AN2585

Implementing QTouch PTC Subsystem on SAMA5D2 MPU

Scope

This document provides the recommended configuration values to optimize the QTouch® Peripheral Touch Controller (PTC) module embedded in the Microchip SAMA5D2. Once the PTC is working with the SAMA5D2-PTC-EK board, a customer touch board can be connected via the XPRO1 and XPRO2 connectors. Either board (EK or customer) can then be used as the main board. The drivers and firmware do not change.

Reference Documents

Title	Document Type	Lit. No.
QTouch on SAMA5D2 MPU	Application Note	AN2472

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1. QTouch Peripheral Touch Controller (PTC) Overview

The QTouch Peripheral Touch Controller (PTC) subsystem 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 sensitivity and noise tolerance, as well as self-calibration, and minimizes the sensitivity tuning effort by the user.

2. Optimizing Parameters for Self- or Mutual Capacitor Measurement

This section defines the optimal parameters to achieve a fast and accurate touch sensor.

A methodology will be described for self- or mutual capacitance touch method.

2.1 Conditions and Objectives for Optimization

Optimizing nodes and keys depends on the use of the sensor and on external conditions, e.g. whether the touch is weak or strong, whether the touch is on the complete sensor surface or not, etc. These conditions affect the parameters. Optimization depends on:

- Thickness of the isolation between the metal of the sensor and the finger
- Finger touch in a contact condition and evaluation of the Delta touch value
- The sensitivity objectives
- The Delta level in a contact touch condition to define the threshold level
- The noise measurement of the node in a contact touched condition
- The target of noise rejection objectives
- The measurement of the Compensation capacitance (CC) value of the sensor to obtain the timing parameters

Note: The node has an index from 0 to n-1 following the order of channel definition 1 to n. Optimization is made index by index by touching the sensor.

2.1.1 Random Noise Reduction

Noise is measured as a Root Mean Square (RMS) value.

The formula is:

$$\text{RMS} = 1/\text{N}\sum_{n=0}^{N-1}(sample - mean)^2$$

where N is about 1024 samples and mean is the sample average.

When the sensor is not touched, the noise is less than 2 LSB of 10 bits.

In a touched condition, the noise increases by up to 10 to 20 times. However, this can be limited with the filtering resistance (Rs) or with an oversampling.

The first step to reduce noise is to increase the resistance selection (Rsel), which makes the analog filtering more efficient.

In a second step, oversampling can average the noise. The drawback is a cost scanning speed reduction of the touch panel.

The target of acceptable noise is based on the Signal-to-Noise ratio (SNR) of the touch Delta.

If SNR is a value between 18 to 34 dB, then the noise is within an acceptable range.

2.2 Methodology for Optimization

2.2.1 Variables

Data Acquisition

- idx=Index of the channel.
- Signal and Reference, Delta= abs(Signal minus Reference)
- CC=Compensation capacitance
- Key status

Delta Parameters

- gaina=Value of the analog gain
- gaind=Value of the digital gain
- Dyn=1024×GainD, maximum Dynamic of the Signal code
- Rs=Serial resistance, 0, 20, 50, 100 kOhm programmable via Rsel selector field
- Detection threshold

Timing Parameters

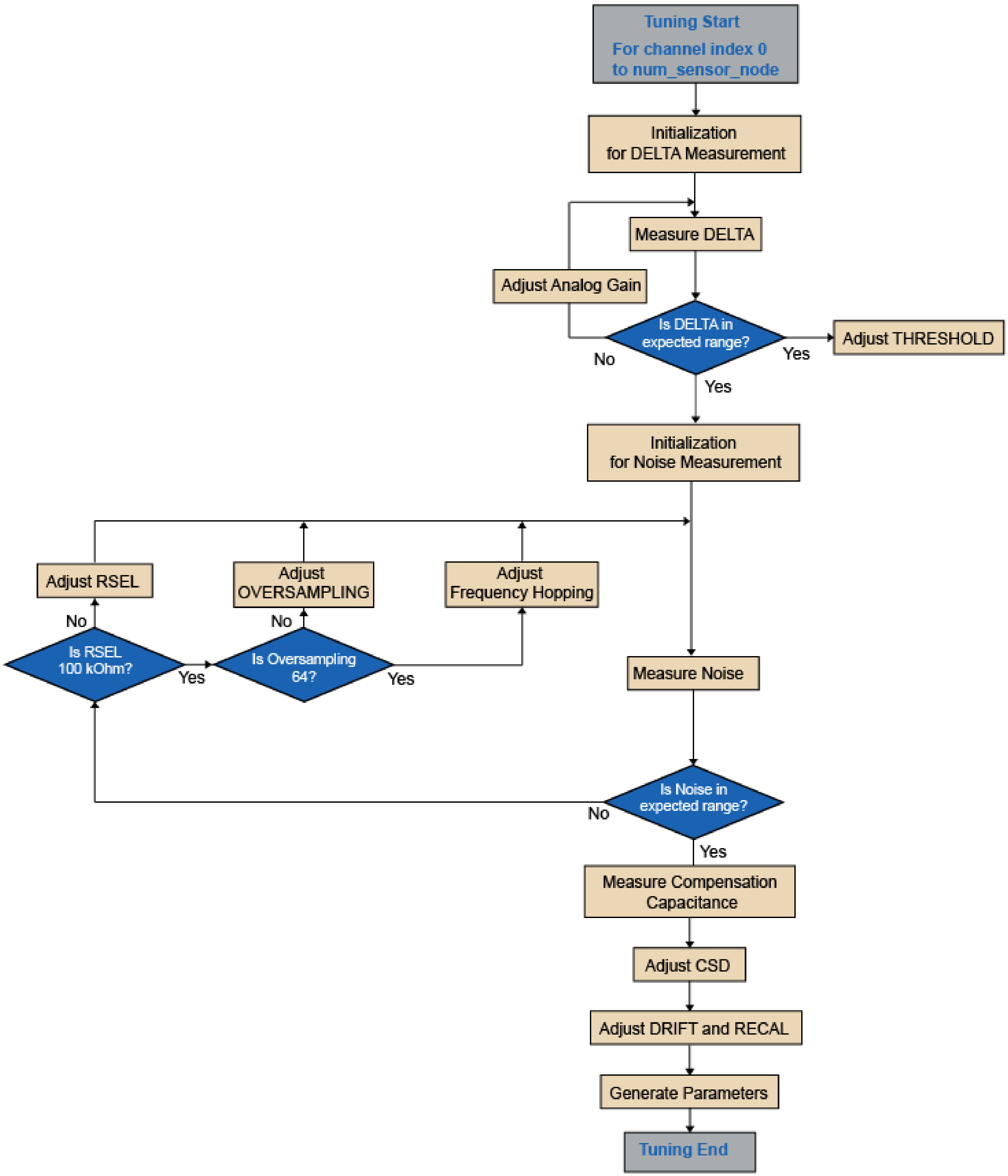
- CSD=Charge Share Delay
- OSR=Oversampling ration of the digital filter
- Tb=Value of time base in μs, always given to the fastest 1μs

