AT15291: Migrating QTouch Designs from SAM D MCUs to SAM C MCUs

APPLICATION NOTE

Scope

This application note is a guide to assist users in migrating QTouch® designs from Atmel® | SMART SAM D MCUs to Atmel SAM C MCUs. This document mainly covers the enhanced features of PTC peripheral in SAM C MCUs.

For complete device details, refer to the most recent version of SAM C MCU datasheet.

Features

- Hardware and firmware considerations
- Enhanced features of PTC in Atmel SAM C MCUs
  - Supports 32 Y-line (sense line)
  - Configurable Charge Share Delay
  - +5V operation

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1. Abbreviations and Definitions

Electrode: The patch of conductive material on the substrate that forms the sensor. An electrode is usually made from copper, carbon, silver ink, Indium Tin Oxide (ITO).

Peripheral Touch Controller (PTC): This is a microcontroller peripheral, which acquires signals to detect touch on capacitive sensors.

Channel: A channel is a logical group of pins used to perform the touch acquisition measurement.

Sensor: A channel or group of channels used to form a touch sensor. The three types of sensors are Buttons, Sliders and Wheels.

Self-capacitance Sensor: A sensor with only one direct connection to the sensor controller. A self-capacitance sensor tends to emit electric fields in all directions.

Mutual capacitance Sensor: A sensor with connections to two parts of the sensor, an X (transmit) electrode and a Y (receive) electrode. The controller measures the mutual capacitance from X to Y.

Signal: Signal value is the raw measurement data on a given touch channel.

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

Delta: Delta value of a touch channel represents difference between signal and reference.

CSD: Charge Share Delay.

QTouch Library: This makes it simple for developers to embed capacitive-touch button, slider, wheel functionality into general-purpose Atmel SMART | ARM and AVR® microcontroller applications.

QTouch Composer: PC software available as part of Atmel Studio extension gallery allows for QTouch project generation using desired sensor configuration.

2. PTC Signal Description

The number of Y sense lines supported in SAM C MCUs is increased to 32, whereas SAM D MCUs support maximum of 16 Y-lines. Among the 32 Y sense lines, 16 are standalone and 16 are dual-function with PTC X-lines (drive lines).

The following table provides maximum number of Self-capacitance and Mutual capacitance channels supported across different SAM C/D device variants.

Refer Appendix A for PTC Pin mapping details.

Table 2-1. Channels Supported Across Device Variants

PTC Measurement Method	SAM C2xE (32 Pin)	SAM C2xG (48 Pin)	SAM C2xJ (64 Pin)	SAM D2xE (32 Pin)	SAM D2xG (48 Pin)	SAM D2xJ (64 Pin)
Self-capacitance	16 Channels	20 Channels	32 Channels	6 Channels	10 Channels	16 Channels
Mutual capacitance	60 Channels (10X x 6Y)	120 Channels (12X x 10Y)	256 Channels (16X x 16Y)	60 Channels (10X x 6Y)	120 Channels (12X x 10Y)	256 Channels (16X x 16Y)

3. Migrating QTouch Designs to SAM C MCUs

This section describes the changes required for migrating QTouch Designs from SAM D MCUs to SAM C MCUs.

3.1. Need for Migration

QTouch designs need porting to SAM C MCUs for the following reasons.

1. 5V operation.
2. Supports up to 32 self-capacitance channels.
3. Enhanced noise countermeasure i.e., configurable CSD.

3.2. Hardware Consideration

The SAM C MCUs are pin to pin compatible with SAM D MCUs. PTC sense lines (X and Y) I/O pin mapping is similar for both SAM C and D MCUs. This allows porting QTouch designs with no changes in hardware. The requirements for external components such as series resistor on the Y-line remains the same.

