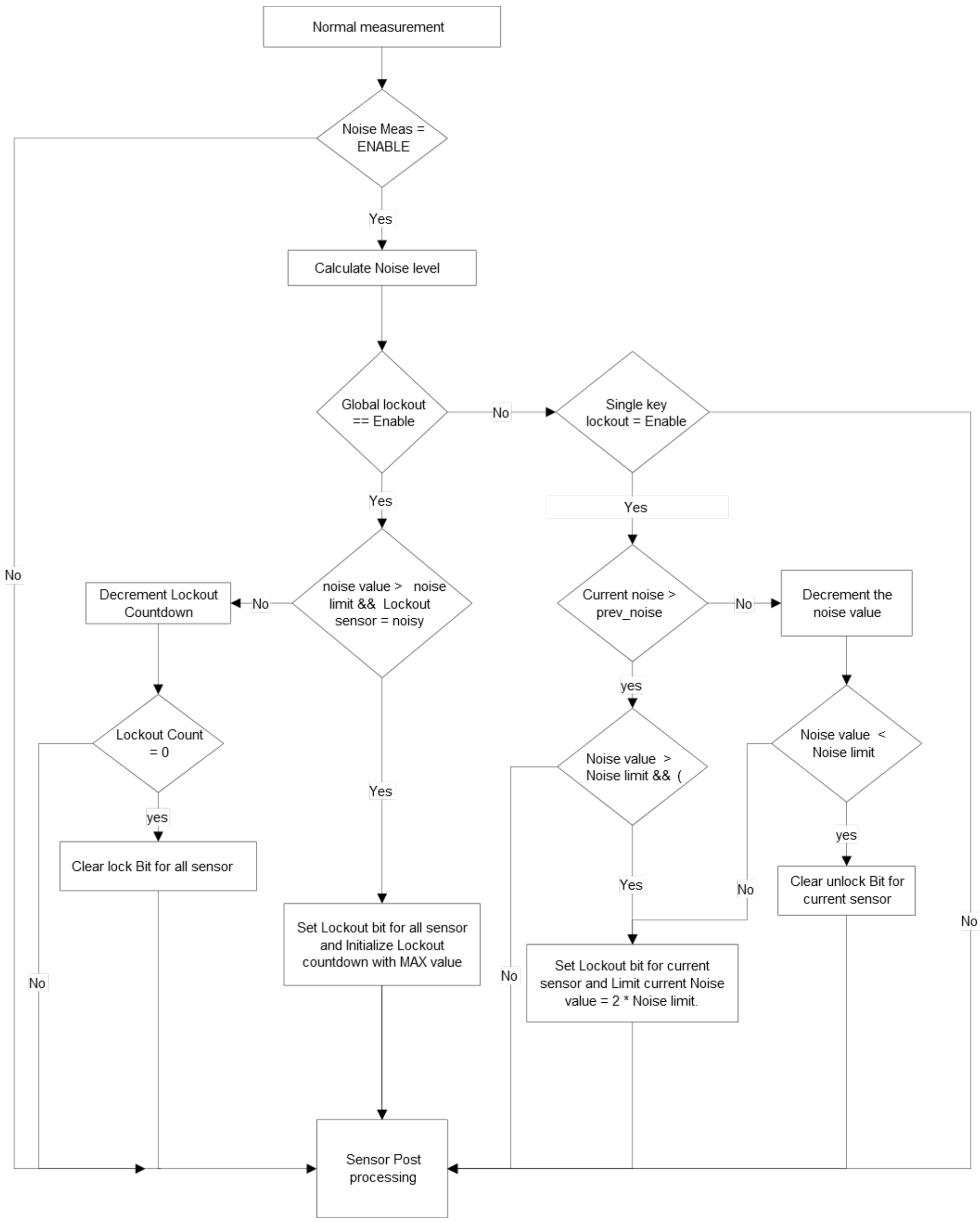
Noise is calculated using the following algorithm:

```
 if (swing count > 2)
   {
    Nk = ((|Sn - Sn-1| > DEF_XXXXCAP_NOISE_MEAS_SIGNAL_STABILITY))?(0):(|Sn-Sn-1|-
DEF_XXXXCAP_NOISE_MEAS_SIGNAL_STABILITY))
   }
 else
   {
    Nk = 0
   }
```

The swing count is number of signal changes that exceed `DEF_MUTLCAP_NOISE_MEAS_SIGNAL_STABILITY_LIMIT` limit during buffer window period.

When the measured noise exceeds `DEF_MUTLCAP_NOISE_LIMIT`, the touch library locks out sensors, reports no touch detection and drifting is stopped. Noise measurement is provided for all the channels. Each byte in `p_xxxxcap_measure_data-> p_nm_ch_noise_val` provides the noise level associated with that channel. Noise indication is provided for all the sensors configured by the application. A bit is available in `p_xxxxcap_measure_data-> p_sensor_noise_status` for each sensor to determine whether the sensor is noisy or not. The following code snippet provides the sample code to read the noise status of a particular sensor.

Figure 5-9. Noise Calculation



Noise Measurement Signal Stability Limit

The parameter DEF_XXXXAP_NOISE_MEAS_SIGNAL_STABILITY_LIMIT is the variance in sensor signal value under noisy environment. Any noise level over and above the noise signal stability limit contributes to the Noise limit.

It is recommended to keep this setting close to the lowest sensor detect threshold of the system and tune it further based on the noise.

Signal values can change from sample to sample during a window buffer period. The difference between adjacent buffer value is compared to the user configured stability limit.

Noise is reported only when two changes occur within the specified window period and only if both of which exceed the stability limit.

Range: 1 to 1000

Noise Limit

The DEF_XXXXCAP_NOISE_LIMIT specifies the limit to the total noise accumulated over the noise buffer count. If the accumulated noise exceeds the noise limit, then lockout is triggered. There are two purposes for this parameter:

- If the noise level calculated during a running window exceeds DEF_XXXXCAP_NOISE_LIMIT, then the corresponding sensor are declared noisy and sensor global noisy bit is set as '1'.
- If the noise level calculated during a running window exceeds DEF_XXXXCAP_NOISE_LIMIT, then system triggers the sensor lockout functionality.

  Range: 1 to 255

Noise Measurement Buffer Count

The DEF_XXXXCAP_NOISE_MEAS_BUFFER_CNT parameter is used to select the buffer count for noise measurement buffer.

Range: 3 to 10 (If N number of samples differences have to be checked, define this parameter as "N + 1") If N = 4 then set DEF_XXXXCAP_NOISE_MEAS_BUFFER_CNT as 5u.

Sensor Lockout Selection

This feature locks out the sensors when the measured noise exceeds DEF_XXXXCAP_NOISE_LIMIT and does not report a touch. This prevents post-processing. So, the high level of noise cannot cause the channel to report false touch drift or recalibrate incorrectly.

The DEF_XXXXCAP_LOCKOUT_SEL parameter is used to select the lockout functionality method.

- If DEF_XXXXCAP_LOCKOUT_SEL is set to SINGLE_SENSOR_LOCKOUT and a sensor's noise level is greater than DEF_XXXXCAP_NOISE_LIMIT, then corresponding sensor is locked out from touch detection and drifting is disabled.
- If DEF_XXXXCAP_LOCKOUT_SEL is set to GLOBAL_SENSOR_LOCKOUT and any sensor's noise level is greater than DEF_XXXXCAP_NOISE_LIMIT, then all sensors are locked out from touch detection and drifting is disabled.
- If DEF_XXXXCAP_LOCKOUT_SEL is set to NO_LOCKOUT, then lockout feature is disabled.

Note: Global sensors noisy bit will be available for SINGLE_SENSOR_LOCKOUT and GLOBAL_SENSOR_LOCKOUT. Global sensors noisy bit will not be available for NO_LOCK_OUT.

Range: 0 to 2

Sensor Lockout Countdown

If the sensor signal moves from noisy to a good condition and stays there for a `DEF_XXXXCAP_LOCKOUT_CNTDOWN` number of measurements, the sensor is unlocked and sensors are ready for touch detection and drifting is enabled.

Note: This parameter is valid only for global lockout.

Range: 1 to 255

5.2.7. Sensor Acquisition Frequency Auto Tuning Parameters

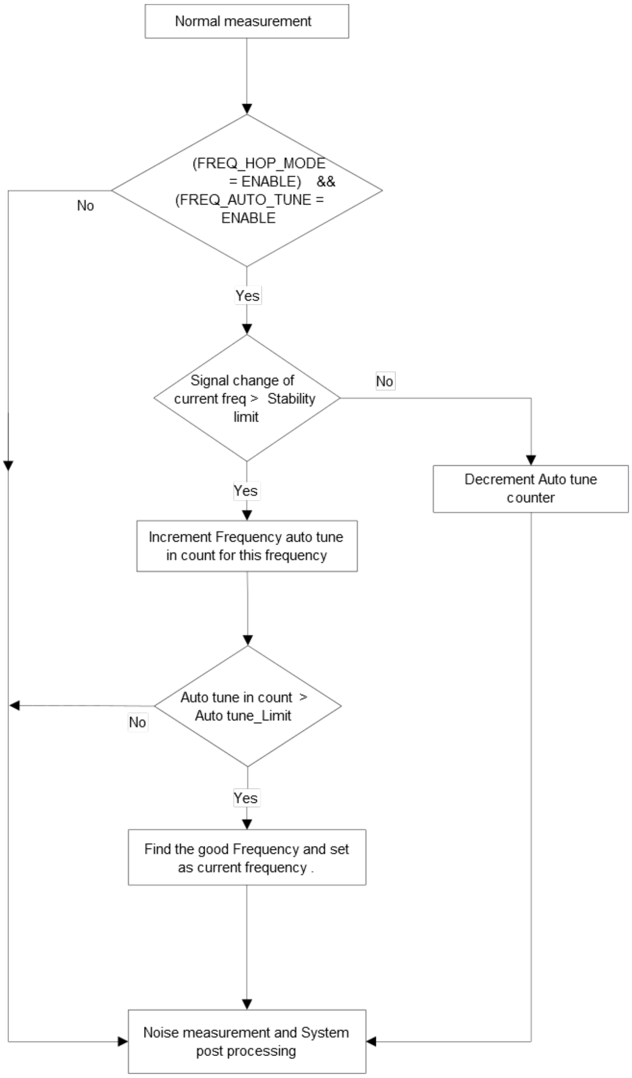
The Frequency Auto Tune feature provides the best quality of signal data for touch detection by automatically selecting acquisition frequencies showing the best SNR in `FREQ_MODE_HOP` mode. During each measurement cycle, the signal change since the last acquisition at the same frequency is recorded for each sensor. After the cycle, when all sensors have been measured at the present acquisition frequency, the largest signal variation of all sensors is stored as the variance for that frequency stage.

The variance for each frequency stage is compared to the `DEF_XXXXCAP_FREQ_AUTO_SIGNAL_STABILITY_LIMIT` limit, and if the limit is exceeded, a per-stage counter is incremented. If the measured variance is lower than the limit, the counter is decremented, if it has not been set as zero. If all frequencies display noise exceeding the stability limit, only the counter for the specific frequency stage with the highest variance is incremented after its cycle.

When a frequency counter reaches the `DEF_XXXXCAP_FREQ_AUTO_TUNE_IN_CNT` (auto-tune count in variable), that frequency stage is selected for auto-tuning. A new frequency selection is applied and the counters and variances for all frequencies are reset. After a frequency has been selected for auto-tuning, the count-in for that frequency stage is set to half the original count-in and the process is repeated until either all frequencies have been measured or a frequency is selected which does not re-trigger auto-tuning is determined.

If all frequencies have been tested, and the variation exceeds the `DEF_XXXXCAP_FREQ_AUTO_SIGNAL_STABILITY_LIMIT` limit then the frequency with the lowest variance is selected for the frequency stage currently under tuning. The auto-tune process is re-initialized and further tuning does not take place until a frequency stage's high variance counter again reaches the count in limit.

Figure 5-10. Frequency Auto Tune



Frequency Auto Tune Signal Stability

The DEF_XXXXCAP_FREQ_AUTO_SIGNAL_STABILITY_LIMIT is the variance in sensor signal value under noisy environment. A signal stability limit level is set to auto tune acquisition frequency on noise presence. It is recommended to keep this setting close to the lowest sensor detect threshold of the system and tune it further based on the noise.

Range: 1 to 1000

Frequency Auto Tune in Counter

The DEF_XXXXCAP_FREQ_AUTO_TUNE_IN_CNT parameter is used to trigger the frequency auto tune.If sensor signal change at each frequency exceeds the value specified as DEF_XXXXCAP_FREQ_AUTO_SIGNAL_STABILITY_LIMIT for DEF_XXXXCAP_FREQ_AUTO_TUNE_IN_CNT, then frequency auto tune will be triggered at this frequency.

Range: 1 to 255

Note: The Frequency Auto Tune feature and related parameters are available only in FREQ_MODE_HOP mode.

5.2.8. Quick Re-burst Parameter

Quick Reburst

This macro is used to enable or disable quick re-burst feature. When Quick re-burst is enabled, upon user touch and release, only that touched sensor or channel is subsequently measured to resolve detect integration (or debounce). Enabling this feature results in best touch response time.

When Quick re-burst is disabled, upon user touch and release, all sensors or channels are measured to resolve detect integration (or debounce). This feature should only be disabled when developing any special application involving all sensor measurements during user activity.

Within an AKS (Adjacent Key suppression) group, all the sensors within that group are measured during user touch independent of this feature being enabled or disabled.

5.2.9. Common Parameters

Measurement Period

The measurement period setting is used to set the periodic interval for touch sensor measurement. The minimum measurement period setting should be greater than the time taken to complete measurement on all sensors. This can be simply determined by calling the `touch_xx_sensors_measure API` in a while loop and then toggling a GPIO pin in the measurement complete callback.

```
main()
 {
   while(1)
     {
      touch_ret =
touch_mutlcap_sensors_measure(touch_time.current_time_ms,NORMAL_ACQ_MODE,touch_mutlcap_measure
_complete_callback);
     }
 }

void touch_mutlcap_measure_complete_callback( void )
 {
     if (!(p_mutlcap_measure_data->acq_status & TOUCH_BURST_AGAIN))
      {
          /* Set the Mutual Cap measurement done flag. */
          p_mutlcap_measure_data->measurement_done_touch = 1u;
          port_pin_toggle_output_level(PIN_PB00);
      }
  }
```

Setting	Configuration Name	Data Type	Unit	Values	Max	Typical
Sensor measurement interval	`DEF_TOUCH_MEASUREMENT_PERIOD_MS`	`uint16_t`	millisecond	Should be found through GPIO pin toggle procedure.	65535	20

PTC Interrupt Priority Level

The Nested Vectored Interrupt Controller (NVIC) in the SAM has four different priority levels. The priority level of thePTC end of conversion ISR can be selected based on application requirements to accommodate time critical operations. Setting the PTC interrupt priority level to lowest can have an impact on the touch response time, depending on the execution time taken by other higher priority interrupts.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
PTC interrupt priority level	`DEF_TOUCH_PTC_ISR_LVL`	`uint8_t`	None	0 (Highest Priority)	3 (Lowest Priority)	3

To avoid stack overflow, ensure that adequate stack size has been set in the user application.This configuration is applicable only for SAM devices.

touch_suspend_app_cb

Callback function pointer that must be initialized by the application before a touch library API is called. Touch library would call the function pointed by this function when suspension operation has to be carry on by the application.

Setting	Configuration Name	Data Type	Returns
Suspend Callback	`touch_suspend_app_cb`	`void(* volatile touch_suspend_app_cb) (void)`	`void`

Low power Sensor Event Periodicity

When the CPU returns to standby mode from active, the sensor configured as the low power sensor is scanned at this interval. A high value for this parameter will reduce power consumption but increase response time for a low power sensor.

The following macros are used for configuring the low power sensor event periodicity:

- The macro `LOWPOWER_PER0_SCAN_3_P_9_MS` sets the scan rate at 3.9ms
- The macro `LOWPOWER_PER1_SCAN_7_P_8_MS` sets the scan rate at 7.8ms
- The macro `LOWPOWER_PER2_SCAN_15_P_625_MS` sets the scan rate at 15.625ms
- The macro `LOWPOWER_PER3_SCAN_31_P_25_MS` sets the scan rate at 31.25ms
- The macro `LOWPOWER_PER4_SCAN_62_P_5_MS` sets the scan rate at 62.5ms
- The macro `LOWPOWER_PER5_SCAN_125_MS` sets the scan rate at 125ms
- The macro `LOWPOWER_PER6_SCAN_250_MS` sets the scan rate at 250ms
- The macro `LOWPOWER_PER7_SCAN_500_MS` sets the scan rate at 500ms

Low power Sensor Drift Periodicity

This parameter configures the scan interval for a single active measurement during low power mode. This active measurement is required for reference tracking of low power sensor.

Setting	Configuration Name	Data Type	Unit	Min	Max	Typical
Low power sensor drift rate	`DEF_LOWPOWER_SENSOR_DRIFT_PERIODICITY_MS`	`uint16_t`	milliseconds	0	65535	2000

Low power sensor ID

The macro `DEF_LOWPOWER_SENSOR_ID` is used to configure a sensor as low power sensor. Only one sensor can be configured as low power sensor. Low power sensor can be a normal sensor or a lumped sensor.

5.2.10. Moisture Parameters

Moisture Tolerance Enable

The macro `DEF_XXXXCAP_MOIS_TOLERANCE_ENABLE` is used to Enable or disable Moisture detection feature.

Moisture Quick Reburst

The macro `DEF_XXXXCAP_MOIS_QUICK_REBURST_ENABLE` is used to enable or disable quick re-burst feature within a given moisture group. When enabled, if within a given moisture group, when any sensor is touched, repeated measurements are done only that sensor to resolve detect integration or de-bounce. When disabled, if within a given moisture group, when any sensor is touched, repeated measurements are done on all sensors within the moisture group to resolve detect integration or de-bounce. It is recommended to enable this feature for best touch response time.

Moisture groups

The macro `DEF_XXXXCAP_NUM_MOIS_GROUPS` specifies the total number of individual moisture group present the system.

5.2.11. PTC Lines Ground Feature

PTC GPIO State

The macro `DEF_XXXXCAP_PTC_GPIO_STATE` is used to set the unmeasured self/mutual capacitance PTC lines to Ground / Vcc in between PTC measurement cycle. Setting the PTC lines to `GND_WHEN_NOT_MEASURED` will set the state of the pin to low whenever the pin is unmeasured. Setting the PTC lines to `PULLHIGH_WHEN_NOT_MEASURED` will make the PTC lines to float in between sensor measurement in a measurement cycle. It is recommended to set `GND_WHEN_NOT_MEASURED` configuration to get low power.

