User's Guide

QTouch® Modular Library Peripheral Touch Controller User's Guide

Description

The Microchip 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
- 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 V_{DD} Range
- No Need for Temperature or V_{DD} Compensation
- Hardware Noise Filtering and Noise Signal De-Synchronization for High Conducted Immunity
- Atmel Start QTouch Configurator Support – Wizard Guided Touch Project Creation

Product Support

For assistance related to QTouch capacitive touch sensing software libraries and related issues, contact your local microchip sales representative or visit https://www.microchip.com/support/.

Table of Contents

1. Introduction

The QTouch® Modular Library (QTML) provides the touch sensing functionality of a QTouch Library under a modular architecture. By dividing the library into functional units, it is possible for an application developer to include only those modules which provide functionality relevant to the target application, thereby saving both device memory and processing time.

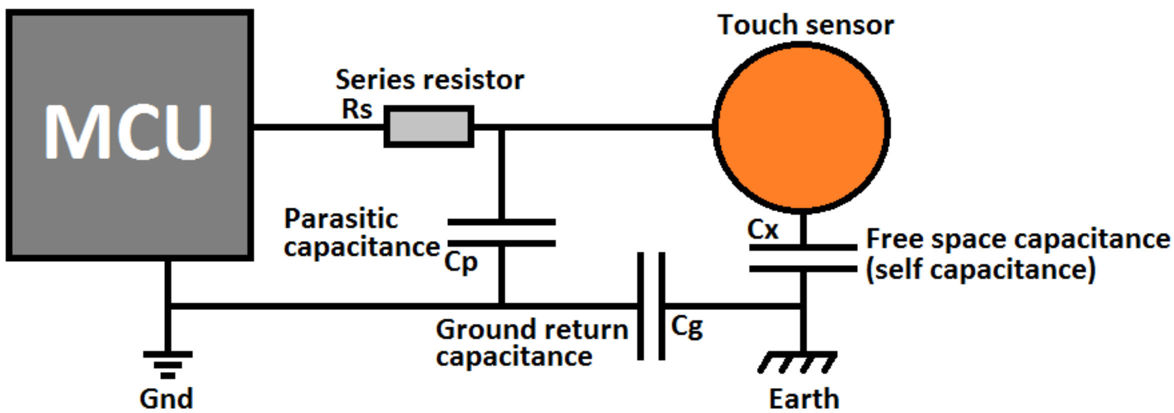
2. Capacitive Touch Measurement

The QTouch Modular Library supports PTC measurement of self-capacitance and mutual capacitance touch sensors on a selection of AVR® and SAM® microcontrollers.

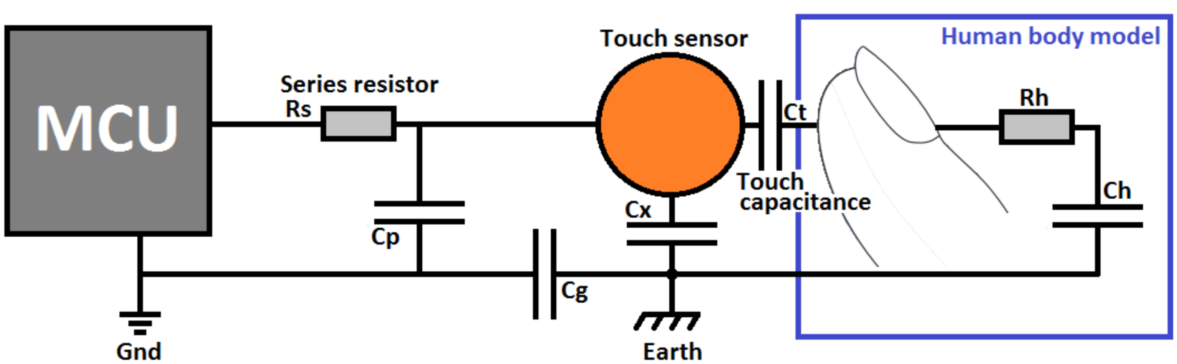
In all current capacitive touch measurement methods, one of two basic functional approaches is implemented: self-capacitance or mutual capacitance.

2.1 Self-Capacitance

Self-capacitance refers to a capacitive measurement using a single sensor electrode to measure the apparent capacitance between the electrode and the DC ground of the touch sensor MCU circuit.



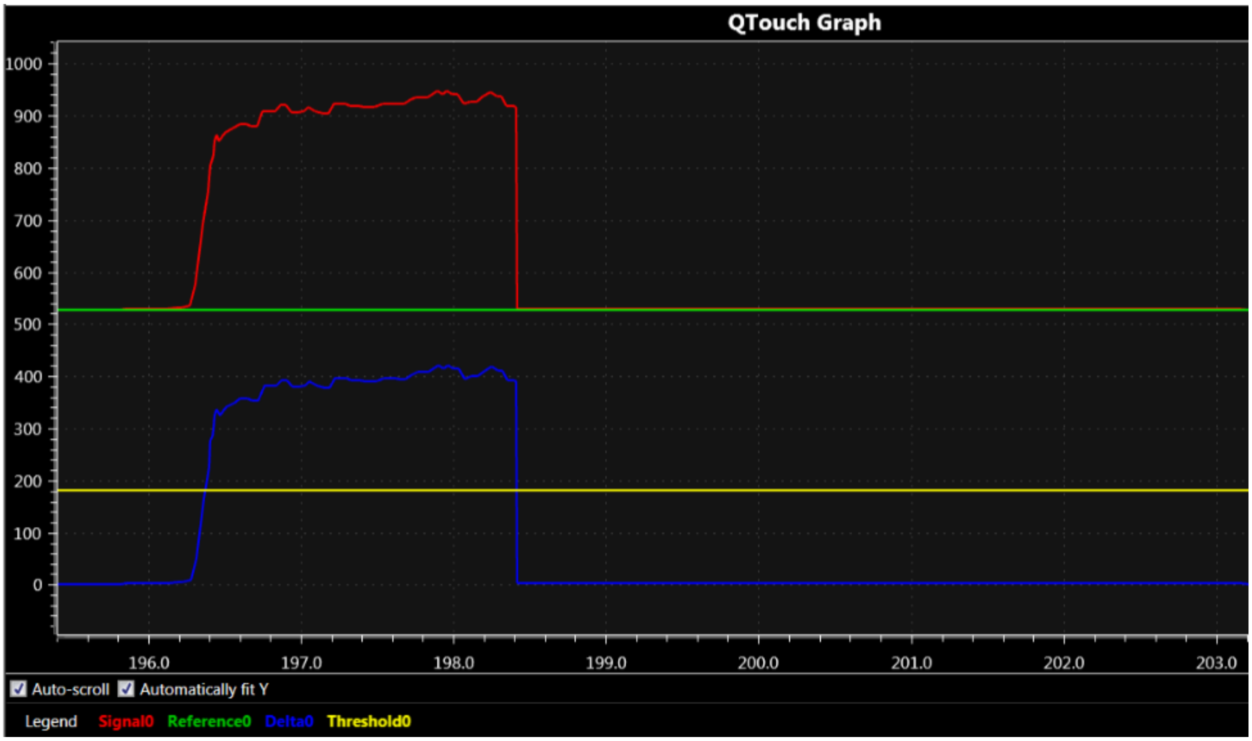
At power-on or Reset, a baseline measurement of the capacitance is recorded and assumed to be the *'Out Of Touch'* capacitance. Reference capacitance is the combination of Cp in parallel to the series pair Cg and Cx.



When a touch contact is applied, the capacitance is increased by the introduction of a parallel path to Earth, via the series combination of Ct and Ch. The increase is compared to the touch threshold, and if exceeded, the sensor is indicated to be *'In Touch'*.

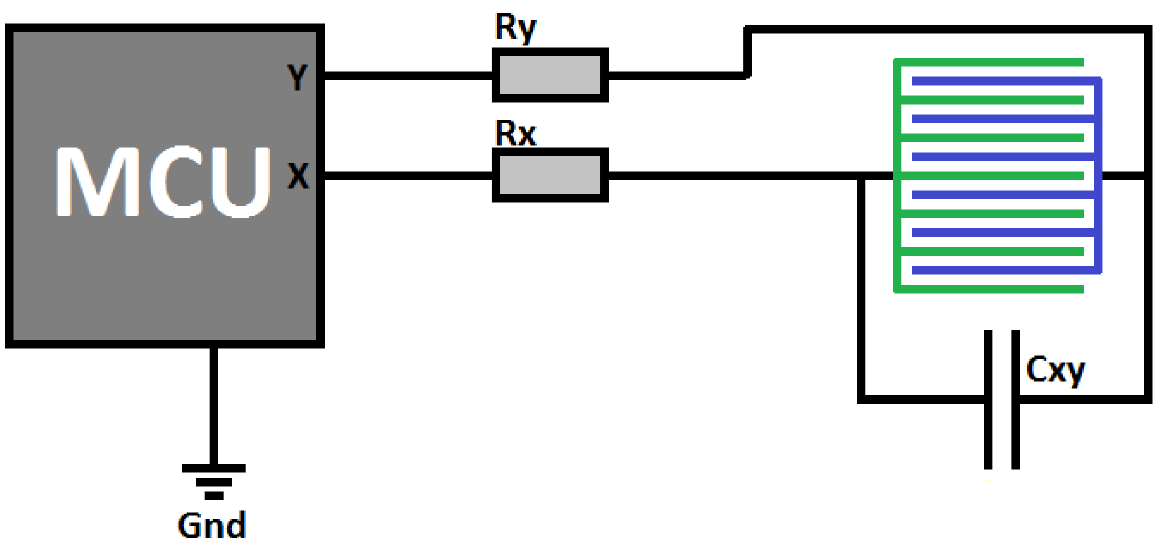
Note: Cx, the human body capacitance, varies by person and surroundings and is typically in the order of 100 pF to 200 pF. The touch contact Ct, however, is more consistent and much smaller at typically 1 pF to 5 pF, depending primarily on the design and construction of the touch sensor and secondly on the size of the finger used to activate the sensor.

As the dominant component in a pair of series capacitors is the smaller one, in this case Ct, a well-designed and tuned sensor shows very consistent sensitivity to touch contact with little dependence on the user.

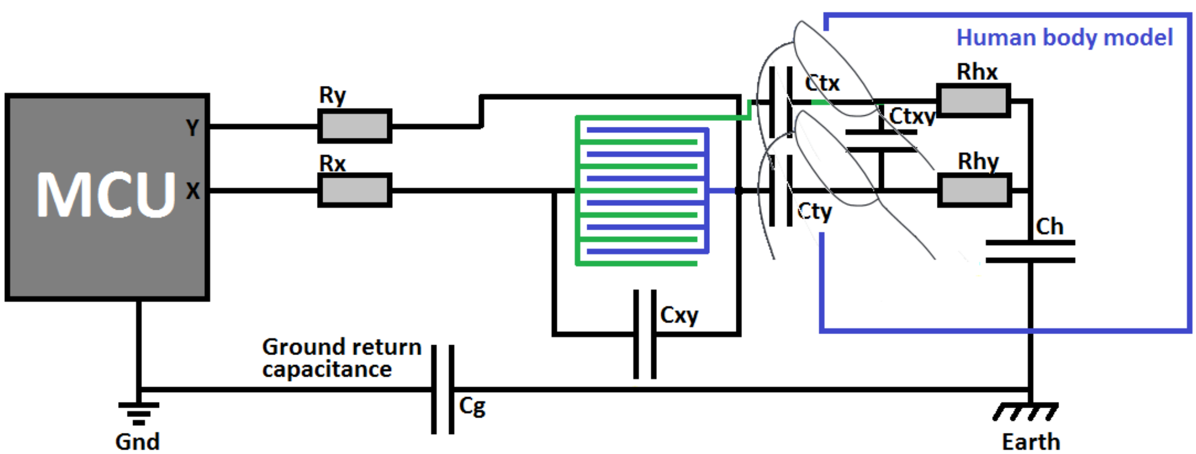


2.2 Mutual Capacitance

Mutual capacitance refers to a capacitive measurement using a pair of sensor electrodes to measure the apparent capacitance between them. Typically, one electrode acts as the Driver (X), while the other is the receiver (Y). Each physical location where an X electrode transfers charge to a Y electrode is a sensor node, and this is the location of touch sensitivity.



As with self-capacitance, a baseline measurement of the capacitance is recorded and assumed to be the *'Out Of Touch'* capacitance. Reference capacitance is the apparent capacitance between the X electrode and the Y electrode. Unlike self-capacitance, the reference capacitance does not depend on an earth return.



Interaction between a mutual capacitance sensor and the human body is more complex. It may be modeled by considering two separate touch contacts to the X and Y electrodes, where each is capacitively coupled to the body, resistively connected to each other inside the body and capacitively coupled to earth via the human body capacitance.

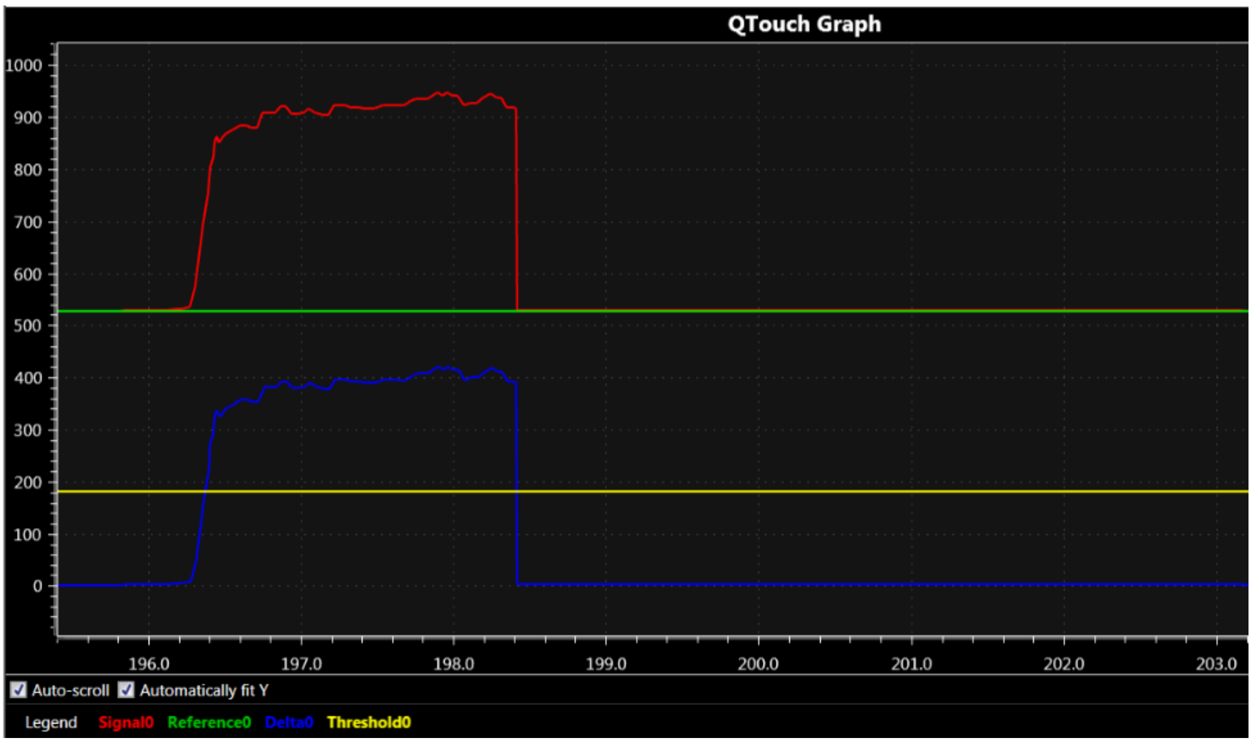
A touch contact has two competing effects:

- The introduction of a conductive plate (finger) to both X and Y electrodes increases the capacitance between X and Y. This occurs if any conductive part is placed over the sensor

- The addition of another capacitance (Ch + Cg) at the XY node provides an alternative path for the energy emitted by X electrode, reducing the amount of charge accumulated on the sensor. This effect is manifested as an apparent reduction in the XY capacitance. This occurs only if the body of material connected to the conductive part has a significant self-capacitance.

When a real touch contact is placed, the second (reducing) effect is much greater than the first (increasing) effect, and so a touch contact on a mutual capacitance sensor is indicated by an apparent reduction in sensor capacitance.

This apparent change in capacitance (delta) is compared to the configured touch threshold, and if it exceeds the threshold then the sensor is deemed to be in detect.



3. Touch Sensors

Capacitive sensors may be implemented to simply detect contact as a button replacement, or functionally extended to provide a relative measurement of distance (proximity), 1D position (slider or wheel), 2D position (QTouch Surface), or 3D position (QTouch Surface with proximity).

In each case, the modular library detects a touch contact by a change in capacitance exceeding a pre-configured threshold. Once a contact has been confirmed, the various post-processing modules use the calculated touch delta to interpolate amongst neighboring sensors and calculate the location of the touch position or relative proximity.

3.1 Buttons

The simplest implementation of a capacitive sensor is a button, where the sensor consists of a single node (one electrode for self-capacitance, one pair of electrodes for mutual capacitance) and is interpreted as a binary state; In Detect or Out of Detect.

3.2 Proximity Sensor

An extension of the button is a proximity sensor. A single sensor node is monitored for a change in capacitance exceeding a pre-configured threshold. In the same way as the button, the sensor is considered to be *‘In Detect’* when that threshold is exceeded. Once in detect, a relative measurement of the contact distance is made by scaling the touch delta between two thresholds, the initial *‘Detect’* threshold and a second *‘Full Contact’* threshold.

Note: As the proximity sensor relies on the capacitive load of a distant object, the ‘apparent distance’ to the contact will depend on the shape and size of the contact.

i.e., an open hand in proximity at 10 cm will ‘appear’ closer than an extended finger at 10cm, as it has a larger influence on capacitance due to a larger surface area at the same distance.

Capacitance (C) is proportional to Area (A) and inversely proportional to distance (d).

$$C \propto \frac{A}{d}$$

3.3 Lumped Sensor

A Lumped sensor is implemented as a combination of multiple sense lines (self-capacitance measurement) or multiple drive and sense lines (mutual capacitance measurement) to act as one single sensor. This provides the application developer with greater flexibility in the touch sensor implementation.

- Improve the touch sensor responsiveness by reducing the number of measurements and therefore, the time required for initial touch detection
- Fast position resolution by binary search
- Improved moisture rejection through ‘All but one’ key lumping in a touch button application
- Provide wake-on-touch functionality on any key (up to maximum capacitance limits) with significantly lower power consumption as only one sensor measurement is required for all keys
- Dual purpose sensor electrodes – e.g., individual keys may be lumped together to form a proximity sensor

Touch detection on a lumped sensor is implemented in the same way as a single node touch button.

3.4 Linear Sensors

A linear sensor utilizes the touch delta of two or more adjacent sensor nodes arranged in a row to calculate the position of a touch contact along that row. The sensor layout is designed and the threshold configured in such a way that a contact anywhere along the sensor will cause:

1. **A touch delta exceeding the threshold on at least one sensor node.** The node with the strongest touch delta is determined to be the center node of the touch contact and identified the approximate location of the touch contact.
2. **Some touch delta on neighbouring nodes, used for position interpolation between nodes.** The relative delta on the nodes to the left and right of the center node are used to adjust the calculated touch position towards the side with the strongest delta.

A linear sensor may be formed into any physical shape, with or without a wrap-around from the last sensor to the first. A sensor with wrap-around is configured as a *'Wheel'*, while one without is configured as a *'Slider'*. In the case of the wheel, a touch contact centered on the 1st key uses the last key for *'left'* interpolation and vice-versa while the slider option implements a dead band at the ends.

3.5 2D Position Sensors

Where a linear sensor is physically implemented as a line of keys, the same approach may be extended to 2D position detection through a grid of keys. The keys are designed such that interpolation may be made in either the vertical or horizontal direction, and multiple separate touch contacts may be individually resolved in their interpolated positions.

3.6 Mix and Match

The QTouch Modular Library allows an unprecedented degree of combinations implementing different sensor types and measurement technology, in many cases utilizing the same sensor electrodes in multiple ways and within the same firmware application.

For example, a 2D position sensor using mutual capacitance key sensors may be lumped or partially lumped in Mutual Capacitance mode to provide proximity measurements and the Y lines individually measured in Self-Capacitance mode to improve moisture immunity.

4. PTC

4.1 Overview

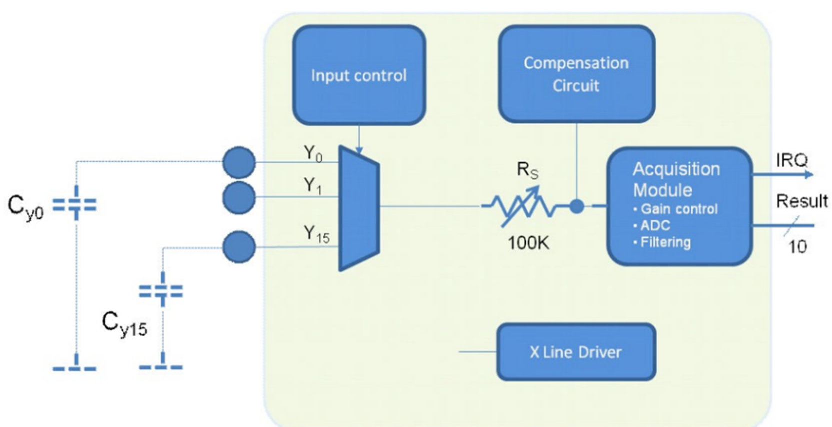
The Microchip QTouch® Peripheral Touch Controller (PTC) offers built-in hardware for capacitive touch measurement on sensors that function as buttons, sliders, and wheels. The PTC supports both mutual and self-capacitance measurement without the need for any external components. It offers superb sensitivity 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.

4.2 Self-Capacitance

In Self-Capacitance mode, the PTC requires only one pin with a Y-line driver for each self-capacitance sensor.

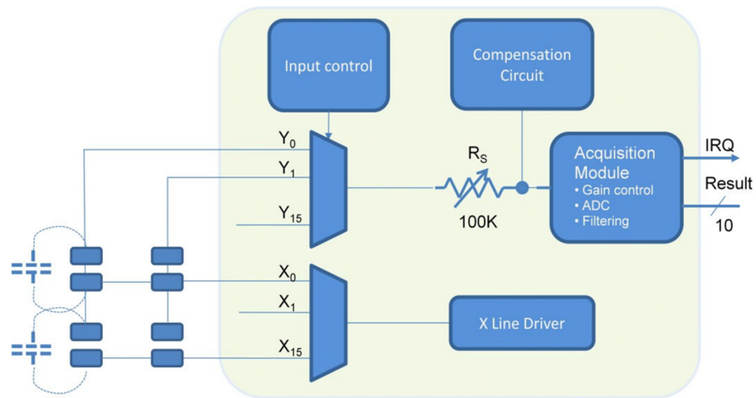
Figure 4-1. Self-Capacitance PTC Measurement



4.3 Mutual Capacitance

In Mutual Capacitance mode, the PTC requires one pin per X-line (drive line) and one pin per Y-line (sense line).

Figure 4-2. Mutual Capacitance PTC Measurement



5. QTouch Modular Library

5.1 Introduction

The QTouch Modular Library provides the touch sensing functionality of a QTouch Library under the redesigned modular architecture. By dividing the library into functional units, it is possible for an application developer to include only those modules which provide functionality relevant to the target application, thereby saving both device memory and processing time.

5.2 QTouch Library Modules

QTouch Library modules can be classified into three types based on the functionality as shown below.

Acquisition Module	Signal Conditioning module	Post processing module
Acquisition auto tune module Acquisition run-time module	Frequency Hop module Frequency Hop Auto tune module	Touch Key module Scroller module
• Touch measurement • Channel sequencing • CC calibration • Auto/manual calibration of prescalar/series resistor/charge share delay	• Hop frequency • Median filter • Noise measurement • Change frequency based on noise	• Buttons post processing • Drifting, Detect integration • AKS groups • Slider/Wheel position • Touch active/inactive status • Hysteresis, IIR filtering

5.3 Module Naming Conventions

The naming conventions followed on the QTouch Library modules are given below.

```
qtm _ <module_name_identifier> _ <device_architecture> _ <module_ID> .
<file extension>
```

`qtm / libqtm`	Acronym indicates QTouch module. All QTouch modules begin with "`qtm_`" for easy identification.

	For GCC modules, "`lib`" is prepended to the module name, thus it would be "`libqtm`".
`module_name_identifier`	`acq` – acquisition module with auto-tune `acq_runtime` – acquisition module without auto-tune code `freq_hop` – Frequency hop module `freq_hop_auto_tune` – frequency hop with auto-tune module
`device_architecture`	`cm0p` – for all cortex M0+ post processing modules `cm4` – for all cortex M4F post processing modules `samd1x` – samd10/d11 acquisition modules only `t81x` – all modules of AVR tiny817 device families `t161x` - all modules of AVR tiny1617 device families `t321x` - all modules of AVR tiny3217 device families `m328pb` - all modules of AVR mega328pb device `m324pb` - all modules of AVR mega324pb device `saml21` - saml21 acquisition module only `saml22` - saml22 acquisition module only `samc21` - samc21 acquisition module only `samc20` - samc20 acquisition module only `samd21` - samd21 acquisition module only `samda1` - samda1 acquisition module only `samha1` - samha1 acquisition module only `samd20` - samd20 acquisition module only
`module_id`	Unique 16-bit identifier for each module
`file_extension`	`.a` – GCC modules of AVR and ARM® devices, IAR modules of ARM devices `.r90` – IAR modules of all AVR modules

Table 5-1. Acquisition module of AVR mega328pb device

GCC module:	`libqtm_acq_m328pb_0x0001.a`
IAR module :	`qtm_acq_m328pb_0x0001.r90`

Touch keys processing module of SAMd10/d11 device

GCC module:	`libqtm_touch_keys_cm0p_0x0002.a`
IAR module :	`qtm_touch_keys_cm0p_0x0002.a`

5.4 QTouch Library Application Interface

In addition to library modules, the various components that are required to build the complete touch application are given below.

1. Module API files
2. `Touch.c` and `Touch.h` files
3. `Common_components_api.h`
4. `Touch_api_ptc.h`
5. Module reburst flag
6. Binding layer module

5.4.1 Module API files

The API for each module is defined in its associated header file. Dependencies between modules are minimized and implemented at the application level. This allows for easy porting of application code from one device to another – only the hardware dependent module configurations must be adjusted. The acquisition auto-tune and acquisition manual tune modules have the same API file. All the other modules have their own API file that needs to be linked to the user application.

5.4.2 `Touch.c` and `Touch.h` files

User options for each module are configured in application code, typically `touch.h` and `touch.c`, and shared with the library module by pointer reference. Similarly, arrays are created in application code for modules' run-time data and provided to the module via a pointer.

Configurations may be modified on-the-fly by application code in between measurement sweeps of the touch sensors. All runtime data is available to application code.

5.4.3 `Common_components_api.h`

The application requires structures and definitions common to all modules. The common definitions, macros and the data structures are placed in the file **"*qtm_common_components_api.h*"**.

5.4.4 `Touch_api_ptc.h`

This file contains all the module API files included in the content and thus this single file is sufficient to be included on the application source files wherever necessary.

5.4.5 Module Reburst Flag

Module configuration and functionality is unique to each module, but any module may require a repeated measurement of specific sensors. In order to achieve this, a signal conditioning module may temporarily change the acquisition configuration, e.g. to disable those sensors not requiring reburst.

This is indicated to the application by the implementation of a common *'Status'* byte at the first location of the signal conditioning group data structure. A '`1`' in bit 7 indicates that the application should re-start measurement on the sensor group without waiting for the measurement cycle timeout.