Statistical Data

- Mean= {n sum of (Delta)}/n, average value of the Delta=abs(Signal minus Reference)
- Stdev=SQRT({n sum of (Delta-Mean) ^{2}}/n), Standard deviation of the Delta (noise measurement)
- SNR=20×LOG10 (Mean/Stdev), Signal-to-Noise ratio of the Delta
- ENOB= (SNR-1.76)/6.02, Effective number of bits of the sensor measurement
- Num= numbers of samples used for Mean, Stdev, SNR and ENOB computation at least 1024

2.2.2 Operation Flow Diagram

The flow diagram illustrates the optimization process.


Tuning Start
For channel index 0
to num_sensor_node
Initialization
for DELTA Measurement
Measure DELTA
Adjust Analog Gain
Is DELTA in
expected range?
No
Yes
Adjust THRESHOLD
Yes
Initialization
for Noise Measurement
Adjust RSEL
Adjust
OVERSAMPLING
Adjust
Frequency Hopping
No
No
Is RSEL
100 kOhm?
Yes
Is Oversampling
64?
Yes
Measure Noise
Is Noise in
expected range?
No
Yes
Measure Compensation
Capacitance
Adjust CSD
Adjust DRIFT and RECAL
Generate Parameters
Tuning End

2.2.3 Parameter Initialization for Delta Measurement

Mailbox Parameters

- CSD=20
- Rs=50 kOhm
- Time base Tb=1μs (PRSC=1)
- gaina=16
- gaind=1
- OSR=64
- THRESHOLD=4
- Hysteresis=25%
- Refresh=1
- No frequency hopping
- No autocalibration for Rs, PRSC and CSD

Note: A very low value on the threshold limits the DRIFT and RECAL function affecting the Delta value.

The drift and recalibration parameters are set to large timing values:

- Anti_Touch_Recal_thr=50%
- Anti_Touch_Drift_Rate=50
- Anti_Touch_Di=50
- Drift _hold _time=50
- Touch_DI=3
- Touch_Drift_Rate=50

2.2.4 Delta Measurement

Delta(idx)=abs(Signal(idx) minus Reference(idx)), where idx is the index of the defined channels used on the touch panel and idx=0 up to 63 (max value).

During the Delta Touch measurement, it is recommended to avoid transition values rising or falling from 0 to DELTA.

The parameters are set to reduce the noise influences. A low pass filter is applied on the signal to avoid glitches (High RSEL and Max OVERSAMPLING).

The Delta must be between 50 and max value 200 for a full dynamic of 1024 (no digital gain applied).

The Delta must be measured in Touch conditions and when the Touch Delta is close to its achievable max value.

This process returns the Delta mean value and max value achieved.

2.2.5 Analog Gain Adjustment

The analog gain is the ratio of the touch capacitance Ct and the internal programmable Csh integrator capacitance value. The effect of this gain is to increase the sensitivity of the measurement; however, it also increases the noise capture and the static error deviation, such as offset and gain errors of the measurement. Note that the sensitivity depends also on the key threshold level.

Analog gain should be kept as low as possible. Recommended values are 1 or 2.

If a panel has a thick isolation layer (e.g., 4mm Plexiglas) versus the finger touch, the gain is recommended to be 4 or 8.

Analog gain at 16 may lead to a shift of the reference, noise, ADC saturation. This value must be used with caution and avoided when possible.

If the analog gain exceeds 16, the PTC is saturated and is no longer functional.

The analog gain is used to increase the sensitivity to address thicker dielectric overlay between the sensor metal layer and the finger.