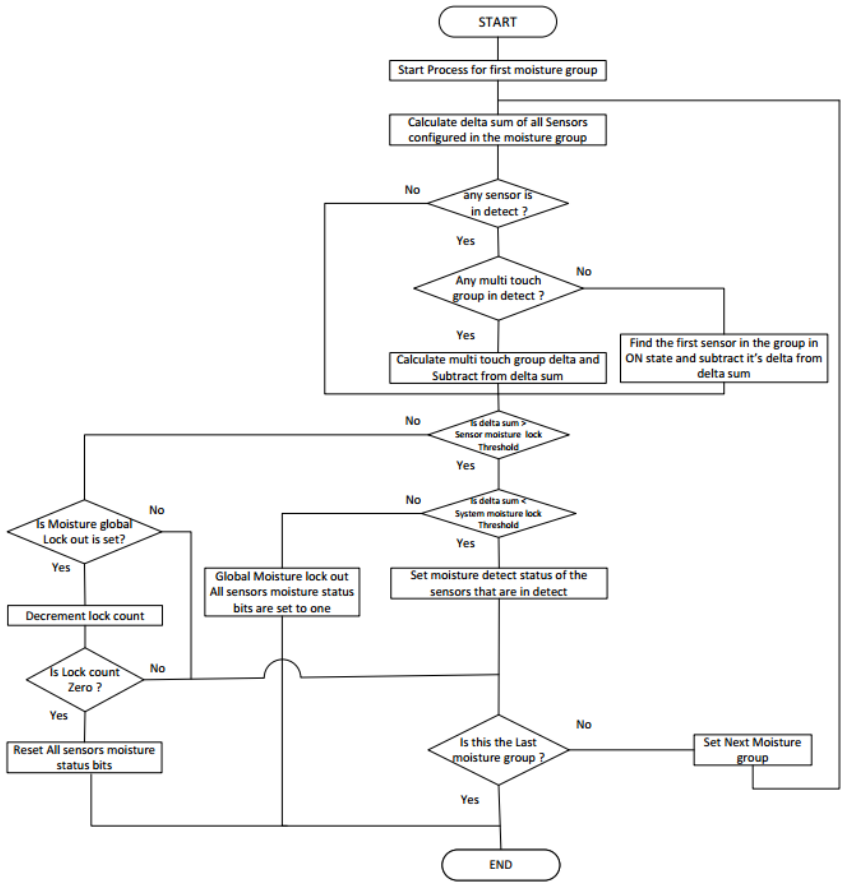
5.3. Moisture Tolerance

Moisture tolerance check executes at the end of each measurement cycle and compares the sum of delta of all sensors in a moisture tolerance group against pre-configured threshold. If delta sum is greater than sensor moisture lock threshold and less than system moisture lock threshold, then the ON-state sensors within moisture tolerance group will be considered as moisture affected.

If delta sum is greater than system moisture lock threshold, all sensors within the moisture tolerance group will be considered as moisture affected. This condition is referred as moisture global lock out. The library will come out of the moisture global lock out state when delta sum is less than threshold for 5 consecutive measurements. Self cap and mutual cap sensors cannot be configured in a single moisture group, Self cap moisture tolerance and mutual cap Moisture tolerance features can be enabled or disabled separately.

Note: Lumped sensor and the sensor which is part of the specific lump should not be assigned to same moisture group.

Figure 5-11. Moisture Tolerance Algorithm



5.3.1. Moisture Tolerance Group

This feature enables the customer application to group a set of sensors in to single moisture tolerance group. If moisture on one sensor might affect other sensors due to physical proximity, they must be grouped together into one Moisture tolerance group.

Using this feature the application can disable moisture tolerance detection for a set of sensors, Multiple Moisture tolerance groups can be formed by the customer application. The library supports up to a maximum of 8 moisture groups.

Note: Changing the moisture tolerance group configuration during runtime is not recommended. However, muti-touch group configuration can be changed during runtime.

5.3.2. Multi-touch Group

If the user wants to touch multiple sensors within the moisture tolerance group simultaneously to indicate a specificrequest, then the application should configure those sensors into single multi-touch group. Multiple multi-touch groups can be formed by the customer application. The library supports a maximum of 8 multi-touch groups within a single moisture tolerance group.

Moisture tolerance feature improves a system's performance under the following scenarios:

- Droplets of water sprayed on the front panel surface
- Heavy water poured on the front panel surface
- Large water puddle on multiple sensors

- Trickling water on multiple sensors

Moisture tolerance feature is not expected to offer any significant performance improvement under the following scenarios:

- Large isolated puddle on single sensor
- Direct water pour on single sensor

Within the same moisture group, user should not configure all the sensors to the single multi-touch group.

5.4. Reading Sensor States

When noise immunity and moisture tolerance features are enabled the validity of the sensor sate is based on the moisture status and noise status. Refer Noise Counter Measures and Moisture Parameters for information on noise immunity and moisture tolerance status of sensors. The state of a sensor is valid only when the sensor is not affected by noise and moisture. If a sensor is noisy or affected by moisture, then the state of sensor must be considered as OFF. The code snippet below depicts the same for mutual-cap sensors.

When a sensor is touched or released during DI, library will burst on channels corresponding to sensors whose state is other than OFF or DISABLED. If any sensor in an AKS group is in a state other than OFF or DISABLED, the library will burst channels corresponding sensors belong to that AKS group. If a sensor in any moisture group is in a state other than OFF or DISABLED, the library will burst on channels corresponding to sensors belonging to that moisture group.

```
if(! (GET_MUTLCAP_SENSOR_NOISE_STATUS(SENSOR_NUMBER)))
    {
      if(! (GET_MUTLCAP_SENSOR_MOIS_STATUS (SENSOR_NUMBER)))
         {
             /*Sensor state is valid Read sensor state */
         }
      else
         {
             /* Sensor is Moisture affected*/
         }
     }
else
    {
         /* Sensor is noisy */
    }
```

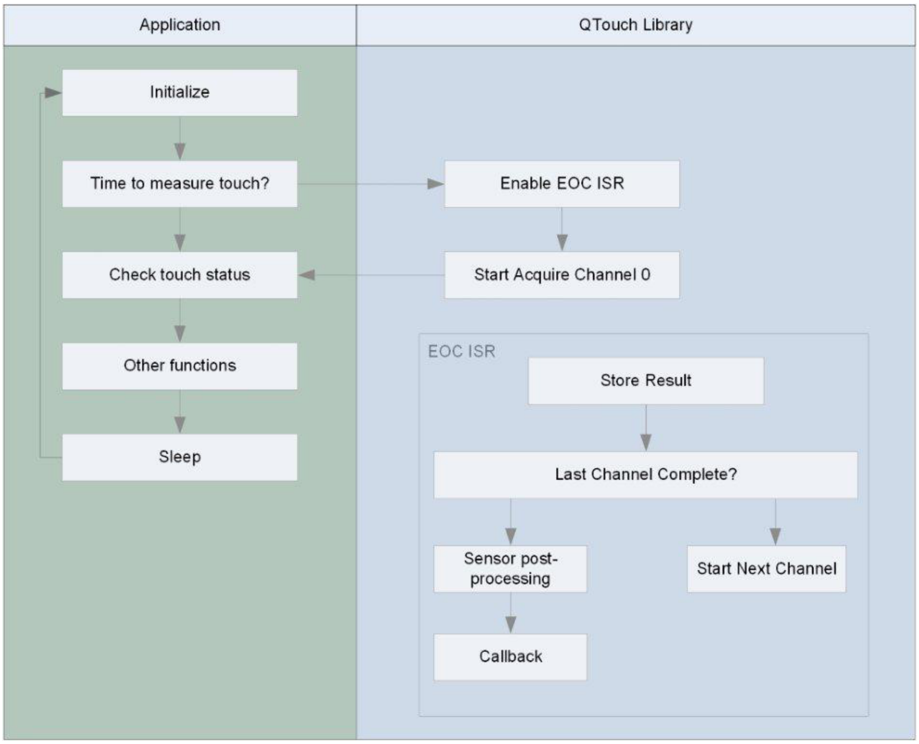
5.5. Application Flow

5.5.1. Application Flow SAM

The application periodically initiates a touch measurement on either mutual capacitance or self-capacitance sensors. At the end of each sensor measurement, the PTC module generates an end of conversion (EOC) interrupt. The touch measurement is performed sequentially until all the sensors are measured. Additional post-processing is performed on the measured sensor data to determine touch status and rotor/slider position. An interrupt callback function is triggered to indicate completion of measurement. The recommended sequence of operation facilitates the CPU to either sleep or perform other functions during touch sensor measurement.

Before using the PTC, the generic clock generator for the PTC peripheral should be set up by the Application. It is recommended to set the PTC generic clock to 4MHz.

Figure 5-12. Application vs QTouch Library Flow

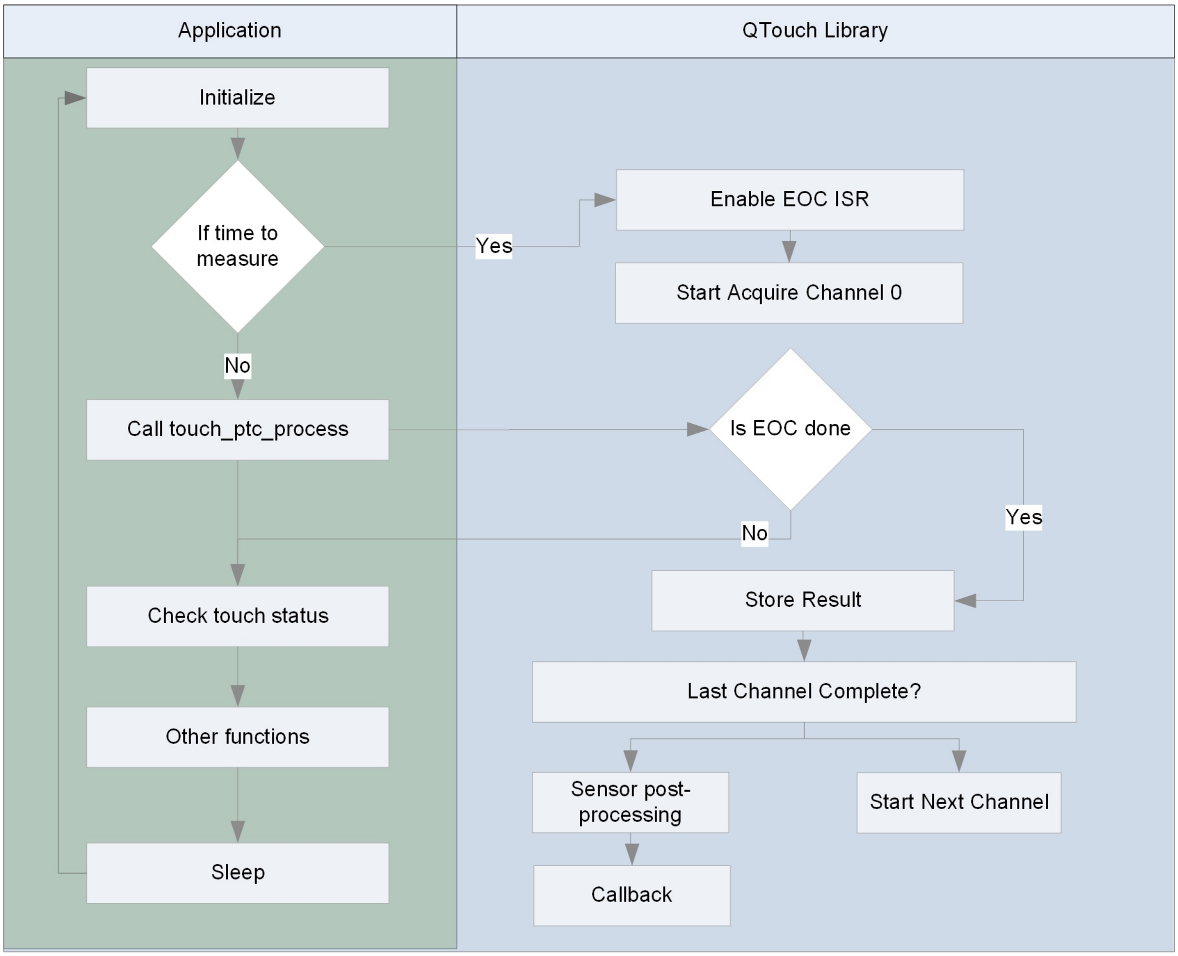


5.5.2. Application Flow - megaAVR

The application periodically initiates a touch measurement on either mutual capacitance or self-capacitance sensors either in polled or interrupt mode. In polling mode, touch API's are blocking API's and will consume more CPU time. In ISR mode, touch API's are non blocking and will generates an end of conversion (EOC) interrupt at the end of each sensor measurement.Touch measurement is intiated on first sensor by calling `touch_xxxxcap_sensors_measure()` API .The touch measurement is initiated sequentially and additional post-processing is performed on the measured sensor data to determine touch status and rotor/slider position by calling `touch_ptc_process()` API in application context instead of interrupt context. A callback function is triggered to indicate completion of measurement .The ISR mode sequence of operation facilitates the CPU to either sleep or perform other functions during touch sensor measurement.

It is recommended to set the PTC clock to 4MHz.

Figure 5-13. Application vs QTouch Library Flow



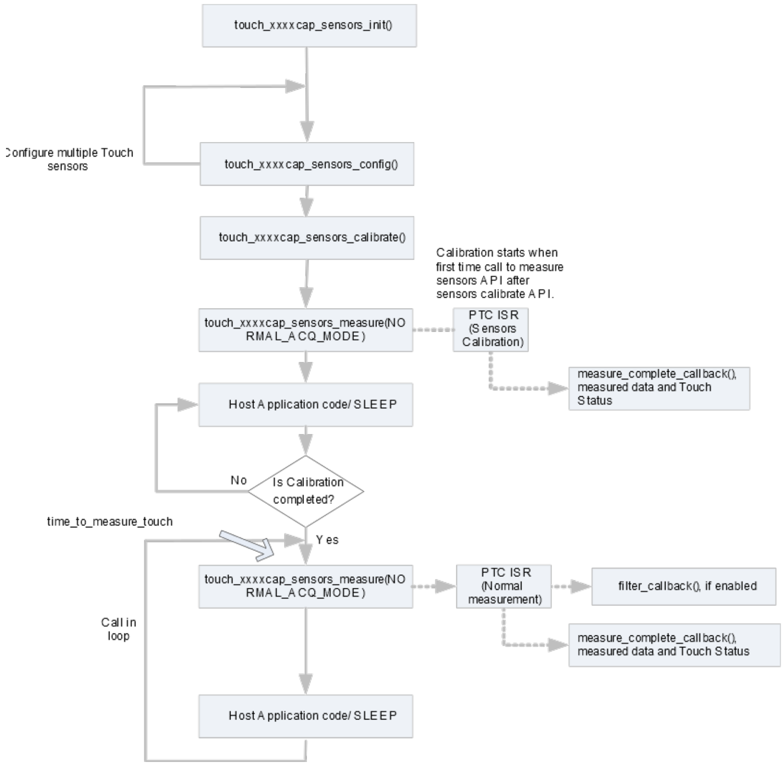
5.6. API Sequence

The `touch_xx_sensors_init` API initializes the QTouch Library as well as the PTC module. It also initializes the mutual or self-capacitance method specific pin, register, and global sensor configuration.

The `touch_xx_sensor_config` API configures the individual sensor. The sensor specific configuration parameters can be provided as input arguments to this API.

The `touch_xx_sensors_calibrate` API calibrates all the configured sensors and prepares the sensors for normal operation. The `touch_xx_sensors_measure` API initiates a sensor measurement on all the configured sensors.

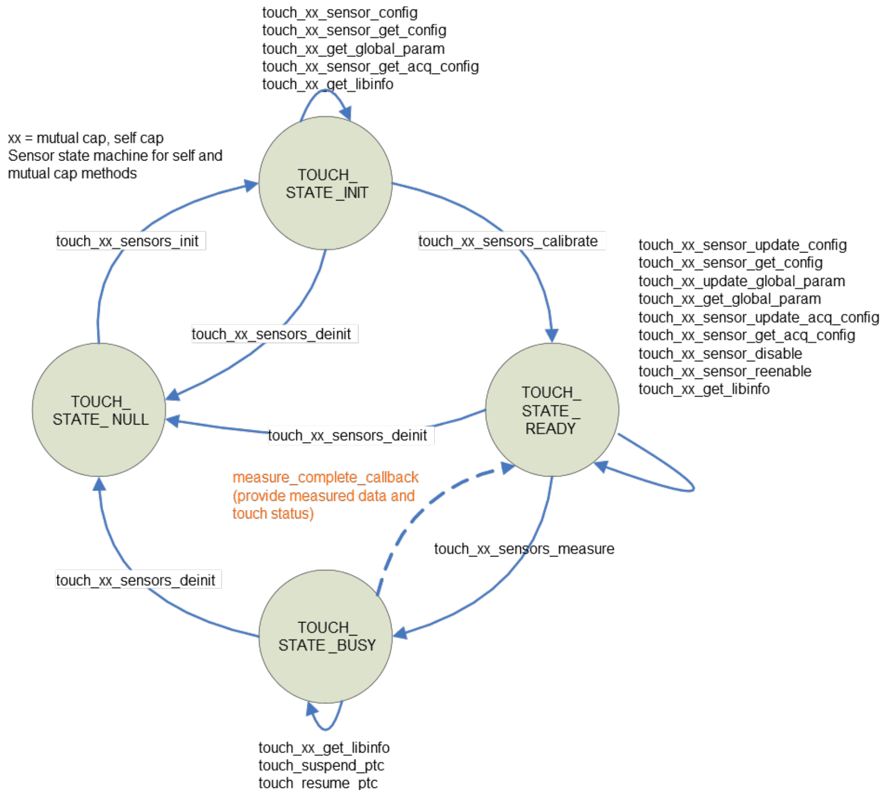
Figure 5-14. API Sequence with Combined self and Mutual Capacitance Sensors Enabled



5.7. State Machine

The PTC QTouch Library state machine that presents the various library States and Event transitions can be found in the figure below. The state machine is maintained separately for each of the touch acquisition method, which means the state of mutual capacitance sensor operation can be different from the state of self-capacitance allowing them to co-exist.

Figure 5-15. Library State Machine



The `touch_xx_sensors_init` API initializes the QTouch Library as well as the PTC module. It also initializes the mutual or self-capacitance method specific pin, register, and global sensor configuration.

The `touch_xx_sensor_config` API configures the individual sensor. The sensor specific configuration parameters can be provided as input arguments to this API.

The `touch_xx_sensors_calibrate` API calibrates all the configured sensors and prepares the sensors for normal operation.