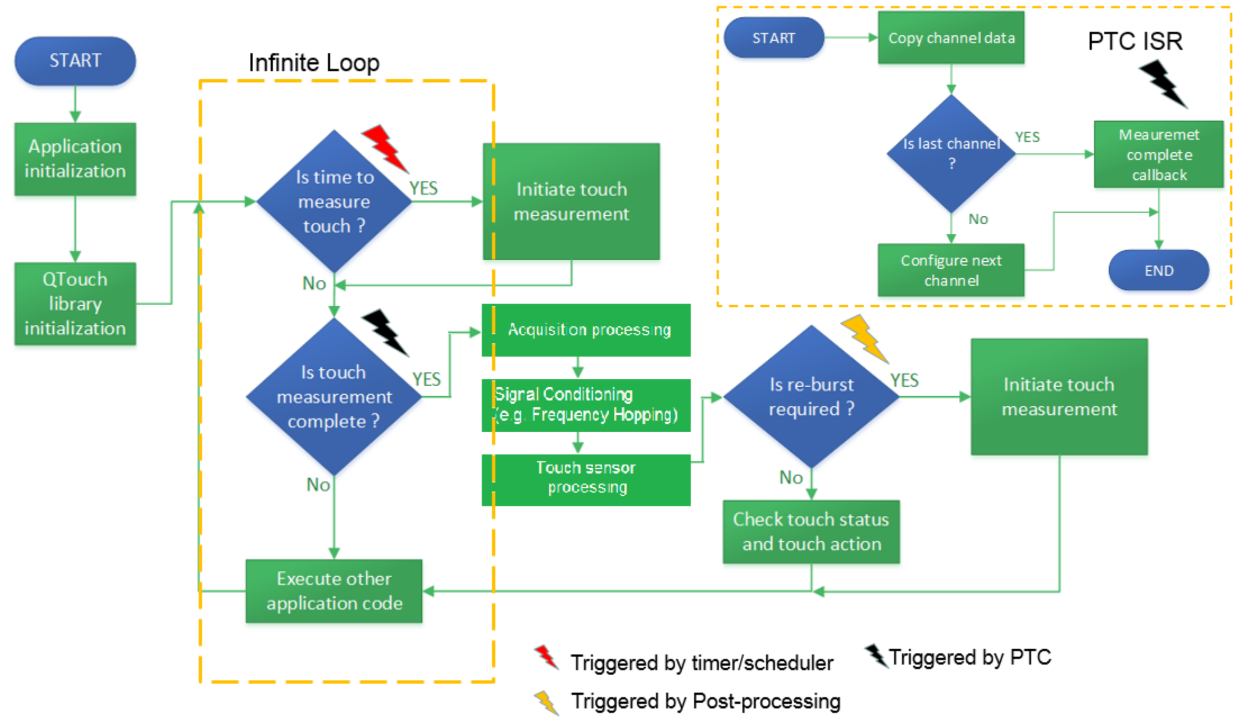
Figure 5-1. **`uint8_t qtm_xxx_status`**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Re-burst	Module specific status flags						

5.4.6 Binding Layer Module

The binding layer module provides easy interface of QTouch modules to the user application. The binding layer binds all the configured modules in the appropriate sequence using minimal API functions. It takes care of initialization of modules, synchronizes the calling procedures and handles the error statuses.

5.5 Application Flow



5.6 MISRA Compliance

QTouch Library modules source code is compliant with the *'Required'* rule set of MISRA 2004, with the following exceptions:

Table 5-2. AVR MCU Acquisition Modules and Exceptions:

Acquisition modules of Mega32xpb, Tiny81x, Tiny161x, Tiny321x devices		
MISRA Rule	**Definition**	**Remarks**
1.1	All code shall conform to ISO 9899:1990 Programming languages – C, amended and	Compiler is configured to allow extensions

Acquisition modules of Mega32xpb, Tiny81x, Tiny161x, Tiny321x devices		
MISRA Rule	**Definition**	**Remarks**
	corrected by ISO/IEC 9899/COR1:1995, ISO/IEC 9899/AMD1:1995, and ISO/IEC 9899/COR2:1996	
8.5	There shall be no definitions of objects or functions in a header file	Inline functions are used in the header files
17.4	Array indexing shall be the only allowed form of pointer arithmetic	Pointer of module data structures are passed as parameter and individual object data are fetched by iterating the data structure as array index.

Table 5-3. AVR Postprocessing Modules & Exceptions:

Touch_key, binding layer, frequency hop auto tune, frequency hop, scroller		
MISRA Rule	**Definition**	**Remarks**
17.4	Array indexing shall be the only allowed form of pointer arithmetic	Pointer of module data structures are passed as parameter and individual object data are fetched by iterating the data structure as array index.

Table 5-4. ARM Acquisition Modules & Postprocessing Modules :

Modules		
MISRA Rule	**Definition**	**Remarks**
1.1	All code shall conform to ISO 9899:1990 Programming languages – C, amended and corrected by ISO/IEC 9899/COR1:1995, ISO/IEC 9899/AMD1:1995, and ISO/IEC 9899/COR2:1996	Compiler is configured to allow extensions
17.4	Array indexing shall be the only allowed form of pointer arithmetic	Pointer of module data structures are passed as parameter and individual object data are fetched by iterating the data structure as array index.

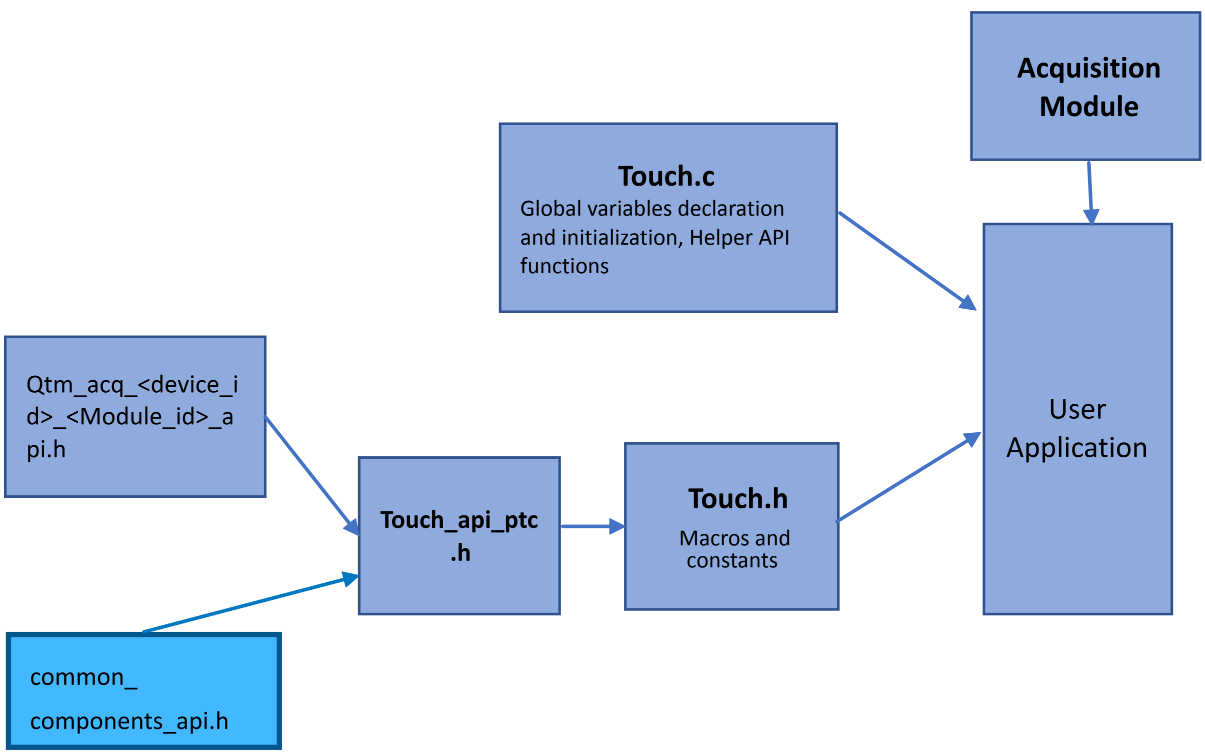
6. Acquisition Module

6.1 Overview

The minimum requirement for a touch sensor application is an acquisition module, which implements all hardware dependent operations for configuration and measurement of capacitive touch or proximity sensors.

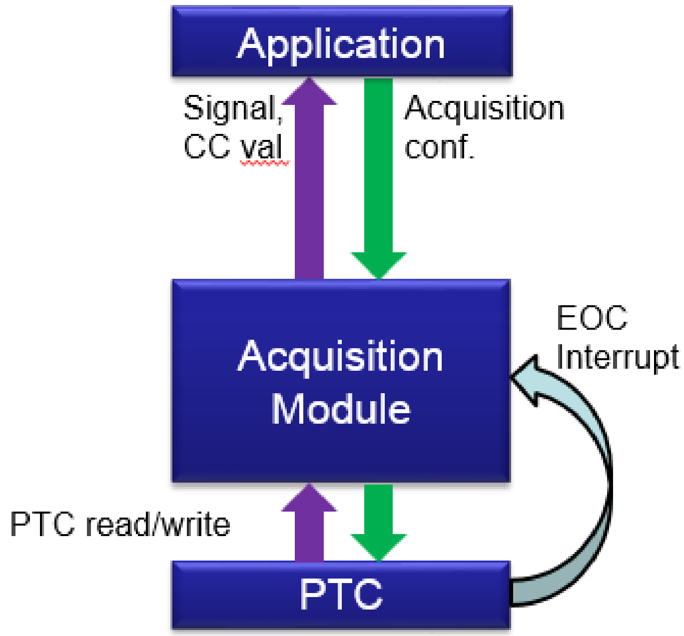
6.2 Interface

The data structure definitions and the API declarations are included in the API file "`qtm_acq_<device_id>_<module_id>_api.h`". The data structure covers all the configurations and output data variables. This file should be included on the common api '`touch_ptc_api.h`' file.



6.3 Functional Description

Acquisition modules are target specific, each having a hardware configuration structure depending on the touch sensing technology and method applied.



Features Implemented in this Acquisition Module

- Hardware calibration for sensor nodes
  - Calibration of Prescaler/Resistor/Charge share delay to compensate for time constant of sensor electrodes
  - Calibration of internal compensation circuit to match sensor load
- Selfcap and mutual cap sensor touch measurement with normal sequencing
- Low-Power mode of automated scanning using Event System (currently not supported on Atmel Start Configurator)

6.4 Data Structures

6.4.1 Configurations

The acquisition module implements all functionality required for making relative measurements of sensor capacitance. This is the only module uniquely built for an individual device, as it must access and control the pins used for touch sensor implementation.

As devices have different hardware features available, different configuration options are available on each device. For most efficient use of system resources – ROM and RAM – different sensor configuration structures are required.

However, where the same variable name is used within the structure, the functionality controlled by that variable is identical. Any dependent function should utilize a reference to the variable, and NOT rely on a reference to the structure and pointer arithmetic.

Acquisition Group Configuration

A reference by pointer to '`&ptc_qtlib_acq_gen1.freq_option_select`' will always point to the correct memory location, regardless of the device. However, any implementation based on pointer arithmetic will require re-factoring if code is to be re-used from one device for another.

Parameter	Size	Range/Options	Usage
`num_sensor_nodes`	16-bit	0 to 65535	The number of sensor nodes configured in the group.
`acq_sensor_type`	8-bit	`NODE_SELFCAP` `NODE_MUTUAL`	Defines the measurement method applied to this group of nodes.

`calib_option_select`	1 byte	**Bits 7:4**
		Calibration type:
		`CAL_AUTO_TUNE_NONE`
		`CAL_AUTO_TUNE_RSEL`
		`CAL_AUTO_TUNE_PRSC`
		`CAL_AUTO_TUNE_CSD`*
			Calibration Type selects which parameter should be automatically tuned for optimal charge transfer.

		Bits 3:0
		Calibration type:
		`CAL_CHRG_2TAU`
		`CAL_CHRG_3TAU`
		`CAL_CHRG_4TAU`
		`CAL_CHRG_5TAU`
			Calibration target applies a limit to the charge transfer loss allowed, where a higher setting of target ensures a greater proportion of full charge is transferred.

`freq_option_select`	1 byte	`FREQ_SEL_0` to `FREQ_SEL_15` Or `FREQ_SEL_SPREAD`	`FREQ_SEL_0` to `FREQ_SEL_15` inserts a delay cycle between measurements during oversampling, where 0 is the shortest delay, 15 the longest. `FREQ_SEL_SPREAD` varies this delay from 0 to 15 in a sawtooth manner during the oversampling set
`PTC_interrupt_priority`**	1 byte	1 to 3	Interrupt priority level for the PTC.
Note: * - Not available on all devices ** - Applicable for ARM cortex devices only			

Node Configuration

Similarly, node configuration structures vary depending on which device is used.

- Number of X lines
- Number of Y lines
- Feature availability

Parameter	Size	Range/Options	Usage
`node_xmask`	1/2/4 Bytes	(Bitfield)	Set the bit(s) at location(s) corresponding to X line number(s). **Example:** X0 only = `0b00000001` = 0x01 X0 and X2 = `0b00000101` = 0x05 1 byte is used for devices with up to 8 "X" lines 2 bytes and 4 bytes are used for devices up to 16 and 32 "X" lines respectively
`node_ymask`	1/2/4 Bytes	(Bitfield)	Set the bit(s) at location(s) corresponding to Y line number(s). **Example:** Y5 only = `0b00100000` = 0x20 Y1, Y2 and Y7 = `0b10000110` = 0x86 1 byte is used for devices with up to 8 "Y" lines 2 byte and 4 bytes are used for devices up to 16 and 32 "Y" lines respectively
`node_csd`*	1 byte	0 to 255	Number of delay cycles to ensure charging of sensor node capacitances. (Applicable for AVR® Tiny, Mega ARM® SAM E54, SAMCx, SAML22 family only)

`node_rsel_prsc`	1 byte	**Bits 7:4 = RSEL**
		`RSEL_VAL_0`
		`RSEL_VAL_3`*
		`RSEL_VAL_6`*
		`RSEL_VAL_20`
		`RSEL_VAL_50`
		`RSEL_VAL_75`*
		`RSEL_VAL_100`
		`RSEL_VAL_200`*
			Internal Y line series resistor selection
			(75k and 200k are available on ARM SAM E54 family and SAML22)

		Bits 3:0 = PRSC
		`PRSC_DIV_SEL_1`
		`PRSC_DIV_SEL_2`
		`PRSC_DIV_SEL_4`
		`PRSC_DIV_SEL_8`
			Clock Prescaler
			Acquisition clock is derived and scaled from CPU Clock for AVR devices
			(Prescalar values 16, 32, 64, 128 are available on AVR Tiny, SAM E5x family, SAM D51)

Parameter	Size	Range/Options	Usage
		PRSC_DIV_SEL_16* PRSC_DIV_SEL_32* PRSC_DIV_SEL_64* PRSC_DIV_SEL_128*	
node_gain	1 byte	**Bits 7:4 = Analog Gain** GAIN_1 GAIN_2 GAIN_4 GAIN_8 GAIN_16	**Analog gain setting** Integration capacitor adjusted to control integrator gain.
		Bits 3:0 = Digital Gain GAIN_1 GAIN_2 GAIN_4 GAIN_8 GAIN_16	**Digital gain setting** Accumulated sum is scaled to Digital Gain.
node_oversampling	1 byte	FILTER_LEVEL_1 FILTER_LEVEL_2 FILTER_LEVEL_4 FILTER_LEVEL_8 FILTER_LEVEL_16 FILTER_LEVEL_32 FILTER_LEVEL_64 FILTER_LEVEL_128* FILTER_LEVEL_256* FILTER_LEVEL_512* FILTER_LEVEL_1024*	Number of samples to accumulate for each measurement. **Note**: Oversampling must be configured to be greater than or equal to digital gain for correct operation. (Higher filter level values > 64 are available only on ARM SAM E54 family only)
Note: * - Not available on all devices			

6.4.2 Status and Output Data

While different target hardware requires that the configuration structure for sensor nodes varies from one device to another, all acquisition modules conform to a standard sensor node data structure. Processed module output data are stored in this data structure during run-time.

The outputs/status information may be used by other post processing modules or by the application.

Parameter	Size	Range/Options	Usage
node_acq_status	1 byte	Bit 7	Indicates node calibration error NODE_CAL_ERROR
		Bit 6	Rise Time calibration complete
		Bit 5	-
		Bit <4:2> (three bits) **Node calibration state** NODE_MEASURE NODE_CC_CAL NODE_PRSC_CAL NODE_RSEL_CAL NODE_CSD_CAL	Indicates whether a calibration is ongoing and its current stage.
		Calibration Request	Write to 1 to trigger calibration sequence on this node. (Reset to '0' by module once actioned)
		Enabled	Write to '1' to enable this node for measurement
node_acq_signals	2 bytes	Most recent measurement for this sensor node.	16-bit unsigned value Accumulated and scaled as per node_oversampling and node_gain_digital settings.
node_comp_caps	2 bytes	Hardware calibration data	Indicates the tuning of the compensation circuit for this node.

Table 6-1. `node_acq_status`

Bit	7	6	5	4	3	2	1	0
	Node Calibration Error	Rise time calibration complete	-	Node State			Calibrate request	Enabled

NODE_MEASURE	0
NODE_CC_CAL	1
NODE_PRSC_CAL	2
NODE_RSEL_CAL	3
NODE_CSD_CAL*	4

Note: * - CSD Calibration is not available on SAMD10/D11, SAMD2x, SAML21 devices.

Acquisition Library State

Table 6-2. `touch_lib_state_t`

TOUCH_STATE_NULL	0
TOUCH_STATE_INIT	1
TOUCH_STATE_READY	2
TOUCH_STATE_CALIBRATE	3
TOUCH_STATE_BUSY	4

Return Parameter

Table 6-3. `touch_ret_t` **common return type, used by all QTML modules**

TOUCH_SUCCESS	0
TOUCH_ACQ_INCOMPLETE	1
TOUCH_INVALID_INPUT_PARAM	2
TOUCH_INVALID_LIB_STATE	3
TOUCH_INVALID_POINTER	11
TOUCH_LIB_NODE_CAL_ERROR	14
Note: Other values are reserved for future use.	

7. Frequency Hop Module

7.1 Overview

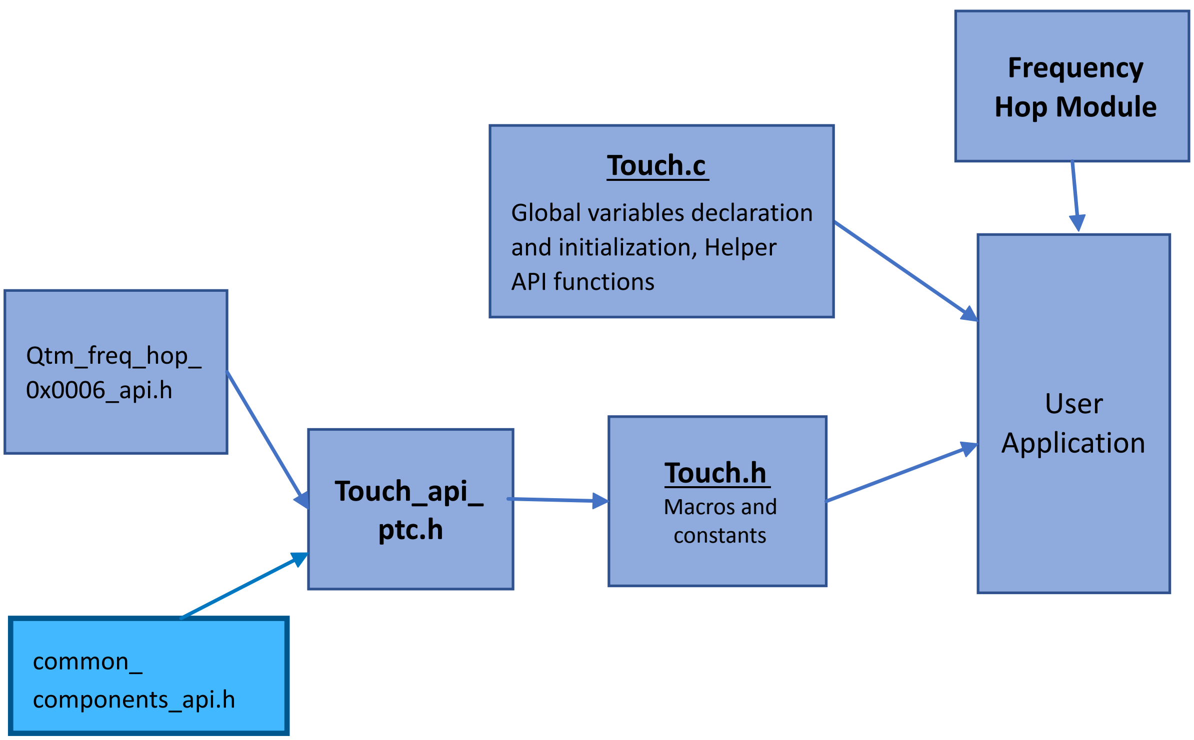
Frequency Hop module provides a way of filtering the noise during the sensor measurement by varying the frequency of bursting the sensors. Module ID for frequency hop module is 0x0006 and the module name is in the format given below.

GCC compiler:	`libqtm_freq_hop_xxxxx_0x0006.a`
IAR compiler (AVR MCU):	`qtm_freq_hop_xxxxx_0x0006.r90`
IAR compiler (ARM MCU):	`qtm_freq_hop_xxxxx_0x0006.a`

Note: "xxxxx" – string based on the device architecture that the module is built.

7.2 Interface

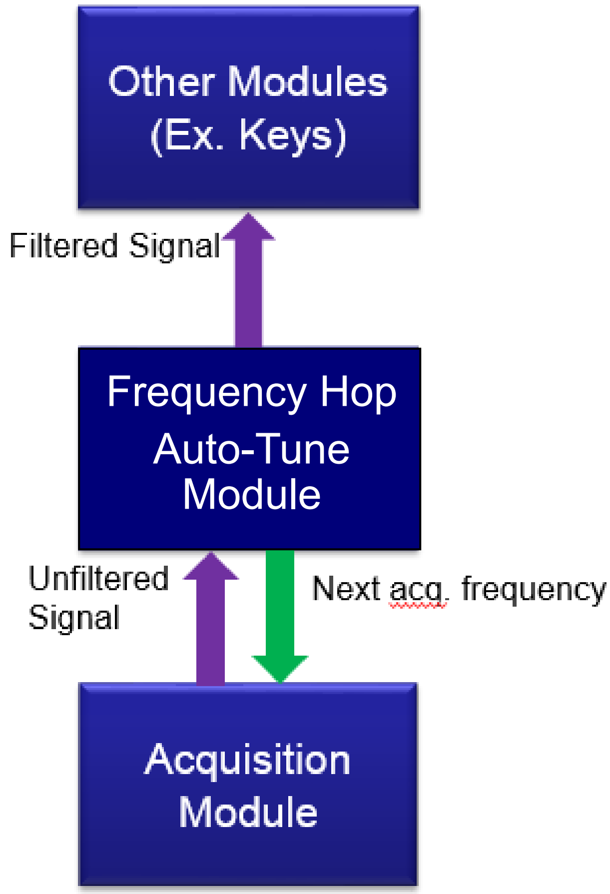
The data structure definitions and the API declarations are included in the API file '`qtm_freq_hop_0x0006_api.h`'. The data structure covers all the configurations and output data variables. This file should be included on the common api '`touch_ptc_api.h`' file.



The default values of configurations should be defined on the `touch.c` and `touch.h` files. Global variables of the data structures have to be initialized in touch.c file and the reference of the structure has to be used on the application files.

7.3 Functional Description

Frequency Hop module is interfaced between acquisition module and rest of post processing modules as shown below.



The Frequency Hop module applies a configurable cyclic frequency hopping algorithm, such that on each measurement cycle a different sampling frequency is used. The module is initialized with predefined frequencies which are set by cyclic order during the consecutive measurement cycles.

The measured raw signal values from the Acquisition module are then passed through **“Median filter”**. Finally, the filtered value is stored back on the memory for further processing by the post processing modules.

More number of frequencies provide effective filtering by processing more samples. However, this also increases the buffer size used by the median filter and takes more number of measurement cycles to report filtered value. So, the number of frequencies should be configured based on the RAM memory available.

7.4 Data Structures

7.4.1 Configurations

Parameter	Size	Range/Options	Usage
num_sensors	1 Byte	0-255	Number of sensors to buffer data for median filter
num_freqs	1 Byte	3-to-7	Number of frequencies to cycle/depth of median filter
*freq_option_select	2/4 Bytes	N/A	Pointer to acquisition library frequency selection parameter
*median_filter_freq	2/4 Bytes	N/A	Pointer to array of selected frequencies

7.4.2 Status and Output Data

Parameter	Size	Range/Options	Usage
module_status	1 Byte	N/A	Module Status – N/A
current_freq	1 Byte	0-to-15	Current frequency step
*filter_buffer	2/4 Bytes	N/A	Pointer to the filter buffer array for measured signals
*qtm_acq_node_data	2/4 Bytes	N/A	Pointer to the node data structure of the acquisition group

Table 7-1. List of Supported Frequencies

PTC Clock = 4 MHz		
PTC frequency Delay Cycles		Frequency (kHz)
0	FREQ_SEL_0	66.67
1	FREQ_SEL_1	62.5
2	FREQ_SEL_2	58.82
3	FREQ_SEL_3	55.56
4	FREQ_SEL_4	52.63
5	FREQ_SEL_5	50
6	FREQ_SEL_6	47.62
7	FREQ_SEL_7	45.45
8	FREQ_SEL_8	43.48

PTC Clock = 4 MHz		
PTC frequency Delay Cycles		Frequency (kHz)
9	FREQ_SEL_9	41.67
10	FREQ_SEL_10	40
11	FREQ_SEL_11	38.46
12	FREQ_SEL_12	37.04
13	FREQ_SEL_13	35.71
14	FREQ_SEL_14	34.48
15	FREQ_SEL_15	33.33
16	FREQ_SEL_SPREAD	Variable frequencies

8. Frequency Hop Auto-tune Module

8.1 Overview

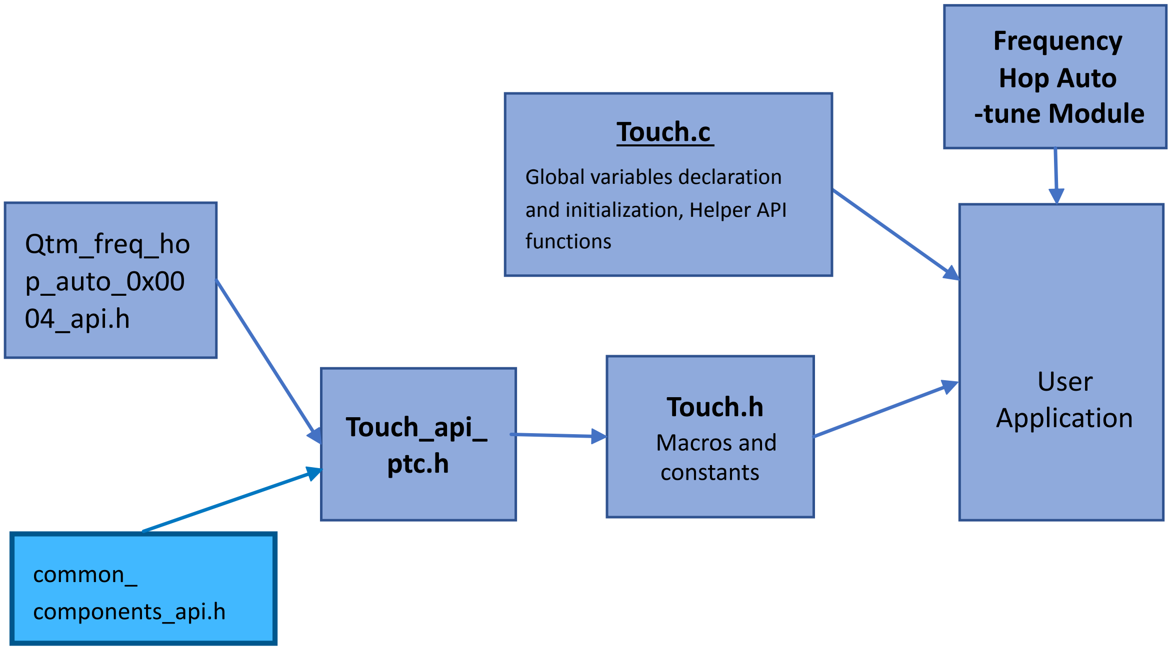
The Frequency Hop auto-tune module is the super set of frequency hop module with additionally providing noise monitoring and tuning the frequency according to the measured noise factor.

The Module ID for the Frequency Hop auto-tune module is '0x0004' and the module name is in the format given below.

GCC compiler :	`libqtm_freq_hop_auto_xxxxx_0x0004.a`
IAR compiler (AVR MCU) :	`qtm_freq_hop_auto_xxxxx_0x0004.r90`
IAR compiler (ARM MCU) :	*`qtm_freq_hop_auto_xxxxx_0x0004.a`*
Note: "xxxxx" – string based on the device architecture that the module is built.	

8.2 Interface

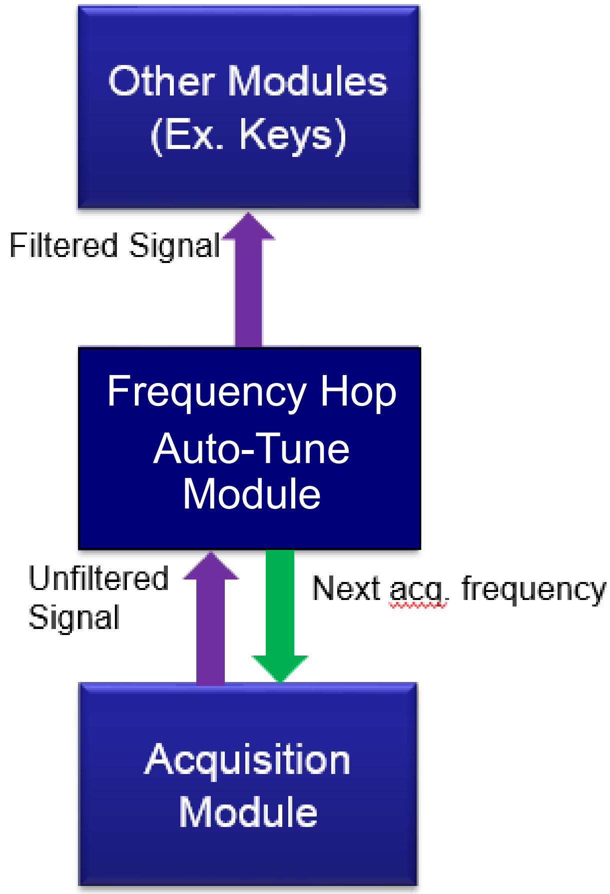
The data structure definitions and the API declarations are included in the API file '`qtm_freq_hop_auto_0x0004_api.h`'. The data structure covers all the configurations and output data variables. This file should be included on the common api `touch_ptc_api.h` file.