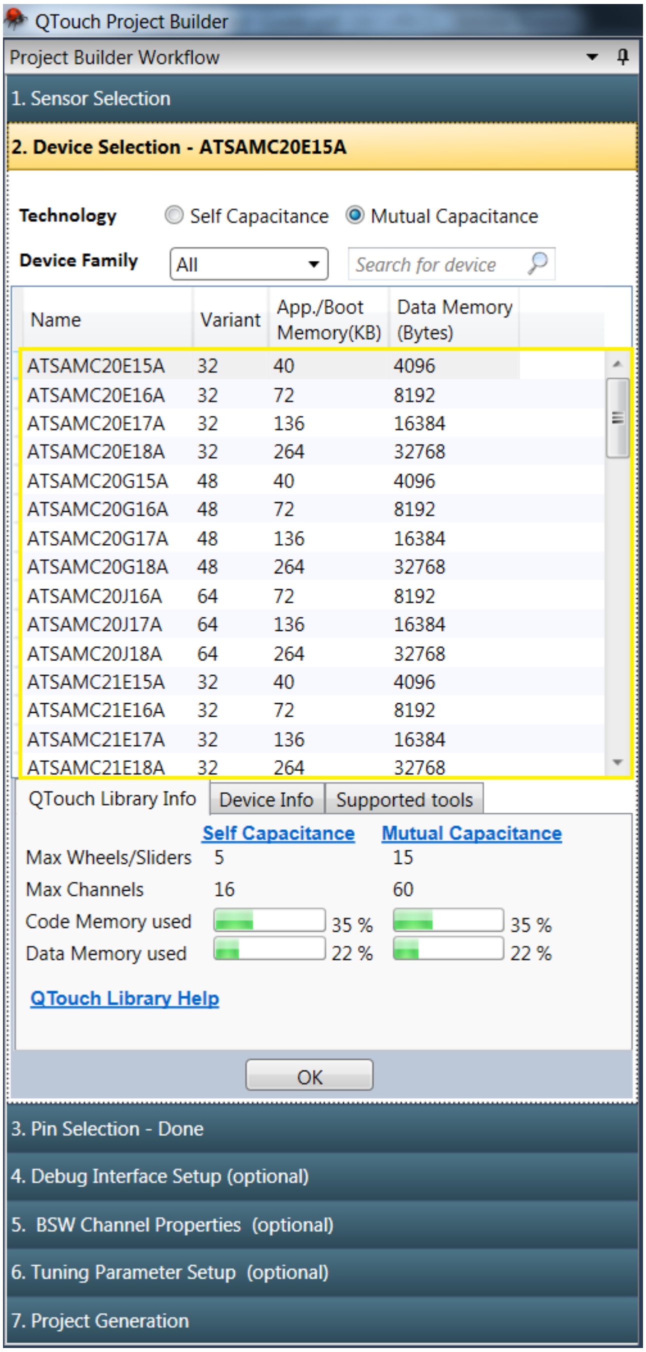
3.3. Firmware Consideration

3.3.1. Project Generation

QTouch project developed for SAM D MCU cannot be used directly for SAM C MCU simply by changing the device selection in project settings. Although the SAM C/D series microcontrollers use 32-bit ARM Cortex-M0+ processor, there are minor deviations in the system architecture. There are differences in several peripherals such as system controller, power manager, oscillator controller, and few other blocks across SAM C/D devices. Refer to respective device datasheet for more information.

QTouch Composer – Project Builder wizard in Atmel Studio, as shown in the following figure can be used to generate QTouch project for SAM C MCUs for the required sensor configuration. Other applications can be manually included to the above QTouch project.

Figure 3-1. QTouch Composer – Project Builder wizard

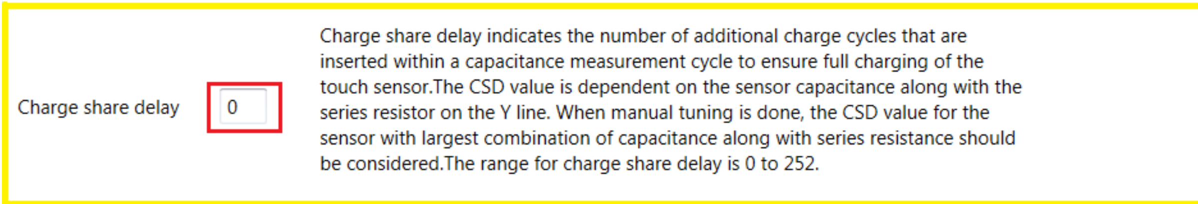


3.3.2. QTouch Library

QTouch Library APIs and parameters are similar for both SAM D and SAM C MCUs. Support for configuring charge share delay (CSD) parameter is included in SAM C QTouch Library.

The only additional parameter that must be configured with SAM C QTouch Library is CSD. This parameter can be configured during project creation using QTouch Composer as shown in the following figure.

Figure 3-2. QTouch Project Builder Wizard – BSW Channel Properties



This configurable global parameter is available in `touch.h` header file. The macro names for self-capacitance and mutual capacitance methods are as follows:

CSD Configuration name:

- `DEF_SELF_CAP_CSD_VALUE` for Self-capacitance
- `DEF_MUTL_CAP_CSD_VALUE` for Mutual capacitance

4. Charge Transfer

Charge transfer is the basic capacitance measurement principle used by PTC. It is essential to ensure that the sensor capacitance is fully charged and discharged during each measurement sample. Adding a series resistor in the sense line forms a low pass filter, which increases the time constant for charging the sensor. The duration of the charge pulse must be sufficiently long to allow complete charging.