The `touch_xx_sensors_measure` API initiates a sensor measurement on all the configured sensors.

The `touch_xx_sensors_deinit` function is used to clear the initialized library state. Used for clearing the internal library data and states. When called will modify the library state to `TOUCH_STATE_NULL`.

The `touch_xxxx_lowpower_sensor_enable_event_measure` API is used to start a event trigger based low power sensor measurement.

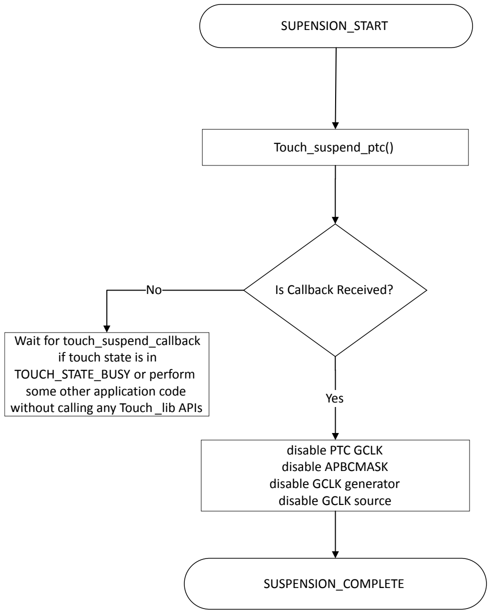
Touch Library Suspend Resume Operation

The touch library provides `touch_suspend_ptc, touch_resume_ptc` API to suspend and resume the PTC.

When suspend API is called, the touch library initiates the suspend operation and return to the application. After completing the current PTC conversion, the touch library will initiate suspend operation and call the application touch suspend callback function pointer. The suspend complete callback function pointer has to be registered by the application.
Note: If it is not registered, then the suspend call will return `TOUCH_INVALID_INPUT_PARAM`.

The application then should disable corresponding clock to reduce the power consumption. The following flowchart depicts the suspend sequence.

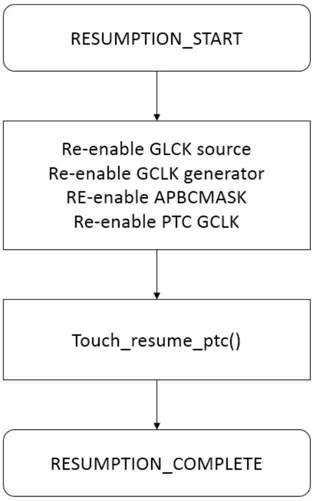
Figure 5-16. Suspend Sequence



If the touch state is not `TOUCH_STATE_BUSY` the user can disable the clock and proceed to complete the suspend routine.

To resume the operations, perform the following sequence:

Figure 5-17. Resume Sequence



The SAM controllers may be configured to operate PTC touch sensing autonomously using the Event System. In this mode, a single sensor channel is designated as the 'Low Power' key and may be periodically measured for touch detection without any CPU action. The CPU may be held in STANDBY throughout the operation, minimizing power consumption.

The low power key may be a discrete electrode with one Y (Sense) line for self-capacitance or one X (Drive) plus one Y (Sense) for mutual capacitance, or it may be a combination of multiple Drive and/or Sense lines as a lumped mode sensor as described.

With this method, a fast response may be achieved even in large key-count applications while operating at an extremely low power level, drawing less than 10uA at 3.3V.

5.8. Operation Modes

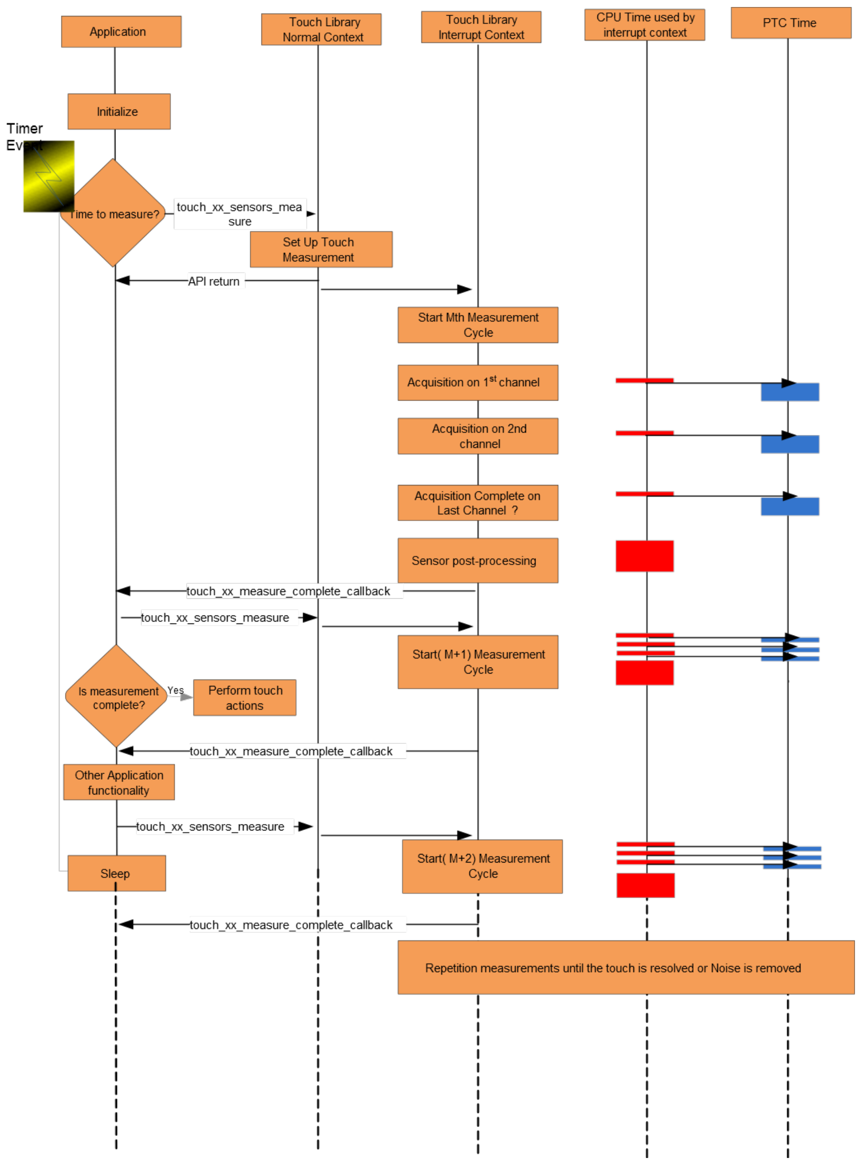
The QTouch Library can operate in the following sensor measurement modes.

- Periodic measurement
- Continuous measurement

5.8.1. Periodic Measurement

In the periodic measurement mode, sensor measurement is initiated by the application through a periodic event such as timer interrupt. The periodic measurement mode scenario is when none of the sensors are touched. While a long measurement period can be used to achieve lower device power consumption, a short measurement period is required for better touch response time. Hence, the measurement period should be tuned to suit a given application. Typical measurement period can range between 20 millisecond to 250 millisecond.

Figure 5-18. Periodic Measurement Mode



5.8.2. Continuous Measurement

In the continuous measurement mode, back to back sensor measurement can be initiated from the touch library. This mode can be triggered to resolve user presence or resolve calibration under the following scenario.

- Resolve user presence, when sensor is touched or released
- Resolve calibration, when
  - Sensor is calibrated using the `touch_xx_sensors_calibrate` API
  - Sensor is in Away from touch re-calibration condition
  - Sensor is in Max-on duration condition

The `TOUCH_BURST_AGAIN` acquisition status data bit field in the measure data structure is set to indicate continuous measurement mode.

```
void touch_mutlcap_measure_complete_callback(void)
           {
            if (!(p_mutlcap_measure_data->acq_status & TOUCH_BURST_AGAIN))
               {
                  /* Set the Mutual Cap measurement done flag. */
                   p_mutlcap_measure_data->measurement_done_touch = 1u;
               }
           }
```

Touch Library Acquisition Status Flags

The touch library acquisition status information during continuous measurement mode is available using the `touch_acq_status_t acq_status` element of the `touch_measure_data_t` touch measure data structure.

Table 5-1. Touch Acquisition Status Bit Fields

Macro	Bitfield	Comment
TOUCH_NO_ACTIVITY	0x0000u	No Touch activity
TOUCH_IN_DETECT	0x0001u	Atleast one Touch channel is in detect
TOUCH_STATUS_CHANGE	0x0002u	Change in Touch status of atleast one Touch channel
TOUCH_ROTOR_SLIDER_POS_CHANGE	0x0004u	Change in Rotor or Slider position of atleast one rotor or slider
TOUCH_CHANNEL_REF_CHANGE	0x0008u	Change in Reference value of atleast one Touch channel
TOUCH_BURST_AGAIN	0x0008u	Indicates that reburst is required to resolve Filtering or Calibration state
TOUCH_RESOLVE_CAL	0x0200u	Indicates that reburst is needed to resolve Calibration
TOUCH_RESOLVE_FILTERIN	0x0200u	Indicates that reburst is needed to resolve Filtering
TOUCH_RESOLVE_DI	0x0800u	Indicates that reburst is needed to resolve Detect Integration
TOUCH_RESOLVE_POS_RECAL	0x1000u	Indicates that reburst is needed to resolve Recalibration

Macro	Bitfield	Comment
TOUCH_CC_CALIB_ERROR	0x2000u	Indicates that CC calibration failed on at least one channel
TOUCH_AUTO_OS_IN_PROGRES S	0x4000u	Indicates that Auto OS in progress to get stable channel signal

The acquisition status flags can be monitored within the measure complete callback as shown.

```
void touch_mutlcap_measure_complete_callback(void)
          {
            if ((p_mutlcap_measure_data->acq_status & TOUCH_BURST_AGAIN))
               {
                  //Denotes acquisition is incomplete.
               }
            if ((p_mutlcap_measure_data->acq_status & TOUCH_RESOLVE_CAL))
               {
                  //Denotes sensor calibration is on-going.
               }
             if (!(p_mutlcap_measure_data->acq_status & TOUCH_BURST_AGAIN))
               {
                  //Denotes acquisition is completed.
                 /* Set the Mutual Cap measurement done flag. */
                 p_mutlcap_measure_data->measurement_done_touch = 1u;
               }
           }
```

Continuous Measurement Post Processing Mode

The sensor data post-processing mode for QTouch library can be selected using the `DEF_xxxxCAP_TOUCH_POSTPROCESS_MODE` configuration item available as part of `touch.h` file.

When `TOUCH_LIBRARY_DRIVEN` mode is selected, the library self-initiates repeated touch measurements to resolve touch press, release and calibration. This mode is suited for best response time.

When `TOUCH_APPLN_DRIVEN` mode is selected, the library does not initiate repeated touch measurement to resolve touch press, release and calibration. This mode suits deterministic PTC interrupt execution time for applications requiring stringent CPU time requirements. As repeated touch measurements are delayed due to other critical application code being executed. This mode can potentially affect the touch response time.

In order to improve the response time with the `TOUCH_APPLN_DRIVEN` mode, the following condition should be applied to initiate sensor measurement, so as to cater for additional measurements without any delay. The same condition can also be applied to other application scenario such as sleep to check for pending acquisitions to be completed before the system can go to sleep.

```
 if ((touch_time.time_to_measure_touch == 1u)||(p_mutlcap_measure_data->acq_status &
TOUCH_BURST_AGAIN))
  {
   /* Start a touch sensors measurement process periodically, or if there is a pending
measurement. */
   touch_ret =
touch_mutlcap_sensors_measure(touch_time.current_time_ms,NORMAL_ACQ_MODE,touch_mutlcap_meas
ure_complete_callback);
  }
```

5.9. Touch Library API Error

The following table provides the touch library API error code information. The API error code type is `touch_ret_t` enum.

ErrorCode Enumeration	Comment
TOUCH_SUCCESS	Successful completion of operation
TOUCH_ACQ_INCOMPLETE	Touch Library is busy with pending previous touch measurement
TOUCH_INVALID_INPUT_PARAM	Invalid input parameter
TOUCH_INVALID_LIB_STATE	Operation not allowed in the current Touch Library state
TOUCH_INVALID_SELFCAP_CONFIG_PARAM	Invalid self-capacitance configuration input parameter
TOUCH_INVALID_MUTLCAP_CONFIG_PARAM	Invalid mutual capacitance configuration input parameter
TOUCH_INVALID_RECAL_THRESHOLD	Invalid Recalibration threshold input value
TOUCH_INVALID_CHANNEL_NUM	Channel number parameter exceeded total number of channels configured
TOUCH_INVALID_SENSOR_TYPE	Invalid sensor type. Sensor type can not be SENSOR_TYPE_UNASSIGNED
TOUCH_INVALID_SENSOR_ID	Invalid sensor number parameter
TOUCH_INVALID_RS_NUM	Number of Rotor/Sliders set as 0, when trying to configure a rotor/slider

The application error codes in touch projects can be enabled or disabled using a macro `DEF_TOUCH_APP_ERR_HANDLER`. By default, the value of macro `DEF_TOUCH_APP_ERR_HANDLER` is set to 0 in order to disable the application error handler. To enable the application error handler, set the macro `DEF_TOUCH_APP_ERR_HANDLER` as 1. When it is enabled, `while(1)` is used to trap errors.

Refer Application Error Code (tag_touch_app_err_t) for further information.

6. Tuning for Noise Performance

The PTC has been designed with great care making it easy to design a capacitive touch solution, while at the same time maintaining high quality of touch and performance. Nevertheless in any touch sensing application, the system designer must consider how electrical interference in the target environment may affect the performance of the sensors.

Touch sensors with insufficient tuning can show failures in tests of either radiated or conducted noise, which can occur in the environment or power domain of the appliance or may be generated by the appliance itself during normal operation. In many applications there are quality standards which must be met where EMC performance criteria are clearly defined. However meeting the standards cannot be considered as proof that the system will never show EMC problems, as the standards include only the most commonly occurring types and sources of noise.

Noise immunity comes at a cost of increased touch response time and power consumption. The system designer must carry out proper tuning of the touch sensors in order to ensure least power consumption. The PTC QTouch library has anumber of user configurable features which can be tuned to give the best balance between touch response time, noise immunity and power consumption.

6.1. Noise Sources

Noise sources that affect touch sensor performance can be classified as follows.

Self-generated

- Motors
- Piezo buzzers
- PWM controls Radiated
- Fluorescent lamp
- Radio transmission
- Inductive cook top Conducted
- Power supply / charger
- Mains supply

Applicable EMC standards

- Conducted Immunity EN61000-4-6

6.2. Noise Counter Measures

The effects of noise are highly dependent on the amplitude of the noise signal induced or injected onto the sensors, and the frequency profile of that noise signal.

Generally, this noise can be classified as -

- Broadband noise
- Narrow band noise

6.2.1. Broadband Noise Counter Measures

Broadband noise refers to noise signals whose frequency components are not harmonically related to the capacitance measurement acquisition frequencies of the PTC.

Provided that the maximum and minimum voltage levels of the acquisition signal combined with noise signals are within the input range of the PTC and a sufficiently large number of samples are taken, broadband noise interference can be averaged out by setting a high value of Filter level (DEF_MUTLCAP_FILTER_LEVEL_PER_NODE, DEF_SELFCAP_FILTER_LEVEL_PER_NODE) and Auto oversample (DEF_MUTLCAP_AUTO_OS_PER_NODE, DEF_SELFCAP_AUTO_OS_PER_NODE) settings.

If the noise amplitude is excessive, then PTC components experience saturation of measurement. In this case the acquisition signals combined with the noise signals are outside the input range of the PTC, which results in clipping of the measurements.

Often the clipping is not observable in the resolved measurement, as it occurs only on a portion of the measurement samples, but the presence of clipped samples prevents effective averaging of the sample points.

In this case, averaging of samples will not result in a noise-free measurement even with large rates of oversampling. The resolved signal will show a shift from its correct level due to asymmetry of signal clipping.

Configuration Parameter	Setting
DEF_MUTLCAP_FILTER_LEVEL_PER_NODE, DEF_SELFCAP_FILTER_LEVEL_PER_NODE	FILTER_LEVEL_64
DEF_MUTLCAP_AUTO_OS_PER_NODE, DEF_SELFCAP_AUTO_OS_PER_NODE	AUTO_OS_DISABLE
DEF_MUTLCAP_FREQ_MODE, DEF_SELFCAP_FREQ_MODE	FREQ_MODE_NONE
DEF_MUTLCAP_CLK_PRESCALE_PER_NODE, DEF_SELFCAP_CLK_PRESCALE_PER_NODE	PRSC_DIV_SEL_1
DEF_MUTLCAP_SENSE_RESISTOR_PER_NODE, DEF_SELFCAP_SENSE_RESISTOR_PER_NODE	RSEL_VAL_100
Auto-tune input to touch_mutlcap_sensors_calibrate(), touch_selfcap_sensors_calibrate API	AUTO_TUNE_PRSC

STEP 1: PREVENT CLIPPING

This requires the implementation of a hardware low pass filter in order to reduce the scale of the noise combined with acquisition signal. The sensor capacitance is combined with a series resistor on the Y (Sense) line, either the PTC internal resistor or externally mounted on the PCB. The external series resistor should be mounted between the Y line of the device to the Sensor, closest to the device pin.

Note: Always use an external series resistor for self-capacitance applications in order to prevent clipping. The internal series resistor of the PTC is limited to 100K. Depending on the noise levels, external series resistors up to1 megaohms can be evaluated.

STEP 2: CHARGE TRANSFER TEST

As an effect of adding a series resistor to form a low pass filter, the time constant for charging the sensors is increased. It is essential to ensure that the sensor capacitance is fully charged and discharged during each measurement sampling.

Insufficient charging can be observed as a reduced touch delta or it may be seen on an oscilloscope by connecting to the sense electrode.

However, this problem may not be apparent in the touch sensor operation; the application may behave perfectly well even in the presence of low-level noise, but show much worse performance during noise tests with the addition of the resistor compared to a configuration which excludes the resistor.

Charge transfer though Auto tuning setting:

The QTouch library Auto tune setting provides a mechanism which carries out a charge transfer test on each enabled key and sets the prescalar to the fastest available setting ensuring full charge transfer.

The following combination of setting should be used.