Table 2-1. Example: Analog gain value for mutual cap 5pF and dielectric overlay spacing

Spacing (mm)	Gain
0	1
1	2
2	2
3	4
4	4
5	8
6	8
>6	8 or 16

The captured noise during the sampling always increases with the gain. Thus it is recommended to keep the analog gain as low as possible and at least 25% to 45% of the full signal dynamic (e.g., for digital gain 1, the dynamic is 1024, so reaching 256 LSB is a target for the Delta signal).

2.2.6 Threshold Adjustment

Threshold=Delta mean/2.

For increased sensitivity, Threshold=Delta mean/4.

Depending on the drift and recalibration behavior, a lower threshold may be suitable.

The value in the field should take into account the digital gain. So for a measured threshold of 60 over a dynamic of 1024 (gain=1), the value to program must be 60×gaind.

2.2.7 Parameter Initialization for Noise Measurement

Mailbox Parameters

- **Node**
  - CSD=30
  - Rs=0 kOhm
  - Time base Tb=1µs
  - gaina=adjusted value from previous Delta optimization step
  - gaind=1
  - OSR=1
  - No autocalibration for Rs, PRSC and CSD
- **Key**
  - Threshold=4×gaina
  - Hysteresis=25%

  - No frequency hopping
- **Other**
  - Refresh=1

The drift and recalibration parameters are set to large timing values:

- Anti_Touch_Recal_thr=50%
- Anti_Touch_Drift_Rate=50
- Anti_Touch_Di=50
- Drift _hold _time=50
- Touch_DI=3
- Touch_Drift_Rate=50

2.2.8 Noise Measurement

The noise energy is measured by computing the RMS of the difference Delta-mean value. This is equal to the statistical data known as the standard deviation (Stdev) on the Delta samples.

This standard deviation is then used to compute the SNR of the Delta as:

SNR=20×LOG10 (Mean/Stdev).

2.2.9 Rs Adjustment

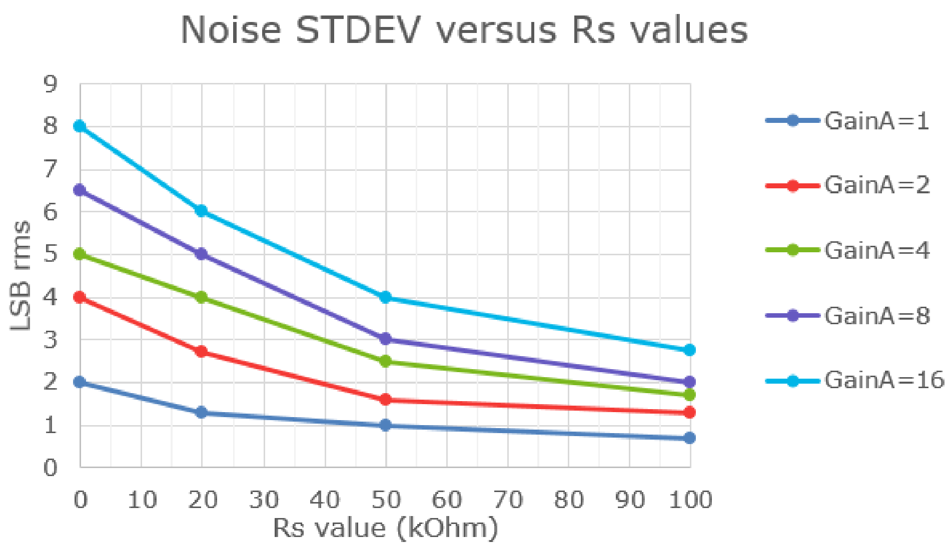
When the noise SNR is considered too low, the Rs resistance can be increased to reduce the noise without affecting the Delta mean value. RSEL field is then increased until the SNR reaches a good value.

The Rs value and OSR should be adjusted together to achieve the best noise performance. Increasing Rs to 100 KOhm without any oversampling may not be necessary and can result in long constant delays which may increase CSD to ensure full sensor charging during an acquisition. The general recommendation is to adjust Rs until the PTC is no longer experiencing saturation (i.e., the majority of single samples when noise is present are within at least 10% of full scale). Once achieved, the OSR should be adjusted until the required SNR is achieved.

2.2.10 Example on QT1 Board Button

The noise has been measured on a QT1 button 1 board as an example of behavior.

The button capacitance is around 5 pF; the effect of the filtering is effective and actually reduces the noise rms value. A tradeoff between analog gain and Rs is GAIN= (1, 2 or 4) and Rs=50 kOhm.