Sensor capacitance can be incompletely charged due to higher series resistance or higher parasitic capacitance. Insufficient charging of sensor capacitance can be observed as reduction in touch delta value and deviation from expected signal value.

The expected signal values for a given combination of Filter Level and Gain setting are mentioned in Atmel QTouch Library Peripheral Touch Controller User Guide. If the deviation between observed signal value and expected signal value is greater than 10 counts, prescaler setting should be increased until the signal value is within the expected range.

When sensor capacitance charging is incomplete, touch delta obtained will be less.

In case of SAM D MCUs, complete charging of sensor capacitance is ensured by adjusting prescaler setting as specified in the following steps:

1. Configure prescaler for which the signal values are within the expected range.
2. Observe the touch delta (X).
3. Increase the prescaler by one step and observe the touch delta (Y).
4. If the difference between Y and X is more than 10% of X, then and go to step 3.
5. If the difference in delta value is not more than 10% then reduce the prescaler setting by one step and use it for touch acquisition.

5. Charge Share Delay (CSD)

Charge share delay is the parameter that controls sensor charge time during touch measurement. Increasing CSD inserts additional PTC clock cycles, which ensures touch sensor is completely charged. CSD setting is dependent on sensor electrode capacitance and Y-line series resistance.

Modifying this parameter alters the touch acquisition waveform with no change in PTC and ADC operating frequencies. This ensures that ADC conversion speed remains unaffected during touch measurement.

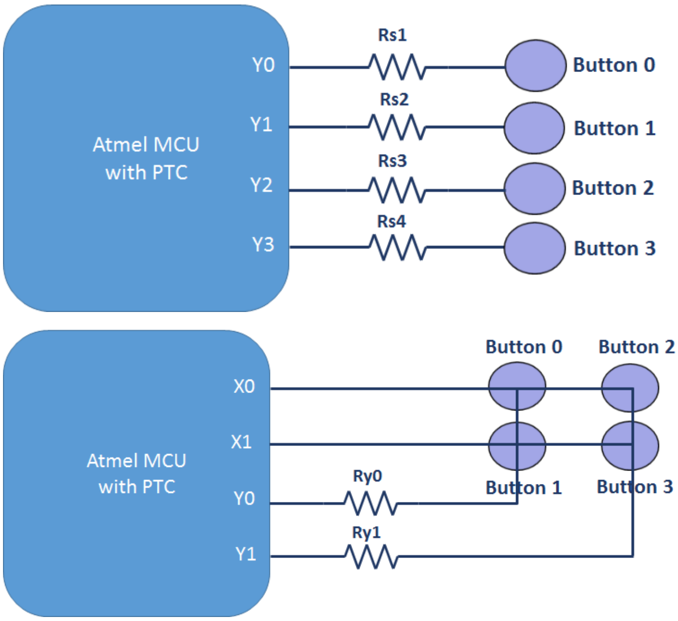
CSD setting helps when the sensor electrode capacitance is larger and having a higher series resistance on the sense lines. Following figure depicts example self-capacitance and mutual capacitance circuits, where touch sensor is connected to PTC pins of MCU through external series resistor.

This is a global parameter in PTC QTouch Library and is common for all sensors available in QTouch design.

CSD Setting Range: 0 to 250

Typical CSD: 0

Figure 5-1. Example Self-capacitance and Mutual capacitance Circuits



5.1. Prescaler Impact

Prescaler setting determines the operating frequency of the PTC. This in turn affects the acquisition frequency and determines the width of the charging pulse. In SAM D PTC, prescaler adjustment can be utilized to ensure complete charging of sensor capacitance. Since the charge share delay parameter is internally set to a fixed value ‘4’.

The prescaler setting provides four selectable clock options. The following table captures one touch acquisition sample duration for different PTC clock inputs and prescaler options. The results are applicable for both Self-capacitance and Mutual capacitance methods.