- `DEF_MUTLCAP_SENSE_RESISTOR_PER_NODE` and `DEF_SELFCAP_SENSE_RESISTOR_PER_NODE` should be set to `RSEL_VAL_100`.
- Auto tune pre-scaler `AUTO_TUNE_PRSC` should be provided as input parameter to `touch_mutlcap_sensors_calibrate( AUTO_TUNE_PRSC )`and `touch_mutlcap_sensors_calibrate(AUTO_TUNE_PRSC)`

Testing for Charge transfer by Manual tuning:

- If the `AUTO_TUNE_NONE` setting is provided as an input to the touch_mutlcap_sensors_calibrate(`AUTO_TUNE_NONE`) and `touch_mutlcap_sensors_calibrate (AUTO_TUNE_NONE)` calibration API, then the PTC uses the user defined settings of the PTC Clock pre-scaler (`DEF_MUTLCAP_CLK_PRESCALE`, `DEF_SELFCAP_CLK_PRESCALE_PER_NODE`) and internal series resistor (`DEF_MUTLCAP_SENSE_RESISTOR_PER_NODE`, `DEF_SELFCAP_SENSE_RESISTOR_PER_NODE`).
- Reference measurement: An acquisition measurement (Signal value) is taken with the prescalar set to maximum, i.e. `PRSC_DIV_SEL_8`

Test measurement: A second measurement (Signal value) is taken with reduced prescalar: `PRSC_DIV_SEL_4`

If the difference between the two measurements is less than ~3% (1/32) of the first value, the conclusion is that fullcharge transfer is achieved with `PRSC_DIV_SEL_4`.

This measurement is repeated for `PRSC_DIV_SEL_2 and PRSC_DIV_SEL_1` to find the fastest PTC operating speed for which full charge transfer is achieved.

STEP 3: ADJUST OVERSAMPLING

Once clipping is prevented by hardware filtering and full charge transfer is ensured the next step is to find the best settings for Filter level (`DEF_MUTLCAP_FILTER_LEVEL_PER_NODE ,` `DEF_SELFCAP_FILTER_LEVEL_PER_NODE`) and Auto over samples (`DEF_MUTLCAP_AUTO_OS_PER_NODE , DEF_SELFCAP_AUTO_OS_PER_NODE`).

Auto over samples feature provides the advantage that additional samples are only taken on a sensor which has showna significant change. In the absence of such a change, the measurement cycle can be much shorter compared to applying (* AUTO_OS) as the oversampling rate on every measurement. Care should be taken when using AUTO_OS to ensure that it does not occur too frequently.

The measurement time for FILTER_LEVEL samples can be represented as:

A+ (B * FILTER_LEVEL)

Where A is the total time for PTC configuration and post-processing, and B is the oversampling period (the per sample measurement time)

When AUTO_OS is applied, this time is increased to:

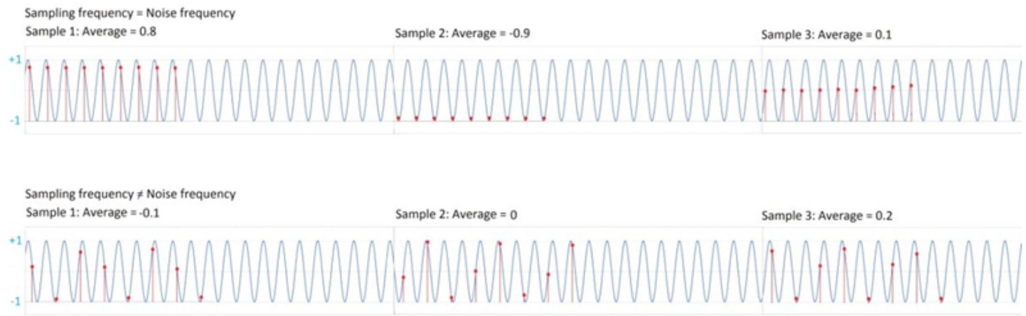
A + (B * FILTER_LEVEL*(1 + AUTO_OS))

FILTER_LEVEL should be sufficiently large to ensure that AUTO_OS is only applied during the worst-case noise circumstances.

6.2.2. Narrowband Noise Counter Measures

If the noise includes a frequency component which is related to the PTC capacitance measurement acquisition frequency, then no amount of oversampling will average out the noise effects. Any batch of measurement samples taken with the same sampling frequency will result in a measurement offset. The actual offset resulting from each measurement depends on the relative phase of the noise component and the sampling frequency.

This effect is illustrated in the following diagram, where the noise is represented by a sine wave.



STEP 4: SELECT FREQUENCY MODE

Note: Step1, Step2 and Step3 provided in the previous section should be used in combination with this step in a system which has both broadband noise and narrow band noise. Default settings provided before STEP1 should be used as a starting point before starting noise tuning.

With `FREQUENCY_MODE_NONE`, a single acquisition frequency is used and samples are taken at the fastest rate possible with the given pre-scalar setting. This gives the best response time, and with sufficient oversampling excellent noise immunity at all noise frequencies which are not related to the sampling frequency.

However in the case where the noise is at (or close to) a frequency which is harmonically related to the sampling frequency then the noise issue becomes severe, as illustrated above.

This is particularly important in applications where a frequency sweep test is required, such as EN61000-4-6.

`FREQUENCY_MODE_SPREAD` applies a modification to the sampling rate, such that the period between successivesamples is modified in a saw-tooth fashion to apply a wider spectrum to the sampling frequency. The sampling frequency F0 is thus spread across the range (F0/2, F0). With relatively low noise amplitude, this can be effective atimproving performance with minimal cost in response time.

`FREQUENCY_MODE_HOP` utilizes 3 base frequencies and a median filter to avoid using measurements taken at anaffected frequency. The frequencies should be selected to minimize the set of crossover harmonics within the problemfrequency band.

Each of the 3 frequencies is used in sequence for each measurement cycle.i.e.

- Cycle 1: All sensors measured with Frequency 0
- Cycle 2: All sensors measured with Frequency 1
- Cycle 3: All sensors measured with Frequency 2
- Cycle 4: All sensors measured with Frequency 0
- Cycle 5: All sensors measured with Frequency 1

If Frequency 0 is related to the noise frequency, then the measurements taken with F0 will show high variation. Using a median filter, this ensures that the outlying measurements will be rejected.

In some applications, self-generated noise may be present which affects one or more of the default HOP frequencies. Insuch a case, the HOP frequencies should be changed to avoid this frequency.

Some noise frequencies can occur which are close to harmonics of two of the HOP frequencies, in which case thesystem must be tuned with higher settings of FILTER_LEVEL or AUTO_OS to provide enough samples to average the noise out of the measurement.

Determining PTC Acquisition Frequency

The PTC acquisition frequency is given by the following formula,

PTC Acquisition Frequency = (1/ PTC Acquisition Time)

The PTC acquisition time is given by the following formula,

PTC Acquisition Time = (Cycles per Acquisition + Hop Freq) * PTC IO Clock Period

Where, Cycles per Acquisition = Number of PTC clock cycles required for each acquisition. This is a fixed value of 15. Hop Freq = PTC acquisition frequency delay setting

This parameter is represented in the `touch.h` file by the symbols `DEF_MUTLCAP_HOP_FREQS` and `DEF_SELFCAP_HOP_FREQS`.

The PTC acquisition frequency is dependent on the Generic clock input to PTC and PTC clock pre- scaler setting. This delay setting inserts n PTC clock cycles between consecutive measurements on a given sensor, thereby changing the PTC acquisition frequency.

`FREQ_HOP_SEL_1` setting inserts 0 PTC clock cycles between consecutive measurements.
`FREQ_HOP_SEL_16` setting inserts 15 PTC clock cycles.

Hence, higher delay setting will increase the total time taken for capacitance measurement on a given sensor as compared to a lower delay setting.A desired setting can be used to avoid noise around the same frequency as the acquisition frequency.

Range: `FREQ_HOP_SEL_1` to `FREQ_HOP_SEL_16`

Three frequency hop delay settings need to be specified when assigning values to this parameter. Duration of each PTC clock period is given by the following formula,

Where,

CLKPTC = Generic clock input to the PTC

Refer `touch_configure_ptc_clock()` API in `touch.c` file for clock configuration.

Prescaler = PTC clock prescaler setting

This parameter is represented in the `touch.h` file by the symbols `DEF_MUTLCAP_CLK_PRESCALE_PER_NODE` and `DEF_SELFCAP_CLK_PRESCALE_PER_NODE`.

Example: If Generic clock input to PTC = 4MHz, then:

- `PRSC_DIV_SEL_1` sets PTC Clock to 4MHz
- `PRSC_DIV_SEL_2` sets PTC Clock to 2MHz
- `PRSC_DIV_SEL_4` sets PTC Clock to 1MHz
- `PRSC_DIV_SEL_8` sets PTC Clock to 500KHz

Example:

When CLKPTC = 4MHz, Prescaler = `PRSC_DIV_SEL_1`, the PTC Acquisition Frequencies obtained are as follows,

Hop Freq	PTC Acquisition Frequency(kHz)
FREQ_HOP_SEL_1	66.67
FREQ_HOP_SEL_2	62.50
FREQ_HOP_SEL_3	58.82
FREQ_HOP_SEL_4	55.56
FREQ_HOP_SEL_5	52.63
FREQ_HOP_SEL_6	50.00
FREQ_HOP_SEL_7	47.62
FREQ_HOP_SEL_8	45.45
FREQ_HOP_SEL_9	43.48
FREQ_HOP_SEL_10	41.67
FREQ_HOP_SEL_11	40.00
FREQ_HOP_SEL_12	38.46
FREQ_HOP_SEL_13	37.04
FREQ_HOP_SEL_14	35.71
FREQ_HOP_SEL_15	34.48
FREQ_HOP_SEL_16	33.33

Note: The acquisition frequencies may vary based on the tolerance of the clock source.

7. Application Design

7.1. Touch Library and Associated Files

The table below provides the mandatory files required to use the QTouch library. In order to add QTouch functionality into an existing user example project, these files and associated library based on the compiler should be added to the user project.

Table 7-1. Touch Library Files

File	Description
`touch_api_ptc.h`	QTouch Library API header file, contains API and Data structure used to interface with the library
`touch.h`	QTouch library configuration header file
`touch.c`	A helper file to demonstrate QTouch library initialization and sensor configuration
`libsamxxx_qtouch_iar.a` or `libsamxxx_qtouch_gcc.a`	QTouch library compiled for IAR or GCC compiler that supports both self-capacitance and mutual capacitance sensors.

7.2. Code and Data Memory Considerations

The table below captures the typical code and data memory required for QTouch library. The typical memory requirements provided in the table are arrived considering only Regular API usage in the application. Usage of Helper API would consume additional code memory.

Each measurement method requires additional data memory from the application for storing the signals, references, sensor configuration information, and touch status. This data memory is provided by the application as 'data block' array. The size of this data block depends on the number of sensors configured. The `PRIV_xx_DATA_BLK_SIZE` macro in `touch_api_ptc.h` calculates the size of this data memory block.

Table 7-2. Mutual Capacitance Method

Series	Code Memory Keys Only	Data Memory Keys Only	Code Memory Keys with Rotor or Slider	Data Memory Keys with Rotor or Slider
`libsamd1x-qtouch-gcc.a`	9602	845	11114	861
`libsamd1x-qtouch-iar.a`	9005	497	10377	513
`libsamd2x-qtouch-gcc.a`	9222	841	10734	857
`libsamd2x-qtouch-iar.a`	8881	497	10254	513
`libsaml21-qtouch-gcc.a`	9282	841	10794	857
`libsaml21-qtouch-iar.a`	9744	497	11115	513
`libsamda1-qtouch-gcc.a`	9222	841	10734	857

Series	Code Memory Keys Only	Data Memory Keys Only	Code Memory Keys with Rotor or Slider	Data Memory Keys with Rotor or Slider
libsamda1-qtouch-iar.a	8881	497	10254	513
libsamc2x-qtouch-gcc.a	9752	841	11264	857
libsamc2x-qtouch-iar.a	9209	501	10567	517
libsamr21-qtouch-gcc.a	9246	841	10758	857
libsamr21-qtouch-iar.a	8905	497	10277	513
libsaml22-qtouch-gcc.a	9886	841	11078	857
libsaml22-qtouch-iar.a	9509	501	10981	517
libatmega328pb_qtouch_gcc.a	13338	503	15760	532
libMega328PB_qtouch.r90	10761	578	12391	607
libatmega324pb_qtouch_gcc.a	14082	482	16520	631
atmega324pb_qtouch_iar.r90	10646	441	12379	562

In case of ATmega328PB, for a single touch channel (mutual capacitance mode) without noise, moisture, auto-tune and qdebug features, RAM usage is 503 bytes. RAM usage gets increased by 36 bytes for each additional channel.

Table 7-3. Self-capacitance Method

Series	Code Memory Keys Only	Data Memory Keys Only	Code Memory Keys with Rotor or Slider	Data Memory Keys with Rotor or Slider
libsamd1x-qtouch-gcc.a	9576	841	10884	849
libsamd1x-qtouch-iar.a	8952	497	10216	505
libsamd2x-qtouch-gcc.a	9198	845	10506	845
libsamd2x-qtouch-iar.a	8841	497	10101	505
libsam121-qtouch-gcc.a	9258	841	10566	845
libsaml21-qtouch-iar.a	9806	497	11070	505
libsamda1-qtouch-gcc.a	9198	845	10506	845
libsamda1-qtouch-iar.a	8841	497	10101	505
libsamc2x-qtouch-gcc.a	9716	841	11024	845
libsamc2x-qtouch-iar.a	9148	501	10400	509
libsamr21-qtouch-gcc.a	9542	841	10850	845

Series	Code Memory Keys Only	Data Memory Keys Only	Code Memory Keys with Rotor or Slider	Data Memory Keys with Rotor or Slider
`libsamr21-qtouch-iar.a`	8851	497	10115	505
`libsaml22-qtouch-gcc.a`	9530	841	11158	845
`libsaml22-qtouch-iar.a`	9410	501	10733	509
`libatmega328pb_qtouch_gcc.a`	13274	500	15260	519
`libMega328PB_qtouch.r90`	10705	594	12041	613
`libatmega324pb_qtouch_gcc.a`	14026	478	16024	593
`libMega328PB_qtouch.r90`	10596	437	12329	558

In case of ATmega328PB, for a single touch channel (self-capacitance mode) without noise, moisture, auto-tune and qdebug features, RAM usage is 500 bytes. RAM usage gets increased by 32 bytes for each additional channel.

Note:

1. The total number of sensors supported by a specific device variant is limited by the number of XY-lines as well as code, data, and stack memory requirements.
2. To save the memory utilized for code and data, new lib-nano C library has been used for GCC example projects.

8. Example Applications

8.1. Atmel Board Example Projects

The GCC Xplained Pro example projects can be accessed through **File>New Example Project** menu option in Atmel Studio.

The IAR Xplained Pro example projects can be accessed through Atmel QTouch Library PTC Partpack.

The following example projects are available for Xplained Pro kits:

- SAM D20 Xplained Pro and QT1 Xplained Pro Mutual Capacitance example application
- SAM D20 Xplained Pro and QT1 Xplained Pro Self Capacitance example application
- SAM D21 Xplained Pro and QT1 Xplained Pro Mutual Capacitance example application
- SAM D21 Xplained Pro and QT1 Xplained Pro Self Capacitance example application
- SAM D20 Xplained Pro and QT1 Xplained Pro Mutual Capacitance example application with Lump-Low Power configuration
- SAM D20 Xplained Pro and QT1 Xplained Pro Self Capacitance example application with Lump-Low Power configuration
- SAM D11 Xplained Pro Self Capacitance example application
- SAM D10 Xplained Mini Self Capacitance example application
- SAM D20 QTouch Robustness Demo Moisture Example Application (self + mutual)
- SAM C20 QTouch Robustness Demo Moisture Example Application
- SAM D20 Xplained Pro and QT3 Xplained Pro Mutual Capacitance example application with Lump-Low Power configuration
- SAM L21 Xplained Pro and QT3 Xplained Pro Mutual Capacitance example application with Lump-Low Power configuration
- SAM DA1 Xplained Pro and QT4 Xplained Pro Self Capacitance example application
- SAM C21 Xplained Pro and QT1 Xplained Pro Mutual Capacitance example application
- SAM C21 Xplained Pro and QT1 Xplained Pro Self Capacitance example application
- SAM C21 Xplained Pro Self Capacitance example application(on-board sensor)
- SAM C21 Xplained Pro and QT5 Xplained Pro Mutual Capacitance example application
- SAM L22 Xplained Pro and Touch Segment LCD Xplained Pro Mutual Capacitance example application
- ATmega328PB Xplained Mini Self Capacitance example application
- ATmega324PB Xplained Pro and QT5 Xplained Pro Mutual Capacitance example application

Note: For SAM L22, it is recommended to set the PTC Clock to 8MHz.

Clock Configuration Changes in Projects:

- For SAM C20/C21 RevB devices, DPLL is used as the main clock and OSC32K is used as reference clock for the DPLL clock source. For SAM C20/C21 RevC devices, OSC48MHz is used as the main clock. This is demonstrated in the example projects by using the same project for both SAM C20/C21 RevB and SAM C20/C21 RevC devices.
- The example projects which have DFLL as main clock source use scaled OSC8MHz/OSC16MHz clock as the reference input clock.
- SAM L22 example project configures DFLL for 16MHZ (performance level - PL2) and utilizes it as the main clock. This clock setting offers high performance.

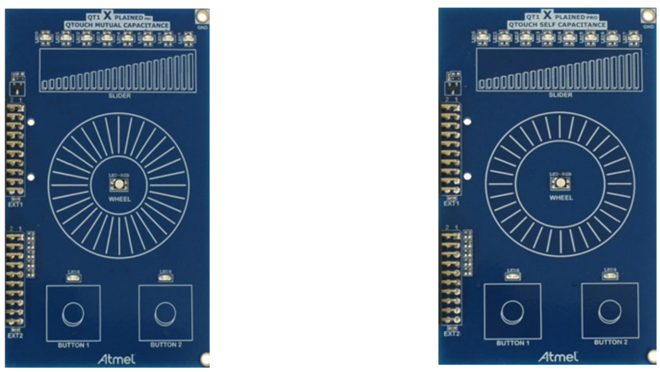
- SAM L22 low power user board project configures DFLL for 8MHZ (performance level - PL0) and utilizes it as the main clock. This clock setting offers low power consumption.
- SAM L21/L22 low power example projects are configured in PL0 (Low power oriented mode) with Buck regulator as the main regulator in standby sleep mode. This is the best suitable configuration to achieve low power numbers.

The example projects make use of Xplained Pro boards and the extension kits for showcasing touch. Those extension kits are explained in the following sections.

QT1 Xplained Pro kit:

The QT1 Xplained Pro self-capacitance and mutual capacitance extension boards are supported by SAM D20, SAM D21, SAM DA1, SAM C21, and SAM L22 Xplained Pro Evaluation kits.