The default values of configurations should be defined on the `touch.c` and `touch.h` files. Global variables of the data structures have to be initialized in touch.c file and the reference of the structure has to be used on the application files.

8.3 Functional Description

The Frequency Hop auto-tune module is interfaced between the acquisition module and the rest of post processing modules as shown below.



The Frequency Hop auto-tune module applies a configurable cyclic frequency-hopping algorithm, such that on each measurement cycle a different sampling frequency is used. A number of preconfigured frequencies are implemented in turn during consecutive measurement cycles.

Where ‘n’ frequencies are included in the cycle, an ‘n’-point median filter is applied to the output data.

To perform auto-tuning, the signals measured on each sensor node are recorded for each selected frequency. When one frequency shows greater variance than others, that frequency is removed from the measurement sequence and replaced with another.

8.4 Data Structures

8.4.1 Configurations

Parameter	Size	Range/ Options	Usage
num_sensors	1 Byte	0 – 255	Number of sensors to buffer data for median filter
num_freqs	1 Byte	3-to-7	Number of frequencies to cycle/depth of median filter
*freq_option_select	Pointer 2/4 Bytes	Pointer	Pointer to acquisition library frequency selection parameter
*median_filter_freq	Pointer 2/4 Bytes	Pointer	Pointer to array of selected frequencies
enable_freq_autotune	1 Byte	0 or 1	Disable (0) or Enable (1) automatic retuning of hop frequencies
max_variance_limit	1 Byte	1-to-255	Signal variance required to trigger returning of hop frequency
Autotune_count_in	1 Byte	1-to-255	Number of occurrences of max_variance_limit to trigger retuning of hop frequency

8.4.2 Status and Output Data

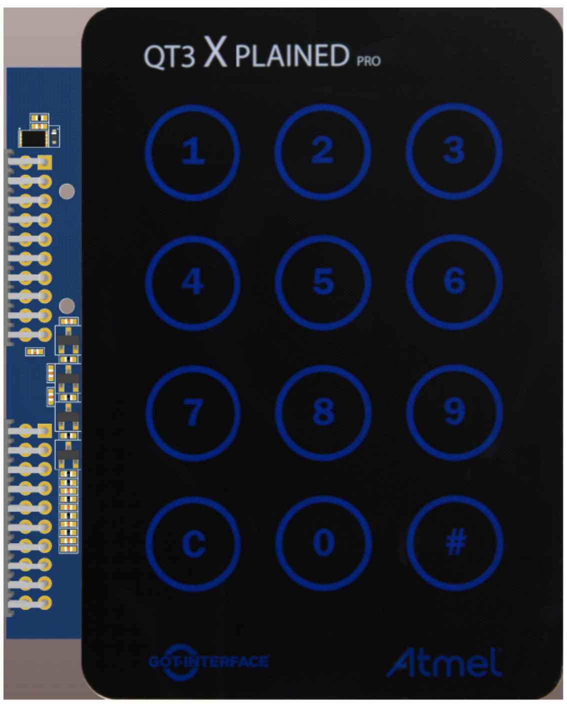
Parameter	Size	Range/Options	Usage
module_status	1 Byte	N/A	Module Status – N/A
current_freq	1 Byte	0-to-15	Current frequency step
*filter_buffer	Pointer 2/4 Bytes	Pointer	Pointer to the filter buffer array for measured signals
*qtm_acq_node_data	Pointer 2/4 Bytes	Pointer	Pointer to the node data structure of the acquisition group
*freq_tune_count_ins	Pointer 2/4 Bytes	Pointer	Pointing to the counter array to trigger frequency change

9. Touch Key Module

9.1 Overview

Touch Key module implements functionality that can handle the key sensors also called as one dimensional touch sensors. The module receives the raw output from the acquisition module, process them and provide touch status of key sensors. The processing includes signal post-processing, environmental drift, touch detection, touch state machine and timing management for the implementation of application touch sensors. Reference touch sensor designs are provided to assist the users to evaluate and design their custom sensor boards. The touch sensor board view and the sensor design of QT3 XPlained Pro sensor board are shown below.

QT3 Sensor Board Overlay



QT3 Sensor Board Design

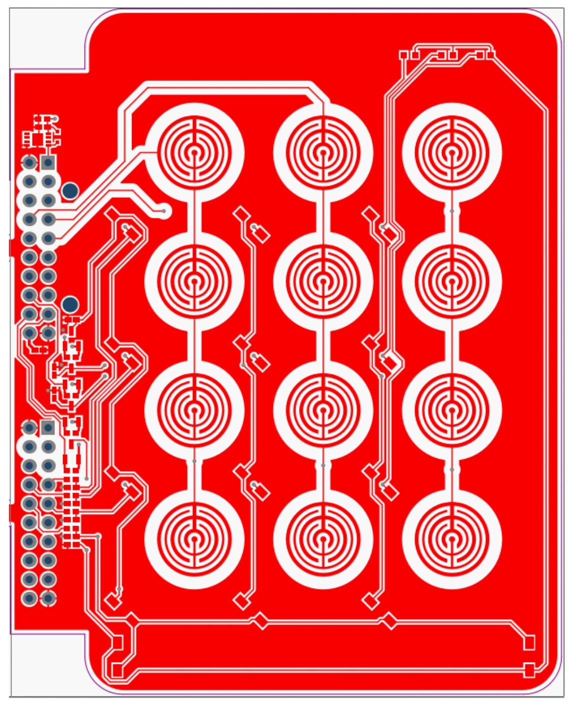
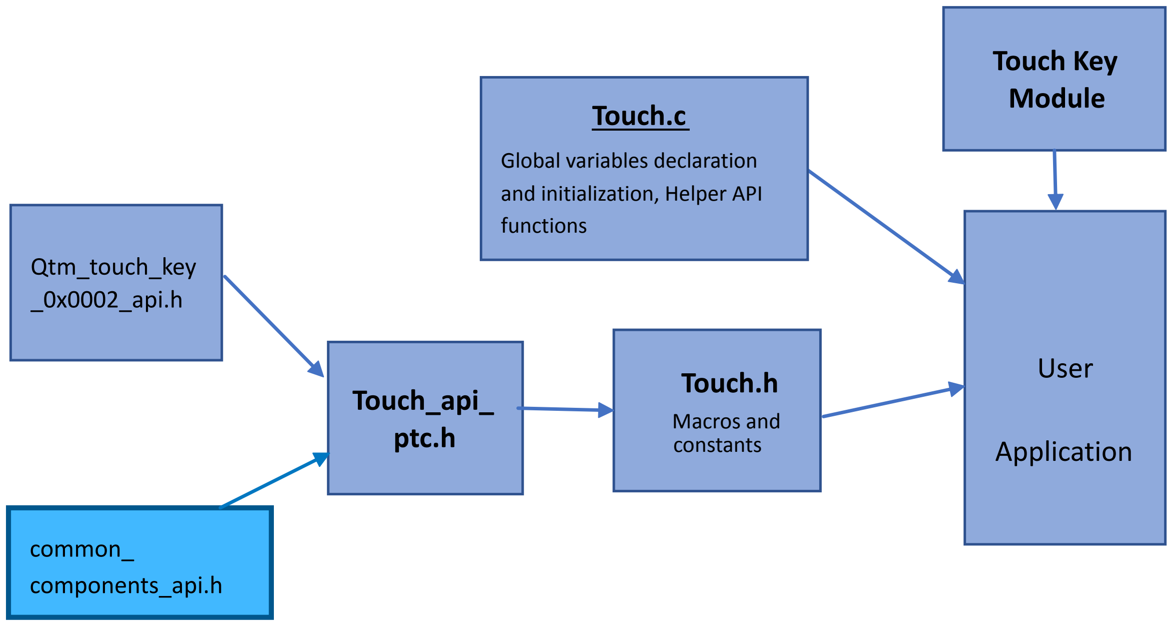


Table 9-1. Module Format

GCC compiler :	`libqtm_touch_key_xxxxx_0x0002.a`
IAR compiler (AVR MCU) :	`qtm_touch_key_xxxxx_0x0002.r90`
IAR compiler (ARM MCU) :	`qtm_touch_key_xxxxx_0x0002.a`

9.2 Interface

The data structure definitions and the API declarations are included in the API file ‘`qtm_touch_key_0x0002_api.h`’. The data structure covers all the configurations and output data variables. This file should be included on the common api `touch_ptc_api.h` file.

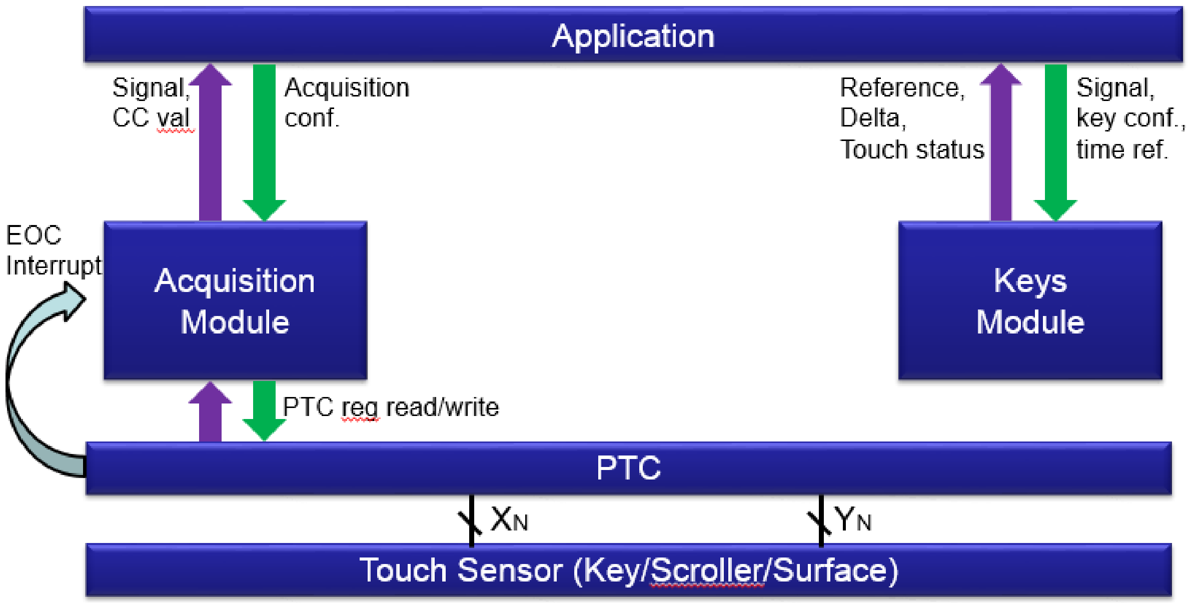


9.3 Functional Description

The Touch Key module is responsible for the detection of a touch contact, where higher-level module(s) carry out position interpolation, gesture recognition, contact tracking etc.

Features implemented in the touch key module:

- Timing management for detecting towards touch, away from touch
- Software calibration
  - Reference Signal
  - Reference Drift
- Touch Detection State Machine



9.4 Data Structures

9.4.1 Configurations

Table 9-2. Group Configuration

Parameter	Size	Range/Options	Usage
num_key_sensors	2 Bytes	1-to-65535	Number of sensor keys in the group
sensor_touch_di	1 Byte	0-to-255	Number of repeat measurements to confirm touch detection
sensor_max_on_time	1 Byte	0 (Disabled), 1-to-255	Number of timer periods with sensor In Detect before automatic 'recal'
sensor_anti_touch_di	1 Byte	0 (Disabled), 1-to-255	Number of repeat measurements to confirm anti-touch recalibration required
sensor_anti_touch_recal_thr	1 Byte	0-to-5	Scale-down of touch threshold to set anti-touch threshold. 0 = 100% Touch Threshold 1 = 50% 2 = 25% 3 = 12.5% 4 = 6.25%

Parameter	Size	Range/Options	Usage
			5 = Maximum Recalibration
sensor_touch_drift_rate	1 Byte	0 (Disabled), 1-to-255	Number of timer periods to countdown between towards touch drifts
sensor_anti_touch_drift_rate	1 Byte	0 (Disabled), 1-to-255	Number of timer periods to countdown between away from touch drifts
sensor_drift_hold_time	1 Byte	0 (Disabled), 1-to-255	Number of timer periods to stop drifting after touch event
sensor_reburst_mode	1 Byte	0 = None 1 = Unresolved (Quick reburst) 2 = All	None – Reburst is never set, measurements according to application schedule. Unresolved – Reburst is set, all sensors suspended but those in same AKS as the target sensor. All – Reburst is set, no sensors are suspended.

Table 9-3. Individual Sensor Configuration

Parameter	Size	Range/Options	Usage
channel_threshold	1 Byte	0-to-255	Minimum signal delta indicating touch contact
channel_hysteresis	1 Byte	0 (50%)-to-4 (3.125%)	Reduction of touch threshold to de-bounce when filtering out removed touch contact
channel_aks_group	1 Byte	0-to-255	Grouping of key sensors controlling simultaneous touch detect.

9.4.2 Status and Output Data

Table 9-4. Group Data

Parameter	Size	Range/Options	Usage
qtm_keys_status	1 Byte	Bit 7: Reburst required Bit 6-1: Reserved Bit 0: Touch Detection	Indicates the current state of the Touch Key Group
acq_group_timestamp	2 Bytes	0-to-65535	Timestamp of last drift period processed
dht_count_in	1 Byte	0-to-‘sensor_drift_hold_time’	Countdown to drift hold release after touch event

Parameter	Size	Range/Options	Usage
tch_drift_count_in	1 Byte	0-to-'sensor_touch_drift_rate'	Countdown to next towards touch drift period
antitch_drift_count_in	1 Byte	0-to-'sensor_anti_touch_drift_rate'	Countdown to next away from touch drift period

Individual Key Sensor Data
The individual key sensor data is required by other post processing modules like Scroller. So, this data structure definition is placed on the `common_compoenents_api.h` file.

Parameter	Size	Range/Options	Usage
sensor_state	1 Byte	Bitfield	Touch key sensor state
sensor_state_counter	1 Byte	0-to-255	Number of repeat measurements to confirm touch detection
*node_data_struct_ptr	2/4 Bytes	Pointer	Pointer to node data structure array
Channel_reference	2 Bytes	0-to-65535	Reference measurement, baseline for touch detection

Table 9-5.

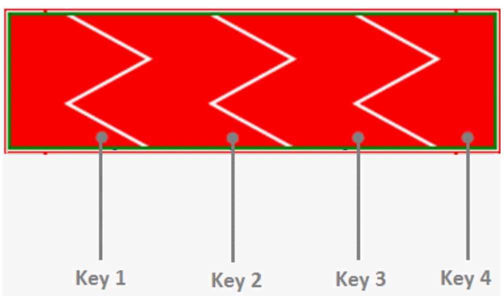
sensor_state	
QTM_KEY_STATE_DISABLE	0x00
QTM_KEY_STATE_INIT	0x01
QTM_KEY_STATE_CAL	0x02
QTM_KEY_STATE_NO_DET	0x03
QTM_KEY_STATE_FILT_IN	0x04
QTM_KEY_STATE_DETECT	0x85
QTM_KEY_STATE_FILT_OUT	0x86
QTM_KEY_STATE_ANTI_TCH	0x07
QTM_KEY_STATE_SUSPEND	0x08
QTM_KEY_STATE_CAL_ERR	0x09
Note: Bit 7 (0x80u) is set in each state where the touch key sensor is 'In Detect'	

10. Scroller Module

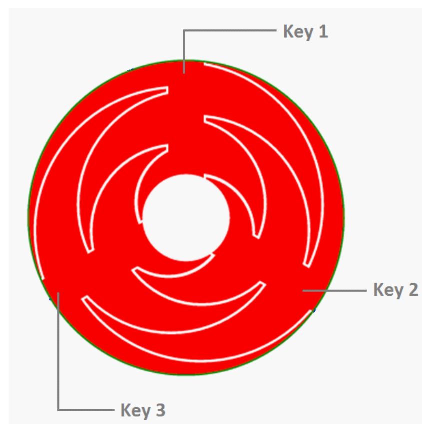
10.1 Overview

The Scroller module processes the group of touch sensors constructed either as linear slider or circular wheel as shown in the figure below. The slider/wheel sensors, also known as one-dimensional surface sensors, track the touch movement scrolled over them and report the state and the position to the user application. The size of the slider/wheel is the underlying number of the touch key sensors that form the linear/circular surface.

Slider Sensor



Wheel Sensor

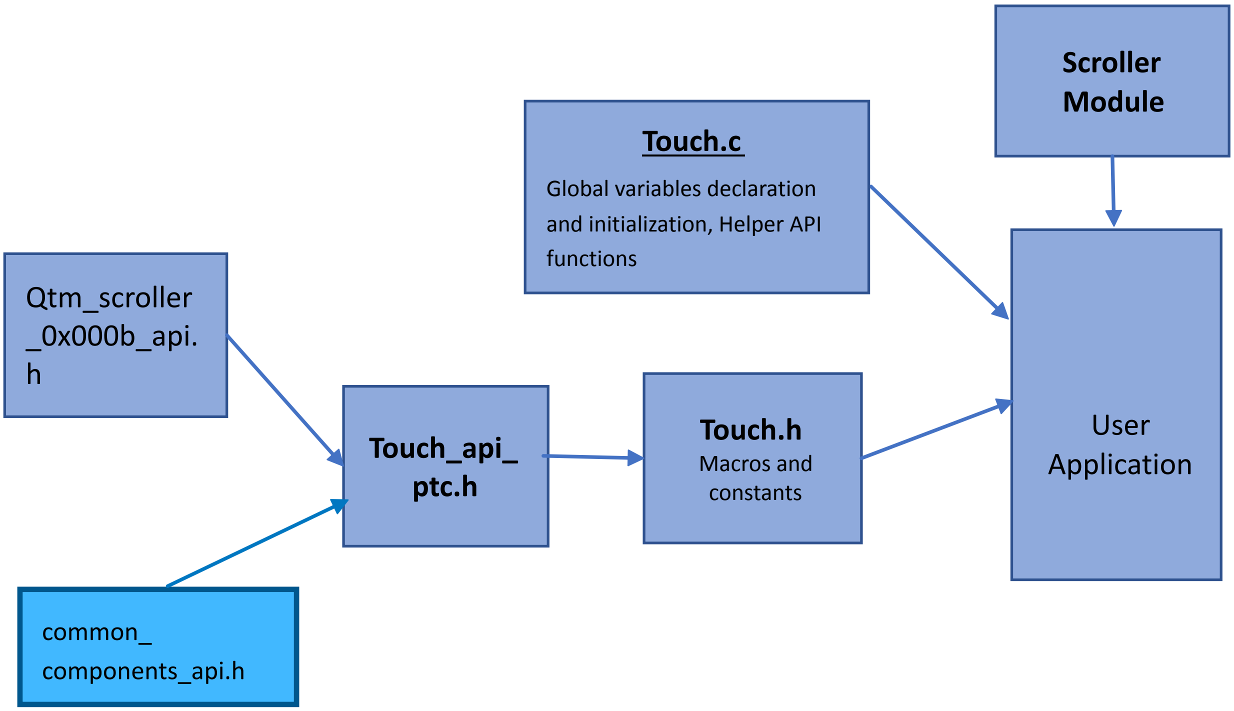


The slider/wheel can be formed by using both self cap and mutual cap sensors. The above figure shows the 4-channel slider and 3-channel wheel sensors based on self-cap technology. To get good linearity on the reported touch positions when the touch is scrolled over the sensor surface, the touch keys should be inter-digitized as shown in the above figure.

GCC compiler :	`libqtm_scroller_xxxxx_0x000B.a`
IAR compiler (AVR MCU) :	`qtm_scroller_xxxxx_0x000B.r90`
IAR compiler (ARM MCU) :	`qtm_scroller_xxxxx_0x000B.a`

10.2 Interface

The data structure definitions and the API declarations are included in the API file '`qtm_scroller_0x000b_api.h`'. The data structure covers all the configurations and output data variables. This file should be included on the common api `touch_ptc_api.h` file.



10.3 Functional Description

The Scroller module processing is dependent on the Touch Key module output. After the keys are processed and statuses are updated in the data structures, they are checked by the slider module. Based on the key status, the slider/wheel position is calculated from the current signal values available on the acquisition module variables.

The possible use cases and the sequence of operation under each use case are given below.

Use Case 1: Touch contact made on slider/wheel sensor

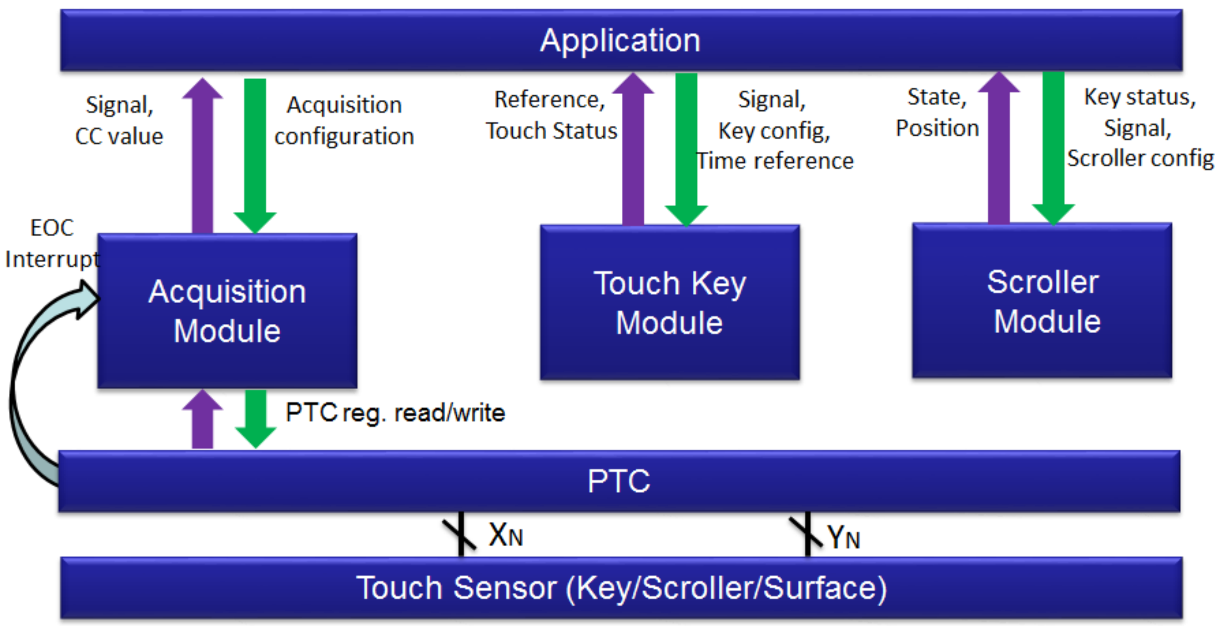
1. The module checks the status of all keys in the scroller for a touch contact detection.
2. If any key is in detect state, the touch position is calculated using the signal values of three adjacent keys.
3. Both raw position and filtered position are calculated.
4. The scroller state comes to “TOUCH_ACTIVE” and the scroller reburst flag is set.
5. The “`POSITION_CHANGE`” flag is set now. The flag is cleared on the next measurement cycle if the touch is stationary and no change in touch position.

Use Case 2: Touch contact scrolling over the slider/wheel surface

1. Module checks all keys for touch contact
2. If no key is in detect, the module searches for a pair of neighboring keys whose touch delta exceeds the minimum contact threshold
3. If such a contact is found then the new position is calculated **OR**
4. If no such contact is found the scroller returns to ‘No Detect’ condition

Use Case 3: Touch contact removed from slider/wheel sensor

1. The module checks the status of all keys in the scroller for a touch contact detection.
2. If no key is in detect, the module searches for a pair of neighboring keys whose touch delta exceeds the minimum contact threshold.
3. If such a contact is found then the new position is calculated **OR**
4. If no such contact is found the scroller returns to 'No Detect' condition. That is the flag "TOUCH_ACTIVE" is cleared.



10.4 Data Structures

10.4.1 Configurations

Table 10-1. Group Configuration

Parameter	Size	Range/Options	Usage
`*qtm_touch_key_data`	Pointer 2/4 Bytes	`qtm_touch_key_data_t`	Pointer to touch key data for the underlying set of touch keys
`num_scrollers`	1 Byte	1-to-255*	Number of scrollers implemented in this group

Table 10-2. Individual Sensor Configuration

Parameter	Size	Range/Options	Usage
`type`	1 Byte	0 = Linear Slider	Type of scroller

Parameter	Size	Range/Options	Usage
		1 = Wheel	
`start_key`	2 Bytes	0-to-65535*	Key number which forms the first component key of the scroller
`number_of_keys`	1 Byte	2-to-255	Number of component keys to form the scroller. The minimum number of keys required to make a slider is two and the minimum number of keys to make a wheel is three.
`resol_deadband`	1 Byte	Bits 7:4 = Resolution 2 to 12 bits	Full scale position resolution reported for the scroller
		Bits 3:0 = Deadband 0% to 15% (each side)	Size of the edge correction deadbands as a percentage of the full scale range
`position_hysteresis`	1 Byte	0-to-255	The minimum travel distance to be reported after contact or direction change
`contact_min_threshold`	2 Bytes	0-to-65535	The minimum contact size measurement for persistent contact tracking. Contact size is the sum of two neighboring keys' touch deltas forming the touch contact

10.4.2 Status and Output Data

Table 10-3. Group Data

Parameter	Size	Range/Options	Usage
`scroller_group_status`	1 Byte	**Bitfield** Bit 7: Reburst required Bit 0: Touch detection	Reburst Required = 1 Indicates that some scroller in the group requires reburst of sensors. Touch Detection = 1 Indicates that some scroller in the group is in 'Touch Detect'

Individual Key Sensor Data

Parameter	Size	Range/Options	Usage
`scroller_status`	1 Byte	**Bitfield** Bit 7: Reburst required Bit 1: Contact moved Bit 0: Touch detection	Reburst Required = 1 Indicates that some scroller in the group requires reburst of sensors. Touch contact reported position has changed Touch Detection = 1

Parameter	Size	Range/Options	Usage
			Indicates that some scroller in the group is in 'Touch Detect'
`right_hyst`	1 Byte	Hysteresis limit	Indicates when a contact is moving 'Right', ie., The direction of increasing touch position
`left_hyst`	1 Byte	Hysteresis limit	Indicates when a contact is moving 'Left', ie., The direction of reducing touch position
`raw_position`	2 Bytes	0-to-4095	The calculated location of the touch contact prior to motion filtering
`position`	2 Bytes	0-to-4095	The calculated location of the touch contact after motion filtering
`contact_size`	2 Bytes	0-to-65535	The sum of two neighbouring keys' touch deltas comprising the touch contact

11. Binding Layer Module

11.1 Overview

The binding layer is the generic framework that binds the QTouch Library modules and automates the initialization and processing of modules. The binding layer is configured with data pointers and function pointers of the QTouch modules which are used to execute the module API functions in the appropriate sequence. The binding module also provides callback on completion of every stage to the user application.

The binding includes the acquisition module, signal conditioning modules and post processing modules. Controlling all the modules with unified application interface reduces the complexity of handling multiple modules, their states and errors and callback functions. The user application code can also be built as library module and automated using the binding layer provided the user module conforms to the QTouch modular library architecture.