Table 5-1. Touch Sample Duration for Different Prescaler Settings

PTC Prescaler	One Sample Duration (µs)			
	PTC – 4MHz	PTC – 2MHz	PTC – 1MHz	PTC – 0.5MHz
PRSC_1	15	30	60	120
PRSC_2	30	60	120	240
PRSC_4	60	120	240	480
PRSC_8	120	240	480	960

5.2. Advantages of CSD

Configurable feature of CSD in SAM C MCUs allows fine tuning of charge transfer duration in noisy environments. This feature eliminates the need for prescaler tuning in QTouch designs. Tuning of CSD parameter alone is sufficient enough to obtain touch performance similar to that obtained using higher prescaler setting.

Changing the CSD parameter does not impact the ADC conversion rate. CSD parameter provides more granularity compared to prescaler. The prescaler renders only four selectable clocks. Whereas CSD offers 250 different delay settings for each prescaler input.

This helps in altering the touch acquisition frequency which is advantageous to handle narrow band noise issues in QTouch designs.

5.3. CSD Setting Inference

For a given CSD, mutual capacitance has lower measurement time compared to self-capacitance.

Each unit increase of CSD parameter inserts,

- Three PTC clock cycles delay in mutual capacitance
- Six PTC clock cycles delay in self-capacitance

The following table shows one touch acquisition sample duration with different CSD settings for both self-capacitance and mutual capacitance measurement methods. The PTC clock frequency is 4MHz with prescaler set to 1 (PRSC_1) and CPU speed is 48MHz. PTC operating frequency in this case is 1MHz, due to internal division factor of 4.

For each CSD unit increase,

- In mutual capacitance, delay added = 3 PTC Clock cycles = 3 x 1µs = 3µs
- In self-capacitance, delay added = 6 PTC Clock cycles = 6 x 1µs = 6µs

The delay in touch acquisition for different CSD values, can be observed from the following table.

Table 5-2. One Sample Period for Different CSD

CSD	One Sample Duration (µs)	
	Self-capacitance	Mutual capacitance
0	14	14
1	18	15

CSD	One Sample Duration (µs)	
	Self-capacitance	Mutual capacitance
2	24	18
3	30	21
4	36	24
5	42	27
6	48	30
7	54	33
8	60	36
9	66	39
10	72	42
...	...	...
250	1512	762

Note: Sample duration for self and mutual capacitance provided in this table does not include the ADC conversion time.

5.4. CSD Tuning

It is recommended to fix prescaler setting to 1 (PRSC_1) and then tune the CSD values.

- While adjusting the CSD, the delay can be increased by configuring higher value for prescaler setting such as PRSC_8. This is evident from results captured in Table 5-2 One Sample Period for Different CSD on page 10.
- Granularity of changing CSD is more effective with the prescalar setting PRSC_1 compared to a higher prescaler setting.

Following procedure explains the steps for manual tuning of CSD:

1. Increase the CSD value in steps of one (CSD = 1, 2, 3 …250). Modify the CSD, recompile the application project and program the MCU with updated hex file generated.
2. Monitor touch delta value with each setting using QTouch Analyzer by enabling QDebug interface in application.
3. Repeat steps 1 and 2, until the increase in touch delta value is insignificant.
4. Identify the maximum CSD setting that provides maximum touch delta. Ensure that increasing CSD beyond the maximum does not have significant increase in touch delta. No significant change in touch delta value indicates that the sensor electrode is completely charged.
5. Repeat steps 1 to 4, for all touch sensors. Each sensor might require different CSD value.
6. Use the maximum CSD value obtained, that ensures proper charging on all touch sensors.

Note: Increasing the CSD increases the touch measurement duration. This affects the touch response time and power consumption. But, the impact would be less compared to prescaler adjustment.

5.5. Waveform

5.5.1. Prescaler impact in SAM D MCUs

Self-capacitance waveforms captured with different prescaler values are as follows:

Figure 5-2. One Sample Duration with PRSC_1

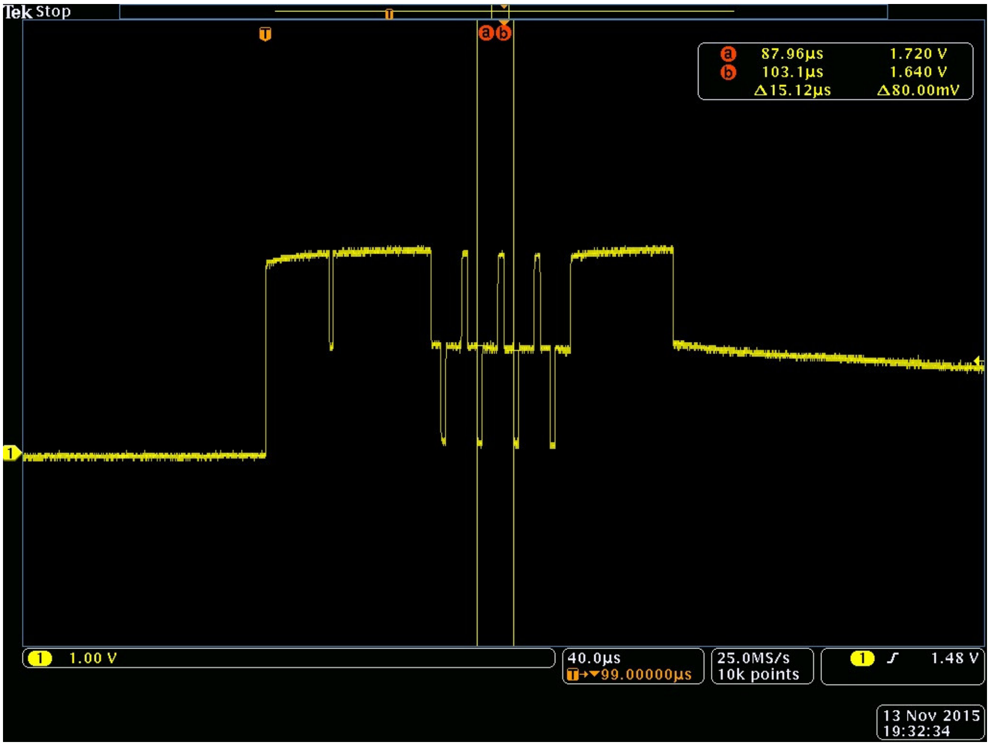


Figure 5-3. One Sample Duration with PRSC_2