Figure 8-1. QT1 Xplained Pro Mutual Capacitance and Self-capacitance



Note: SAM C21 Xplained Pro can operate at 3.3V and 5V Vcc, while the QT1 Xplained Pro can operate at a maximum voltage of 3.6V. Please make sure to put the Vcc selection header on the SAM C21 Xplained Pro in the 3.3V position.

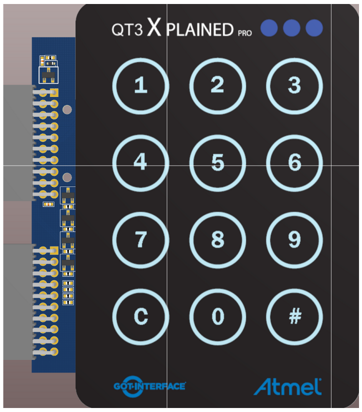
The QT1 Xplained Pro boards demonstrate the following combinations of buttons, slider, and wheels.

- 2 buttons + 2 yellow LED
- 1 slider + 8 yellow LED
- 1 wheel + 1 RGB LED

QT3 Xplained Pro kit:

The QT3 Xplained Pro extension board has 12 mutual capacitance buttons on it and it is supported by SAM D20, SAM D21, SAM DA1, SAM L21, SAM L22 and SAM C21 Xplained Pro Evaluation kits.

Figure 8-2. QT3 Xplained Pro

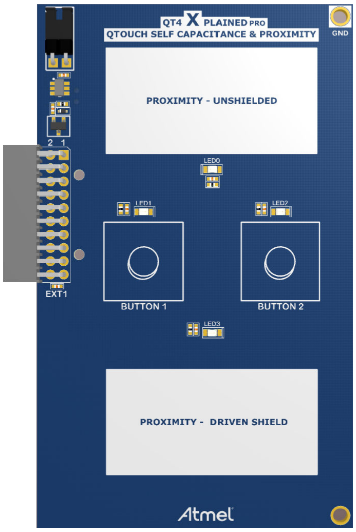


QT4 Xplained Pro kit:

The QT4 Xplained Pro boards demonstrate the following arrangement.

- Two self-capacitance buttons
- One unshielded proximity sensor
- One proximity sensor with driven shield with external op-amp driver
- One LED indicator for each self-capacitive button
- One LED indicator for each proximity sensor

Figure 8-3. QT4 Xplained Pro

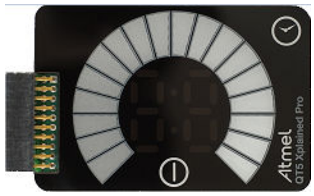


QT5 Xplained Pro kit:

The QT5 Xplained Pro board demonstrates the following arrangement.

- One 4-channel (4X x 1Y) mutual capacitance curved slider
- Two mutual capacitance buttons
- 16 LEDs arranged as two 7-segment digits separated with a colon
- IS31FL3728 I2C LED matrix controller from ISSI

Figure 8-4. QT5 Xplained Pro



8.2. User Board Example Projects

Atmel Studio QTouch Composer can be used to create GCC projects based on the sensor and pin configuration defined by the requirements of a user board. The generated example projects also allow for QDebug data streaming to QTouch Analyzer.

The User board example project can be generated by accessing the QTouch Composer using the following menu options in the Atmel Studio.

File > New Project > GCC C QTouch Executable Project > Create QTouch Library Project

The QTouch Project Builder wizard appears as shown in the screenshot. Selection of sensors, devices, pins, debug interface and tuning of parameters can be done according to user preferences and project can be generated. The figure shows one of the user board generated projects.

Figure 8-5. QTouch Project Builder

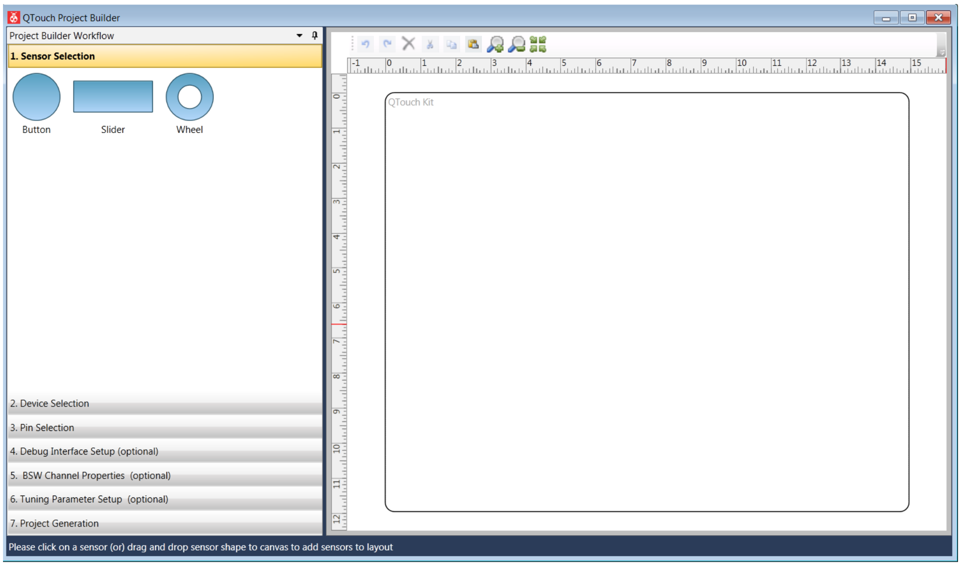
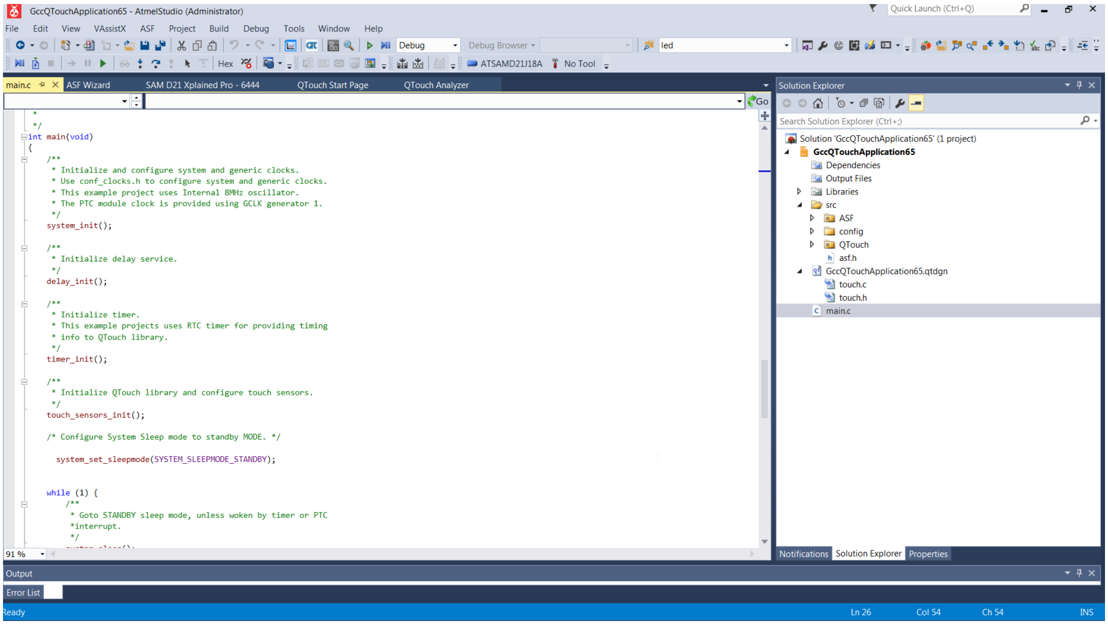


Figure 8-6. User Board Example Project



8.3. Using Atmel Software Framework (ASF) with the Example Projects

The example projects are based on Atmel Software Framework (ASF). For more information on ASF refer to Atmel Software Framework User Guide http://www.atmel.com/.

The Atmel® Software Framework (ASF) is a MCU software library providing a large collection of embedded software for Atmel flash MCUs: mega AVR, AVR XMEGA, AVR UC3 and SAM devices.

- It simplifies the usage of microcontrollers, providing an abstraction to the hardware and high- value middleware
- ASF is designed to be used for evaluation, prototyping, design and production phases
- ASF is integrated in the Atmel Studio IDE with a graphical user interface or available as standalone for GCC, IAR compilers
- ASF can be downloaded for free

8.4. Using Xplained Pro Kit to Program User Board

The SAM D20 Xplained Pro features a Cortex® Debug Connector (10-pin) for programming and debugging an external target. The connector is limited to the SWD interface and is intended for in-system programming and debugging of SAM D20 devices in the final product developed by the users. For more information refer SAM D20 Xplained Pro User Guide (www.atmel.com).

8.5. Using QDebug Touch Data Debug Communication Interface

When using IAR and GCC example projects, QDebug touch data debug communication interface can be enabled. This allows the communication between the touch device and QTouch Analyzer.

To enable or disable QDebug, configure `DEF_TOUCH_QDEBUG_ENABLE` in the `touch.h` file.

When QDebug is enabled and touch debug data is being updated in the QTouch Analyzer, touch response time will be slower due to the debug communication data transfer which increases the delay in the response time.

After tuning the touch sensors using QTouch Analyzer, disable the QDebug for optimized touch performance.

Figure 8-7. Atmel DGI Interface for QDebug Data

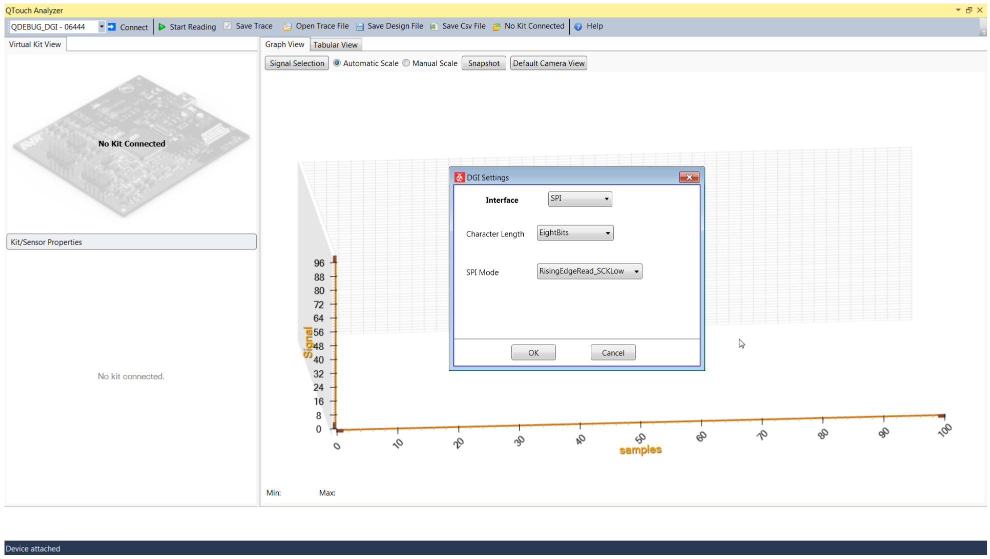
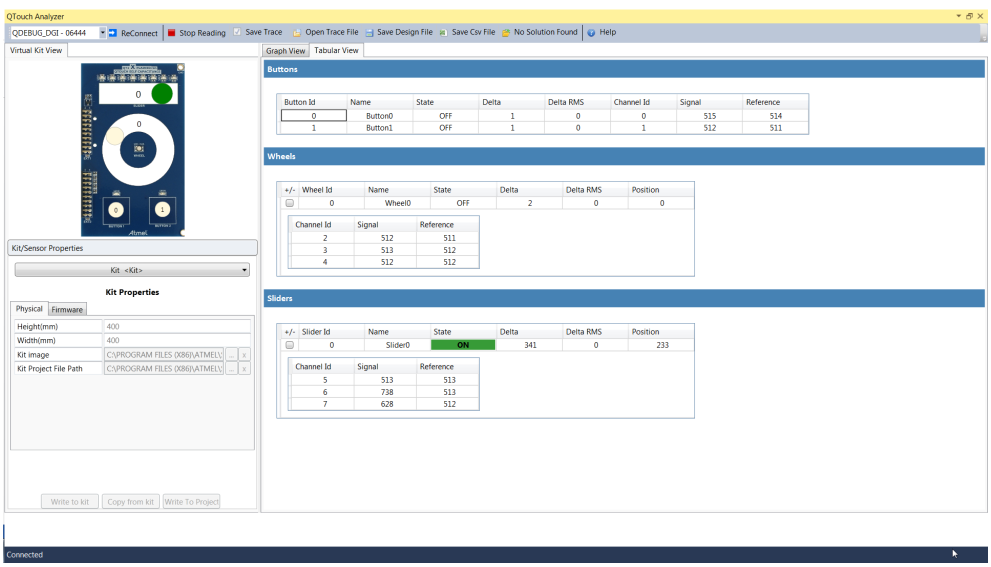


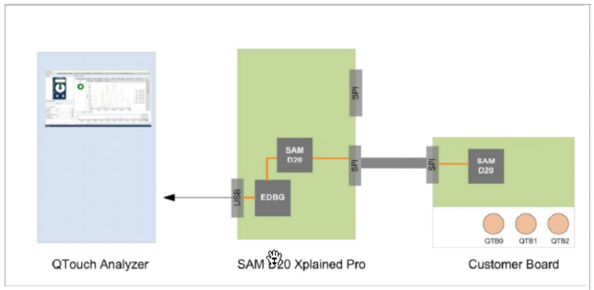
Figure 8-8. QTouch Analyzer view



8.6. Using Xplained Pro Kit for QDebug Data Streaming from User Board

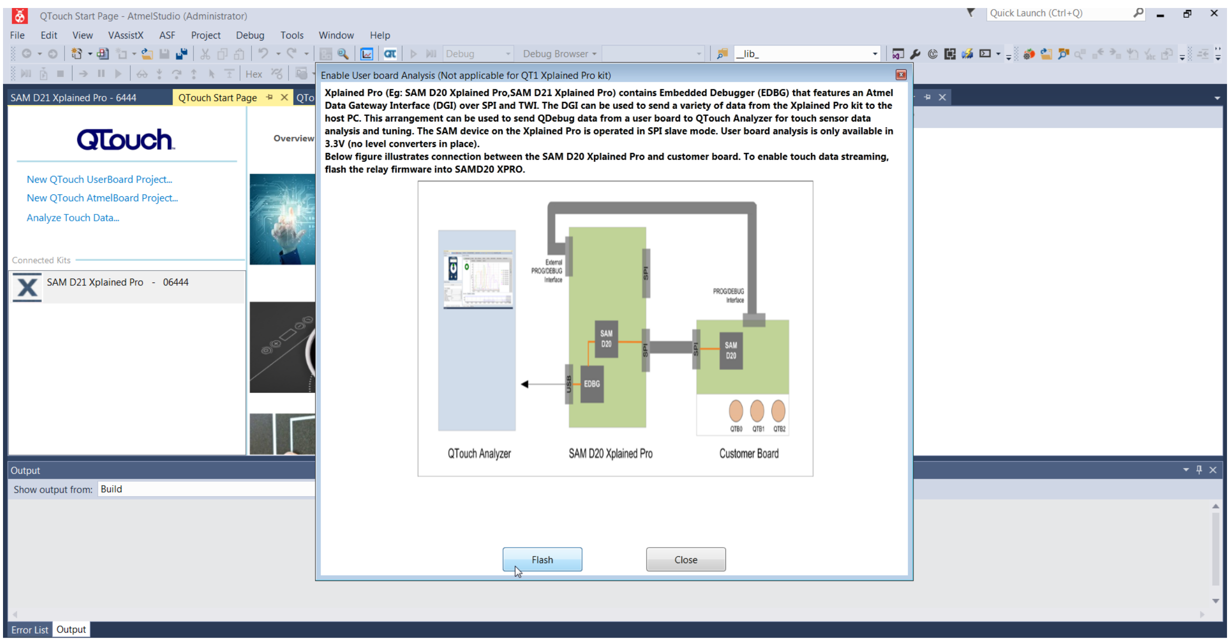
SAM D20 Xplained Pro contains Embedded Debugger (EDBG) that features an Atmel Data Gateway Interface (DGI) over SPI and TWI. The DGI can be used to transmit a variety of data from the Xplained Pro kit to the host PC. This arrangement can be used to send QDebug data from a user board to Atmel Studio QTouch Analyzer for touch sensor data analysis and tuning.

Figure 8-9. Using Xplained Pro for Data Streaming from User Board



The example project generated using QTouch composer makes use of SPI for data transfer. To stream QDebug data from user board, a relay firmware should be flashed onto the SAM D20/D21 microcontroller on the Xplained Pro kit. After connecting the SAM D20/D21 Xplained Pro to the PC, the device name appears in the connected kits of QTouch Start Page. Right click the device name and choose **Enable User Board Analysis** to flash the relay firmware.

Figure 8-10. Flash Relay Firmware



The following table indicates the SPI connection between SAM D20 Xplained Pro Kit and User Board:

Table 8-1. SPI Connection Information

SAMD20 Xplained Pro Extension header EXT3		UserBoard Pin
Pin on EXT3	Function	
16	SPIMOSI (PB22)	MOSI
17	SPIMISO (PB16)	MISO
18	SPISCK(PB23)	SCK
-		SS-Connect to GND
19	GND	GND

8.7. Using Atmel ICE for QDebug Data Streaming from User Board

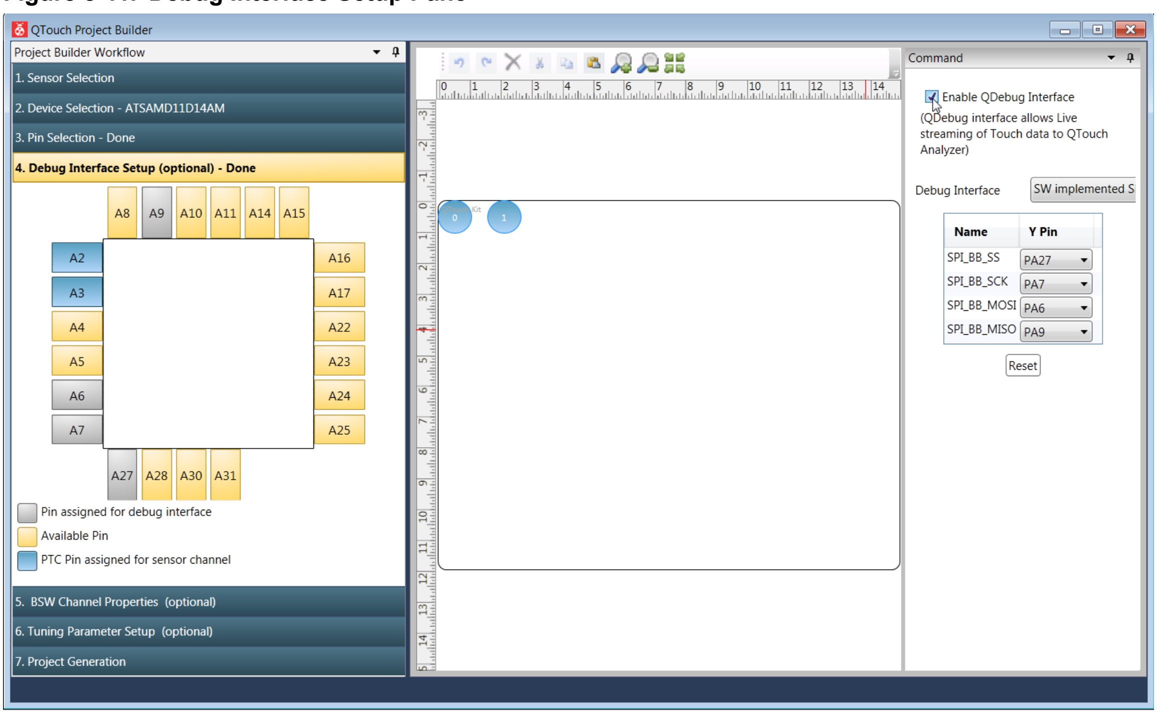
Atmel ICE can be used to stream data from the user board.