Figure 11-1. Binding Layer Framework Block Diagram

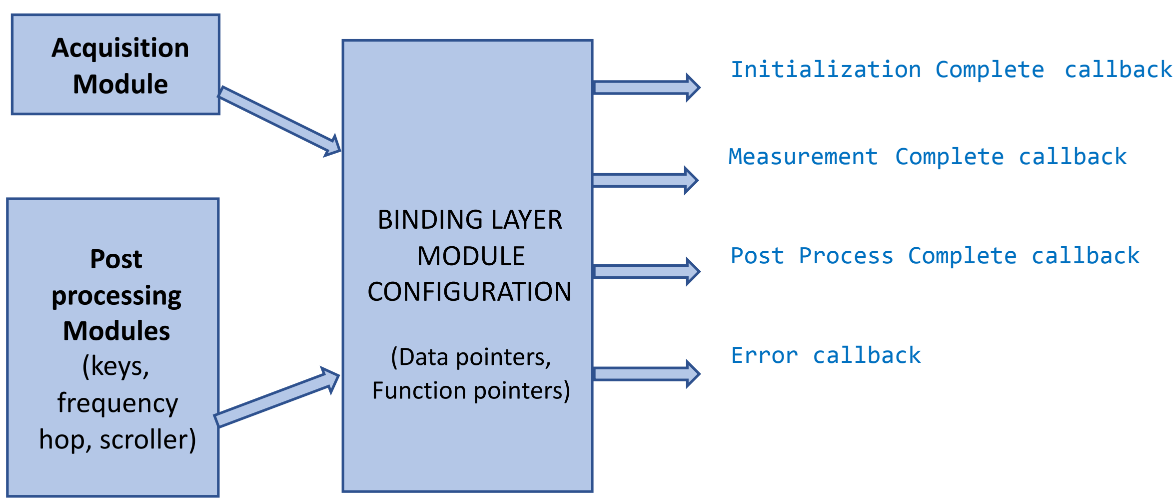
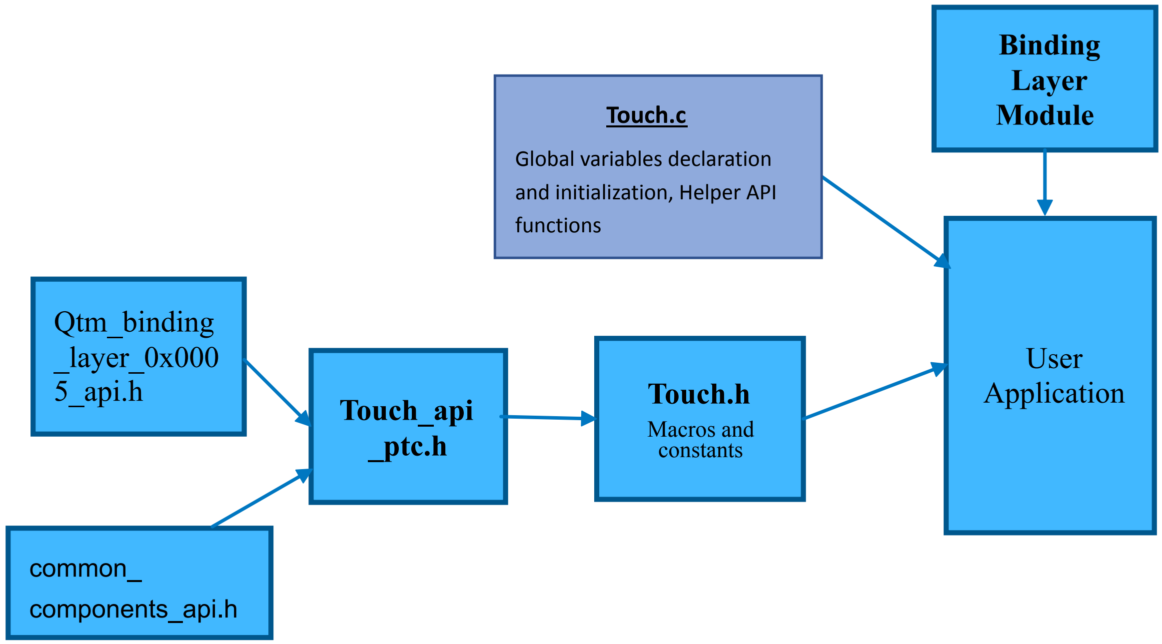


Table 11-1. Module Format

GCC compiler :	`libqtm_binding_layer_xxxxx_0x0005.a`
IAR compiler (AVR MCU) :	`qtm_binding_layer_xxxxx_0x0005.r90`
IAR compiler (ARM MCU) :	`qtm_binding_layer_xxxxx_0x0002.a`

11.2 Interface

The data structure definitions and the API declarations are included in the API file '`qtm_binding_layer_0x0005_api.h`'. The data structure covers all the configurations and output data variables. This file should be included on the common api `touch_ptc_api.h` file.

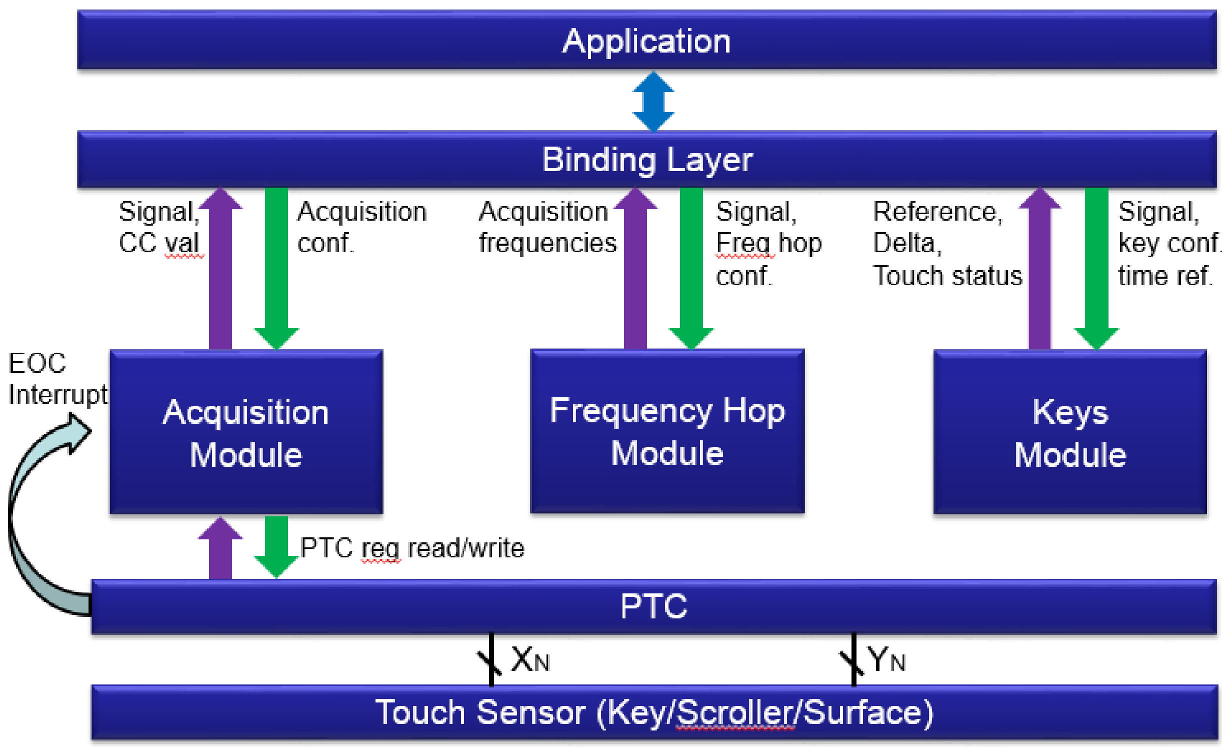


11.3 Functional Description

Binding layer automates the following processes of each module.

1. Module initialization
2. Capture success/error and report through callback
3. Module post processing
4. Capture success/error and report through callback
5. Capture “module reburst” flag and retriggers the acquisition based on the ‘Reburst’ status

Figure 11-2. Binding Layer-based QTouch® Application



Error handling support by binding layer module:
The individual module errors are validated inside the binding layer and they are encoded and passed to the application as single error code.

The error code is decoded in the touch.c file and displayed on the data visualizer software. The error code format is given below.

```
Acquisition Module Error codes: 0x8<error code>
    0x81 - Qtm init
    0x82 - start acq
    0x83 - cal sensors
    0x84 - cal hardware

Post processing Modules error codes: 0x4<process_id>
    0x40, 0x41, 0x42, ...
process_id is the sequence of process IDs listed in #define LIB_MODULES_PROC_LIST macro.
Process IDs start from zero and maximum is 15

        Examples:
        0x40 -> error in post processing module 1
        0x42 -> error in post processing module 3

Decoded Module_error_codes:
    Acquisition module error = 1
    post processing module1 error = 2
    post processing module2 error = 3
    ... and so on
```

11.4 Data Structures

11.4.1 Configurations

The container structure that holds the entire configuration of binding layer is given below.

```
typedef struct qtm_control_tag
{
    uint8_t binding_layer_flags;

    module_init_t *library_modules_init;
    module_proc_t *library_modules_proc;
    module_acq_t  *library_modules_acq;

    module_arg_t *library_module_init_data_model;
    module_arg_t *library_module_proc_data_model;
    module_arg_t *library_modules_acq_dm;

    qtm_acq_pp_t *qtm_acq_pp;

    /*******************************/
    /* Callbacks for Binding layer */
    /*******************************/
    qtm_library_init_complete_t qtm_init_complete_callback;
    qtm_error_callback_t        qtm_error_callback;
    qtm_measure_complete_t      qtm_measure_complete_callback;
    qtm_pre_process_callback_t  qtm_pre_process_callback;
    qtm_post_process_callback_t qtm_post_process_callback;

} qtm_control_t;
```

Parameter	Description
*library_modules_init	Pointer to the array that contains the list of module initialization function pointers.
*library_modules_proc	Pointer to the array that contains the list of module post processing function pointers.
*library_modules_acq	Pointer to the array that contains the list of acquisition module function pointers.
*library_module_init_data_model	Pointer to the array which contains the Data Pointers of the acquisition modules.
*library_module_proc_data_model	Pointer to the array which contains the Data Pointers of the post processing modules.
*library_modules_acq_dm	Pointer to the array which contains the pointers of acquisition groups.
qtm_init_complete_callback	Callback provided by binding layer module after executing all the module initializations.
qtm_error_callback	Callback function triggered only if there is any error encountered by the binding layer during the module processes.
qtm_measure_complete_callback	Callback triggered by binding layer module after the completion of measurement and before post processing.

Parameter	Description
`qtm_pre_process_callback`	Callback triggered after the acquisition process and before post processing. This is provided to enable user to implement custom filtering modules.
`qtm_post_process_callback`	Callback triggered by binding layer module after the completion of all the post processing of modules.

11.4.2 Status and Output Data

Parameter	Description
`binding_layer_flags`	Three status flags are set inside the binding layer callback functions to perform further processing the Application. Three binding layer flags are supported in the current version as below.
	`time_to_measure_touch:` This flag is set on the timer ISR handler and when any module reburst is requested. This flag is used to trigger the measurement on either one of the above conditions met.
	`node_pp_request:` This flag is set in the measurement complete callback to indicate post processing is required. This flag is handled in the `touch_process` function.
	`reburst_request:` This flag is set in the post process complete callback and this is set based on the individual module reburst flags. This flag is handled on the `touch_process` function.

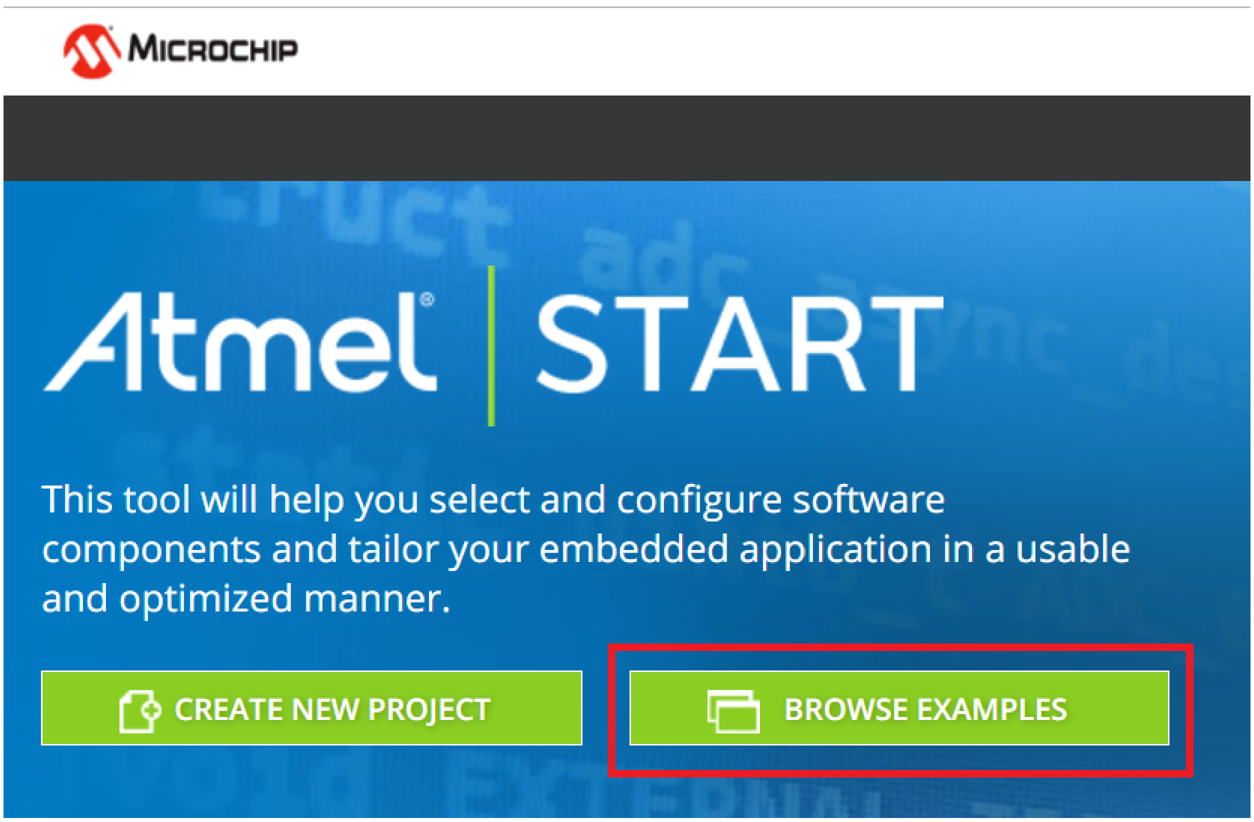
12. Building Applications Using Atmel START

Atmel START helps the user to select and configure software components for Microchip MCUs. The QTouch project can be created using Atmel START. The user can add sensors and configure QTouch parameters represented in graphical ways. The created project supports GCC and IAR compilers.

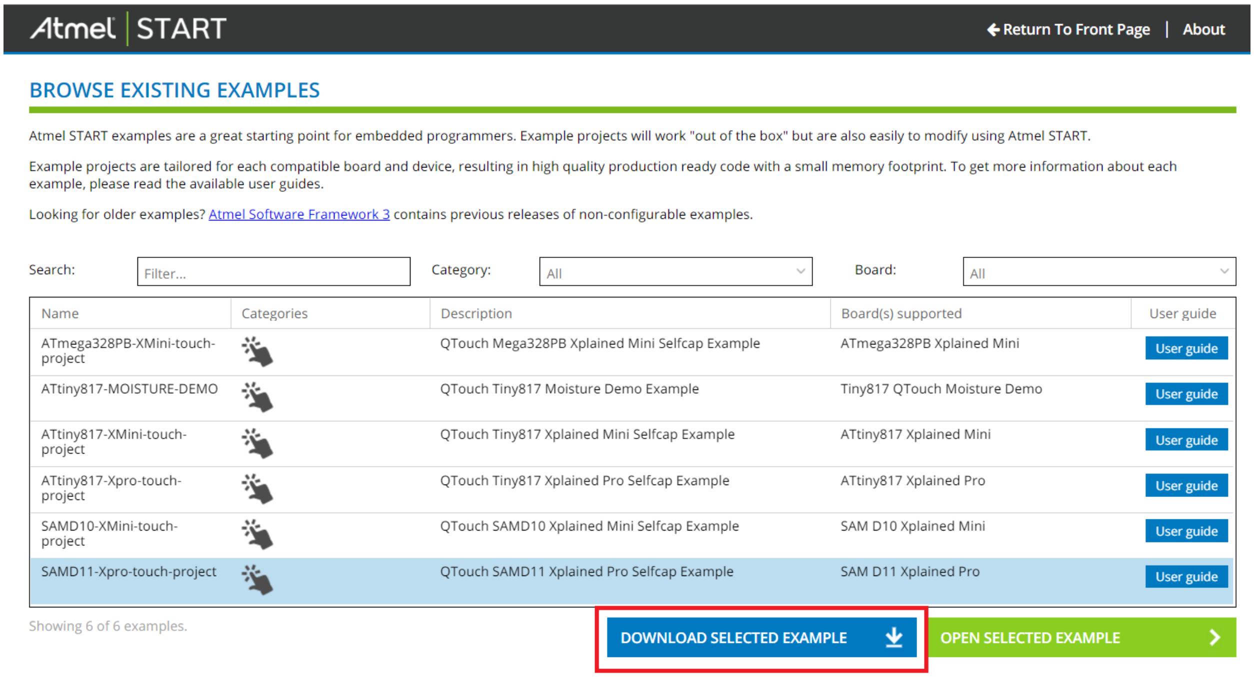
12.1 Working With KIT Example Projects

Atmel START provides example projects for standard Xplained Pro and Xplained Mini kits. The kit examples are a good way to get up and running with touch applications. The projects can be downloaded and built with the following steps.

Step 1:
Open Atmel START main page and click '*Browse Examples*'



Step 2:
Select one of the listed KIT example projects by clicking on the description. Click the '*Download selected example*' button and save the `atzip` file.



Step 3:
Import the `atzip` file into Atmel studio or IAR IDE and build the example. Flash the built binary on the target MCU.

Step 4:
Open the data visualizer software and configure the path to the directory "`<example_project_directory>\qtouch\datastreamer\`".

Step 5:
Connect the data visualizer to the target hardware using a serial port channel and verify the ON button touch status. The on-board LED will turn on when touch is made and vice-versa.

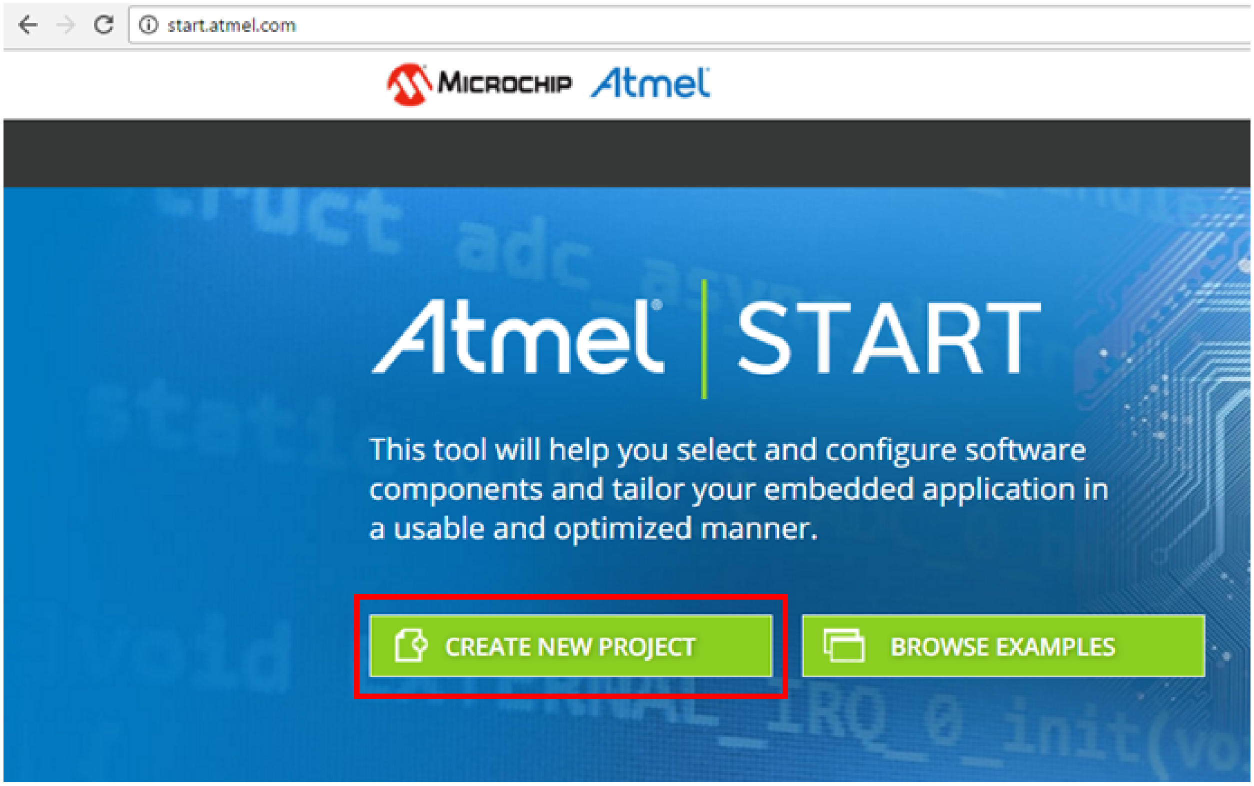
For more details, refer to the guides present on the Microchip developer page link http://microchipdeveloper.com/touch:generate-atmel-board-touch-project

12.2 Creating User-Board Projects

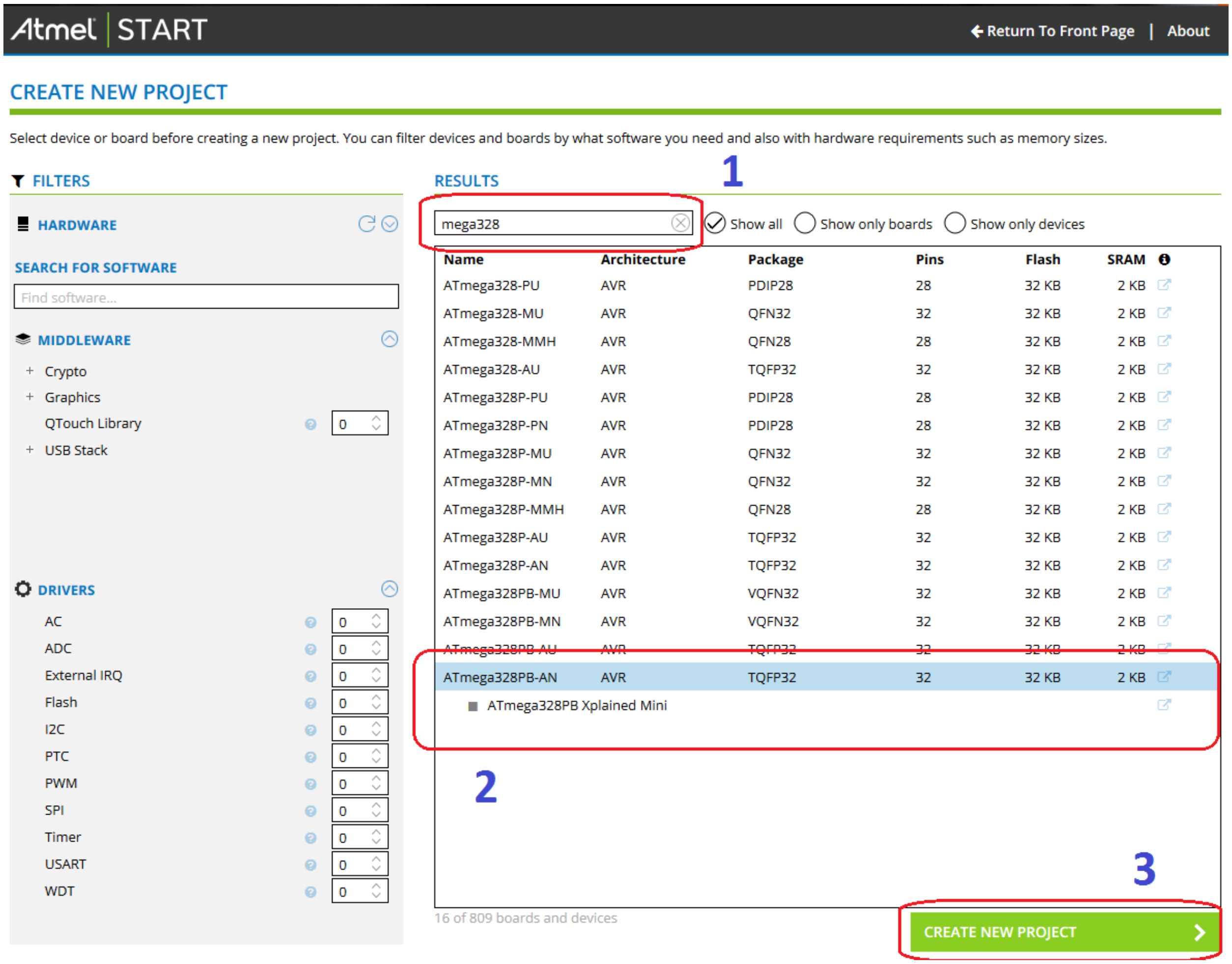
The following steps describe the procedure to create touch projects for the custom/user specific hardware boards.

Step 1:
Open Atmel START main page and click '**Browse Examples**'.

Step 2:
Select '*Create New Project*' option.

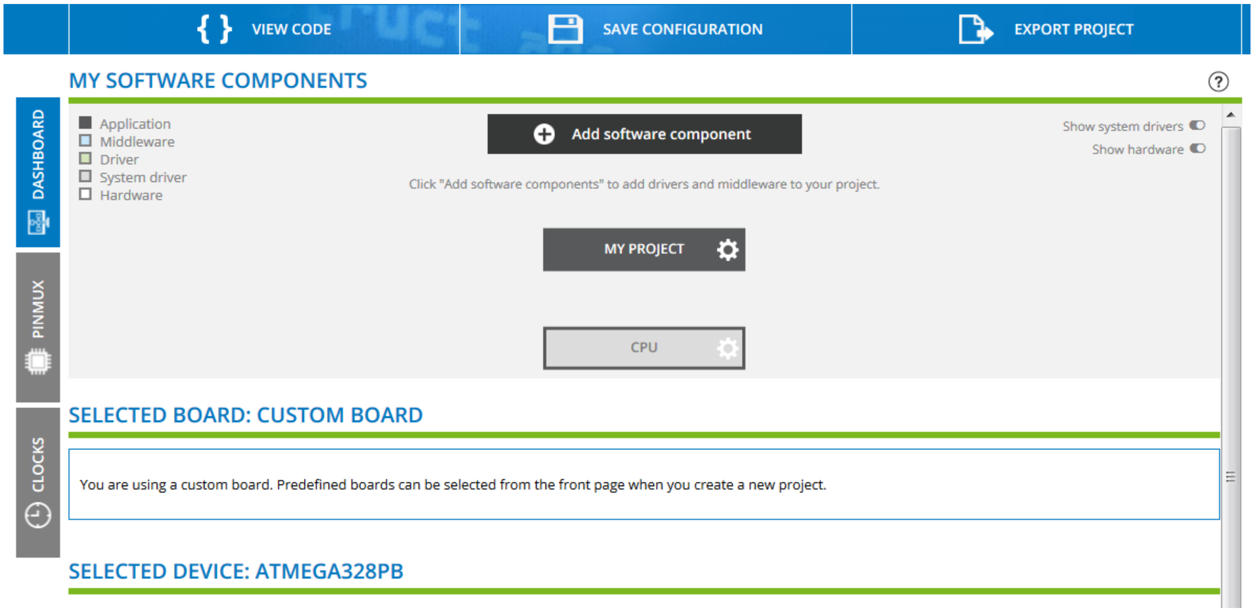


Step 3
Type '*mega328*' in the '*Filter on text…*' field. Select *ATmega328PB-AN* from the list and click **CREATE NEW PROJECT**.