2.2.11 Oversampling (OSR) Adjustment

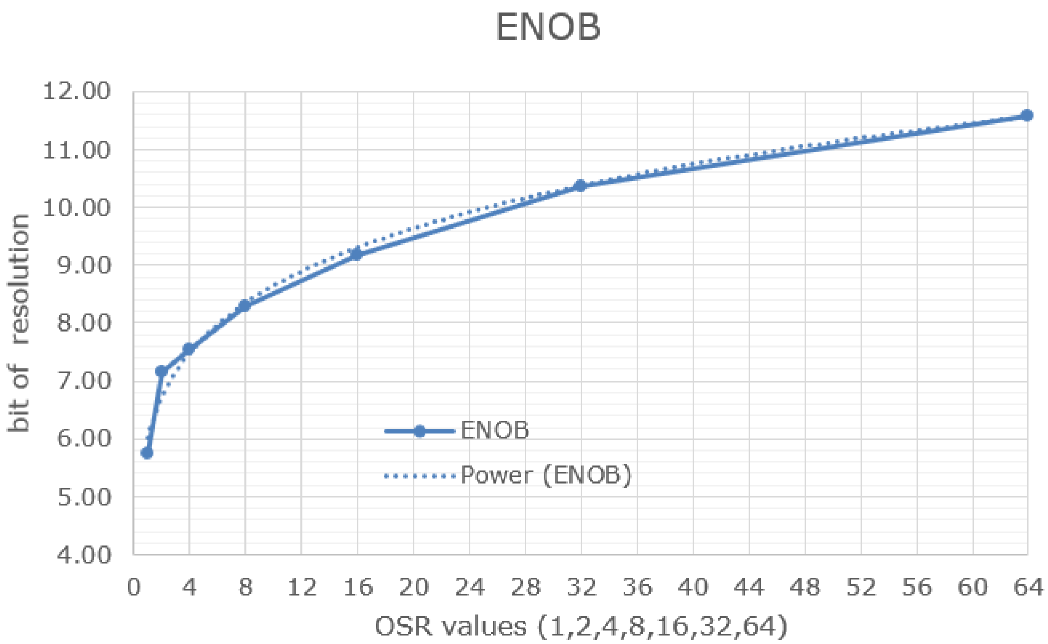
When the Rs reaches the max value of 100 kOhm and the noise is still too high, it is necessary to use oversampling to reduce the noise.

Oversampling is reducing the random noise by digital filtering on the channel. Note that noise is higher in touched condition.

The table below is a QT1 button example in noise reduction by averaging in the initial condition (Rs=0) with Analog Gain=4.

It shows that the ENOB (Effective Number Of Bits), which is the resolution of the PTC, does not exceed 12 bits. The digital gain does not need to be more than 4, the useful Dynamic (Dyn=1024×GainD) is then 4096 in filtering conditions.

Dynamic	Gain D	OSR	STDEV	SNR	ENOB
1024	1	1	5.00	36.31	5.74
2048	2	2	11.72	44.90	7.16
4096	4	4	17.98	47.23	7.55
8192	8	8	21.60	51.61	8.28
16384	16	16	23.14	57.02	9.18
32768	32	32	22.56	64.15	10.36
32768	32	64	11.94	71.57	11.59



2.2.12 Oversampling vs. Frequency Hopping

Frequency hopping eliminates any synchronous noise affecting the channel at a specific frequency.

Frequency hopping consists of retaining only 1 of 3 sampled data, thereby eliminating deviation from median points. When an averaging (e.g. OVERSAMPLING=16) is applied before the frequency hopping algorithm, the sampling process is applied on the averaged values. In this case, a noisy sample is merged with other sample in the averaging process. The averaged sample error is reduced by the digital filter but the frequency hopping still operates.

2.2.13 Refresh vs. Frequency Hopping

Frequency hopping is when the timing of the ADC sampling is shifted by some period of the time base Tb (from the 12 MHz RC).

Refresh is based on a different clock (the Slow clock 32 µs period) and is shifting the touch panel from scan (all index) to another scan (all index).

The Refresh timing is then resynchronized by the measurement engine on the edge of the 12 MHz RC. This introduces a random delay in the ADC sampling acting like a spread spectrum producing almost the same effect as the frequency hopping algorithm.

A first test should be done by using a refresh time only and then checking for noise. If synchronous noise trouble remains, then the frequency hopping can be activated.

2.2.14 Digital Gain

The digital gain works with the digital accumulator filter (OVERSAMPLING). A setup of digital gain value will require at least the same value for oversampling.

2.3 Timing Optimization

After measuring the CC at initialization, increase the value by 20% to include process variation and provide some safety margin to the computations.

2.3.1 PRSC

To maintain a rapid touch scan, the PRSC field is maintained at 0. The time base of the measurement is then Tb=1 µs. The customer may use other values but note that this could slow down the measurement.

2.3.2 Compensation Capacitance (CC)

The compensation capacitance can be very useful in order to optimize other parameters, such as the CSD, clock speed and Rs.

The PTC measures the sensor capacitance (field comp_caps) at initialization and in case of reference drift detection. This measurement is fully automated and establishes the value of the reference field for each node used for key detection.

CC is an integrated capacitance that varies from part to part depending on the silicon process variation, where the variation is about ±20% from nominal value.

For each index of channels, a CC value is extracted.

Example:

In mutual capacitance, a capacitance of exact value 10pF is placed between X and Y.

The comp_caps field is measured at a hexadecimal value equal to 1234. The computation of the capacitance is then CC=1×(7pF)+ 2×(0.7pF)+ 3×(0.07pF)+ 4×(0.007pF)=8.638 pF. (comp_caps changed to decimal).

There is an error of approx. -14% that is mainly attributed to the process deviation.

The knowledge of comp_caps values is important for the timing optimization. These values must be increased by 20%. Then the used value CC×1.2 is worst case to be considered for the computations that follow.

2.3.3 Single Node Acquisition Time: Tacq

The timing of the PTC acquisition depends on the clock frequency 12MHz RC divided by 3 in the picoPower Processor (pPP) and the following prescale “prsc”.