Refer the following table and connect the mini squid cable from AVR header of Atmel ICE to user board.

Atmel-ICE AVR port pins	Target pins	Mini-squid pin
Pin 1 (TCK)	**SCK**	1
Pin 2 (GND)	GND	2
Pin 3 (TDO)	**MISO**	3
Pin 4 (VTG)	VCC	4
Pin 5 (TMS)	**SS**	5
Pin 6 (nSRST)	-	6
Pin 7 (Not Connected)	-	7
Pin 8 (nTRST)	-	8
Pin 9 (TDI)	**MOSI**	9
Pin 10 (GND)	-	0

While creating the project using QTouch composer project builder wizard, the pins SCK, MISO, SS and MOSI can be chosen from the debug interface setup pane as shown in the figure.

Figure 8-11. Debug Interface Setup Pane



When the connections are made correctly and debug interface setup is also done in the project, flash the project in the user board. Data can be streamed and visualized via QTouch Analyzer.

Note: Atmel ICE would be listed in QTouch Analyzer as QDEBUG_DGI.

9. Known Issues

1. PTC in Self-capacitance Mode

The following errata is applicable for SAM D20 (Revision B)

Description:

The two lowest gain settings are not selectable and an attempt by the QTouch Library to set enable of these may result in a higher sensitivity than optimal for the sensor. The PTC will not detect all touches.This errata does not affect mutual capacitance mode which operates as specified.

Fix/workaround:

Use SAM D20 revision C or later for self-capacitance capacitive touch sensing.

2. Touch acquisition may fail and stop working

The following errata is applicable for QTouch Library versions up to 5.0.7. This issue has been fixed in QTouch Library version 5.0.8 or later.

Description:

In QTouch applications, where either a single interrupt or a chain of nested non-PTC interrupts has duration longer than the total touch measurement time, the touch acquisition may fail and stop working. This issue occurs most likely in applications with few touch channels (2-3 channels) and a low level of noise handling (filter level 16 or lower and no frequency hopping).

In an application with single touch channel and filter level 16, the total measurement time is ~350µs. The total measurement time doubles for two touch channels, and triples for 3 touch channels. It increases up to 10 times or 3.5ms with 10 touch channels.

Fix/workaround:

- Recommended workaround:
  - Use QTouch Library version 5.0.8 or later.
- Other alternatives:
  1. Always ensure that the duration of a single interrupt or a chain of nested non-PTC interrupts does not exceed the total touch measurement time. (or)

  2. Add a critical section by disabling interrupts for the `touch_xxxxcap_sensors_measure()` function as shown in the following code snippet.

```
    Disable_global_interrupt();
    touch_ret = touch_xxxxcap_sensors_measure( touch_time.current_time_ms, NORMAL_ACQ_MODE,
touch_xxxxcap_measure_complete_callback);
    Enable_global_interrupt();
```

The Interrupt Blocking Time while executing `touch_xxxxcap_sensors_measure` API for various CPU frequencies are as follows.

CPU Frequency (in MHz)	Interrupt Blocking Time (in µs)
48	~77
24	~124
16	~176
12	~223

The interrupt blocking time varies based on the PTC_GCLK frequency, CPU frequency, and the library version. The actual blocking time can be measured by toggling a GPIO pin before and after the `touch_xxxxcap_sensors_measure` function.

When IAR compiler is used, utilize the `system_interrupt_enable_global()` and `system_interrupt_disable_global()` functions to enable and disable the global interrupts, respectively. In case of AVR, use `cli()` and `sei()` instructions to disable and enable the global interrupts.

10. FAQ on PTC Qtouch

Table 10-1. Frequently Asked Questions

Query	Answer
When can we change an acquisition, sensor configuration or global sensor parameter? After changing an acquisition parameter do we need to recalibrate or reinitialize the sensors and PTC?	Its best to call the helper APIs to update these parameter when the measurement_done_touch flag (part of `touch_measure_data_t` structure) is true, which means the library is not in the middle of an (previously started) incomplete acquisition. Changing Gain and Filter level settings can affect the Signal value, so recalibration is mandatory by invoking the `touch_sensors_calibrate()` API.
Can sensors be disabled and re-enabled run time? For example, scan 2 sensors while sleeping and then scan all sensors when the system wakes up.	Yes, this is possible using the `touch_xxxcap_sensor_disable()` and `touch_xxxcap_sensor_reenable()` API.
There is a low amplitude pulse prior to the 16 acquisition samples and a large amplitude pulse after the 16 acquisition samples.	These pulses are part of setting up the sense line's initial conditions.
Is Detect integration calculated inside the PTC or by QTouch library?	This is done by QTouch library.
When Auto Oversampling is enabled how can one determine touch timing?	The absolute maximum cycle, is the case that auto oversamples is applied to all channels: (Normal acquisition time) x (1 + `auto_os`). This can only happen with a poorly tuned system, as `FILTER_LEVEL` should be sufficient to prevent `AUTO_OS` happening except on a touched key under noisy conditions.
Can sensor signal lines (Y or X lines) be used to drive LEDs, etc., when not being used for sensor acquisitions?	No. This is not recommended

11. Appendix

11.1. Macros

11.1.1. Touch Library Acquisition Status Bit Fields

Keyword	Type	Description
TOUCH_NO_ACTIVITY	0x0000u	No touch activity.
TOUCH_IN_DETECT	0x0001u	Atleast one touch channel is in detect.
TOUCH_STATUS_CHANGE	0x0002u	Change in touch status of at least one Touch channel.
TOUCH_ROTOR_SLIDER_POS_CHANGE	0x0004u	Change in the position of at least one rotor or slider.
TOUCH_CHANNEL_REF_CHANGE	0x0008u	Changein the reference value of at least one touch channel.
TOUCH_BURST_AGAIN	0x0100u	Indicates that re-burst is required to resolve filtering or calibration state.
TOUCH_RESOLVE_CAL	0X0200u	Indicates that re-burst is required to resolve calibration.
TOUCH_RESOLVE_FILTERIN	0x0400u	Indicates that re-burst is required to resolve calibration.
TOUCH_RESOLVE_DI	0x0800u	Indicates that re-burst is needed to resolve Detect Integration.
TOUCH_RESOLVE_POS_RECAL	0x1000u	Indicates that re-burst is needed to resolve recalibration.
TOUCH_CC_CALIB_ERROR	0X2000u	Indicates that CC calibration failed on at least one channel.
TOUCH_AUTO_OS_IN_PROGRESS	0X4000u	Indicates that Auto-os in progress to get stable channel signal.

11.1.2. Sensor State Configurations

GET_SENSOR_STATE (SENSOR_NUMBER)

To get the sensor state (whether detect or not) for parameter that corresponds to the sensor specified using the `SENSOR_NUMBER`.

The macro returns either 0 or 1. If the bit value is 0, the sensor is not in detect. If the bit value is 1, the sensor is in detect.

```
#define GET_XXXXCAP_SENSOR_STATE(SENSOR_NUMBER) p_xxxxcap_measure_data-
>p_sensor_states
[(SENSOR_NUMBER / 8)] & (1 << (SENSOR_NUMBER % 8))) >> (SENSOR_NUMBER %8)
```

GET_XXXXCAP_SENSOR_MOIS_STATUS (SNSR_NUM)

To get the moisture status of a particular sensor. The return value is 1 in case of sensor is affected by moisture and returns 0 if sensor is affected by moisture.

```
#define GET_XXXXCAP_SENSOR_MOIS_STATUS(SNSR_NUM) ((p_xxxxcap_measure_data-
>p_sensor_mois_status
[(SNSR_NUM)/8] & (1<<((SNSR_NUM)%8))) >>(SNSR_NUM %8))
```

GET_XXXXCAP_MOIS_GRP_SUM_DELTA (GRP_ID)

To get the xxxxcap moisture group sum delta.

The return value is 32 bit integer indicating the sum delta of moisture group.

```
#define GET_XXXXCAP_MOIS_GRP_SUM_DELTA(GRP_ID)(mois_XXXX_grp_delta_arr[(GRP_ID)-1])
```

GET_XXXXCAP_MOIS_GRP_ADJ_DELTA (GRP_ID)

To get the xxxxcap moisture group Adjacent delta .The return value is 32 bit integer indicating the adjacent delta of moisture group.

```
#define GET_MUTLCAP_MOIS_GRP_ADJ_DELTA(GRP_ID)(mois_mutl_grp_adj_delta_arr[(GRP_ID)-1])
```

GET_MOIS_XXXX_GLOB_LOCK_STATE

To get the moisture lock status of xxxxcap moisture groups. The return value is 1 if any moisture group is in moisture global lockout and 0 if no moisture group is in moisture global lockout.

```
#define GET_MOIS_MUT_GLOB_LOCK_STATE(mois_lock_global_mutl)
```

GET_XXXXCAP_SENSOR_NOISE_STATUS (SENSOR_NUMBER)

To get the noise status of a particular sensor. The return value is 1 in case of sensor is noisy and returns 0 if sensor is not noisy.

```
#define GET_XXXXCAP_SENSOR_NOISE_STATUS (SENSOR_NUMBER)(p_xxxxcap_measure_data-
>p_sensor_noise_status
[(SENSOR_NUMBER / 8)] & (1 <<(SENSOR_NUMBER % 8))) >> (SENSOR_NUMBER % 8)
```

GET_ROTOR_SLIDER_POSITION (ROTOR_SLIDER_NUMBER)

To get the rotor angle or slider position. These values are valid only when the sensor state for corresponding rotor or slider state is in detect.

`ROTOR_SLIDER_NUMBER` is the parameter for which the position is being obtained.

The macro returns rotor angle or sensor position.

```
#define
GET_XXXXCAP_ROTOR_SLIDER_POSITION(ROTOR_SLIDER_NUMBER)p_xxxxcap_measure_data-
>p_rotor_slider_values
 [ROTOR_SLIDER_NUMBER]
```

`DEF_TOUCH_MUTLCAP` must be set to 1 in the application to enable the Mutual capacitance touch acquisition method.

`DEF_TOUCH_SELFCAP` must be set to 1 in the application to enable the Self-capacitance touch acquisition method.

11.2. Typedef

Field	Unit	Description
`threshold_t`	`uint8_t`	An unsigned 8-bit number setting a sensor detection threshold.
`sensor_id_t`	`uint8_t`	Sensor number type.
`touch_current_time_t`	`uint16_t`	Current time type.
`touch_delta_t`	`int16_t`	Touch sensor delta value type.
`touch_acq_status_t`	`uint16_t`	Status of touch measurement.
`mois_snsr_threshold_t`	`int32_t`	Moisture threshold for individual sensor.
`mois_system_threshold_t`	`int32_t`	Moisture threshold for the entire system.

11.3. Enumeration

11.3.1. Gain Setting (`tag_gain_t`)

Gain per touch channel.

Gain is applied on a per-channel basis to allow a scaling-up of the touch sensitivity on contact.

Range: `GAIN_1` (no scaling) to `GAIN_32` (scale-up by32)

Data Fields

- `GAIN_1`
- `GAIN_2`
- `GAIN_4`
- `GAIN_8`
- `GAIN_16`
- `GAIN_32`

11.3.2. Filter Level Setting (`tag_filter_level_t`)

Touch library FILTER LEVEL setting.

The filter level setting controls the number of samples acquired to resolve each acquisition. A higher filter level setting provides improved signal to noise ratio under noisy conditions, while increasing the total time for measurement which results in increased power consumption. Refer `filter_level_t` in `touch_api_ptc.h`

Range: `FILTER_LEVEL_1` (one sample) to `FILTER_LEVEL_64` (64 samples).

Data Fields

- `FILTER_LEVEL_1`
- `FILTER_LEVEL_2`
- `FILTER_LEVEL_4`
- `FILTER_LEVEL_8`
- `FILTER_LEVEL_16`
- `FILTER_LEVEL_32`

- `FILTER_LEVEL_64`

11.3.3. Auto Oversample Setting (`tag_auto_os_t`)

Auto oversample controls the automatic oversampling of sensor channels when unstable signals are detected with the default setting of 'Filter level'. Enabling Auto oversample results in 'Filter level' x 'Auto Oversample' number of samples taken on the corresponding sensor channel when an unstable signal is observed. In a case where 'Filter level' is set to `FILTER_LEVEL_4` and 'Auto Oversample' is set to `AUTO_OS_4`, 4 oversamples are taken with stable signal values and 4+16 oversamples are taken when unstable signal is detected.

Range: `AUTO_OS_DISABLE` (oversample disabled) to `AUTO_OS_128` (128 oversamples).

Data Fields

- `AUTO_OS_DISABLE`
- `AUTO_OS_2`
- `AUTO_OS_4`
- `AUTO_OS_8`
- `AUTO_OS_16`
- `AUTO_OS_32`
- `AUTO_OS_64`
- `AUTO_OS_128`

11.3.4. Low Power Sensor Scan Rate (`tag_lowpower_scan_int_t`)

When the CPU returns to standby mode from active, the sensor configured as the low power sensor is scanned at this interval. A high value for this parameter will reduce power consumption but increase response time for a low power sensor.
Note: This enum is applicable only for ATmega devices.

Range: `LOWPOWER_PER0_SCAN_3_P_9_MS` to `LOWPOWER_PER7_SCAN_250_MS`

Data Fields

- `LOWPOWER_PER0_SCAN_3_P_9_MS`
- `LOWPOWER_PER1_SCAN_7_P_8_MS`
- `LOWPOWER_PER2_SCAN_15_P_625_MS`
- `LOWPOWER_PER3_SCAN_31_P_25_MS`
- `LOWPOWER_PER4_SCAN_62_P_5_MS`
- `LOWPOWER_PER5_SCAN_125_MS`
- `LOWPOWER_PER6_SCAN_250_MS`

11.3.5. Library Error Code (`tag_touch_ret_t`)

Touch Library error codes.

Data Fields

- `TOUCH_SUCCESS` Successful completion of touch operation.
- `TOUCH_ACQ_INCOMPLETE` Library is busy with pending previous touch measurement.
- `TOUCH_INVALID_INPUT_PARAM` Invalid input parameter.
- `TOUCH_INVALID_LIB_STATE` Operation not allowed in the current touch library state.
- `TOUCH_INVALID_SELFCAP_CONFIG_PARAM` Invalid self-capacitance configuration input parameter.

- `TOUCH_INVALID_MUTLCAP_CONFIG_PARAM` Invalid mutual capacitance configuration input parameter.
- `TOUCH_INVALID_RECAL_THRESHOLD` Invalid recalibration threshold input value.
- `TOUCH_INVALID_CHANNEL_NUM` Channel number parameter exceeded total number of channels configured.
- `TOUCH_INVALID_SENSOR_TYPE` Invalid sensor type. Sensor type must NOT be `SENSOR_TYPE_UNASSIGNED`.
- `TOUCH_INVALID_SENSOR_ID` Invalid sensor number parameter.
- `TOUCH_INVALID_RS_NUM` Number of rotor/sliders set as 0, while trying to configure a rotor/slider.

11.3.6. Application Error Code (`tag_touch_app_err_t`)

The application error codes are listed below.

Data Fields

- `TOUCH_INIT_CONFIG_ERR` The `touch_xxxxcap_sensors_init` is fed with an incompatible / incomplete parameter.
- `TOUCH_SENSOR_CONFIG_ERR` The `touch_xxxxcap_sensor_config` is fed with an incompatible parameter / Touch Library state is not in `TOUCH_STATE_INIT`.
- `TOUCH_INIT_CALIB_ERR` The `touch_xxxxcap_sensors_calibrate` is fed with an invalid parameter / Touch Library state is `TOUCH_STATE_NULL`/ `TOUCH_STATE_BUSY`.
- `TOUCH_MEASURE_INCOMPLETE` The `touch_measure api` has error due to an invalid input param / it was on an invalid Touch Library state.
- `TOUCH_MEASURE_CC_CAL_FAILED` Hardware calibration error; check the hardware and ensure it is proper. If the error persists, check the user manual for sensor design guidelines.

11.3.7. Touch Channel (`tag_channel_t`)

Sensor start and end channel type of a Sensor. Channel number starts with value 0.

Data Fields

`CHANNEL_0` to `CHANNEL_255`

11.3.8. Touch Library State (`tag_touch_lib_state_t`)

Touch library state.

Data Fields

- `TOUCH_STATE_NULL` Touch library is un-initialized. All sensors are disabled.
- `TOUCH_STATE_INIT` Touch library has been initialized
- `TOUCH_STATE_READY` Touch library is ready to start a new capacitance measurement on enabled sensors.
- `TOUCH_STATE_CALIBRATE` Touch library is performing calibration on all sensors.
- `TOUCH_STATE_BUSY` Touch library is busy with on-going capacitance measurement.

11.3.9. Sensor Type (`tag_touch_lib_state_t`)

Sensor types available.

Data Fields

- `SENSOR_TYPE_UNASSIGNED` Sensor is not configured yet
- `SENSOR_TYPE_KEY` Sensor type key

- SENSOR_TYPE_ROTOR Sensor type rotor
- SENSOR_TYPE_LUMP Sensor type lump
- SENSOR_TYPE_SLIDER Sensor type slider
- MAX_SENSOR_TYPE Max value of enum type for testing

11.3.10. Touch Sensing Type (tag_touch_acq_t)

Based on the two types of charge transfer technology, the capacitive touch sensing may be either mutual capacitance sensing or self-capacitance sensing.