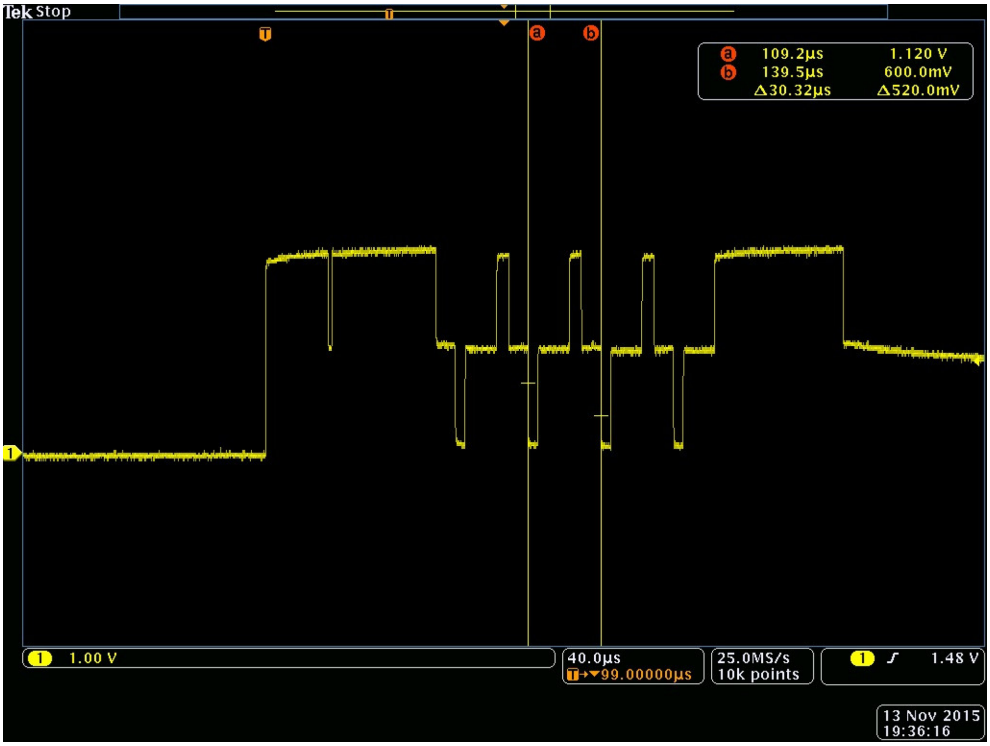


Figure 5-4. One Sample Duration with PRSC_4

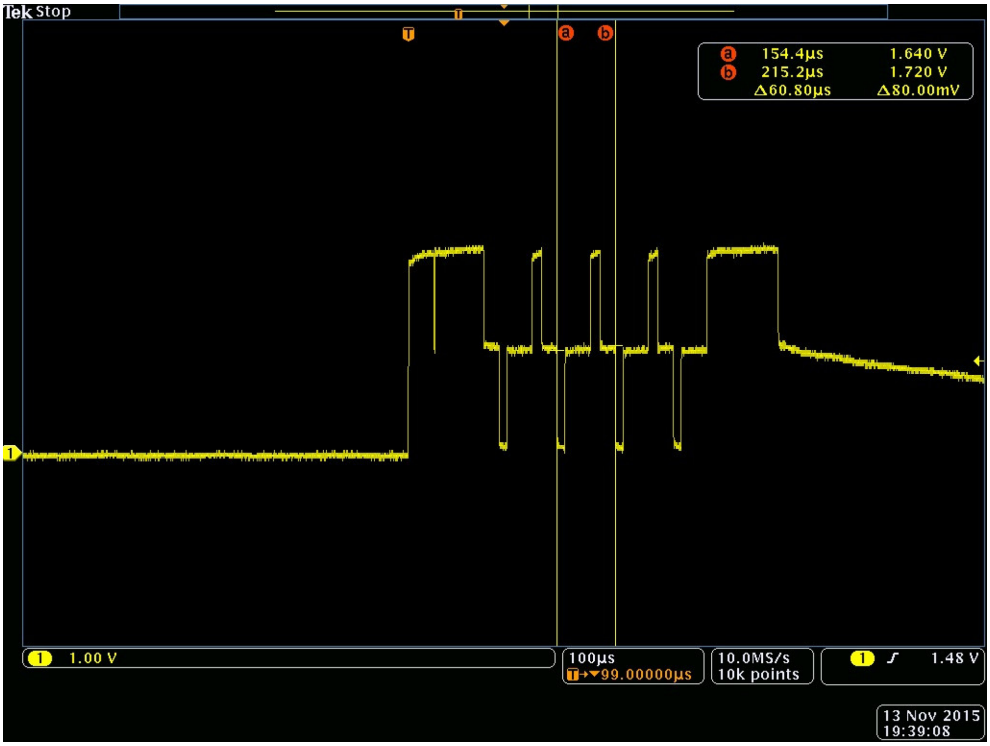
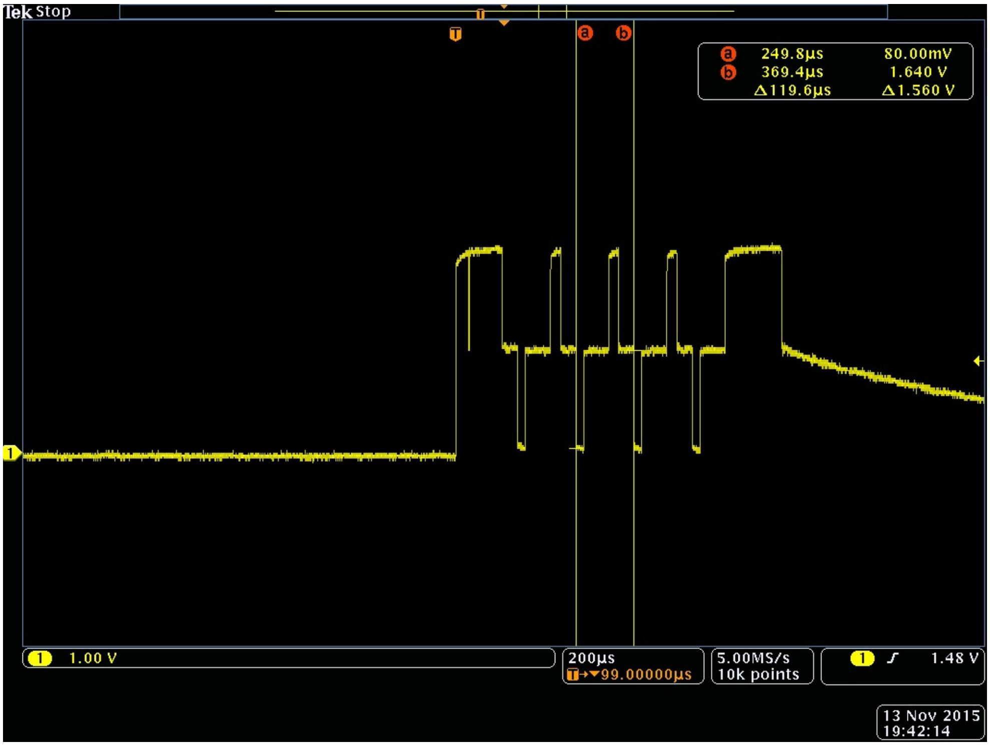