The final clocks used are:

- 4 MHz divided by 4 for fixed and not programmable delays.
- ADC_Clock=4 MHz divided by 4×Prsc for programmable delays (CSD).

ADC_clock defines a time base period at Tb=1µs, 2µs, 4µs or 8µs. It is recommended to keep the ADC_clock at the fastest value at 1 MHz (Tb=1µs). There is no need to reduce this frequency value.

The timing also depends on the parameters CSD and oversampling.

- CSD 0 to 255 of ADC_clock is a delay introduced to enlarge the capacitance switching time.
- Oversampling is the parameter defining the Filtering level X=1 to 64, is the number of samples used for the averaging.

The following table shows timing measurements for all Filter levels and CSD values up to 6. These values are given with an accuracy of ±20%. The CSD parameter at 0 to 3 has no influence on the measurement time. It does influence quality, and it is recommended to use CSD=3.

Starting from CSD=4 and above, a simplified formula can estimate the acquisition timing:

Tacq=3.Tb× (OSR×CSD+4)+3×X+16 in µs

- Tb: Time base in µs
- X: Oversampling filter level 1 to 64

- CSD: 0 to 255

Table 2-2. Tacq in µs for Tb=1µs

Tacq/node	PTC_FILTER_LEVEL_x						
CSD	x=1	x=2	x=4	x=8	x=16	x=32	x=64
CSD=0 CSD=1 CSD=2 CSD=3	35	48	76	131	242	462	902
CSD=4	36	51	81	141	261	501	981
CSD=5	39	57	93	165	309	597	1173
CSD=6	42	63	105	189	357	693	1365

Table 2-3. Tacq in µs for Tb=2µs

Tacq/node	PTC_FILTER_LEVEL_x						
CSD	x=1	x=2	x=4	x=8	x=16	x=32	x=64
CSD=0 CSD=1 CSD=2 CSD=3	59	87	142	252	472	912	1790
CSD=4	60	87	141	249	465	897	1761
CSD=5	66	99	165	297	561	1089	2145
CSD=6	72	111	189	345	657	1281	2529

Table 2-4. Tacq in µs for Tb=4µs

Tacq/node	PTC_FILTER_LEVEL_x						
CSD	x=1	x=2	x=4	x=8	x=16	x=32	x=64
CSD=0 CSD=1 CSD=2 CSD=3	109	164	274	495	935	1816	3573
CSD=4	112	163	265	469	877	1693	3325
CSD=5	124	187	313	565	1069	2077	4093
CSD=6	136	211	361	661	1261	2461	4861

Table 2-5. Tacq in µs for Tb=8µs

Tacq/node	PTC_FILTER_LEVEL_x						
CSD	x=1	x=2	x=4	x=8	x=16	x=32	x=64
CSD=0 CSD=1 CSD=2 CSD=3	209	320	542	977	1860	3612	7146
CSD=4	211	310	508	904	1696	3280	6448
CSD=5	235	358	604	1096	2080	4048	7984
CSD=6	259	406	700	1288	2464	4816	9520

2.3.4 Panel Nodes Acquisition Time: Tscan

When a panel uses count nodes, the total scan of the panel can be expressed as follows:

Tscan=sum of (Tacg (from idx=0 to count-1)) + 85µs + refresh × (20µs).

Refresh is a programmable delay. A value up to 100 introduces a delay up to 2ms.

This delay is based on the pPP timer and a different clock than the 12 MHz RC.

When the refresh is not null, a clock re-synchronization occurs, then a natural jitter is introduced during the acquisition. This jitter acts like a spread spectrum on the measurement and so decorrelates the synchronous noise.

2.3.5 CSD Optimization versus Rs Serial Filtering Resistance

The following tables are established for a settling time limited at 5 Tau (recommended value).

Rs = 100 kOhm

CSD	**Cy (pF)**			
Tb (µs)	**5**	**10**	**20**	**30**
1	5	10	20	30
2	3	5	10	15
4	2	3	5	8
8	1	2	3	4

Rs = 100 kOhm

Tacq(µs)	**Cy (pF)**			
Tb (µs)	**5**	**10**	**20**	**30**
1	39	61	91	121
2	59	66	103	133
4	109	109	124	163
8	209	209	209	211

Rs = 50 kOhm

CSD	**Cy (pF)**			
Tb (µs)	**5**	**10**	**20**	**30**
1	3	5	10	15
2	2	3	5	8
4	1	2	3	4

Rs = 50 kOhm

Tacq(µs)	**Cy (pF)**			
Tb (µs)	**5**	**10**	**20**	**30**
1	35	39	61	76
2	59	59	66	91
4	109	109	109	112

8	1	1	2	2

8	209	209	209	209

Rs = 20 kOhm

CSD	Cy (pF)			
Tb (µs)	**5**	**10**	**20**	**30**
1	1	2	4	6
2	1	1	2	3
4	1	1	1	2
8	1	1	1	1

Rs= 20 kOhm

Tacq(µs)	Cy (pF)			
Tb (µs)	**5**	**10**	**20**	**30**
1	35	39	36	42
2	59	59	59	59
4	109	109	109	109
8	209	209	209	209

Rs = 0 kOhm

CSD	Cy (pF)			
Tb (µs)	**5**	**10**	**20**	**30**
1	0	0	0	0
2	0	0	0	0
4	0	0	0	0
8	0	0	0	0

Rs = 0 kOhm

Tacq(µs)	Cy (pF)			
Tb (µs)	**5**	**10**	**20**	**30**
1	35	35	35	35
2	59	59	59	59
4	109	109	109	109
8	209	209	209	209

2.4 Parameter Diagnostics

The following checks should be made before finalizing the parameter values:

- Check Delta value versus key Threshold detection level.
- Check noise level versus target.
- Check mutual and self-capacitance value versus max value of 30 pF.