Data Fields

- TOUCH_MUTUAL Mutual capacitance sensing
- TOUCH_SELF Self-capacitance sensing
- MAX_TOUCH_ACQ Max value of enum

11.3.11. Touch Library Acquisition Mode (tag_touch_acq_mode_t)

Touch library acquisition mode.

Data Fields

RAW_ACQ_MODE

When raw acquisition mode is used, the measure_complete_callback function is called immediately once a fresh value of signals are available. In this mode, the Touch Library does not perform any post processing. So, the references, sensor states or rotor/slider position values are not updated in this mode.

NORMAL_ACQ_MODE

When normal acquisition mode is used, the measure_complete_callback function is called only after the Touch Library completes processing of the signal values obtained. The references, sensor states and rotor/slider position values are updated in this mode.

11.3.12. Calibration Auto tune Setting (tag_auto_tune_type_t)

Touch library PTC prescaler clock and series resistor auto tuning setting

Data Fields

- AUTO_TUNE_NONE Auto tuning mode disabled. This mode uses the user defined PTC prescaler and series resistor values.
- AUTO_TUNE_PRSC Auto tune PTC prescaler for best noise performance . This mode uses the user defined series resistor value.
- AUTO_TUNE_RSEL Auto tune series resistor for least power consumption. This mode uses the user defined PTC prescaler value.

11.3.13. PTC Acquisition Frequency Mode Setting (tag_freq_mode_sel_t)

The frequency mode setting option enables the PTC acquisition to be configured for the following modes.

- Frequency hopping and spread spectrum disabled.
- Frequency hopping enabled with median filter.
- Frequency spread spectrum enabled without median filter.
- Frequency spread spectrum enabled with median filter.

Range: FREQ_MODE_NONE (no frequency hopping & spread spectrum) to FREQ_MODE_SPREAD_MEDIAN (spread spectrum with median filter)

Data Fields

- `FREQ_MODE_NONE` 0u
- `FREQ_MODE_HOP` 1u
- `FREQ_MODE_SPREAD` 2u
- `FREQ_MODE_SPREAD_MEDIAN` 3u

11.3.14. PTC Clock Pre-scaler Setting (`tag_prsc_div_sel_t`)

Refer `touch_configure_ptc_clock()` API in `touch.c`

Example:

If generic clock input to PTC = 4 MHz,

- `PRSC_DIV_SEL_1` sets PTC Clock to 4 MHz.
- `PRSC_DIV_SEL_2` sets PTC Clock to 2 MHz.
- `PRSC_DIV_SEL_4` sets PTC Clock to 1 MHz.
- `PRSC_DIV_SEL_8` sets PTC Clock to 500 kHz.

Data Fields

- `PRSC_DIV_SEL_1`
- `PRSC_DIV_SEL_2`
- `PRSC_DIV_SEL_4`
- `PRSC_DIV_SEL_8`

11.3.15. PTC Series Resistor Setting (`tag_rsel_val_t`)

For mutual capacitance mode, this series resistor is switched internally on the Y-pin. For self-capacitance mode, the series resistor is switched internally on the sensor pin.

Example:

- `RSEL_VAL_0` sets internal series resistor to 0 Ohms.
- `RSEL_VAL_20` sets internal series resistor to 20 Kohms.
- `RSEL_VAL_50` sets internal series resistor to 50 Kohms.
- `RSEL_VAL_100` sets internal series resistor to 100 Kohms.

Data Fields

- `RSEL_VAL_0`
- `RSEL_VAL_20`
- `RSEL_VAL_50`
- `RSEL_VAL_100`

11.3.16. PTC Acquisition Frequency Delay Setting (`tag_rsel_val_t`)

The PTC acquisition frequency is dependent on the generic clock input to PTC and PTC clock prescaler setting. This delay setting inserts n PTC clock cycles between consecutive measurements on a given sensor, thereby changing the PTC acquisition frequency. `FREQ_HOP_SEL_1` setting inserts 0 PTC clock cycle between consecutive measurements. `FREQ_HOP_SEL_16` setting inserts 15 PTC clock cycles. Hence, higher delay setting will increase the total time required for capacitance measurement on a given sensor as compared to a lower delay setting.

A desired setting avoids noise in the same frequency as the acquisition frequency.

Data Fields

- FREQ_HOP_SEL_1
- FREQ_HOP_SEL_2
- FREQ_HOP_SEL_3
- FREQ_HOP_SEL_4
- FREQ_HOP_SEL_5
- FREQ_HOP_SEL_6
- FREQ_HOP_SEL_7
- FREQ_HOP_SEL_8
- FREQ_HOP_SEL_9
- FREQ_HOP_SEL_10
- FREQ_HOP_SEL_11
- FREQ_HOP_SEL_12
- FREQ_HOP_SEL_13
- FREQ_HOP_SEL_14
- FREQ_HOP_SEL_15
- FREQ_HOP_SEL_16

11.3.17. AKS Group (`tag_aks_group_t`)

It provides information about the sensors that belong to specific AKS group. `NO_AKS_GROUP` indicates that the sensor does not belong to any AKS group and cannot be suppressed. `AKS_GROUP_x` indicates that the sensor belongs to the AKS group x.

Data Fields

- NO_AKS_GROUP
- AKS_GROUP_1
- AKS_GROUP_2
- AKS_GROUP_3
- AKS_GROUP_4
- AKS_GROUP_5
- AKS_GROUP_6
- AKS_GROUP_7
- `MAX_AKS_GROUP` Max value of enum type for testing.

11.3.18. Sensor Hysteresis Setting (`tag_hysteresis_t`)

A sensor detection hysteresis value. This is expressed as a percentage of the sensor detection threshold. HYST_x = hysteresis value is x% of detection threshold value (rounded down).

Note: A minimum value of 2 is used.

Example: If detection threshold = 20,

- `HYST_50` = 10 (50% of 20)
- `HYST_25` = 5 (25% of 20)
- `HYST_12_5` = 2 (12.5% of 20)
- `HYST_6_25` = 2 (6.25% of 20 = 1, but value is hard limited to 2)

Data Fields

- HYST_50

- HYST_25
- HYST_12_5
- HYST_6_25
- MAX_HYST Max value of enum type for testing.

11.3.19. Sensor Recalibration Threshold (tag_recal_threshold_t)

This is expressed as a percentage of the sensor detection threshold. RECAL_x = recalibration threshold is x% of detection threshold value (rounded down).

Note: A minimum value of 4 is used.

Example: If detection threshold = 40,

- RECAL_100 = 40 (100% of 40)
- RECAL_50 = 20 (50% of 40)
- RECAL_25 = 10 (25% of 40)
- RECAL_12_5 = 5 (12.5% of 40)
- RECAL_6_25 = 4 (6.25% of 40 = 2, but value is hard limited to 4)

Data Fields

- RECAL_100
- RECAL_50
- RECAL_25
- RECAL_12_5
- RECAL_6_25
- MAX_RECAL Max value of enum type for testing.

11.3.20. Rotor Slider Resolution (tag_resolution_t)

For rotors and sliders, the resolution of the reported angle or position.

- RES_x_BIT = rotor/slider reports x-bit values.

Example: If slider resolution is RES_7_BIT, then reported positions are in the range 0..127.

Data Fields

- RES_1_BIT
- RES_2_BIT
- RES_3_BIT
- RES_4_BIT
- RES_5_BIT
- RES_6_BIT
- RES_7_BIT
- RES_8_BIT
- MAX_RES Max value of enum type for testing.

11.3.21. PTC Sensor Noise Lockout setting (nm_sensor_lockout_t)

The sensor lockout setting option allows the system to be configured in the following modes.

- SINGLE_SENSOR_LOCKOUT Single sensor can be locked out.
- GLOBAL_SENSOR_LOCKOUT All the sensors are locked out for touch detection.
- NO_LOCK_OUT All the sensors are available for touch detection.

Range: SINGLE_SENSOR_LOCKOUT to NO_LOCK_OUT.

Data Fields

- SINGLE_SENSOR_LOCKOUT 0u
- GLOBAL_SENSOR_LOCKOUT 1u
- NO_LOCK_OUT 2u

11.3.22. 11_3_21_PTC_GPIO_STATE(ptc_gpio_state_t)

Detailed Description

PTC lines state in unmeasured condition can be set using this enum

- PULLHIGH_WHEN_NOT_MEASURED Indicates that default state of PTC lines are at vcc.
- GND_WHEN_NOT_MEASURED Indicates that default state PTC lines are grounded.

Range: PULLHIGH_WHEN_NOT_MEASURED=0 and GND_WHEN_NOT_MEASURED.

Data Fields

- PULLHIGH_WHEN_NOT_MEASURED
- GND_WHEN_NOT_MEASURED

11.3.23. Moisture Group Setting (moisture_grp_t)

Detailed Description

Sensor can be configured in the moisture group using this type.

- MOIS_DISABLED Indicates that the sensor does not belong to any moisture group.
- MOIS_GROUP_X Indicates that the sensor belongs to the moisture group x.

Range: MOIS_DISABLED = 0 to MOIS_GROUP_7.

Data Fields

- MOIS_DISABLED=0
- MOIS_GROUP_0
- MOIS_GROUP_1
- MOIS_GROUP_2
- MOIS_GROUP_3
- MOIS_GROUP_4
- MOIS_GROUP_5
- MOIS_GROUP_6
- MOIS_GROUP_7
- MOIS_GROUPN

11.3.24. Multi-touch Group Setting (mltch_grp_t)

Detailed Description

Sensor can be configured in the multi-touch group using this type

- MLTCH_NONE Indicates that the sensor does not belong to any multi-touch group.
- MLTCH_GROUP_X Indicates that the sensor belongs to the multi-touch group x.

Range: MLTCH_NONE=0 to MOIS_GROUP_7.

Data Fields

- `MLTCH_NONE=0`
- `MLTCH_GROUP_0`
- `MLTCH_GROUP_1`
- `MLTCH_GROUP_2`
- `MLTCH_GROUP_3`
- `MLTCH_GROUP_4`
- `MLTCH_GROUP_5`
- `MLTCH_GROUP_6`
- `MLTCH_GROUP_7`
- `MLTCH_GROUPN`

11.3.25. Touch Mode Configuration (`tag_tch_mode`)

Touch mode can be configured.

Note: This is applicable only for ATmega devices.

Data Fields

- `TCH_MODE_POLLED` Polled mode
- `TCH_MODE_ISR` Interrupt mode
- `TCH_MODE_NONE` Touch mode is null.

11.3.26. Trigger Mode (`tag_trigger_mode`)

Trigger source for continuous hardware PTC acquisition. It is n clock cycles of internal 128Khz clock.

Note: This is applicable only for ATmega devices.

Data Fields

- `TCH_TRIGGER_128KHZ_4MS`
- `TCH_TRIGGER_128KHZ_8MS`
- `TCH_TRIGGER_128KHZ_16MS`
- `TCH_TRIGGER_128KHZ_32MS`
- `TCH_TRIGGER_128KHZ_64MS`
- `TCH_TRIGGER_128KHZ_128MS`
- `TCH_TRIGGER_128KHZ_256MS`

11.4. Datastructures

11.4.1. Touch Library Timing Info (`tag_touch_time_t`)

Touch library time parameter.

Data Fields

Field	Unit	Description
measurement_period_ms	uint16_t	Touch measurement period in milliseconds. This variable determines how often a new touch measurement must be done.
current_time_ms	volatile uint16_t	Current time set by timer ISR.
time_to_measure_touch	volatile uint8_t	Flag set by timer ISR when it is time to measure touch.

11.4.2. Sensor Info (`tag_sensor_t`)

Sensor structure for storing sensor related information.

Data Fields

Keyword	Type	Description
state	uint8_t	Sensor state (calibrate, on, off, filter-in, filter-out, disable, pos-recal)
general_counter	uint8_t	General purpose counter used for calibrating, drifting, etc
ndil_counter	uint8_t	Counter used for detect integration
type_aks_pos_hyst	uint8_t	bits 7..6: sensor type: {00: key,01: rotor,10: slider,11: reserved} bits 5..3: AKS group (0..7): 0 = no AKS group bit 2 : positive recal flag bits 1..0: hysteresis
threshold	uint8_t	Sensor detection threshold
from_channel	uint8_t	Sensor from channel for keys: from channel = to channel. Rotors: Top channel. Sliders : Left most channel **Note:** We need `to_channel` for rotors/sliders only
to_channel	uint8_t	For keys, this is unused. For rotors: Bottom left channel. For sliders: Middle channel
index	uint8_t	Index into array of rotor/slider values

11.4.3. Global Sensor Configuration Info (`tag_touch_global_param_t`)

Touch library global parameter.

Data Fields

Field	Unit	Description
di	uint8_t	Detect Integration (DI) limit.
atch_drift_rate	uint8_t	Sensor away from touch drift rate.
tch_drift_rate	uint8_t	Sensor towards touch drift rate.
max_on_duration	uint8_t	MaximumON time duration.
drift_hold_time	uint8_t	Sensor drift hold time.
atch_recal_delay	uint8_t	Sensor away from touch recalibration delay.

Field	Unit	Description
cal_seq_1_count	uint8_t	Sensor calibration dummy burst count.
cal_seq_2_count	uint8_t	Sensor calibration settling burst count.
recal_threshold	recal_threshold_t	Sensor away from touch recalibration threshold.
touch_postprocess_mode	Uint16_t	Sensor post-processing mode.
auto_os_sig_stability_limit	uint8_t	Stability limit for Auto Oversample feature.
auto_tune_sig_stability_limit	uint16_t	Stability limit for frequency auto tune feature.
auto_freq_tune_in_cnt	uint8_t	Frequency auto tune In counter.
nm_sig_stability_limit	uint16_t	Stability limit for noise measurement.
nm_noise_limit	uint8_t	Noise limit.
nm_enable_sensor_lock_out	nm_sensor_lockout_t	Sensor lockout feature variable.
nm_lockout_countdown	uint8_t	Lockout countdown for noise measurement.
Charge_share_delay	uint8_t	Charge share delay value; applicable only for SAM C20, SAM C21, SAM L22 and ATmega devices.

11.4.4. Filter Callback Data Type (`tag_touch_filter_data_t`)

Touch library filter callback data type.

Data Fields

Field	Unit	Description
num_channel_signals	uint16_t	Length of the measured signal values list.
p_channel_signals	uint16_t	Pointer to measured signal values for each channel.

11.4.5. Measure Data Type (`tag_touch_measure_data_t`)

Touch library measure data type.

Data Fields

Field	Unit	Description
measurement_done_touch	volatile uint8_t	Flag set by touch_xxxxcap_measure_complete_callback() function when a latest Touch status is available.
acq_status	touch_acq_status_t	Status of touch measurement.
num_channel_signals	uint16_t	Length of the measured signal values list.
*p_channel_signals	uint16_t	Pointer to measured signal values for each channel.
num_channel_references	uint16_t	Length of the measured reference values list.
*p_channel_references	uint16_t	Pointer to measured reference values for each channel.
num_sensor_states	uint8_t	Number of sensor state bytes.
*p_sensor_states	uint8_t	Pointer to touch status of each sensor.
num_rotor_slider_values	uint8_t	Length of the rotor and slider position values list.
*p_rotor_slider_values	uint8_t	Pointer to rotor and slider position values.
num_sensors	uint16_t	Length of the sensors data list.
*p_cc_calibration_vals	uint16_t	Pointer to calibrated compensation values for a given sensor channel.
*p_sensors	sensor_t	Pointer to sensor data.
*p_sensor_noise_status	uint8_t	Pointer to noise status of the sensors.
*p_nm_ch_noise_val	uint16_t	Pointer to noise level value of each channel.
*p_sensor_mois_status	uint8_t	Pointer to moisture status
*p_auto_os_status	uint8_t	Pointer to auto-oversamples status
cc_calib_status_flag	uint8_t	Flag is set when CC-calibration is ongoing.

11.4.6. Sensor Configuration Parameter (`tag_touch_selfcap_param_t,tag_touch_mutlcap_param_t`)

Touch library self-capacitance and mutual capacitance sensor parameter.

Data Fields

Field	Unit	Description
aks_group	aks_group_t	Which AKS group, the sensor belongs to.
detect_threshold	threshold_t	An unsigned 8-bit number setting a sensor detection threshold.
detect_hysteresis	hysteresis_t	A sensor detection hysteresis value. This is expressed as a percentage of the sensor detection threshold. HYST_x = hysteresis value is x% of detection threshold value (rounded down). A minimum value of 2 is used. Example: If detection threshold = 20, HYST_50= 10 (50% of 20) HYST_25= 5 (25% of 20) HYST_12_5 = 2 (12.5% of 20) HYST_6_25 = 2 (6.25% of 20 = 1, but value is hard limited to 2)
position_resolution	resolution_t	For rotors and sliders, the resolution of the reported angle or position. RES_x_BIT = rotor/slider reports x-bit values. Example: If slider resolution is RES_7_BIT, then reported positions are in the range 0..127
position_hysteresis	uint8_t	Sensor position hysteresis. This is valid only for a rotor or slider. bits 1..0: hysteresis. **Note:** This parameter is valid only for mutual capacitance method.

11.4.7. Sensor Acquisition Parameter (tag_touch_selfcap_acq_param_t,_tag_touch_mutlcap_acq_param_t)

Sensor acquisition parameter.

Data Fields

Field	Unit	Description
*p_xxxxcap_gain_per_node	gain_t	Pointer to gain per node.
touch_xxxxcap_freq_mode	Freq_mode_sel_t	Set-up acquisition frequency mode.
*xxxxcap_ptc_prsc	prsc_div_sel_t	Pointer to PTC clock pre-scaler value.
*xxxxcap_resistor_value	rsel_val_t	Pointer to PTC series resistor value.
p_xxxxcap_hop_freqs	*freq_hop_sel_t	Pointer to acquisition frequency settings.
*p_xxxxcap_filter_level	filter_level_t	Pointer to filter level.
*p_xxxxcap_auto_os	auto_os_t	Pointer to auto oversampling.

Field	Unit	Description
*xxxxcap_ptc_prsc_cc_cal	prsc_div_sel_t	Pointer to PTC clock prescale value during CC calibration.
*xxxxcap_resistor_value_cc_cal	rsel_val_t	Pointer to PTC sense resistor value during CC calibration.

11.4.8. Self-capacitance Sensor Configuration (`touch_selfcap_config_t`)

Touch Library self-capacitance configuration input type.