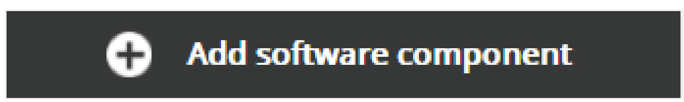


Step 4:

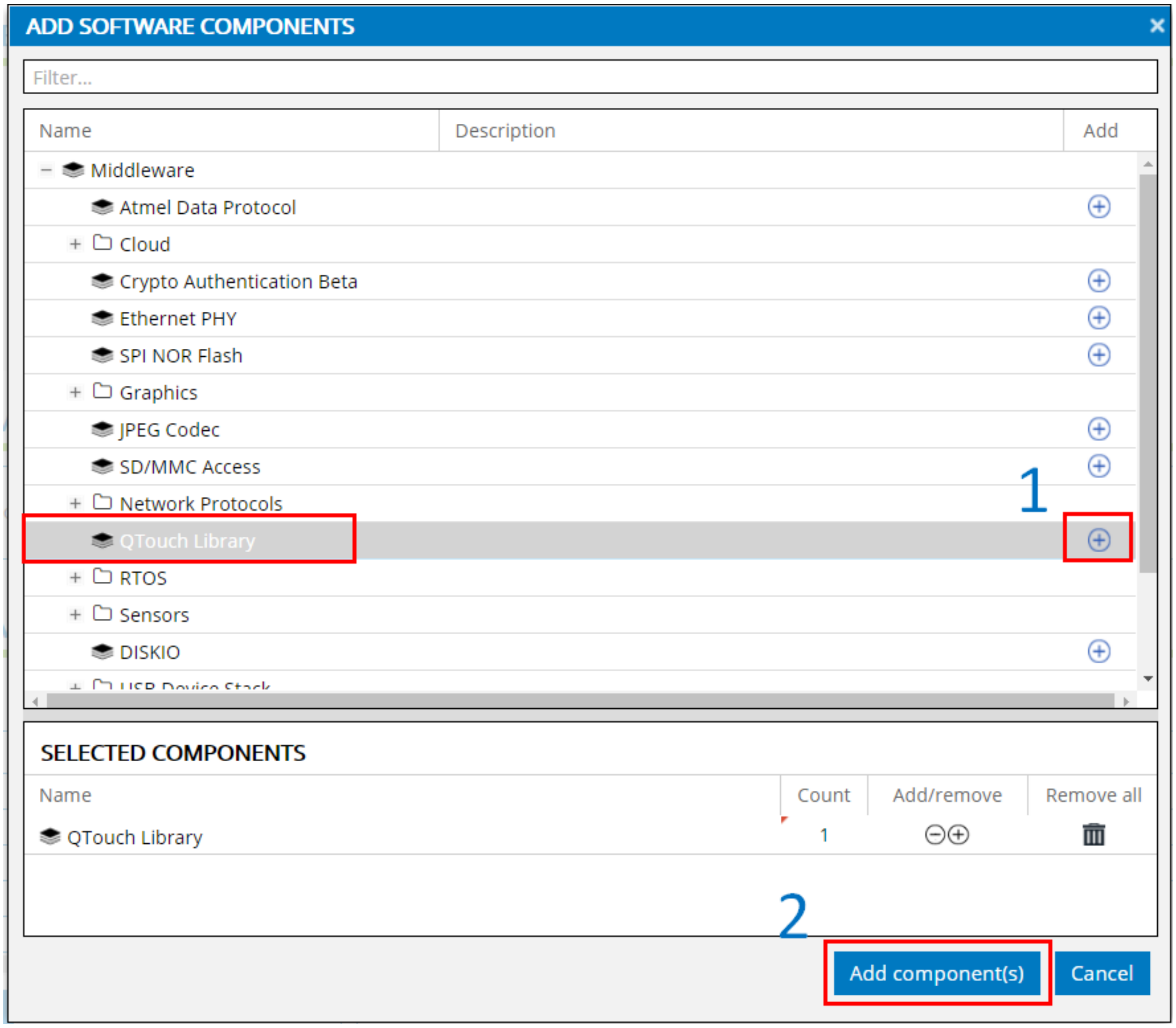
The project will be created with default initialization and the project dashboard is displayed as below.



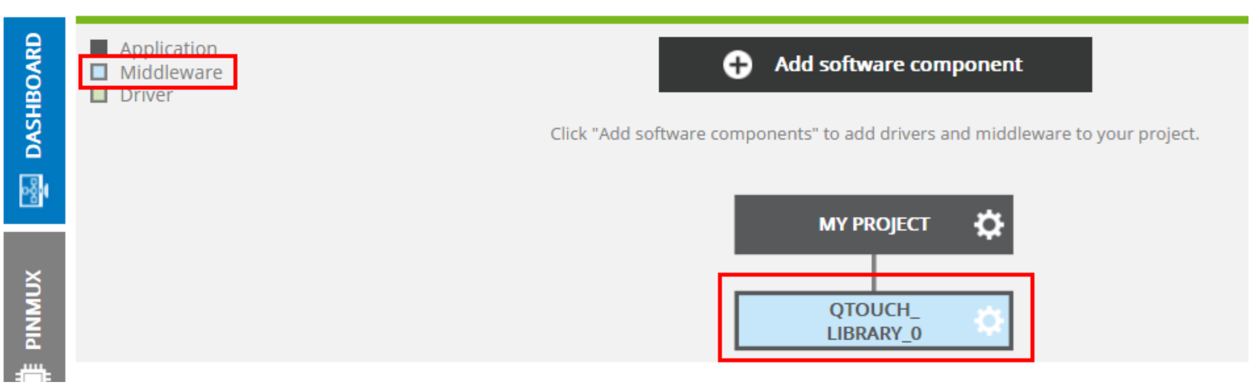
Step 5:
Click **Add Software Component** to add QTouch Library.



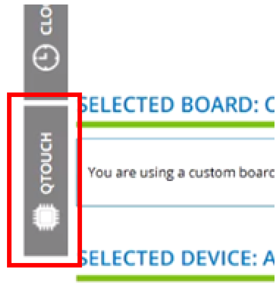
Step 6:
In "*ADD SOFTWARE COMPONENT*" window, add QTouch Library by clicking **+** icon and then '**Add Component** ' button.



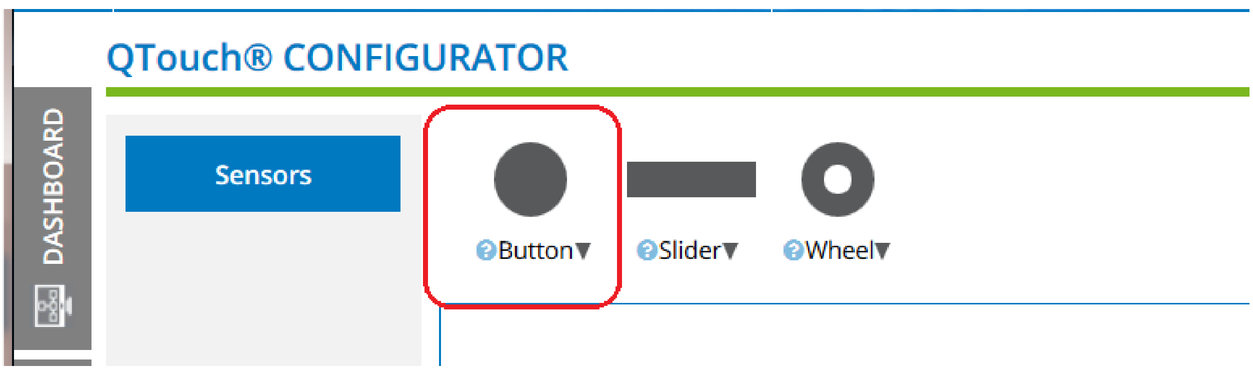
Step 7:
'**QTouch Library Middleware**' will be added to the project.



Step 8:
Select **QTouch** tab.

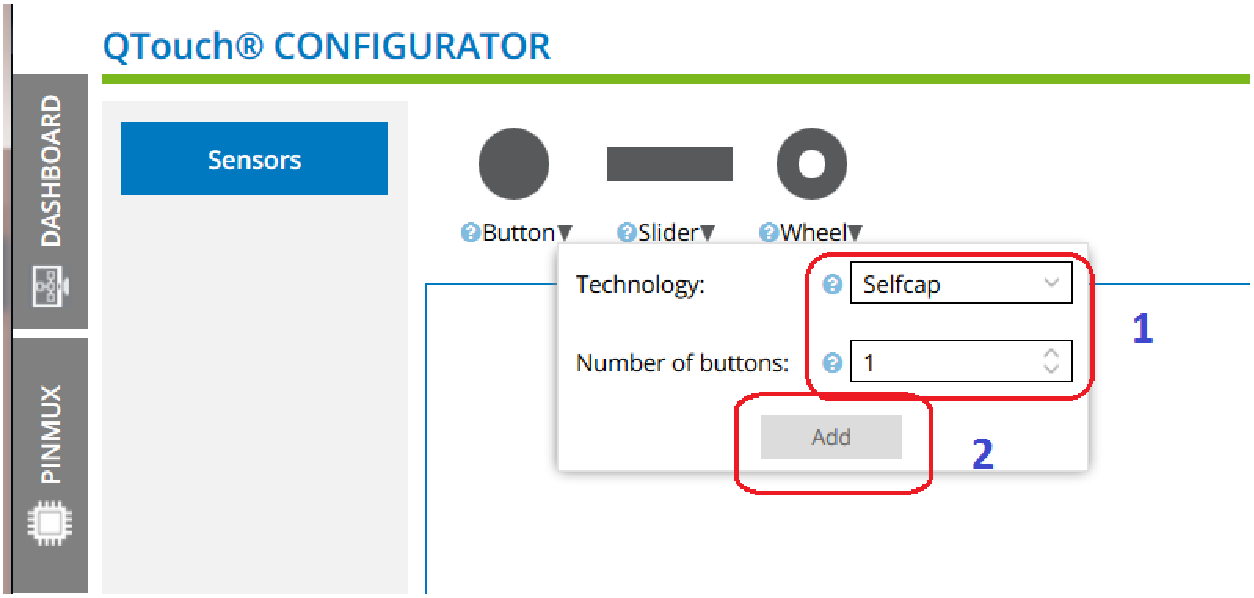


Step 9:
QTouch Configuration options appears as follows. Select **Add Button** option.

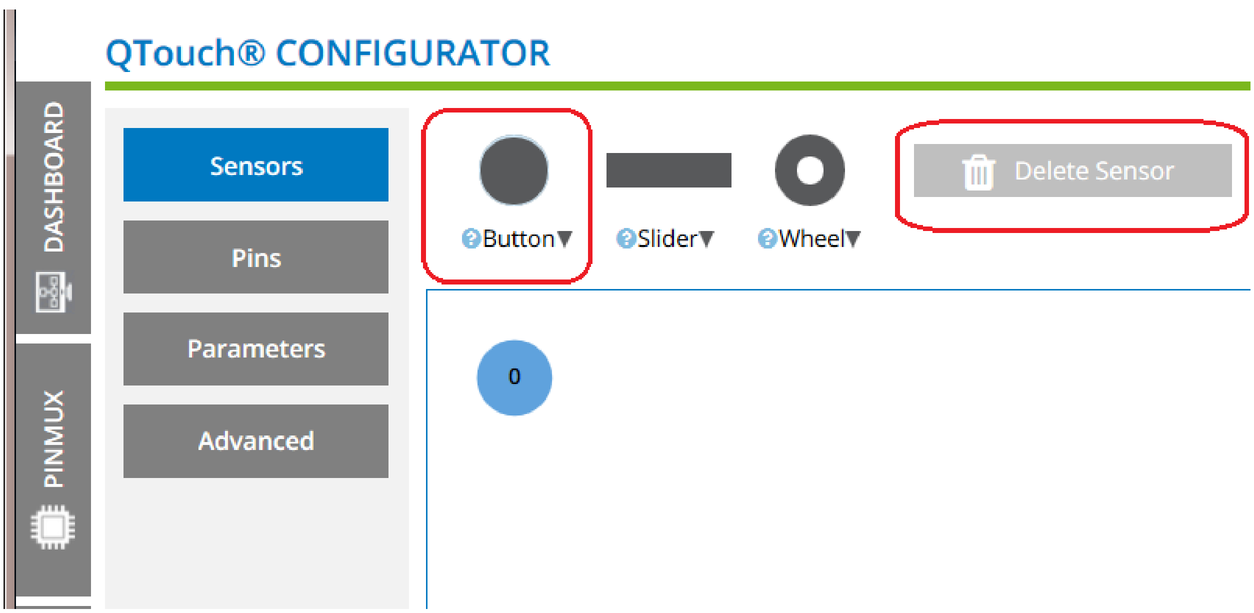


Step 10:
Select the following in '*Add Sensor*' window and click **Add Sensor**.

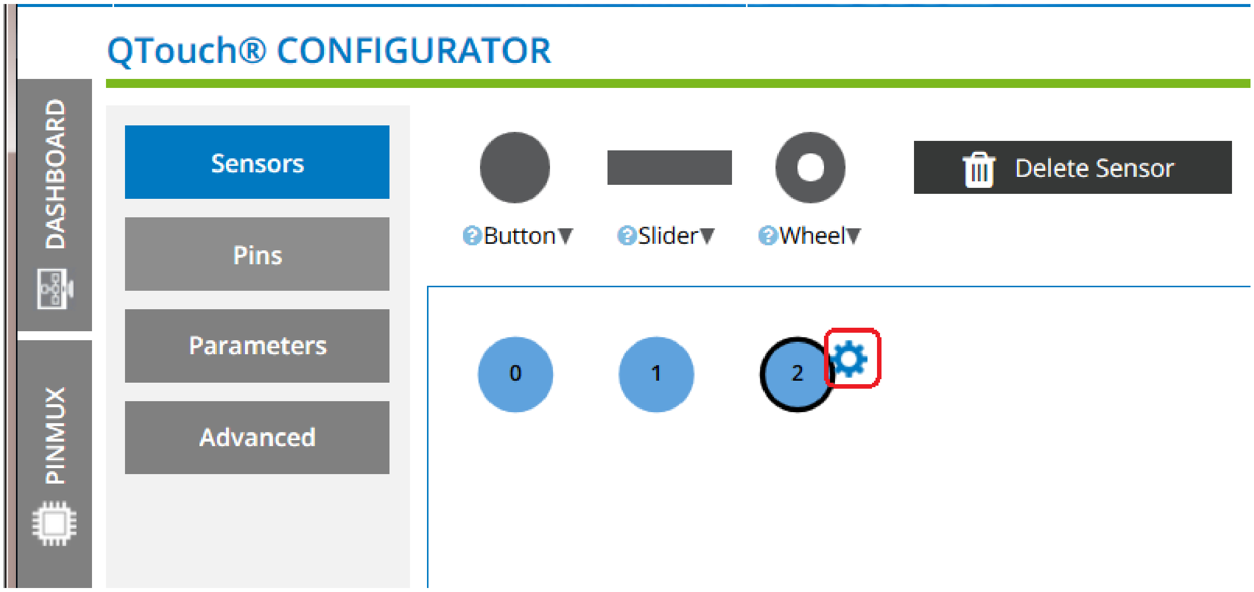
- Sensor Count: 1
- Technology: SelfCap



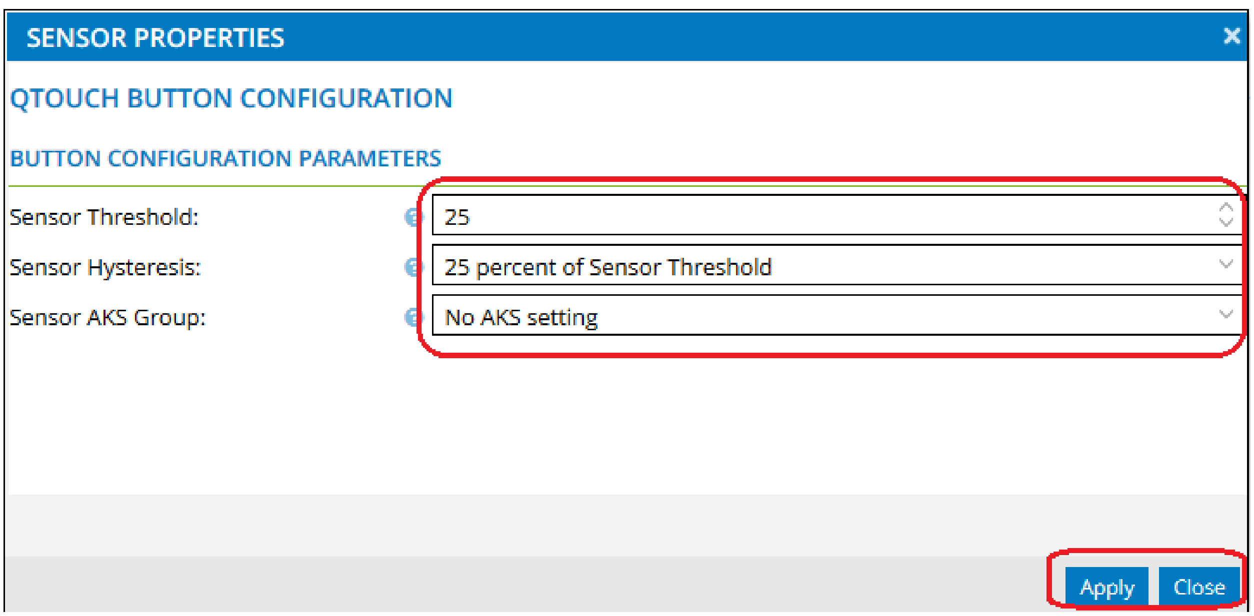
Step 11:
Simply click the '**Button**' icon to add more buttons. To delete sensor, select the sensor by single clicking on the sensor icon and click the '**Delete Sensor**'. Three Buttons are added as shown in following figure.



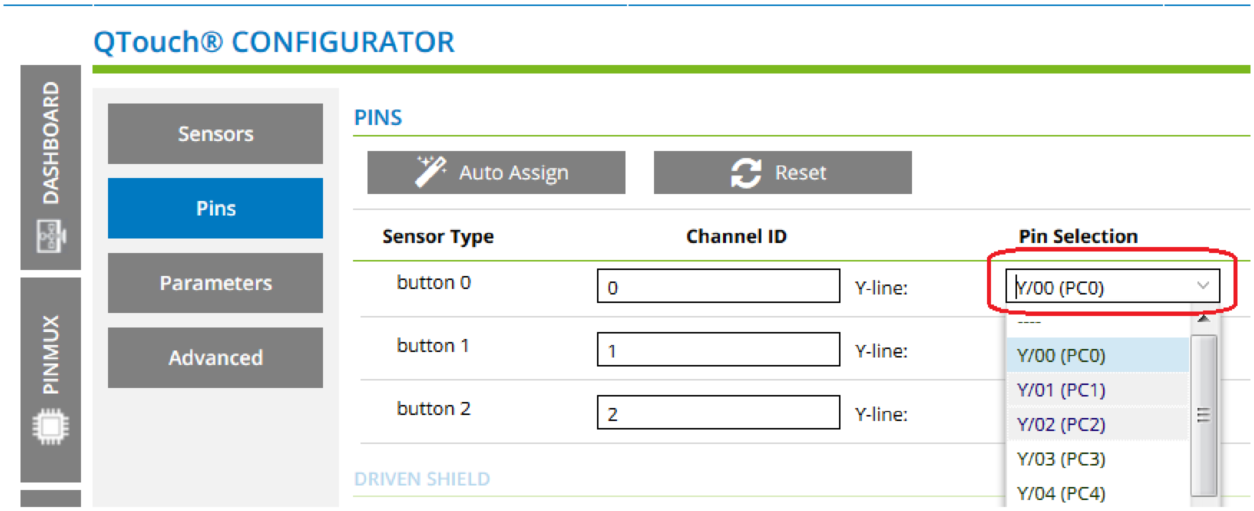
Step 12:
Select the **Button** and click on cogwheel icon.



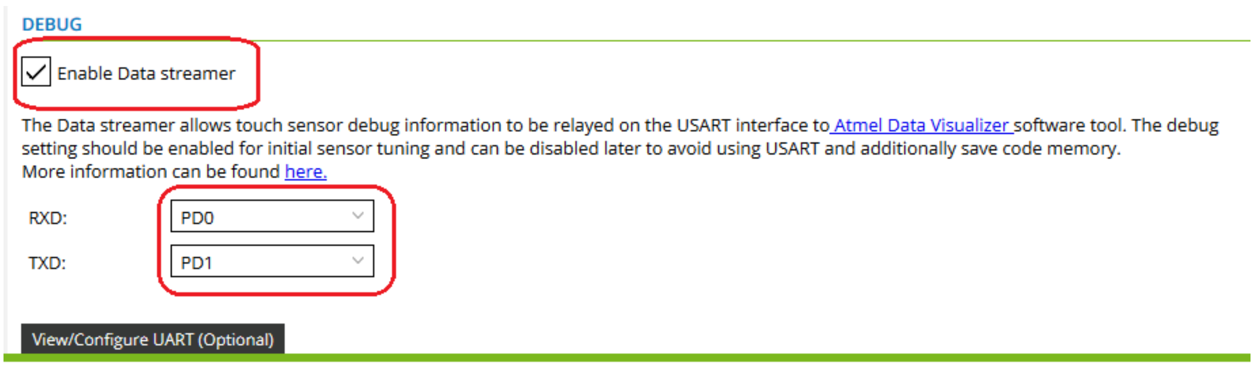
Step 13:
Sensor Properties are displayed as shown in the following figure. *Sensor Threshold*, *Hysteresis* and *AKS* can be configured in this option.



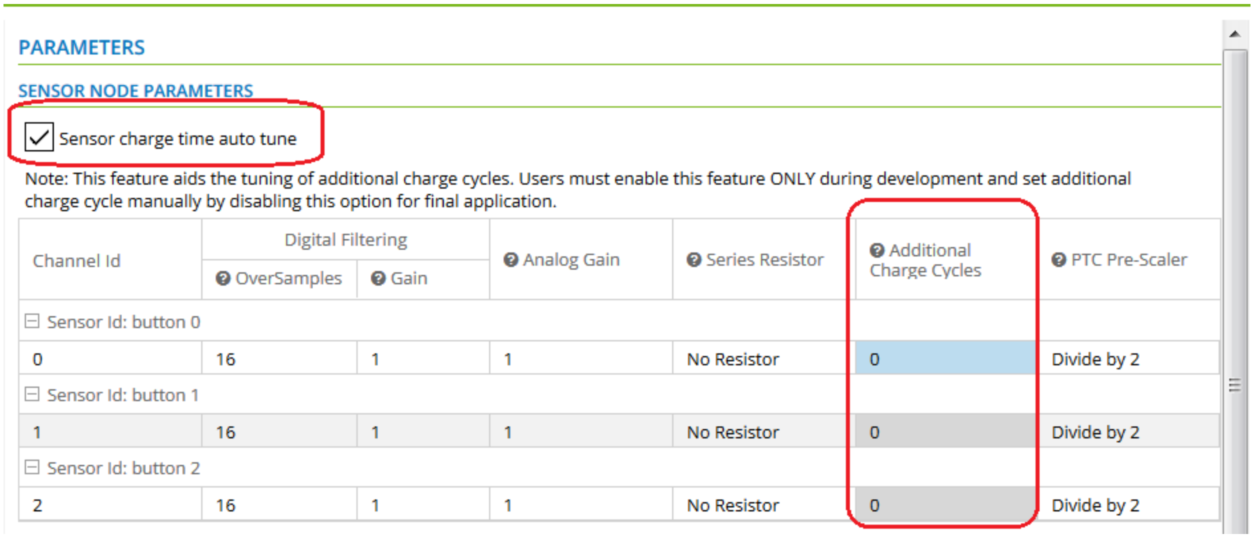
Step 14:
Select **Pin Selection** tab and select the correct Y lines for each button.

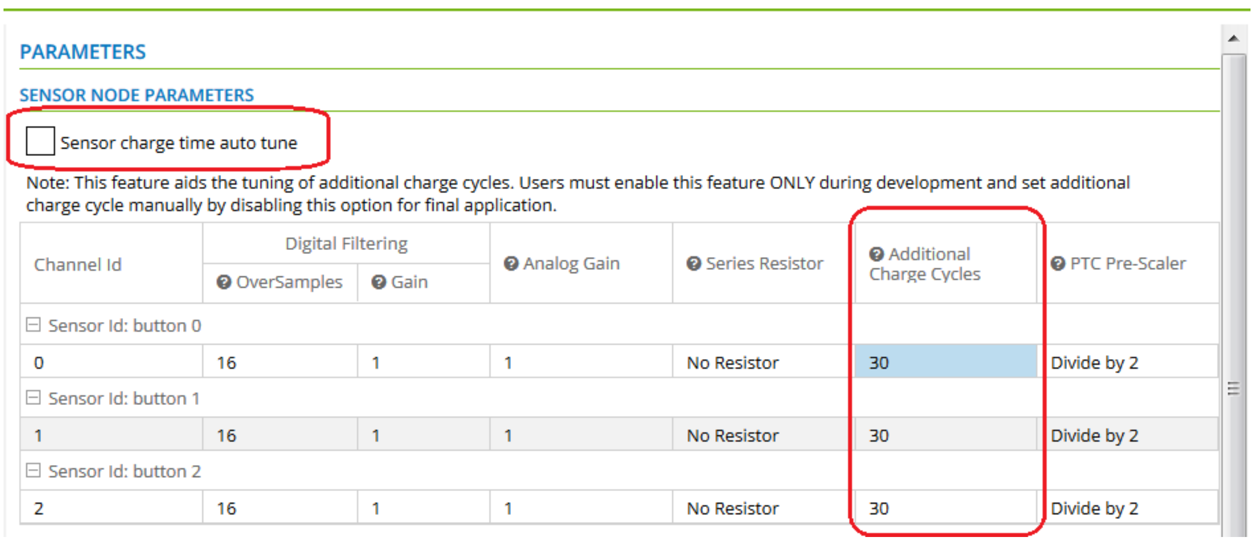


Step 15:
In '***Pin Selection***' tab, the **Debug Interface** can be enabled as follows. Select the correct interface.



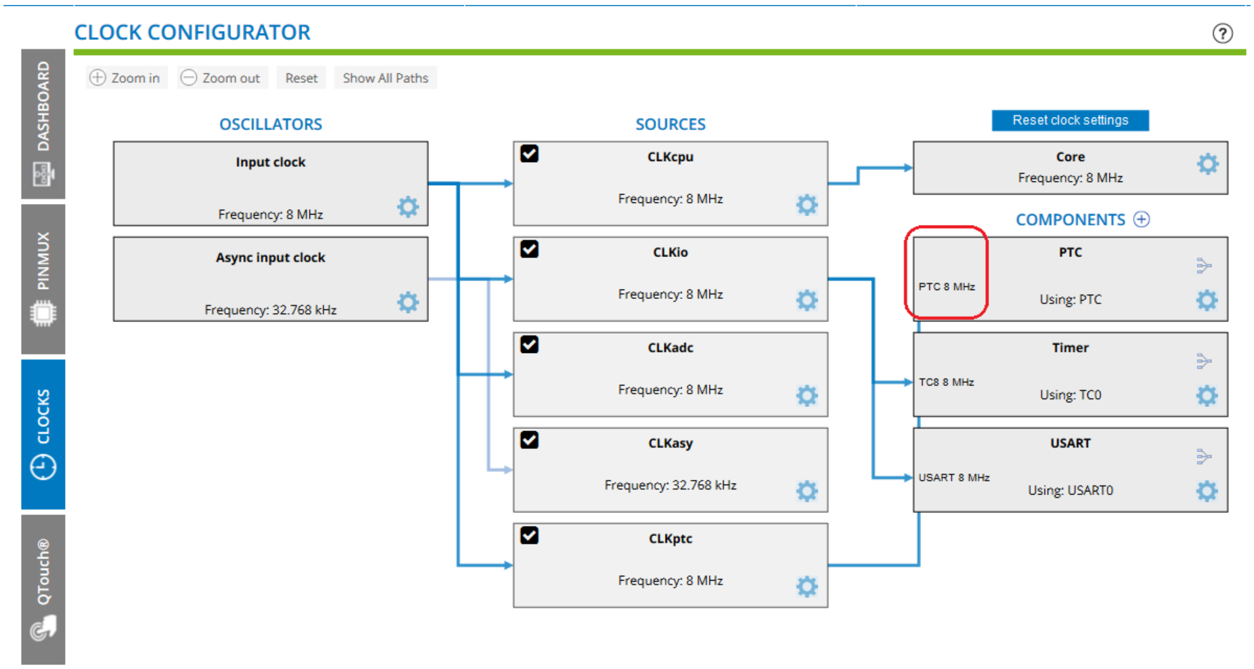
Step 16
Select '***Parameter Selection***' tab. These touch channel properties like *Prescaler*, *Gain*, *Filter Level*, *CSD* can be changed in this tab.

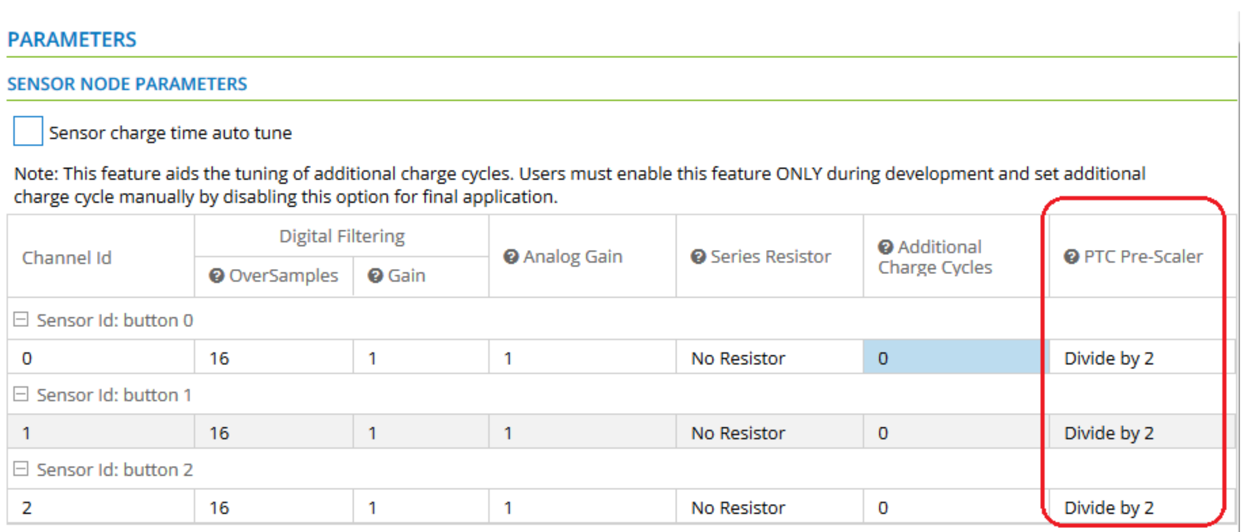




Note: The maximum allowed clock frequency for PTC is 4 MHz. In megaAVR and tinyAVR, the PTC uses the same CPU clock. The prescaler option in the ***Parameter Selection*** tab needs to be changed to all buttons such that the PTC clock frequency is less than 4 MHz.