Figure 5-5. One Sample Duration with PRSC_8



5.5.2. CSD Impact in SAM C MCUs

The self-capacitance waveforms captured with different CSD values are as follows:

Figure 5-6. One Sample Duration with CSD_1

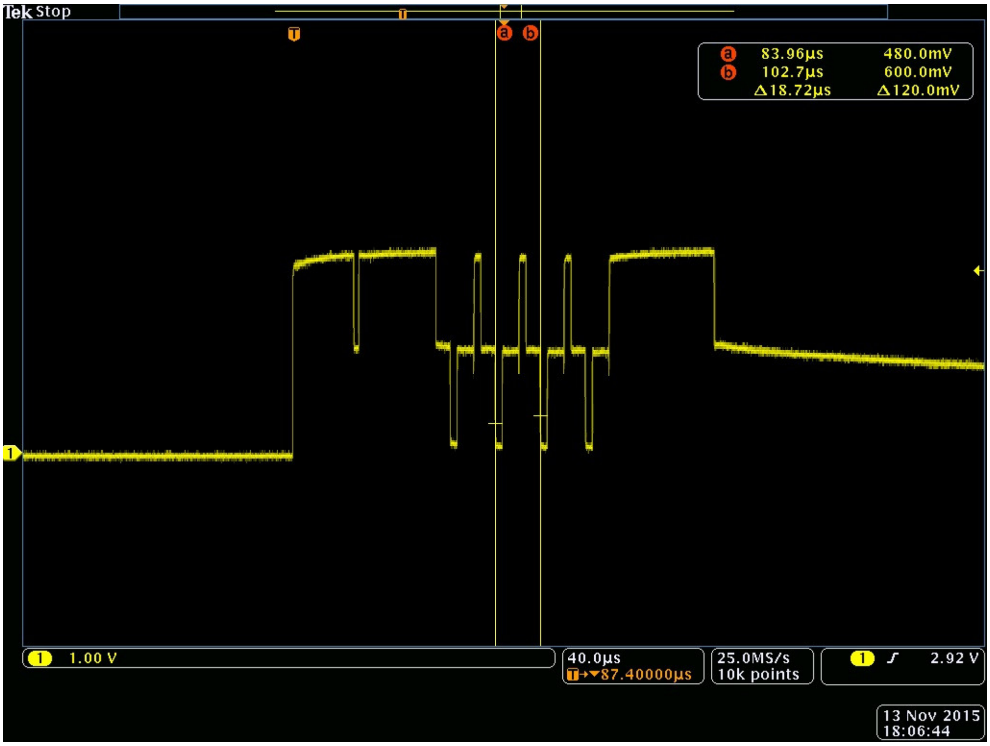


Figure 5-7. One Sample Duration with CSD_5

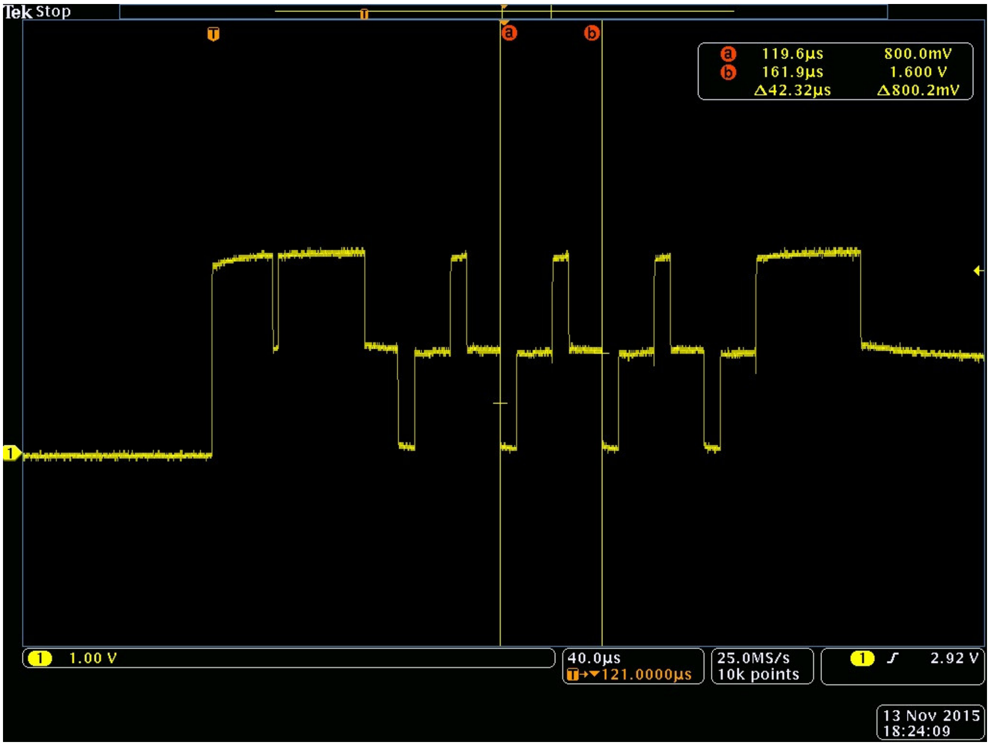


Figure 5-8. One Sample Duration with CSD_10

Figure 5-9. One Sample Duration with CSD_25

6. References

Peripheral Touch Controller - User Guide: http://www.atmel.com/images/atmel-42195-qtouch-library-peripheral-touch-controller_user-guide.pdf.

7. Appendix A. PTC Pin Mapping

I/O Pin	PTC Pins					
	SAM C2xE (32 Pin)	SAM C2xG (48 Pin)	SAM C2xJ (64 Pin)	SAM D2xE (32 Pin)	SAM D2xG (48 Pin)	SAM D2xJ (64 Pin)
PA02	Y[0]	Y[0]	Y[0]	Y[0]	Y[0]	Y[0]
PA03	Y[1]	Y[1]	Y[1]	Y[1]	Y[1]	Y[1]
PA04	Y[2]	Y[2]	Y[2]	Y[2]	Y[2]	Y[2]
PA05	Y[3]	Y[3]	Y[3]	Y[3]	Y[3]	Y[3]
PA06	Y[4]	Y[4]	Y[4]	Y[4]	Y[4]	Y[4]
PA07	Y[5]	Y[5]	Y[5]	Y[5]	Y[5]	Y[5]
PB00			Y[6]			Y[6]
PB01			Y[7]			Y[7]
PB02		Y[8]	Y[8]		Y[8]	Y[8]
PB03		Y[9]	Y[9]		Y[9]	Y[9]
PB04			Y[10]			Y[10]
PB05			Y[11]			Y[11]
PB06			Y[12]			Y[12]
PB07			Y[13]			Y[13]