Data Fields

Field	Unit	Description
num_channels	uint16_t	Number of channels.
num_sensors	uint16_t	Number of sensors.
num_rotors_and_sliders	uint8_t	Number of rotors/ sliders.
global_param	touch_global_param_t	Global sensor configuration information.
touch_selfcap_acq_param	touch_selfcap_acq_param_t	Sensor acquisition parameter information.
*p_data_blk	uint8_t	Pointer to data block buffer.
buffer_size	uint16_t	Size of data block buffer.
*p_selfcap_y_nodes	uint16_t	Pointer to self-capacitance nodes.
self_quick_reburst_enable	uint8_t	Quick re-burst enable.
(touch_filter_data_t *p_filter_data)	void(*filter_callback)	Self-capacitance filter callback.
enable_freq_auto_tune	uint8_t	Frequency auto tune enable.
enable_noise_measurement	uint8_t	Noise measurement enable.
nm_buffer_cnt	uint8_t	Memory allocation buffer.
self_mois_tlrnce_enable	uint8_t	Self-capacitance moisture tolerance enable flag.
self_mois_groups	uint8_t	Number of self-capacitance moisture groups.

Field	Unit	Description
self_mois_quick_reburst_enable	uint8_t	Moisture Quick re-burst enable.
self_ptc_gpio_state	ptc_gpio_state_t	GPIO state for Self-capacitance PTC pins
tlib_feature_list	tlib_init_fn_ptr	Library feature list.

11.4.9. Mutual Capacitance Sensor Configuration (`touch_mutlcap_config_t`)

Touch Library mutual capacitance configuration input type.

Data Fields

Field	Unit	Description
num_channels	uint16_t	Number of channels.
num_sensors	uint16_t	Number of sensors.
num_rotors_and_sliders	uint8_t	Number of rotors/ sliders.
global_param	touch_global_param_t	Noise measurement enable/disable.
touch_xxxxcap_acq_param	touch_xxxxcap_acq_param_t	Sensor acquisition parameter info.
*p_data_blk	uint8_t	Pointer to data block buffer.
*buffer_size	uint16_t	Size of data block buffer.
*p_mutlcap_xy_nodes	uint16_t	Pointer to xy-nodes.
mutl_quick_reburst_enable	uint8_t	Quick re-burst enable.
(touch_filter_data_t *p_filter_data)	void(* filter_callback)	Mutual capacitance filter callback.
enable_freq_auto_tune	uint8_t	Frequency auto tune enable.
enable_noise_measurement	uint8_t	Noise measurement enable.
nm_buffer_cnt	uint8_t	Memory allocation buffer.
mutl_mois_tlrnce_enable	uint8_t	Mutual capacitance moisture tolerance enable flag.
mutl_mois_groups	uint8_t	Number of mutual capacitance moisture groups.

Field	Unit	Description
mutl_mois_quick_reburst_enable	uint8_t	Moisture Quick re-burst enable.
mutl_ptc_gpio_state	ptc_gpio_state_t	GPIO state for mutual capacitance PTC pins
tlib_feature_list	tlib_init_fn_ptr	Library feature list.

11.4.10. Moisture Structure (**`tag_snsr_mois_t`**)

Structure for storing moisture and multi-touch group information.

Data Fields

Field	Unit	Description
mois_grp	uint8_t	Moisture group member
multch_grp	uint8_t	Multi-touch group member

11.4.11. Touch Library Input Configuration (**`touch_config_t`**)

Touch Library Input Configuration Structure.

Data Fields

Field	Unit	Description
p_mutlcap_config	touch_mutlcap_config_t	Pointer to mutual capacitance configuration structure.
p_selfcap_config	touch_selfcap_config_t	Pointer to self-capacitance configuration structure.
ptc_isr_lvl	uint8_t	PTC ISR priority level. **Note:** This is applicable only for SAM devices.
tch_mode	tch_mode_t	Touch mode configuration. **Note:** This is applicable only for ATmega devices.

11.4.12. Library Function List (**`tag_tlib_init_fn_ptr_t`**)

Touch Library support functions initializer.

Data Fields

Field	Unit	Description
auto_tune_init	void(*auto_tune_init)	Auto-tune function initializer
auto_os_init	uint32_t (*auto_os_init)	Auto-OS function initializer
lk_chk	void(*lk_chk)	Sensor lock-out function initializer
enable_aks	void enable_aks(void)	AKS function initializer

11.4.13. Touch Library Information (**`tag_touch_info_t`**)

Touch Library information structure.

Data Fields

Field	Unit	Description
tlib_state	touch_tlib_state_t	Touch library state is specified
num_channels_in_use	unit16_t	Number of channels in use; irrespective of the corresponding sensor being disabled or enabled
num_sensors_in_use	uint16_t	Number of sensors in use; irrespective of the sensor being disabled or enabled
num_rotors_sliders_in_use	uint8_t	Number of rotor sliders in use; irrespective of the Rotor/Slider being disabled or enabled
max_channels_per_rotor_slider	uint8_t	Max possible number of channels per rotor or slider

11.4.14. Touch Library Version Information (`touch_libver_info_t`)

Touch Library version information structure.

Data Fields

Field	Unit	Description
chip_id	unit32_t	Chip ID
product_id	uint16_t	Product ID
fw_version	uint16_t	Touch Library Version Bits[12:15] Reserved Bits[8:11] TLIB_MAJOR_VERSION Bits[4:7] TLIB_MINOR_VERSION Bits[0:3] TLIB_PATCH_VERSION

11.5. Global Variables

Field	Unit	Description
touch_time	touch_time_t	This holds the library timing info
touch_acq_status	touch_acq_status_t	This holds the Touch Library acquisition status
cc_cal_max_signal_limit	uint16_t	CC calibration maximum signal limit variable
cc_cal_min_signal_limit	uint16_t	CC calibration minimum signal limit variable

Field	Unit	Description
*p_selfcap_measure_data	touch_measure_data_t	This holds the self-capacitance method measure data pointer
*p_mutlcap_measure_data	touch_measure_data_t	This holds the mutual capacitance method measure data pointer
wake_up_touch	uint8_t	Wake up touch status from Library to Application
low_power_mode	uint8_t	Low power mode status from Library to Application
mois_lock_global_mutl	uint8_t	Moisture global lock variable for mutual capacitance method
mois_lock_global_self	uint8_t	Moisture global lock variable for self-capacitance method

11.6. API

11.6.1. Sensor Init and De-init

```
touch_ret_t touch_mutlcap_sensors_init (touch_config_t * p_touch_config)
```

```
touch_ret_t touch_selfcap_sensors_init (touch_config_t * p_touch_config)
```

This API is used to initialize the Touch Library with Mutual cap or Self cap method pin, register and sensor configuration provided by the user.

Parameters:`p_touch_config` Pointer to Touch configuration structure.

Returns:`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_sensors_deinit(void)
```

```
touch_ret_t touch_selfcap_sensors_deinit(void);
```

This API can be used to de-initialize the sensor for specific sensing group.

Parameters:

void.

Returns:

`touch_ret_t`: Touch Library Error status.

11.6.2. Sensor Setup and Configuration

```
touch_ret_t touch_mutlcap_sensor_config (sensor_type_t sensor_type, channel_t from_channel,
channel_t to_channel, aks_group_t aks_group, threshold_t detect_threshold, hysteresis_t
detect_hysteresis, resolution_tposition_resolution, uint8_t position_hysteresis, sensor_id_t
* p_sensor_id)
```

```
touch_ret_t touch_selfcap_sensor_config (sensor_type_t sensor_type, channel_t from_channel,
channel_t to_channel, aks_group_t aks_group, threshold_t detect_threshold, hysteresis_t
detect_hysteresis, resolution_tposition_resolution, sensor_id_t * p_sensor_id)
```

This API can be used to configure a sensor of type key, rotor or slider.

Data Fields:

Field	Description
sensor_type	can be of type key, lump, rotor, or slider.
from_channel	the first channel in the slider sensor.
to_channel	the last channel in the slider sensor.
aks_group	which AKS group (if any) the sensor is in.
detect_threshold	the sensor detection threshold.
detect_hysteresis	the sensor detection hysteresis value.
position_resolution	the resolution of the reported position value.
position_hysteresis	the hysteresis for position value (available only for mutual capacitance mode).
p_sensor_id	the sensor id value of the configured sensor is updated by the Touch Library.

Returns: `touch_ret_t`: Touch Library Error status.

11.6.3. Sensor Calibration

```
touch_ret_t touch_mutlcap_sensors_calibrate (auto_tune_type_t )
```

```
touch_ret_t touch_selfcap_sensors_calibrate (auto_tune_type_t )
```

This API is used to calibrate the sensors for the first time before starting a Touch measurement. This API can also beused to force calibration of sensors when any of the Touch sensor parameters are changed during runtime.

Returns:`touch_ret_t`: Touch Library Error status.

11.6.4. Sensor Measure

```
touch_ret_t touch_mutlcap_sensors_measure (touch_current_time_t current_time_ms,
touch_acq_mode_tmutlcap_acq_mode, void(*)(void) measure_complete_callback)
```

```
 touch_ret_t touch_selfcap_sensors_measure (touch_current_time_t current_time_ms,
touch_acq_mode_tselfcap_acq_mode, void(*)(void) measure_complete_callback)
```

This API can be used to start a Touch measurement.

Parameters:

`current_time_ms` Current time in millisecond.

`measure_complete_callback` Interrupt callback to indicate measurement completion.

Returns:

`touch_ret_t`: Touch Library Error status.

11.6.5. Sensor Suspend and Resume

```
touch_ret_t touch_suspend_ptc(void)
```

```
touch_ret_t touch_resume_ptc(void)
```

The `touch_suspend_ptc` function suspends the PTC library's current measurement cycle. The completion of the operation is indicated through callback pointer that must be initialized by the application. Refer Sensor Global Parameters.

The `touch_resume_ptc` function resumes the PTC library's current measurement which was suspended using `touch_suspend_ptc`. After the `touch_resume_ptc` function is called by the application, the `touch_xxxxcap_sensors_measure` API should be called only after the measurement complete callback function is received.

Parameters:

void.

Returns:

`touch_ret_t`: Touch Library Error status.

11.6.6. Sensor Disable and Re-enable

```
touch_ret_t touch_mutlcap_sensor_disable (sensor_id_t sensor_id)
```

```
touch_ret_t touch_selfcap_sensor_disable (sensor_id_t sensor_id)
```

This API can be used to disable any sensor.

Parameters:

`sensor_id` Sensor number which needs to be disabled

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_sensor_reenable (sensor_id_t sensor_id, uint8_t no_calib)
```

```
touch_ret_t touch_selfcap_sensor_reenable (sensor_id_t sensor_id, uint8_t no_calib)
```

This API can be used to re-enable a disabled sensor.

Parameters:

`sensor_id` Sensor number which needs to be reenabled

`no_calib` When value is set to 1, force calibration is not applicable. When value is set to 0, force calibration is applied

Returns:

`touch_ret_t`: Touch Library Error status.

11.6.7. Read-back Sensor Configuration

```
touch_ret_t touch_mutlcap_sensor_get_acq_config (touch_mutlcap_acq_param_t *
p_touch_mutlcap_acq_param)
```

```
touch_ret_t touch_selfcap_sensor_get_acq_config (touch_selfcap_acq_param_t *
p_touch_selfcap_acq_param)
```

This API can be used to read back the sensor acquisition parameters.

Parameters:

`p_touch_mutlcap_acq_param` The acquisition parameters for the mutual capacitance.

`p_touch_selfcap_acq_param` The acquisition parameters for the self-capacitance.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_sensor_get_config (sensor_id_t sensor_id, touch_mutlcap_param_t
*p_touch_sensor_param)
```

```
touch_ret_t touch_selfcap_sensor_get_config (sensor_id_t sensor_id, touch_selfcap_param_t
*p_touch_sensor_param)
```

This API can be used to read back the sensor configuration parameters.

Parameters:

`sensor_id` The sensor id for which the parameters has to be read-back.

`p_touch_sensor_param` The sensor parameters for the mutual or self-capacitance.

Returns:

`touch_ret_t:` Touch Library Error status.

```
touch_ret_t touch_mutlcap_sensor_get_delta (sensor_id_t sensor_id, touch_delta_t * p_delta)
```

```
touch_ret_t touch_selfcap_sensor_get_delta (sensor_id_t sensor_id, touch_delta_t * p_delta)
```

This API can be used to retrieve the delta value corresponding to a given sensor.

Parameters:

`sensor_id` The sensor id for which delta value is being seeked.

`p_delta` Pointer to the delta variable to be updated by the Touch Library.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_get_global_param (touch_global_param_t * p_global_param)
```

```
touch_ret_t touch_selfcap_get_global_param (touch_global_param_t * p_global_param)
```

This API can be used to read back the global parameter.

Parameters:

`p_global_param` The pointer to global sensor configuration.

Returns:

`touch_ret_t`: Touch Library Error status.

11.6.8. Update Sensor Configuration

```
touch_ret_t touch_mutlcap_sensor_update_acq_config (touch_mutlcap_acq_param_t
*p_touch_mutlcap_acq_param)
```

```
touch_ret_t touch_selfcap_sensor_update_acq_config (touch_selfcap_acq_param_t *
p_touch_selfcap_acq_param)
```

This API can be used to update the sensor acquisition parameters.

Parameters:

`p_touch_mutlcap_acq_param` The acquisition parameters for the mutual capacitance.

`p_touch_selfcap_acq_param` The acquisition parameters for the self-capacitance.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_sensor_update_config (sensor_id_t sensor_id, touch_mutlcap_param_t
*p_touch_sensor_param)
```

```
touch_ret_t touch_selfcap_sensor_update_config (sensor_id_t sensor_id, touch_selfcap_param_t
*p_touch_sensor_param
```

This API can be used to update the sensor configuration parameters.

Parameters:

`sensor_id` The sensor id whose configuration parameters has to be changed.

`p_touch_sensor_param` The touch sensor parameter structure that will be used by the Touch Library to update.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_update_global_param (touch_global_param_t * p_global_param)
```

```
touch_ret_t touch_selfcap_update_global_param (touch_global_param_t * p_global_param)
```

This API can be used to update the global parameter.

Parameters:

`p_global_param` The pointer to global sensor configuration.

Returns:

`touch_ret_t`: Touch Library Error status.

11.6.9. Get Library Information and Version

```
touch_ret_t touch_mutlcap_get_libinfo (touch_info_t * p_touch_info)
```

```
touch_ret_t touch_selfcap_get_libinfo (touch_info_t * p_touch_info)
```

This API can be used to get the Touch Library configuration.

Parameters:

`p_touch_info` Pointer to the Touch info data structure that will be updated by the Touch Library.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_library_get_version_info (touch_libver_info_t * p_touch_libver_info)
```

This API can be used to get the Touch Library version information.

Parameters:

`p_touch_libver_info` Pointer to the Touch Library Version info data structure that will be updated by the Touch Library.

11.6.10. Moisture Tolerance API

```
touch_ret_t touch_mutlcap_cnfg_mois_mltchgrp(sensor_id_t snsr_id, moisture_grp_t mois_grpid,
mltch_grp_t mltch_grpid)
```

```
touch_ret_t touch_selfcap_cnfg_mois_mltchgrp(sensor_id_t snsr_id, moisture_grp_t mois_grpid,
mltch_grp_t mltch_grpid)
```

This API can be used to assign moisture group and multi touch group for a sensor.

Parameters:

`snsr_id` - sensor ID

`mois_grpid` - moisture group ID

`mltch_grp_t` - multi-touch group

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_cnfg_mois_threshold(moisture_grp_t mois_grpid,
mois_snsr_threshold_t snsr_threshold, mois_system_threshold_t system_threshold)
```

```
touch_ret_t touch_selfcap_cnfg_mois_threshold(moisture_grp_t mois_grpid,
mois_snsr_threshold_t snsr_threshold, mois_system_threshold_t system_threshold)
```

This API is used to assign moisture sensor threshold and moisture system threshold to a moisture group ID

Parameters:

`mois_grpid` - moisture group ID

`snsr_threshold` - moisture sensor threshold

`system_threshold` - moisture system threshold

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_mois_tolrnce_enable(void)
```

```
touch_ret_t touch_selfcap_mois_tolrnce_enable(void)
```

This API is used to enable moisture tolerance check during run time.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_mois_tolrnce_quick_reburst_enable(void)
```

```
touch_ret_t touch_selfcap_mois_tolrnce_quick_reburst_enable(void)
```

This API is used to enable moisture tolerance quick re- burst feature during run time.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_mois_tolrnce_disable(void)
```

```
touch_ret_t touch_selfcap_mois_tolrnce_disable(void)
```

This API is used to disable moisture tolerance check during run time.

Returns:

`touch_ret_t`: Touch Library Error status.

```
touch_ret_t touch_mutlcap_mois_tolrnce_quick_reburst_disable(void)
```

```
touch_ret_t touch_selfcap_mois_tolrnce_quick_reburst_disable(void)
```

This API is used to disable moisture tolerance quick re- burst feature during run time.

Returns:

`touch_ret_t`: Touch Library Error status.

12. Revision History

Doc. Rev.	Date	Comments
Rev.M	07/2016	1. Updated the latest software version numbers in Section 1 2. Added a new errata in Section 9
Rev.L	04/2016	Updated Sections 1, 5, and 8 with reference to the latest extension release
Rev.K	02/2016	Added ATmega324PB support. Updated Sections 1, 5 and 8 with reference to the latest extension release
Rev.J	01/2016	Included the following new sections: 1. Compensation Circuit 2. Using Atmel ICE for Qdebug Data Streaming 3. Application flow for megaAVR Updated Sections 5 and 8 with reference to the latest extension release
Rev.I	09/2015	Included Charge share delay Updated Section 5 .2.8 and 5.2.10 - Library parameters for quick re-burst and moisture parameters added Updated Section 11.6.8 - Moisture API's Added Updated section 8 - Example projects updated
Rev.H	06/2015	Revised Section 2 - Device Variants Supported and included information on device multiplexing option Updated Section 7.2 - Code and data memory considerations Updated Section 5.2.1 - Pin, Channel, and Sensor Parameters
Rev.G	04/2015	Updated Section 2 - Device Variants Supported and included information on device multiplexing option
Rev.F	02/2015	Included relevant information regarding low-power and lumped mode support
Rev.E	11/2014	Included Section 5.2.6 and 5.2.7 regarding noise counter measures. Included Section 3 regarding overview of capacitive touch technology.
Rev.D	02/2014	Global updates across the document related to QTouch Library and QTouch Composer 5.3
Rev.C	10/2013	Included Section 3.3.4, Using QDebug Touch Data Debug Communication Included a note on interrupt handler for IAR example project in Section 3.3.3

Doc. Rev.	Date	Comments
Rev.B	10/2013	Updated errata in Section 4, Known Issues
Rev.A	09/2013	Initial document release

Atmel | Enabling Unlimited Possibilities®

Atmel Corporation 1600 Technology Drive, San Jose, CA 95110 USA **T:** (+1)(408) 441.0311 **F:** (+1)(408) 436.4200 | **www.atmel.com**