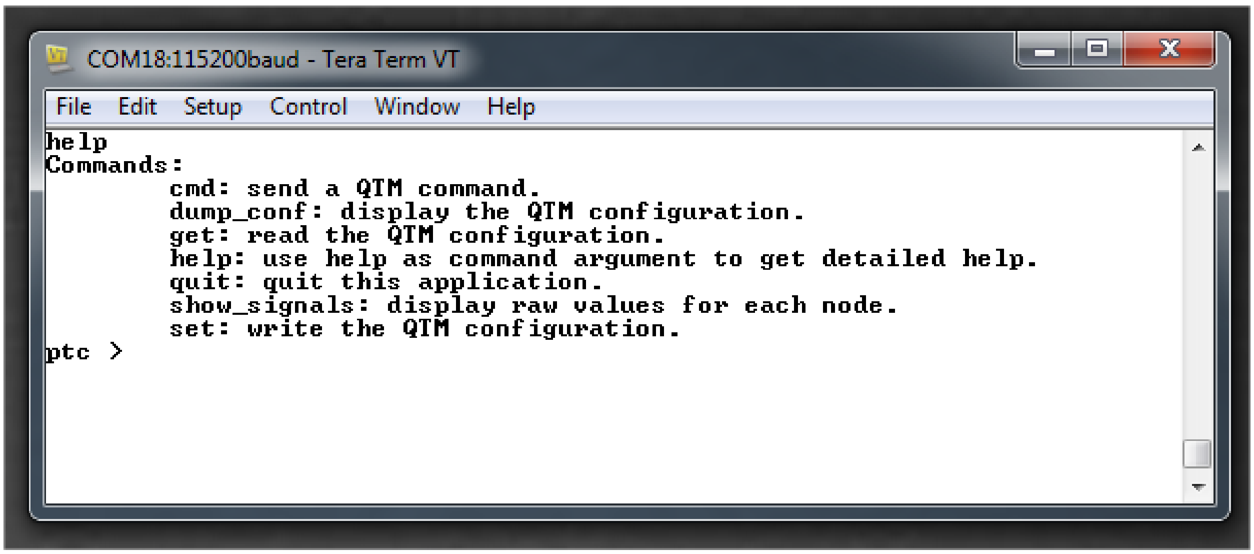
3. PTC Toolbox

A PTC Toolbox is available with some basic commands used on a VT100 compatible terminal. The SAMA5D2-PTC EK board is configured with an external UART port. This port is used to communicate with the PTC toolbox running on the SAMA5D2.

3.1 PTC Console Command

The PTC toolbox is a set of Read/Write console instructions used to configure the PTC for topology and parameters.

Data of the touch signal is read using this tooling.



3.1.1 Help Command

- cmd: send a QTM (QTouch Mailbox) command
- dump_conf: display the whole QTM configuration
- get: read the QTM configuration
- help: use help as command argument to get detailed help
- quit: quit this application
- show_signals: display raw values for each node
- set: write the QTM configuration

3.1.2 ptc > cmd help

- cmd firm_version
- cmd init [number_of_nodes]
- cmd run [number_of_nodes]
- cmd status
- cmd stop
- cmd set_acq_mode_on_demand
- cmd set_acq_mode_timer [delay]

3.1.3 ptc > get help

- get node_group_config
- get node_config [node number]
- get node_data [node number]
- get key_group_config
- get key_config [key number]
- get auto_scan_config
- get scroller_group_config
- get scroller_config [scroller number]
- get fh_autotune_config
- get fh_freq
- get touch_events

3.1.4 ptc > set help

- set node_group_config
- set node_config [node number]
- set node_data [node number]
- set key_group_config
- set key_config [key number]
- set auto_scan_config
- set scroller_group_config
- set scroller_config [scroller number]
- set fh_autotune_config
- set fh_freq
- set touch_events

3.1.5 ptc > show_signals help

- show_signals [output] [number of captures] [delay between captures] [nodes]
  - output: mandatory, stdout of file name
  - number of captures: number of captures to perform
  - delay between captures: delay between successive captures in microseconds
  - nodes: list of node IDs or nothing to select all nodes
- Example: to capture signals of node 0, 1, 2, 3, 10 times every 100us and display it on the console
- show_signals stdout 10 100 0 1 2 3

4. Development Tools

4.1 Introduction

The following tools are required to develop QTouch on SAMA5D2 devices:

- SAMA5D2 PTC Evaluation Kit (SAMA5D2-PTC-EK)
- PTC subsystem firmware
- User interface header files

Drivers are provided to the user via the Softpack or Linux. All configurations are available through a console or via configuration files.