PB08		Y[14]	Y[14]		Y[14]	Y[14]
PB09		Y[15]	Y[15]		Y[15]	Y[15]
PA08	X[0] / Y[16]	X[0] / Y[16]	X[0] / Y[16]	X[0]	X[0]	X[0]
PA09	X[1] / Y[17]	X[1] / Y[17]	X[1] / Y[17]	X[1]	X[1]	X[1]
PA10	X[2] / Y[18]	X[2] / Y[18]	X[2] / Y[18]	X[2]	X[2]	X[2]
PA11	X[3] / Y[19]	X[3] / Y[19]	X[3] / Y[19]	X[3]	X[3]	X[3]
PA16	X[4] / Y[20]	X[4] / Y[20]	X[4] / Y[20]	X[4]	X[4]	X[4]
PA17	X[5] / Y[21]	X[5] / Y[21]	X[5] / Y[21]	X[5]	X[5]	X[5]
PA18	X[6] / Y[22]	X[6] / Y[22]	X[6] / Y[22]	X[6]	X[6]	X[6]
PA19	X[7] / Y[23]	X[7] / Y[23]	X[7] / Y[23]	X[7]	X[7]	X[7]
PA20		X[8] / Y[24]	X[8] / Y[24]		X[8]	X[8]
PA21		X[9] / Y[25]	X[9] / Y[25]		X[9]	X[9]
PA22	X[10] / Y[26]	X[10] / Y[26]	X[10] / Y[26]	X[10]	X[10]	X[10]
PA23	X[11] / Y[27]	X[11] / Y[27]	X[11] / Y[27]	X[11]	X[11]	X[11]
PB12			X[12] / Y[28]			X[12]

I/O Pin	PTC Pins					
	SAM C2xE (32 Pin)	SAM C2xG (48 Pin)	SAM C2xJ (64 Pin)	SAM D2xE (32 Pin)	SAM D2xG (48 Pin)	SAM D2xJ (64 Pin)
PB13			X[13] / Y[29]			X[13]
PB14			X[14] / Y[30]			X[14]
PB15			X[15] / Y[31]			X[15]

8. Revision History

Doc. Rev.	Date	Comments
42655A	01/2016	Initial document release

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