The CPU clock frequency can be configured in the **Clock** tab as shown below. Click on the Settings icon to configure the clock frequency.





PARAMETERS

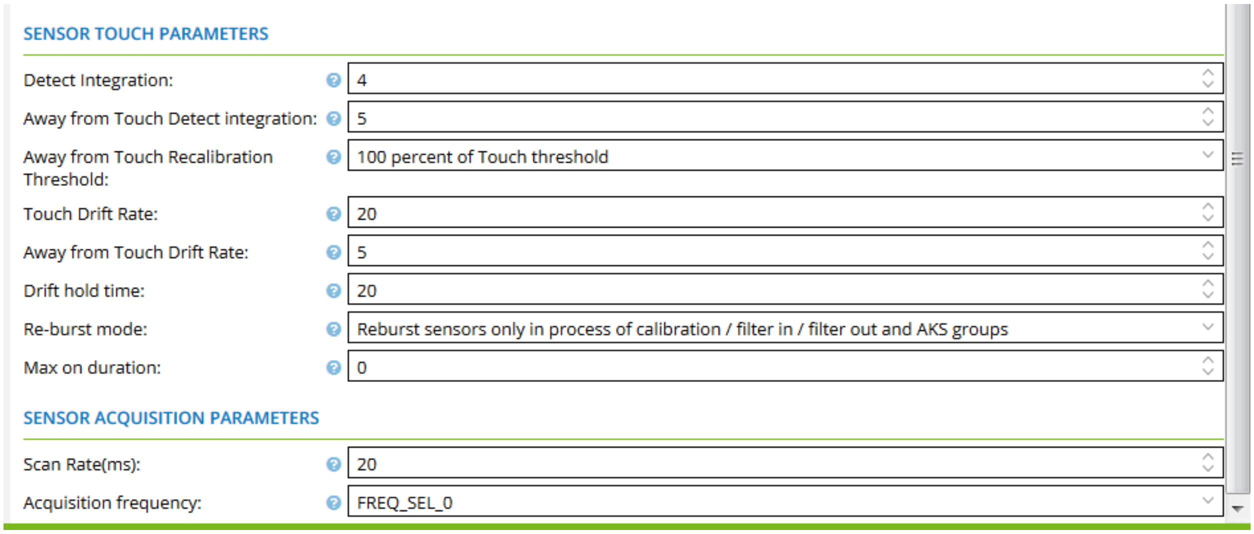
SENSOR NODE PARAMETERS

Sensor charge time auto tune

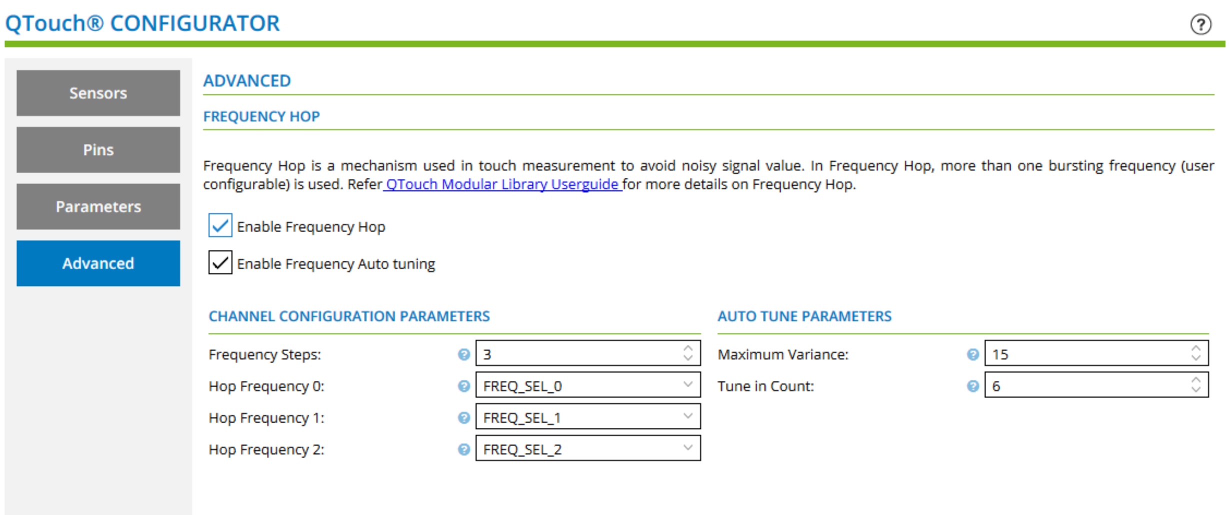
Note: This feature aids the tuning of additional charge cycles. Users must enable this feature ONLY during development and set additional charge cycle manually by disabling this option for final application.

Channel Id	Digital Filtering		Analog Gain	Series Resistor	Additional Charge Cycles	PTC Pre-Scaler
	OverSamples	Gain				
Sensor Id: button 0						
0	16	1	1	No Resistor	0	Divide by 2
Sensor Id: button 1						
1	16	1	1	No Resistor	0	Divide by 2
Sensor Id: button 2						
2	16	1	1	No Resistor	0	Divide by 2

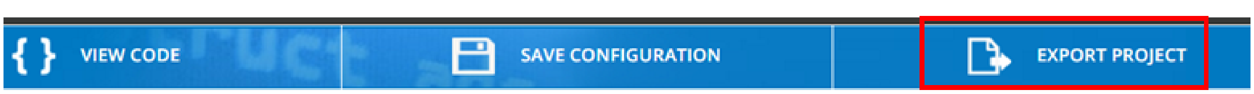
Step 17:
In '***Parameter Selection***' tab, Key group configuration parameters like *DI*, *MOD* and acquisition configuration parameters like *Acquisition Frequency*, *Measurement Period* can be configured as follows.



Step 18:
In the '***Advanced Selection***' tab, the frequency hop option can be enabled by selecting the **Enable Frequency Hop** tick-box. When Frequency Hop is enabled, configuration parameters related frequency hopping can be changed.

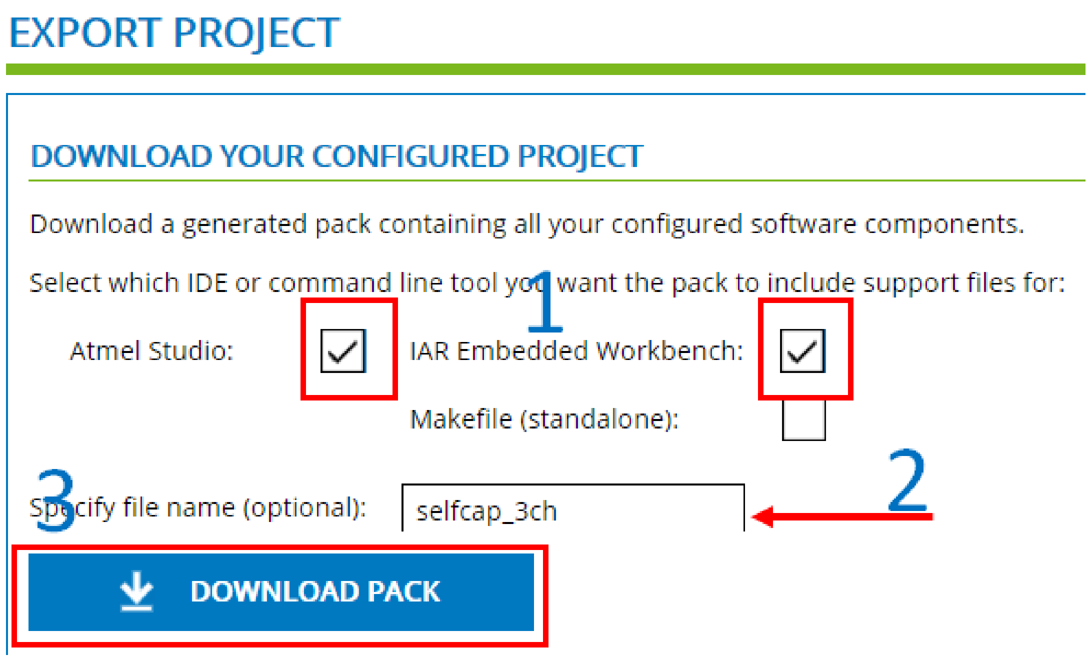


Section 19:
After completing all the configuration, click **Export Project** option.



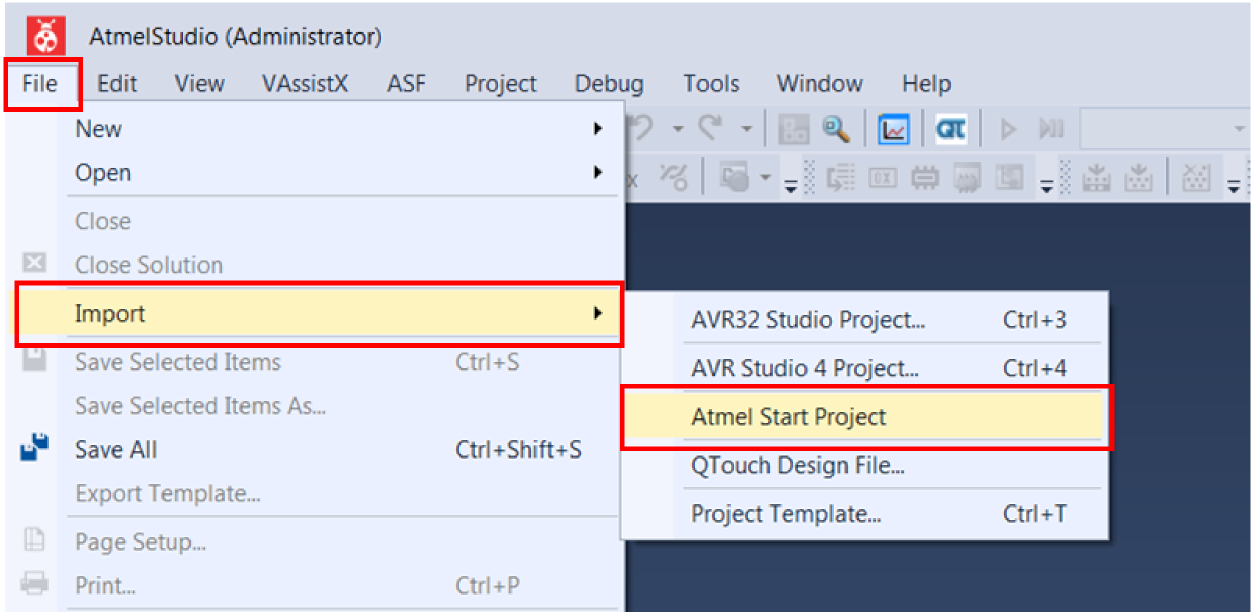
In the '*Export Project*' window,

- Select **Atmel Studio** and **IAR Embedded Workbench** (Both configurations will be available in single pack).
- enter the file name as "`selfcap_3ch`"
- Click **Download Pack**



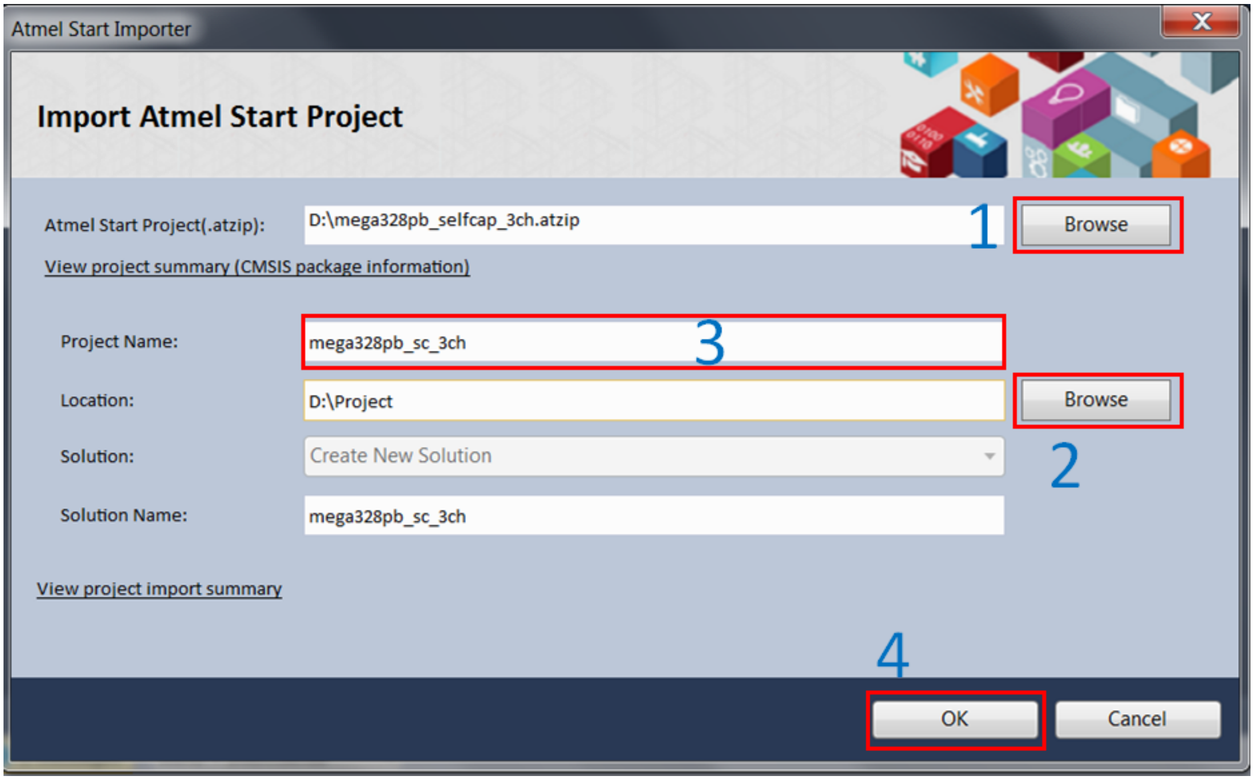
12.3 Import Project Using Atmel Studio

Step 1:
Open *Atmel Studio 7*. Select *File->Import->Atmel Start Project*.

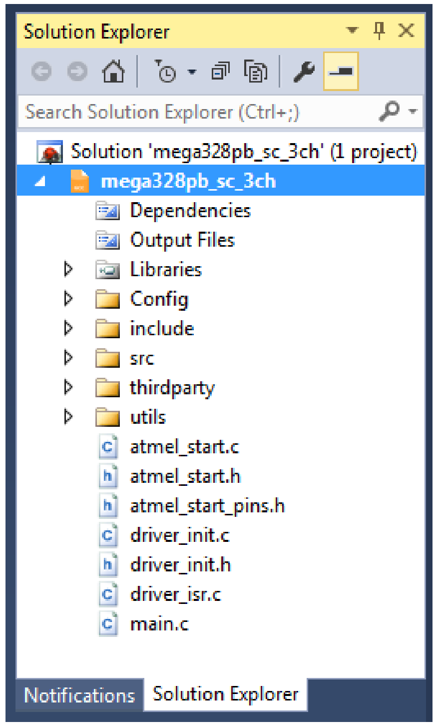


Step 2:
In Atmel Start Importer option,

1. Browse and select the downloaded '`.atzip`' file
2. Browse and select the desired project location
3. Provide the project name
4. Click **OK** to generate project



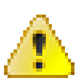
Step 3:
Verify the project created as shown below.



12.4 Import Project Using IAR™ Workbench

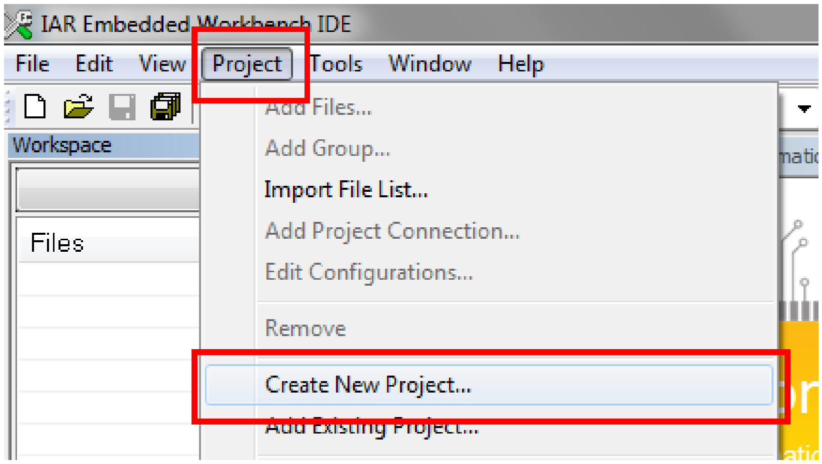
Step 1:
Create a folder '`selfcap_3ch`' in a desired location.

Step 2:
Rename the '`selfcap_3ch.atzip`' file to '`selfcap_3ch.zip`'. Extract the content to '`selfcap_3ch`' folder.

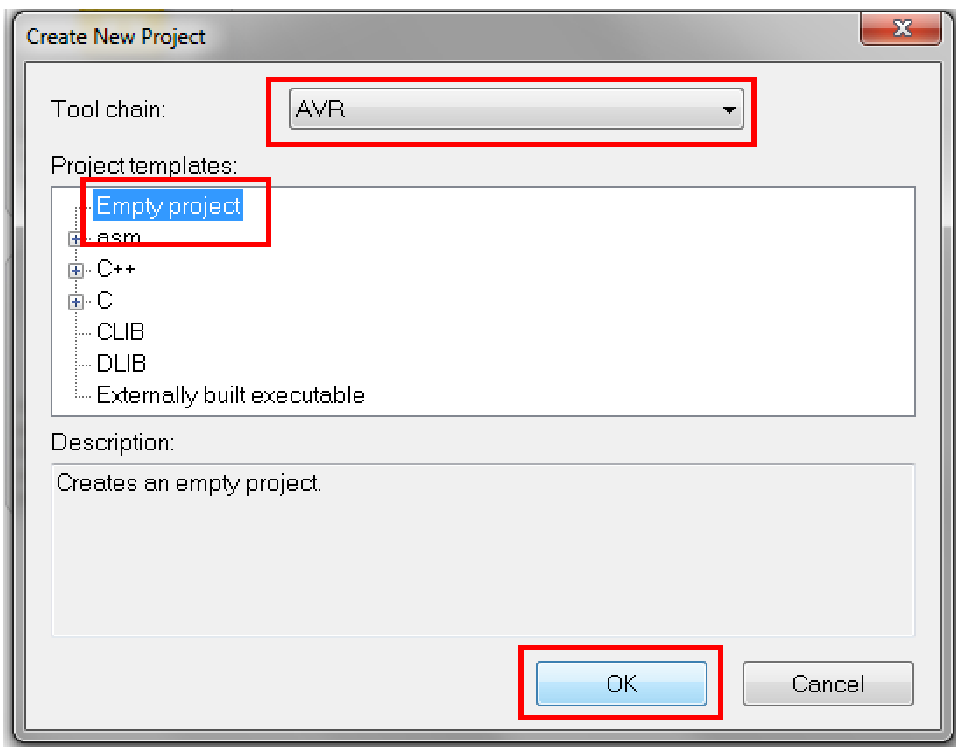


Attention: Do not extract to a sub folder.

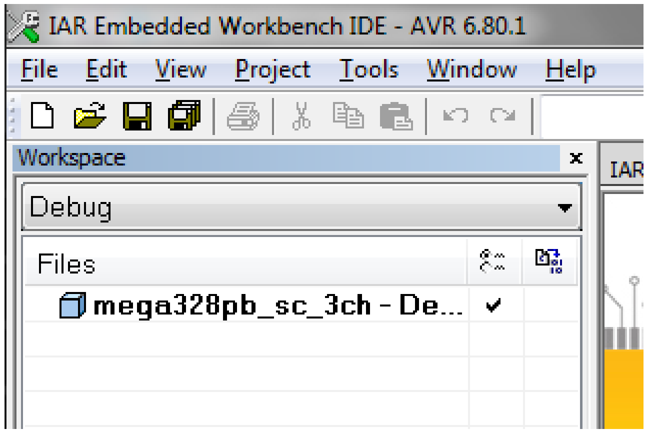
Step 3:
Open *IAR Embedded Workbench*. Select *Project->New Project*.



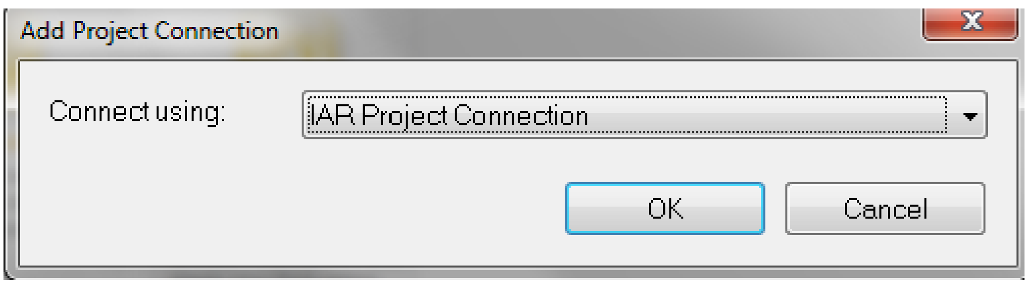
Step 4:
Select *Empty Project* option and *AVR* as toolchain.



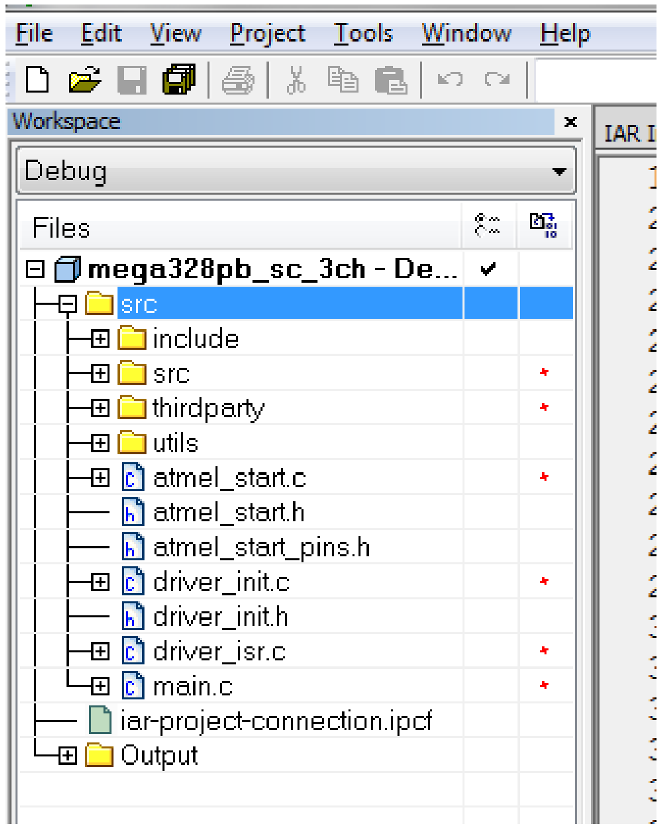
Step 5:
Browse the '`selfcap_3ch`' folder created above and give it a project name. The project will be created and will be displayed in workspace.



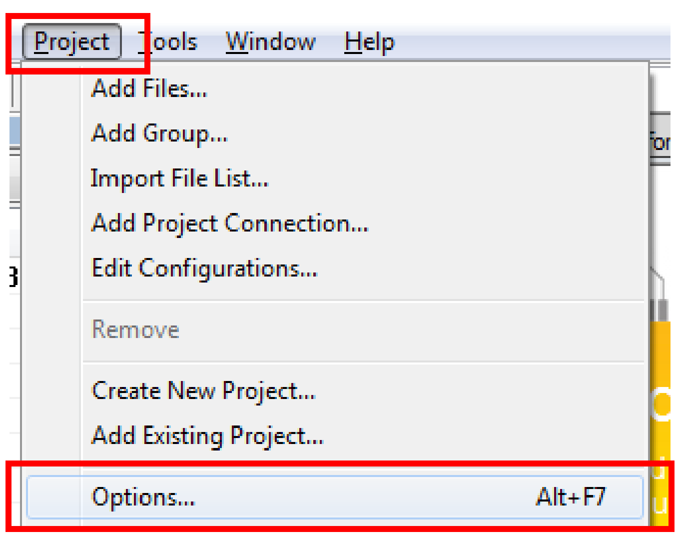
Step 6:
Select *Project->Add Project Connections* option and select *IAR Project Connection* option in the subsequent window.



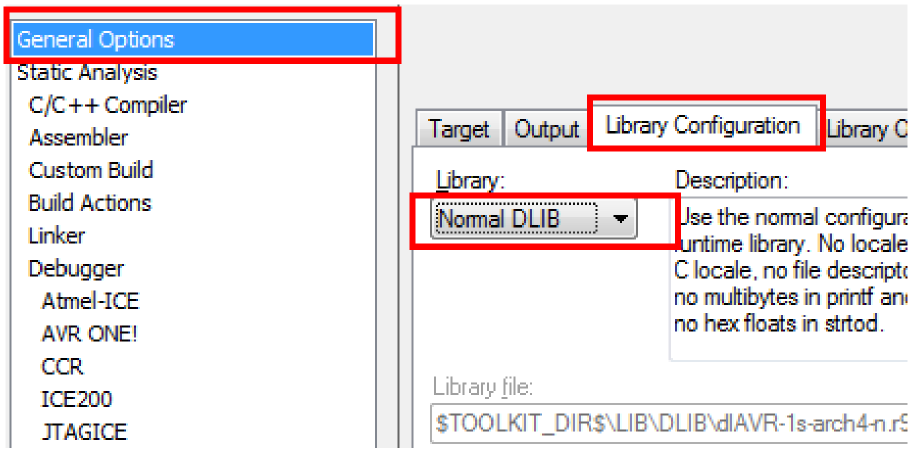
Step 7:
Browse the '`iar-project-connection.ipcf`' file from '`selfcap_3ch`' folder and click **OK**. Ignore any warning that appears. The source files generated from Atmel START will be added to the IAR project file. If additional files have to be included into the project, then the '`iar-project-connection.ipcf`' file should be removed from the project.



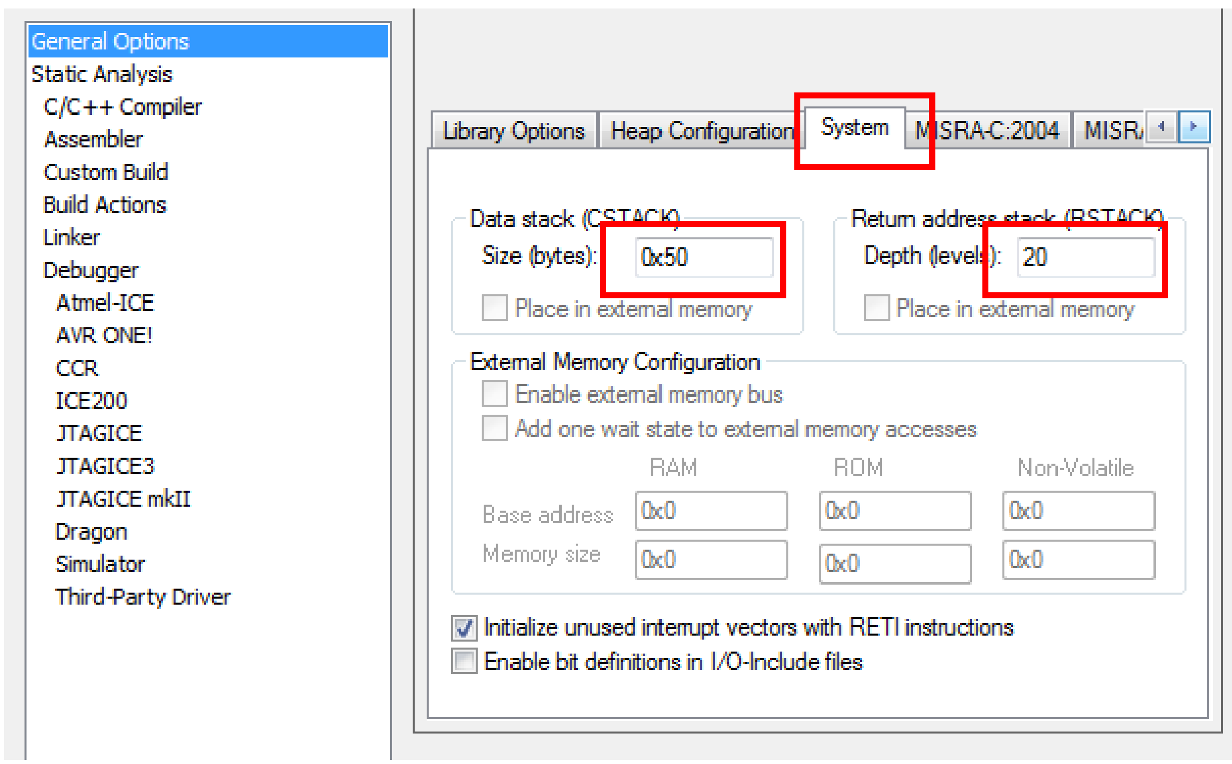
Step 8:
Select *Project->Options*.