4.2 SAMA5D2 PTC Software

Development Environment for IAR Compiler:

- Software Framework: https://github.com/atmelcorp/atmel-software-package

Linux Development Environment:

- Linux Drivers: http://www.at91.com/linux4sam/bin/view/Linux4SAM/

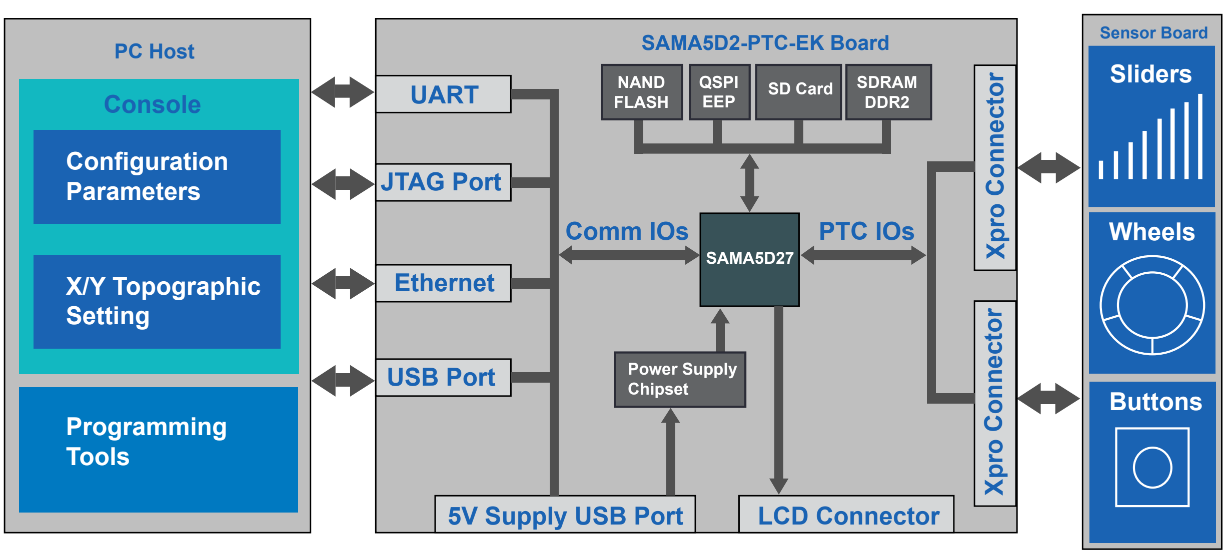
4.3 SAMA5D2 PTC Evaluation Kit Board

The SAMA5D2-PTC-EK board can be used to operate the PTC using the provided development tooling.

The SAMA5D2-PTC-EK is compatible with existing touch boards such as ATQT1 sliders, wheels, buttons (self-capacitance and mutual capacitance configurations) and others such as ATQT2 Surface and ATQT6 pads. The board is connected to a PC via a JTAG or USB SAMBA port (Linux). A UART console is used to control interactively the PTC topology and parameters.

For a custom touch panel, the QTouch library parameters need to be adjusted to the new hardware. The same link to the PC host can be used together with a set of APIs.

Figure 4-1. PTC Tooling Configuration



Note: The processor mounted on the board is the SAMA5D27.

4.4 Standard Touch Boards: QT1, QT2, QT6 Xplained Pro

QT1 Xplained Pro

- Surface size: 60mm x 100mm
- 10 nodes – self or mutual capacitance
- LEDs indicating touch position

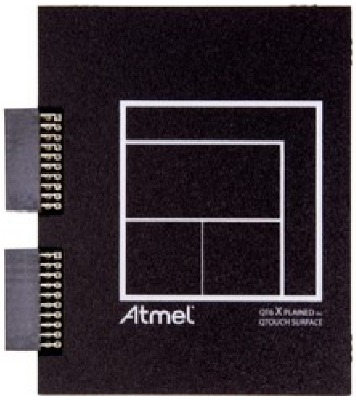
For details, see QT1 Xplained Pro Extension Kit.

QT2 Xplained Pro

- Surface size: 38mm x 32mm
- 16 nodes mutual – 10mm node pitch
- 14mm edge-edge touch separation
- 49 LEDs indicating touch position

For details, see QT2 Xplained Pro.

QT6 Xplained Pro



- Surface size: 50mm x 50mm
- 64 nodes mutual – 5mm node pitch
- 2mm edge-edge touch separation

For details, see QT6 Xplained Pro.

4.5 Customer PCB

The application developer can use the Microchip QT Xplained boards or his own Touch board and use the same software and drivers to optimize the touch parameters to a custom Touch configuration.

It is best to place the chip near the touch keys on the same PCB so as to reduce X and Y trace lengths, thereby reducing the chances for EMC problems. Long connection traces act as RF antennas. The Y (receive) lines are much more susceptible to noise pickup than the X (drive) lines. Even more importantly, all signal-related discrete parts (resistors and capacitors) should be very close to the body of the chip. Wiring between the chip and the various resistors and capacitors should be as short and direct as possible to suppress noise pickup. Ground planes and traces should NOT be used around the keys and the Y lines from the keys. Ground areas, traces, and other adjacent signal conductors that act as AC ground (such as Vdd) absorb the received key signals and reduce signal-to-noise ratio (SNR) and thus are counterproductive. Ground planes around keys also make water film effects worse.

4.6 Startup/Calibration Times

The PTC pPP employs a rigorous initialization and self-check sequence. If the self tests are passed, the last step in this sequence enables the serial communication interfaces. The communication interfaces are not enabled if a safety critical fault is detected during the startup sequence.