Step 9:
In *General Options*, select **Normal DLIB** option in ***Library Configuration*** tab.



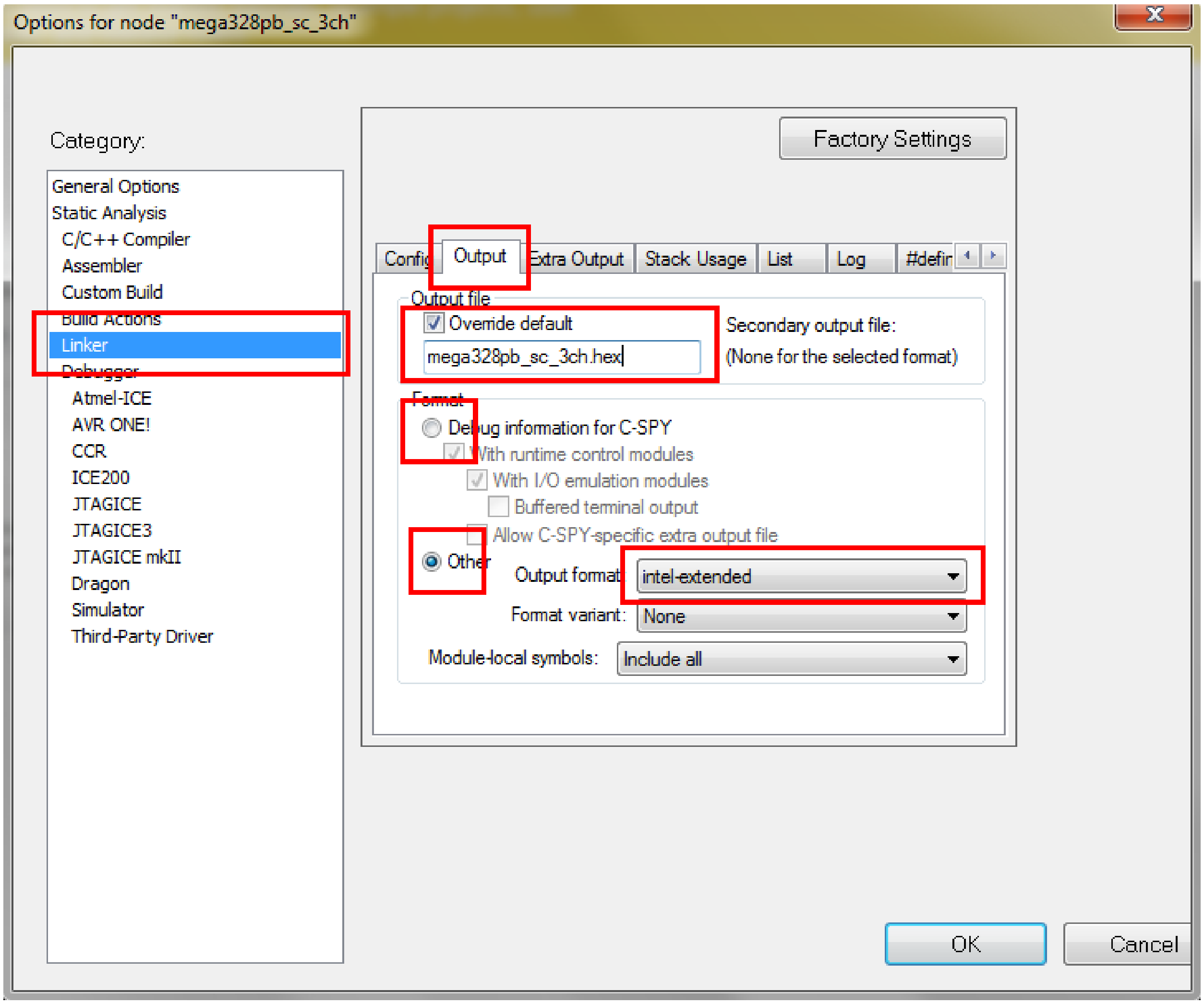
Step 10:
The stack set by default is not sufficient. Select ***System*** tab and update the stack size as shown below.



Step 11:
Change the output format as follows:

1. Select ***Linker->Output***

2. Select **Override Default** tick box and rename the output file to '`.hex`'
3. Select the **Format** to "*Others*" and select "*Intel-extended*" from drop-down menu
4. Click **OK**.



Step 12:
This step is required only if the project is generated for the **ATtiny817** device.

1. Open '*iotiny817.h*' file.
2. Go to `RTC_t typedef` definition.
3. Change clock control register definition as follows:

Default: `register8_t CLKCTRL;` Change to **`register8_t CLKSEL;`**

Step 13:
By default, the '`main()`' contains hardware initialization code and the empty '`while`' loop. The '`touch initialization`' is done in the `atmel_start_init()` function. Touch example functions have to be included as shown below. Include the `touch_example.h` file in the `main.c` file for the touch API

declarations. `cpu_irq_enable();` is done to enable the global interrupt for Tiny/Mega devices and is part of the `touch_example()` function. The `touch_example()` function part of the `touch_example.c` file also contains LED code which can be modified as per application requirements.

```
#include "touch_example.h"
int main(void)
{
    /* Initializes MCU, drivers and middleware */
    atmel_start_init();


    /* Replace with your application code */
    while(1) {
        touch_example();
    }
}
```

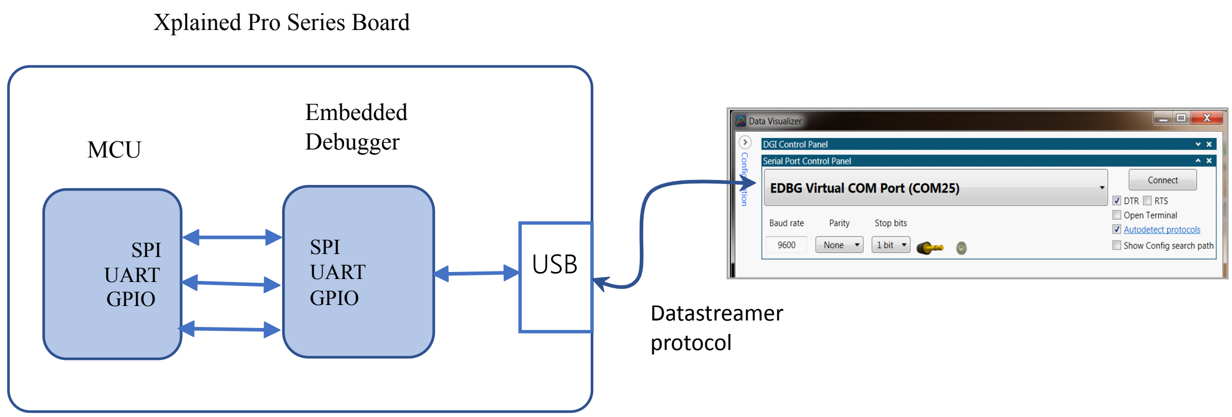
Step 14:
The project is now ready to be built and tested. Press **F7** to build the project.

13. Using Data Visualizer with QTouch® Applications

13.1 Overview

Data Visualizer (DV) is a program used for processing and visualization of run-time data from the target hardware. Data Visualizer can receive data from various sources such as the Embedded Debugger Data Gateway Interface (DGI) and serial port (COM port).

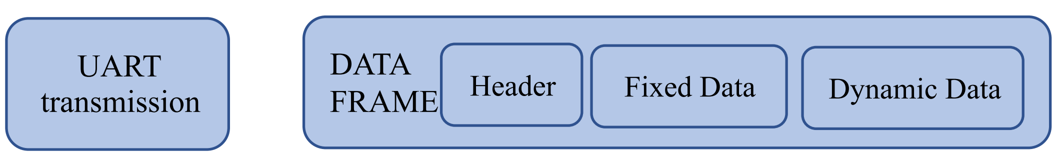
Typical connection models of the data visualizer with target hardware is shown below.



13.2 Datastreamer Module

Datastreamer module embeds with simple mono-directional data transfer protocol and the data frame that is transmitted to the data visualizer software. The current version of datastreamer provides support only for UART port communication.

Figure 13-1. Datastreamer Module Block Diagram



UART Transmission:
The UART transmission function is device-dependent and the Atmel START automatically picks up the right driver and includes it on the user board/kit example project. Simple Asynchronous mode (non-interrupt driven) of driver is used in all the devices.

Data frame:
Data frame contains header, fixed module data and dynamic module data bytes.

Header details:
The header contains 19 bytes, and needs to be transmitted as part of the packet. The header need not be transmitted on every packet, rather transmitted once every 15 packet transmissions. The header packet details are listed below.

```
// uint8_t data[] =
// {
//     0x5F,
//     0xB4, 0x00, 0x86, 0x4A,
//     0x51, 0x54, 0x38, 0x31, 0x37, 0x54, 0x4F, 0x55, 0x43, 0x48, 0x55, 0xAA,
//     0xF9,
//     0xA0
// };
```

Bytes	Description
Byte 0	Start token. Contains fixed value ‘0x5F’
Bytes 1 to 14	Checksum type. Corresponds to LRC8 (XOR sum of packet, excluding start and end token)
Bytes 5 to 16	GUID, an identifier for the target hardware
Byte 17	Checksum of the header packet
Byte 18	End token. Contains fixed value ‘0xA0’

Fixed module data:
1. Basic button sensor data of all the configured button sensors
2. Error status data.

Dynamic module data:
1. Acquisition auto-tune parameters are included when auto-tune is enabled in Atmel START QTouch configurator.
2. Frequency hop auto-tune data is included as per the configurations done on the Atmel START.
3. Scroller module parameters are transmitted when the Slider/Wheel sensors are configured on Atmel START.

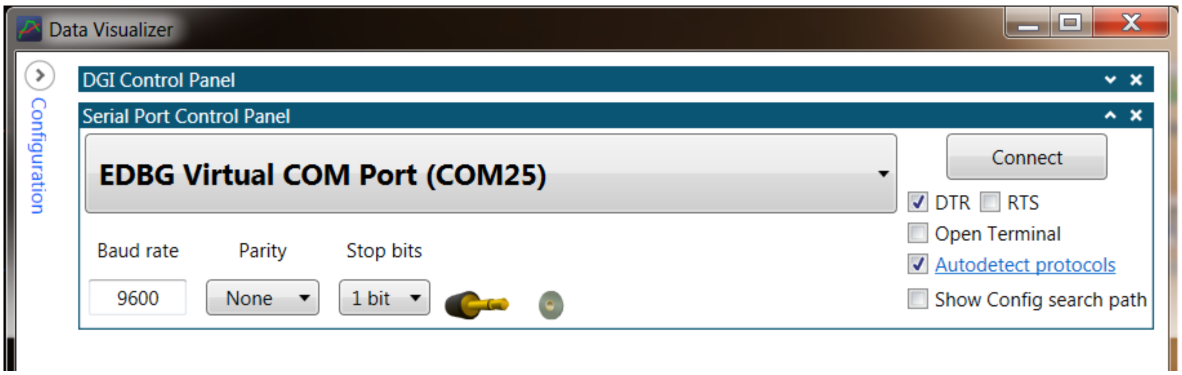
13.3 Debugging Using Data Visualizer

Data visualizer supports many widgets to visualize the data like terminal, label, graph, etc. The continuous data and their types are parsed and displayed on the appropriate elements using three scripts files having extensions of `*.db`, `*.ds`, `*.sc`. These script files are automatically generated by the Atmel START platform based on the project configuration and just the path of the scripts needs to be configured on the data visualizer software. Data visualizer software is available both as stand-alone installable version as well as an extension on Atmel Studio IDE and can be downloaded from the following link: https://gallery.atmel.com/Products/Details/0b2891f4-167a-49fc-b3f0-b882c7a11f98.

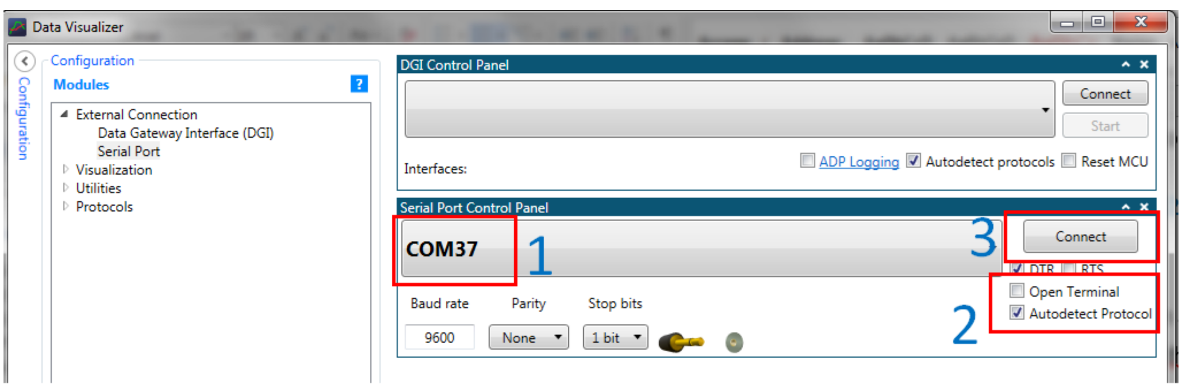
The sequence of steps used for debugging are given below.
1. Create a configuration folder “dv_config” for data visualizer in a desired location.
2. Copy the dashboard configuration (.db, .ds, .sc) files from “..\thirdparty\qtouch\datastreamer” project folder to “dv_config” folder.

Note: These files are not source files. They will not be automatically extracted to the project folder. To extract these files, rename the `selfcap_3ch.atzip` file to `selfcap_3ch.zip`. Then extract the content.

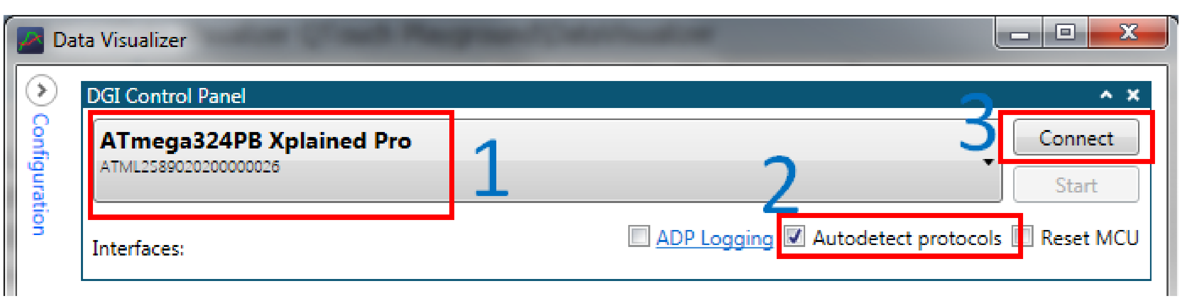
3. Open **Data Visualizer**.
   Note: If QTouch Debug data is sent using SPI or I²C interface, go to Step 6. If QTouch Debug data is sent using COM port, continue.
4. Double-click the serial port control panel and click "**Connect**" button to make connection to target. Close the DGI control panel tab.



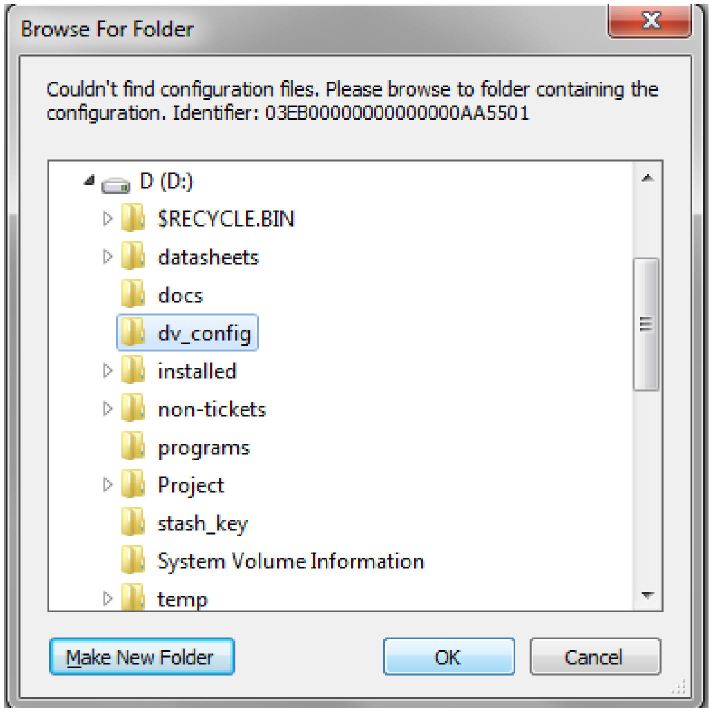
5. Another way to make the connection is through the **Configuration** option on the left side. Expand Configuration option and under **External Connection** option, double-click on **Serial Port** option and click the "**Connect**" button on the serial port control panel. Restore the configuration option to minimized state



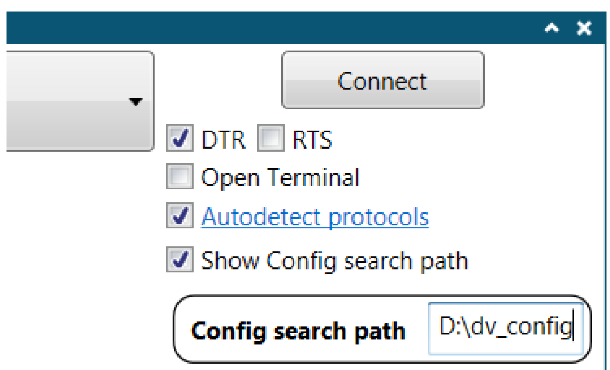
6. Select the desired kit, select **Autodetect protocol** check-box and click **Connect**.



7. For the very first time, Data Visualizer will prompt the user to select the folder containing configuration information as follows. Browse and selet the '**`dv_config`**' folder and click **OK**.



Alternatively, the path of the configuration folder '`dv_config`' can be specified in the `config_path` tab as shown below. Click the check box option "**`show config search path`**" to enable the config path tab.



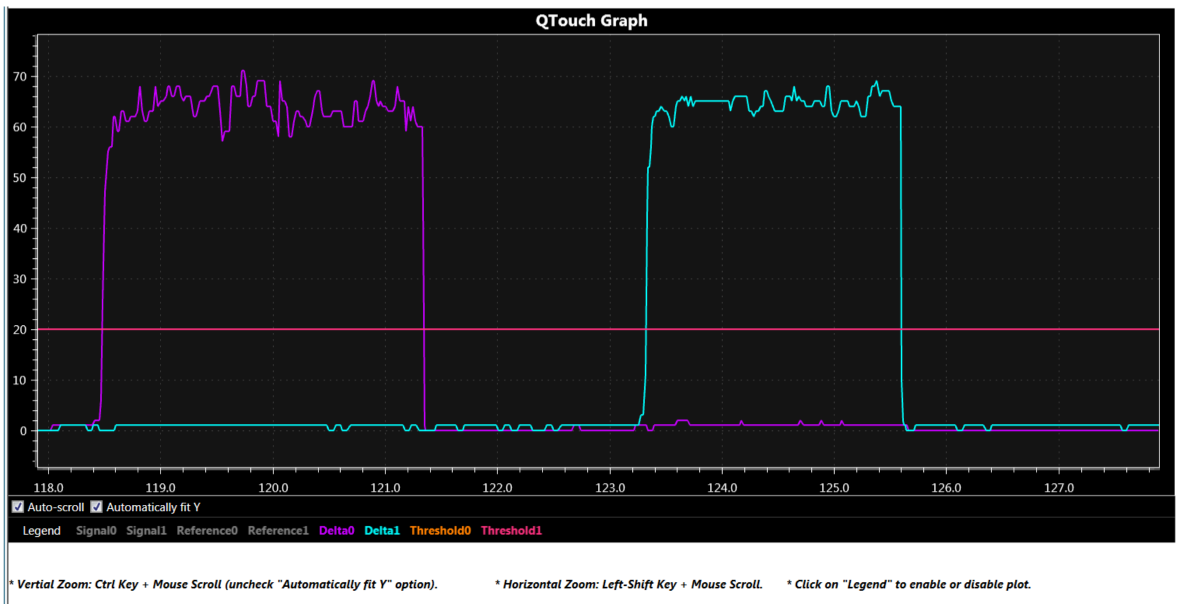
Note: The selected folder will be saved by the Data Visualizer. Data Visualizer will not prompt the user to select a folder for subsequent connections. If the sensor configuration is changed, the new dashboard configuration files from the Atmel START project need to be copied to this folder. Since the configuration file names are the same, the old files should be replaced with the new ones. The file names should not be modified.

8. The dashboard view contains three sections of data displayed. The first section converts the status information of all the configured buttons along with delta and threshold values.

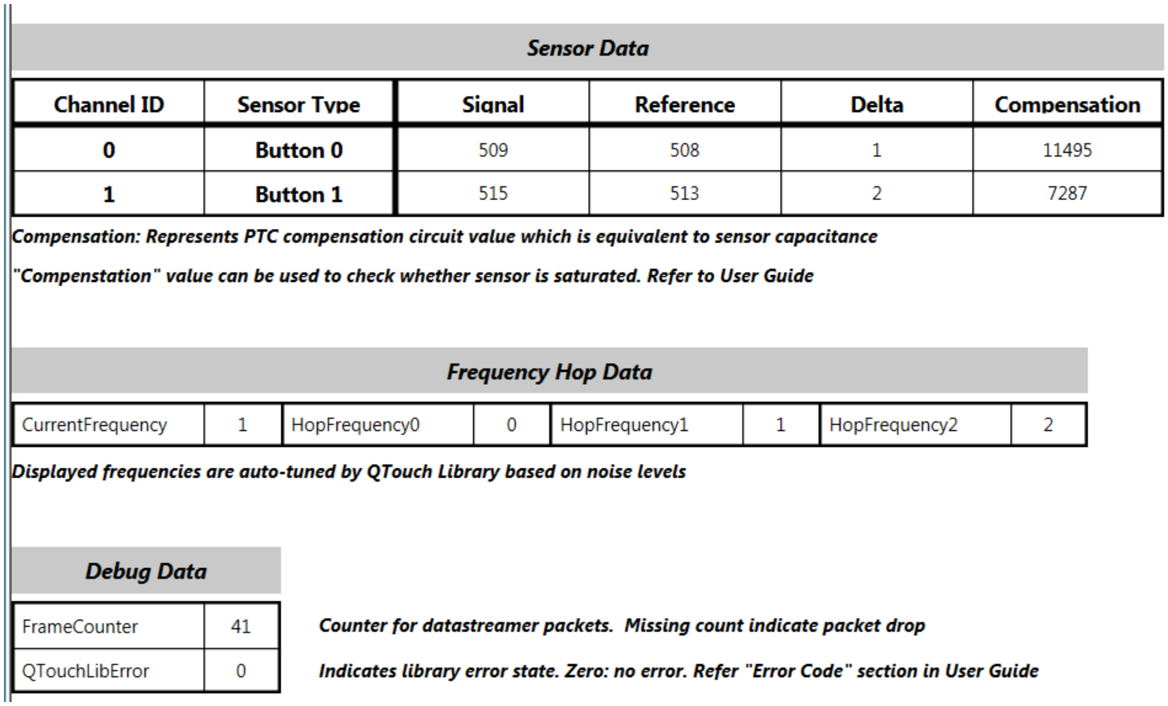
Button Data

Channel ID	Sensor Type	State	Delta	Threshold
0	Button 0	1	65	20
1	Button 1	0	2	20

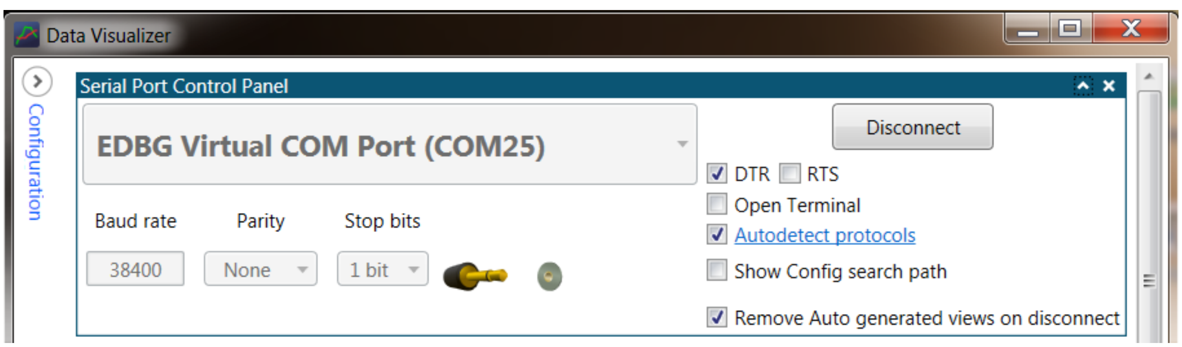
9. Section 2 shows the graph view plotted with the signal, reference and delta values of the configured channels as shown below. The plots can be enbled/disabled by clicking on the legends at the bottom of the graph.



10. The third section displays the table of data from Noise Immunity modules, detailed sensor information including Compensation Capacitance value, Error Status data.



11. To disconnect the hardware, open the **Serial Port Control Panel** by double-clicking on the tab and click '**Disconnect**' button as shown below:



14. Tuning Procedure

14.1 Tuning for Noise Performance

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 QTouch modular library has a number of user configurable features which can be tuned to give the best balance between touch response time, noise immunity and power consumption.

Noise Sources
Noise sources that affect touch sensor performance can occur in a wide variety of applications

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

Applicable EMC standards

- Conducted Immunity EN61000-4-6

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

Or

- Narrow band noise

Broadband Noise Counter Measures
Broadband noise refers to interfering signals whose frequency components are not harmonically related to the capacitance measurement frequency. Provided that the maximum and minimum voltage levels of

the acquisition signal combined with noise signals are within the input range of the measurement system and a sufficiently large number of samples are taken, broadband noise interference can be averaged out by setting a high value of oversampling.

If the noise amplitude is excessive, then sensor circuit components experience saturation of measurement. In this case the acquisition signals combined with the noise signals are outside the input range of the measurement circuit, 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.

14.1.1 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, which may be internal or external to the microcontroller.
Note: Internal series resistor is only available in Mutual Capacitance mode with PTC.

The external series resistor should be mounted between the Y line of the device to the sensor, closest to the device pin.

14.1.2 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 compensation circuit calibration.

However, this problem may not be apparent in the touch sensor operation; the application may behave 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 Calibration

The QTouch® Modular Library provides functionality to automatically adjust timing parameters in order to ensure full charge transfer.

Calibration may be configured to tune one of three parameters, depending on the target device and measurement technology.

`CAL_AUTO_TUNE_RSEL` Clock prescaler and CSD are maintained at the configured setting, while the internal series resistor is adjusted to the maximum value which allows adequate charging for each sensor node.

- Only available with PTC Mutual capacitance acquisition.

`CAL_AUTO_TUNE_PRSC` Series resistor and CSD are maintained at the configured setting, while the prescaler is adjusted to the minimum value which allows adequate charging for each sensor node.

- Incrementing doubles the acquisition time, decrementing halves the acquisition time

CAL_AUTO_TUNE_CSD Both Prescaler and Resistor are maintained at the configured setting, Charge Share Delay is adjusted to the minimum value which allows adequate charging for each sensor node.

- Incrementing CSD adds one cycle to the charge transfer phase of acquisition sequence

14.1.3 Step 3: Adjusting Oversampling

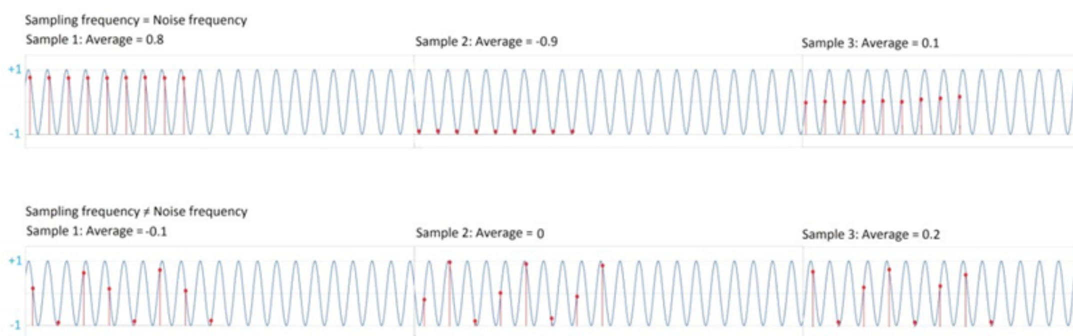
Once clipping is prevented by hardware filtering and full charge transfer is ensured, the next step is to find the optimal settings for oversampling.

This is a trade-off between noise tolerance against response time and power consumption. More samples give better quality data, but take longer to acquire.

Narrow Band Noise Counter Measures

If the noise includes a frequency component which is related to the capacitance measurement 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.



14.1.4 Step 4: Select Frequency Mode

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. In this case the oversampling frequency must be adjusted in order to avoid the noise.

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

Acquisition Module (PTC)

Available frequencies (4 MHz PTC Clk)	
Frequency Selection	**Frequency (kHz)**
FREQ_SEL_0	66.67
FREQ_SEL_1	62.5
FREQ_SEL_2	58.82
FREQ_SEL_3	55.56
FREQ_SEL_4	52.63
FREQ_SEL_5	50
FREQ_SEL_6	47.62
FREQ_SEL_7	45.45
FREQ_SEL_8	43.48
FREQ_SEL_9	41.67
FREQ_SEL_10	40
FREQ_SEL_11	38.46
FREQ_SEL_12	37.04
FREQ_SEL_13	35.71
FREQ_SEL_14	34.48
FREQ_SEL_15	33.33
FREQ_SEL_SPREAD	Variable frequencies

The acquisition module provides two strategies for frequency selection:

1. A single acquisition frequency is selected and oversampling takes place at this frequency only. `FREQ_SEL_0` provides the fastest measurements, `FREQ_SEL_15` the slowest. If no high performance EMC standards are required, but the application equipment generates noise which interferes with a particular acquisition frequency, the designer may simply change the frequency.
2. A variable frequency is used during oversampling. FREQ_SEL_SPREAD varies the frequency during the acquisition oversampling. The delay is varied from 0 to 15 in a sawtooth manner on successive samples during oversampling to apply a wider spectrum of sampling frequency. Compared to single frequency acquisition, the frequency spread option reduces the sensitivity to noise at a particular 'worst-case' frequency, but increases the range of noise frequencies around that worst-case frequency which will show harmonic interference – albiet with reduced severity of the noise effects. In many applications, `FREQ_SEL_SPREAD` is sufficient to achieve the required noise tolerance.

Frequency Hopping Module
Module ID: 0x0006

The Frequency Hopping module utilizes three or more base frequencies and a median filter to avoid using measurements taken with harmonic interference. The frequencies should be selected to minimize the set of crossover harmonics within the problem frequency band.

Each of the selected frequencies is used for acquisition oversampling during successive measurement cycles.

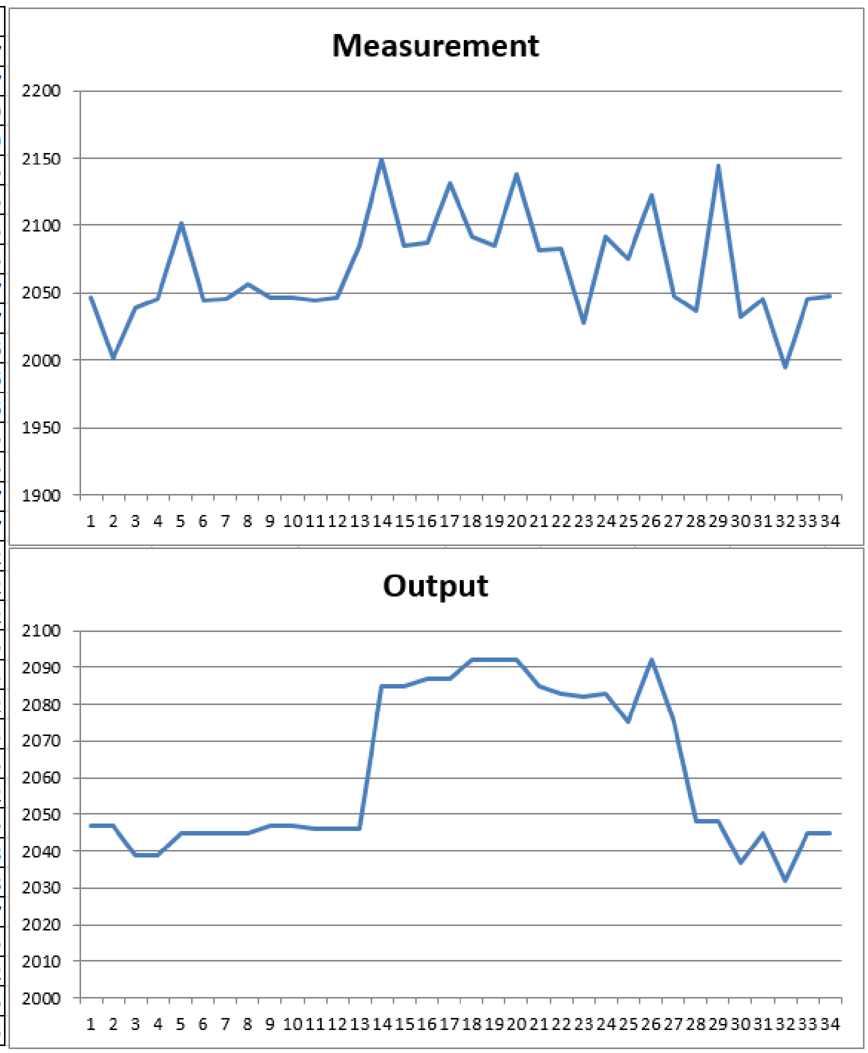
Frequency Hopping with 3 Frequencies:

- **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. By using a median filter, the outlying measurements will be rejected.

Figure 14-1. Measurements Taken at Frequency 1 are Affected by Noise

Cycle	Frequency	Measurement	Output
0	F0	2047	2047
1	F1	2001	2047
2	F2	2039	2039
3	F0	2045	2039
4	F1	2102	2045
5	F2	2044	2045
6	F0	2045	2045
7	F1	2056	2045
8	F2	2047	2047
9	F0	2046	2047
10	F1	2044	2046
11	F2	2046	2046
12	F0	2085	2046
13	F1	2149	2085
14	F2	2085	2085
15	F0	2087	2087
16	F1	2131	2087
17	F2	2092	2092
18	F0	2085	2092
19	F1	2138	2092
20	F2	2082	2085
21	F0	2083	2083
22	F1	2028	2082
23	F2	2092	2083
24	F0	2075	2075
25	F1	2122	2092
26	F2	2048	2075
27	F0	2037	2048
28	F1	2145	2048
29	F2	2032	2037
30	F0	2045	2045
31	F1	1995	2032
32	F2	2045	2045
33	F0	2048	2045



Common Harmonics

No matter which frequencies are chosen, there exists the possibility of noise at higher frequencies which are harmonics of more than one of the selected frequencies.

Further up the spectrum there are frequencies which are harmonics of ALL of all available frequencies but those superset harmonics are at higher frequencies and so are blocked by the low pass filter.

In some applications, the potential for exposure to noise frequencies may be an unknown and variable quantity.

For example, a device utilizing a USB charger may not always be plugged into the charger that it was supplied with. Inexpensive replacement chargers are often found to generate high levels of common-mode noise, and at variable frequencies – often in the same band as the acquisition frequencies.

A similar situation occurs with applications tested to EN61000-4-6 for conducted immunity. The test equipment sweeps through injected noise from 150kHz to 80MHz, in steps of 1%. This gives an excellent chance of hitting an interference frequency which is a common harmonic of the HOP frequencies.

In both cases, no static selection of frequencies can ensure harmonic avoidance by median filter.

Frequency Hopping with Auto-tune
Module ID: 0x0004

Frequency Hopping with auto-tune provides the cyclic frequency hopping with median filter functionality, extended to quantify the variance of signals as measured by each individual frequency.

The module is configured with a stability limit, and when signals measured at a particular oversampling frequency show a repeated variance exceeding this limit then the module switches this frequency to another, searching for a better performing option.

14.2 Tuning the Slider/Wheel Sensor

For instance, two buttons and a three-channel self-cap slider are configured. Let the buttons B0, B1 and the Key sensors that form the slider sensor be Slider0[0], Slider0[1] and Slider0[2].

The Buttons, Slider/Wheel data are displayed in the data visualizer control panel view as shown below.

Button Data

Channel ID	Sensor Type	State	Delta	Threshold
0	Button 0	0	0	20
1	Button 1	0	0	20
2	Slider 0[0]	0	1	70
3	Slider 0[1]	0	1	70
4	Slider 0[2]	0	0	70

Slider & Wheel Data

Sensor	State	SW Delta	SW Threshold	Position
Slider 0	0	0	60	0

The following steps describe the procedure for tuning the slider/wheel sensors.

Step 1:
Make a touch on each key sensor Slider0[0], Slider0[1] and Slider0[2] and note the delta values. For example, the delta observed on slider0[0] is shown below.

Set the individual key sensor threshold to half the value of the delta value observed. In this case, the key threshold should be set to 60.

Slider0[0]

Button Data

Channel ID	Sensor Type	State
0	Button 0	0
1	Button 1	0
2	Slider 0[0]	1
3	Slider 0[1]	0
4	Slider 0[2]	0

Slider0[1]

Button Data

Channel ID	Sensor Type	State
0	Button 0	0
1	Button 1	0
2	Slider 0[0]	0
3	Slider 0[1]	1
4	Slider 0[2]	0

Slider0[2]

Button Dat

Channel ID	Sensor Type	State
0	Button 0	0
1	Button 1	0
2	Slider 0[0]	0
3	Slider 0[1]	0
4	Slider 0[2]	1

Step 2:
Set the calculated key threshold on Step 1 as the SW Threshold and verify the slider sensor goes to detect when the touch made on the individual sensors is as shown below.

Button Data

Channel ID	Sensor Type	State	Delta	Threshold
0	Button 0	0	10	20
1	Button 1	0	0	20
2	Slider 0[0]	1	123	60
3	Slider 0[1]	0	30	60
4	Slider 0[2]	0	8	60

Slider & Wheel Data

Sensor	State	SW Delta	SW Threshold	Position
Slider 0	1	149	60	4

Button Data

Channel ID	Sensor Type	State	Delta	Threshold
0	Button 0	0	11	20
1	Button 1	0	0	20
2	Slider 0[0]	0	10	60
3	Slider 0[1]	1	122	60
4	Slider 0[2]	0	35	60

Slider & Wheel Data

Sensor	State	SW Delta	SW Threshold	Position
Slider 0	1	152	60	157

Button Data

Channel ID	Sensor Type	State	Delta	Threshold
0	Button 0	0	15	20
1	Button 1	0	0	20
2	Slider 0[0]	0	2	60
3	Slider 0[1]	0	21	60
4	Slider 0[2]	1	121	60

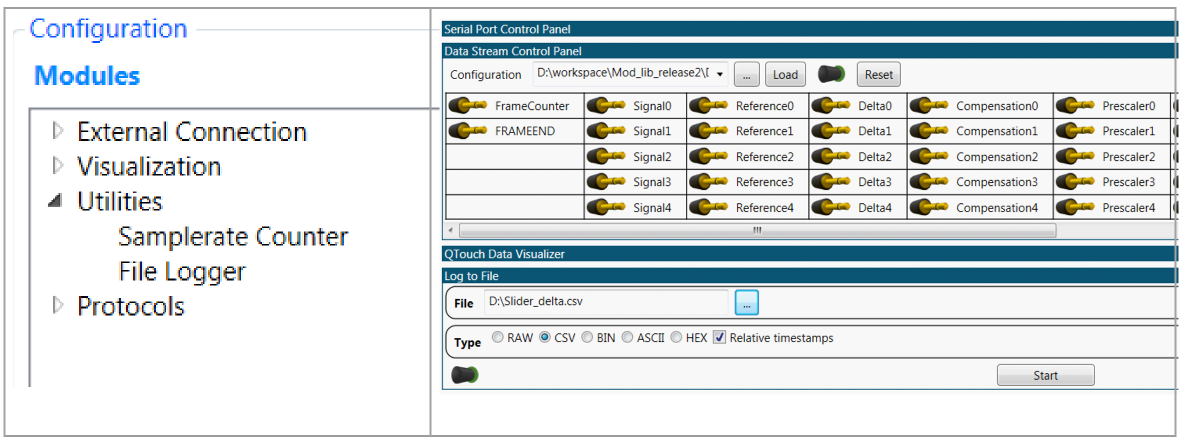
Slider & Wheel Data

Sensor	State	SW Delta	SW Threshold	Position
Slider 0	1	137	60	255

Step 3:
Scroll over the slider sensor back and forth between start and end corners and record the SW delta on a CSV file using the File logger utility.

To use file logger, follow the instructions below:

1. Switch to Edit mode by checking the edit box at the bottom of the debug control panel
2. Open the **File Logger** element *Configurations -> Utilities -> File Logger*
3. Minimize the **QTouch Data Visualizer** view window by double-clicking on the title bar
4. In the **File Logger** view, click the file browser and select the file name to log data.
5. Click the **SWDelta0** connector, drag it and plug it to the file logger socket as shown in the figure below.
6. Now click the **Start/Stop** button to log the data.
7. After logging complete, remove the SWDelta0 connection, uncheck the edit mode check box and close the File Logger.



Step 4:
Open the file log and identify the lowest SWDelta0 value from the samples. A few samples of the SWDelta0 collected from the Slider_delta.csv file are listed below.

103,102,101,106,98,92,86,82,78,76,78,86,0,118,113,109,105,102,100,106,102,93,86,80,76,73,72,73,79, 88,90,90,89,89,89,90,94,87,81,76,72,71,69,72,81,89,94,98,100,102

Set the SW Threshold less than identified minimal value "69". In this case, the SW Threshold is set about 15 counts less than the observed value which is 54. Repeat step3 and step4 for couple of iterations and tune the SW threshold based on the logs.

The Buttons, Slider/Wheel data after the tuning are given below.

Button Data

Channel ID	Sensor Type	State	Delta	Threshold
0	Button 0	0	3	20
1	Button 1	0	0	20
2	Slider 0[0]	0	2	60
3	Slider 0[1]	0	49	60
4	Slider 0[2]	0	34	60

Slider & Wheel Data

Sensor	State	SW Delta	SW Threshold	Position
Slider 0	1	80	54	192

15. Known Issues

Sl. No.	Issue Description	Category	Work-around Solution
1	When PTC is used in Self-Capacitance mode, the internal series resistor is not effective in reducing noise.	PTC	Recommended to use external series resistor
2	Y0 and Y2 pins have higher parasitic capacitance in SAMD2x/SAMDA1/ SAMHA1 devices. Y0, Y26, Y27 pins in SAMC21/C20/CA1.	PTC	1. Avoid these pins if alternate Y lines are available. 2. If it is required to use this pin for touch, then higher charge-time needs to be provided which might impact response time.

16. Appendix A - Revision History

Doc Rev.	Date	Comments
A	11/2016	Initial document release.
B	02/2017	Added SAMD10/D11 Library information
C	06/2017	**Revised sections:** Touch Library introduction, Data Visualizer, Atmel START configurator **Additions:** Acquisition module, Touch key module, Frequency hop module, Frequency Hop Auto-tune module, Slider/Wheel module, Binding Layer module, MISRA report, API Reference for each module, Kit example projects, Module naming conventions, API files interface
A	12/2017	Microchip DS40001986 Revision A replaces Atmel 42805A. **Revised sections:** Updated the screenshots in the KIT example/user board project creation section with the latest QTouch configurator GUI Included Picture for the Touch Key sensors, Included graphs on introduction section **Additions:** New section "Known Issues" is added

17. Appendix B - Acquisition Module API Reference

```
------------------------------------------------------------------------------
touch_ret_t qtm_acquisition_process(void)
------------------------------------------------------------------------------
Purpose: Signal capture and processing
Input  : (Measured signals, config)
Output : touch_ret_t
Notes  : Called by application after 'touch_measure_complete_callback'

------------------------------------------------------------------------------
touch_ret_t qtm_ptc_init_acquisition_module(qtm_acquisition_control_t* qtm_acq_control_ptr);
------------------------------------------------------------------------------
Purpose: Initialize the PTC & Assign pins
Input  : pointer to acquisition set
Output : touch_ret_t: TOUCH_SUCCESS or INVALID_PARAM
Notes  : ptc_init_acquisition module must be called ONLY once with a pointer to each config
set

------------------------------------------------------------------------------
touch_ret_t qtm_ptc_qtlib_assign_signal_memory(uint16_t* qtm_signal_raw_data_ptr);
------------------------------------------------------------------------------
Purpose: Assign raw signals pointer to array defined in application code
Input  : pointer to raw data array
Output : touch_ret_t: TOUCH_SUCCESS
Notes  : none

------------------------------------------------------------------------------
touch_ret_t qtm_enable_sensor_node(qtm_acquisition_control_t* qtm_acq_control_ptr, uint16_t
qtm_which_node_number);
------------------------------------------------------------------------------
Purpose:  Enables a sensor node for measurement
Input  :  Node configurations pointer, node (channel) number
Output : touch_ret_t:
Notes  : none

------------------------------------------------------------------------------
touch_ret_t qtm_calibrate_sensor_node(ptc_seq_acq_settings* qtm_acq_control_l_ptr, uint16_t
which_node_number)
------------------------------------------------------------------------------
Purpose:  Marks a sensor node for calibration
Input  :  Node configurations pointer, node (channel) number
Output : touch_ret_t:
Notes  : none

------------------------------------------------------------------------------
touch_ret_t qtm_ptc_start_measurement_seq(qtm_acquisition_control_t* qtm_acq_control_pointer,
void (*measure_complete_callback) (void));
------------------------------------------------------------------------------
Purpose:  Loads touch configurations for first channel and start,
Input  :  Node configurations pointer, measure complete callback pointer
Output : touch_ret_t:
Notes  : none

------------------------------------------------------------------------------
touch_ret_t qtm_autoscan_sensor_node(qtm_auto_scan_config_t* qtm_auto_scan_config_ptr, void
(*auto_scan_callback)(void));
------------------------------------------------------------------------------
Purpose: Configures the PTC for sleep mode measurement of a single node, with window
comparator wake
Input  : Acquisition set, channel number, threshold, scan trigger
Output : touch_ret_t
Notes  : none

------------------------------------------------------------------------------
touch_ret_t qtm_autoscan_node_cancel(void)
------------------------------------------------------------------------------
Purpose: Cancel auto-scan config
Input  : None
Output : touch_ret_t
Notes  : none

------------------------------------------------------------------------------
```

```
void qtm_ptc_de_init(void)
----------------------------------------------------------------------------
Purpose: Clear PTC Pin registers, set TOUCH_STATE_NULL
Input  : none
Output : none
Notes  : This API function is used to RESET the PTC during runtime without power cycle the
hardware. The application may include this function as part of other soft reset functions to
restart the application at runtime.

----------------------------------------------------------------------------
uint16_t qtm_<device_family>_acq_module_get_id(void)
Applicable <device_family> =
m328pb,m324pb,t81x,t161x,samd1x,samd20,samd21,samda1,same51,same53,same54,samd51,tiny321x,samc
20,samc21,saml21,saml22,samha1
----------------------------------------------------------------------------
Purpose: Returns the module ID
Input  : none
Output : Module ID
Notes  : none

----------------------------------------------------------------------------
uint8_t qtm_<device_family>_acq_module_get_version(void);
Applicable <device_family> =
m328pb,m324pb,t81x,t161x,samd1x,samd20,samd21,samda1,same51,same53,same54,samd51,tiny321x,samc
20,samc21,saml21,saml22,samha1
----------------------------------------------------------------------------
Purpose: Returns the module Firmware version
Input  : none
Output : Module ID - Upper nibble major / Lower nibble minor
Notes  : none

----------------------------------------------------------------------------
void qtm_ptc_clear_interrupt(void) -> ARM Cortex SAMD10,SAMD11,SAME51/E53/E54/D51
----------------------------------------------------------------------------
Purpose :  Clears the eoc/wcomp interrupt bits
Input   :  none
Output  :  none
Notes   :  none

----------------------------------------------------------------------------
void qtm_<device_family>_ptc_handler_eoc(void)
Applicable <device_family> =
m328pb,m324pb,t81x,t161x,samd1x,samd20,samd21,samda1,same51,same53,same54,samd51,tiny321x,samc
20,samc21,saml21,saml22,samha1
----------------------------------------------------------------------------
Purpose :  Captures  the  measurement,  starts  the  next  or  End  Of  Sequence  handler
Input   :  none
Output  :  none
Notes   :  none

----------------------------------------------------------------------------
void qtm_<device_family>_ptc_handler_wcomp(void)
Applicable <device_family> =
m328pb,m324pb,t81x,t161x,samd1x,samd20,samd21,samda1,same51,same53,same54,samd51,tiny321x,samc
20,samc21,saml21,saml22,samha1
----------------------------------------------------------------------------
Purpose :  Captures  the  measurement,  calls the callback
Input   :  none
Output  :  none
Notes   :  none
```

18. Appendix C - Frequency Hop Module API Reference

```
------------------------------------------------------------------------------
touch_ret_t qtm_freq_hop(qtm_freq_hop_control_t *qtm_freq_hop_control);
------------------------------------------------------------------------------
Purpose: Runs freq hop process
Input  : Pointer to container structure
Output : touch_ret_t
Notes  : none

------------------------------------------------------------------------------
uint16_t qtm_get_freq_hop_module_id(void)
------------------------------------------------------------------------------
Purpose: Returns the module ID
Input  : none
Output : Module ID
Notes  : none

------------------------------------------------------------------------------
uint8_t qtm_get_freq_hop_module_ver(void)
------------------------------------------------------------------------------
Purpose: Returns the module Firmware version
Input  : none
Output : Module ID - Upper nibble major / Lower nibble minor
Notes  : none

------------------------------------------------------------------------------
```

19. Appendix D - Frequency Hop Auto-tune Module API Reference

```
-----------------------------------------------------------------------------
touch_ret_t qtm_freq_hop_autotune(qtm_freq_hop_autotune_control_t
*qtm_freq_hop_autotune_control);
-----------------------------------------------------------------------------
Purpose: Runs freq hop auto tune process
Input  : Pointer to container structure
Output : touch_ret_t
Notes  : none

-----------------------------------------------------------------------------
uint16_t qtm_get_freq_auto_module_id(void);
-----------------------------------------------------------------------------
Purpose: Returns the module ID
Input  : none
Output : Module ID
Notes  : none

-----------------------------------------------------------------------------
uint8_t qtm_get_freq_auto_module_ver(void);
-----------------------------------------------------------------------------
Purpose: Returns the module Firmware version
Input  : none
Output : Module ID - Upper nibble major / Lower nibble minor
Notes  : none

-----------------------------------------------------------------------------
```

20. Appendix E - Touch Key Module API Reference

```
----------------------------------------------------------------------------
touch_ret_t qtm_init_sensor_key(qtm_touch_key_control_t* qtm_lib_key_group_ptr, uint8_t
which_sensor_key, qtm_acq_node_data_t* acq_lib_node_ptr)
----------------------------------------------------------------------------
Purpose: Initialize a touch key sensor
Input  : Pointer to key group control data, key number, pointers to sensor node status and
signal
Output : TOUCH_SUCCESS
Notes  : none

----------------------------------------------------------------------------
touch_ret_t qtm_key_sensors_process(qtm_touch_key_control_t* qtm_lib_key_group_ptr)
----------------------------------------------------------------------------
Purpose: Sensor key post-processing (touch detect state machine)
Input  : Pointer to key group control data
Output : TOUCH_SUCCESS
Notes  : none

----------------------------------------------------------------------------
touch_ret_t qtm_key_suspend(uint16_t which_sensor_key, qtm_touch_key_control_t*
qtm_lib_key_group_ptr)
----------------------------------------------------------------------------
Purpose: Suspends acquisition measurements for the key
Input  : Key number, Pointer to key group control data
Output : TOUCH_SUCCESS
Notes  : Used to suspend the key temporarily, like to save the power by avoiding the
continuous scan on all the sensors. A single key can be defined to act as wake up sensor and
other key sensors can be suspended using this API. This API function works in association
with resume API function

----------------------------------------------------------------------------
touch_ret_t qtm_key_resume(uint16_t which_sensor_key, qtm_touch_key_control_t*
qtm_lib_key_group_ptr)
----------------------------------------------------------------------------
Purpose: Resumes acquisition measurements for the key
Input  : Key number, Pointer to key group control data
Output : TOUCH_SUCCESS
Notes  : Can be used along with suspend API function to avoid scanning of sensors
temporarily. For instance, some of the keys may be suspended from scanning during the idle
time and resumes based on touch on a defined key

----------------------------------------------------------------------------
void update_qtlib_timer(uint16_t time_elapsed_since_update)
----------------------------------------------------------------------------
Purpose: Updates local variable with time period
Input  : Number of ms since last update
Output : none
Notes  : none

----------------------------------------------------------------------------
uint16_t qtm_get_touch_keys_module_id(void)
----------------------------------------------------------------------------
Purpose: Returns the module ID
Input  : none
Output : Module ID
Notes  : none

----------------------------------------------------------------------------
uint8_t qtm_get_touch_keys_module_ver(void)
----------------------------------------------------------------------------
Purpose: Returns the module Firmware version
Input  : none
Output : Module ID - Upper nibble major / Lower nibble minor
Notes  : none

----------------------------------------------------------------------------
```

21. Appendix F - Scroller Module API Reference

```
----------------------------------------------------------------------------
touch_ret_t qtm_init_scroller_module(qtm_scroller_control_t *qtm_scroller_control)
----------------------------------------------------------------------------
Purpose: Initialize a scroller
Input  : Pointer to scroller group control data
Output : Touch return status value
Notes  : none

----------------------------------------------------------------------------
touch_ret_t qtm_scroller_process(qtm_scroller_control_t *qtm_scroller_control)
----------------------------------------------------------------------------
Purpose: Scroller position calculation and filtering
Input  : Pointer to scroller group control data
Output : Touch return status value
Notes  : none

----------------------------------------------------------------------------
uint16_t qtm_get_scroller_module_id(void)
----------------------------------------------------------------------------
Purpose: Returns the module ID
Input  : none
Output : Module ID
Notes  : none

----------------------------------------------------------------------------
uint8_t qtm_get_scroller_module_ver(void)
----------------------------------------------------------------------------
Purpose: Returns the module Firmware version
Input  : none
Output : Module ID - Upper nibble major / Lower nibble minor
Notes  : none
----------------------------------------------------------------------------
```

22. Appendix G - Binding Layer Module API Reference

```
-----------------------------------------------------------------------------
void qtm_binding_layer_init(qtm_control_t *qtm_control);
-----------------------------------------------------------------------------
Purpose: This function internally executes the individual module initialization functions
using the pointers. Based on the initialization output, init_complete_callback or the
error_callback function is triggered.
Input  : Pointer to binding layer container structure
Output : none
Notes  : none

-----------------------------------------------------------------------------
void qtm_lib_start_acquisition(qtm_control_t *qtm_control);
-----------------------------------------------------------------------------
Purpose: This function internally executes the "qtm_ptc_start_measurement_seq" function to
start the measurement of sensors. The functions of multiple acquisition groups are executed
sequentially.
Input  : Pointer to binding layer container structure
Output : none
Notes  : none

-----------------------------------------------------------------------------
touch_ret_t qtm_lib_acq_process(void)
-----------------------------------------------------------------------------
Purpose: Executes the acquisition post process functions. The acquisition post process of
multiple groups is executed sequentially according to the configuration.
Input  : none
Output : Touch return status value
Notes  : none

-----------------------------------------------------------------------------
touch_ret_t qtm_lib_post_process(void)
-----------------------------------------------------------------------------
Purpose: Executes the individual module post processes. The sequence of post processes
executed is based on the configuration of qtm_config_t
Input  : none
Output : Touch return status value
Notes  : none

-----------------------------------------------------------------------------
qtm_control_t* qmt_get_binding_layer_ptr(void)
-----------------------------------------------------------------------------
Purpose: Returns the pointer to the binding layer container structure
Input  : none
Output : pointer to the binding layer container
Notes  : none

-----------------------------------------------------------------------------
uint16_t qtm_get_lib_state(void)
-----------------------------------------------------------------------------
Purpose: Returns the binding layer state
Input  : none
Output : Module state
Notes  : none

-----------------------------------------------------------------------------
uint16_t qtm_get_binding_layer_module_id(void)
-----------------------------------------------------------------------------
Purpose: Returns the module ID
Input  : none
Output : Module ID
Notes  : none

-----------------------------------------------------------------------------
uint8_t qtm_get_binding_layer_module_ver(void)
-----------------------------------------------------------------------------
Purpose: Returns the module Firmware version
Input  : none
Output : Module ID - Upper nibble major / Lower nibble minor
Notes  : none
```

23. Appendix H - Device Support

The latest device support list is provided in the link: http://microchipdeveloper.com/touch:release-notes.

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