The PTC determines a reference level for each key by calibrating all the keys immediately after initialization. Each key is calibrated independently and in parallel with all other enabled keys.

5. Noise Immunity Recommendations

5.1 Introduction

The signal Delta values should normally be in the range of 60 to 256 counts with properly designed key shapes.

The signal swing from the smallest finger touch should preferably exceed 10 counts, with 15 being a reasonable target. The signal threshold should be set to a value guaranteed to be less than the signal swing caused by the smallest touch.

5.2 Conducted Noise Definition

Conducted noise refers to unwanted ’noisy’ RF voltages and currents carried by external wires and cables. The source of this unwanted noise can include RF transmitters, switched-mode power supplies and other interconnected devices that have electronic activity in RF range. Conducted noise will generally be in Common-Mode (CM) and appear across all connecting cables to a device. Capacitive touch applications are generally not affected by CM noise until human interaction takes place. This is because the power supply lines maintain a stable difference between VDD and GND and as no return path is provided to the noise source reference (usually earth), the circuit functions normally.

Once human interaction takes place, however, the user’s finger now provides a return path and effectively couples noise directly into the capacitive sensor. When this noise reaches levels where normal filtering algorithms become ineffective, errors are introduced into the touch measurement and the system becomes unreliable. This can manifest itself by way of undetected touches, false touches or in some cases, a complete system lock-up. It is important therefore to understand the environment in which the touch application is designed to operate in, and where appropriately apply suitable techniques to address the effects of unwanted noise disturbances.

5.3 Tuning for Noise Performance

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

5.4 Resilient to VDDANA Changes

The ADC is referenced to the same supply voltage used to charge the capacitors. Therefore the measured signal is independent of VDDANA.

6. Factors Affecting Touch Sensitivity

6.1 Sensor Design

In self-capacitance, ensure capacitance of the sensor, including the electrode and sensor traces, is not more than 30pF.

In mutual capacitance, ensure capacitance of sensor electrode is not more than 30pF.

In case of Sliders/Wheels, the capacitance of each channel should not be more than 30pF.

The Compensation Capacitance (CC) calibration value can be used to find whether the parasitic capacitance is high. If CC calibration value of a channel is equal to 16383, then the channel is considered to be saturated.

Grouping the sensors on the panel can help in achieving better moisture tolerance. The moisture tolerance feature “Adjacent Key suppression” operates on a group of sensors which are physically close to each other.

6.2 Electrode Size for Self-capacitance Measurement

Capacitance is a function of surface area; therefore the larger the surface area of the touch target and the electrode, the larger the change in capacitance. If the electrode is too small there will not be optimal surface area coupling to the finger; therefore the sensor will be operating at reduced sensitivity. If the electrode is too big the extra surface area may add more parasitic capacitance to nearby ground returns, for example, foreign tracks and ground planes.

The optimal electrode size is an electrode that is slightly larger (by a few millimeters) than the touch target, to allow for slightly off-center touches. The touch target is usually a finger – generally around 8 – 12 mm wide.

6.3 Electrode Size for Mutual-capacitance Measurement

The mutual capacitance between the X and Y electrodes is measured. Therefore, the sensitive touch area is the gap between the X and Y electrodes. Key sensitivity is improved by increasing field penetration and density.

Field penetration through the dielectric front panel is improved by increasing the XY gap. The bigger the XY gap, the further sense fields propagate through the dielectric panel towards the users touch. Ideally, the XY gap should be T/2 whereby T is the front panel thickness. If the XY gap is over-large then the sensor may have a proximity effect instead of requiring actual touch. Also, the sensor may become overly sensitive to moisture. Field density is improved by increasing the amount of interleaving between the X and Y electrodes. This means creating more 'teeth' in a QMatrix key. A key with more interleaving (while still adhering to the T/2 rule) will have better sensitivity.

6.4 Dielectric Panel Thickness and Material

The thicker the dielectric front panel, the less sensitive the electrode will be. The higher the relative dielectric constant, the better the material is at propagating charge through it. Therefore, materials which have a higher dielectric constant will perform better with capacitive touch sensors. For example, if the panel thickness is 2 mm, the minimum electrode size is recommended is 8 mm x 8 mm.

6.5 Ground Loading

For the Y line of self- and mutual-cap measurement, having ground tracks or planes nearby will make the sensor less sensitive. This is because the nearby ground increases the parasitic capacitance by providing an alternate return path for the charge. Try to keep all ground away from the sense electrodes/tracks/components if possible. If a ground plane is necessary to shield from noise or provide a stable operating environment (in a portable device), then a hatched ground pattern can be used. Hatched patterns have reduced surface area, thus reducing loading but still providing shielding. It is always beneficial to keep sense tracks as short as possible to reduce loading effects.

For X line of mutual-cap measurement, the X lines (transmitter) are always driven, therefore are virtually immune to ground loading. X lines can simply be routed almost anywhere (except near Y lines, as the XY coupling may form false touch sensors at those locations).

6.6 Ground Return

All capacitive touch sensors rely on a return path for the charge to 'propagate' from the electrode back to the circuit ground of the sensor. A human being, due to its mass and size, can be considered to be earth. Therefore, if the product with the capacitive touch sensor is connected to mains earth, there will be a consistent and good quality return path. Sensitivity is almost constant and improved.

7. Revision History

7.1 Rev. A - 11/2017

This is the initial released version of this application note.

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