AN2812

Low-Power Touch Design

Introduction

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Power consumption remains an important factor in the design of any portable gadget. The Microchip capacitive touch technology using the Peripheral Touch Controller (PTC) or Hardware Capacitive Voltage Divider (HCVD) provides features to design a low-power touch sensor that can wake up on touch from standby Sleep without CPU intervention. HCVD is available in 8-bit PIC® devices and PTC is available in 8-bit AVR® and 32-bit SAM devices.

This document describes the details of designing a low-power touch sensor, different sensor configurations and, tips and tricks to optimize the power consumption.

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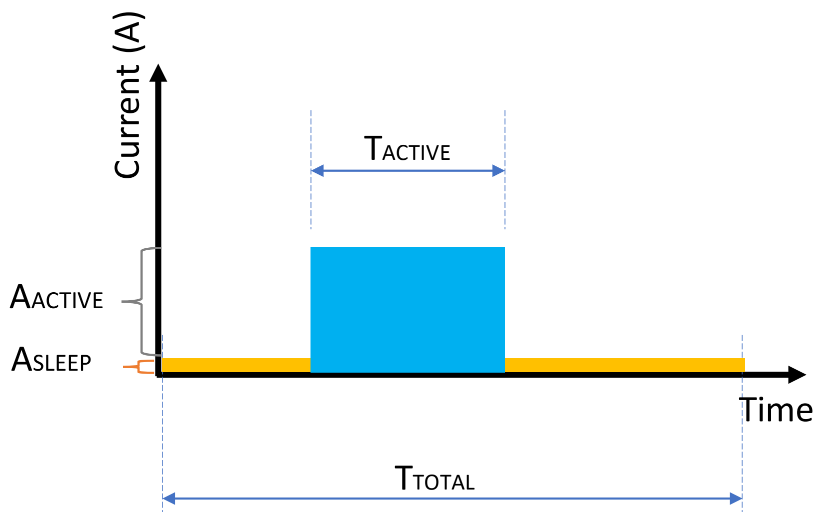
1. Current Consumption in Touch Project

1.1 Current Consumption of an MCU

Assume a typical application where the CPU is performing a task and goes to Sleep. Here, the current consumed by the CPU can be split into:

- Active current: the current consumed by the MCU when the CPU is active
- Sleep current: the current consumed by the MCU when CPU is asleep

Figure 1-1. MCU Current Consumption



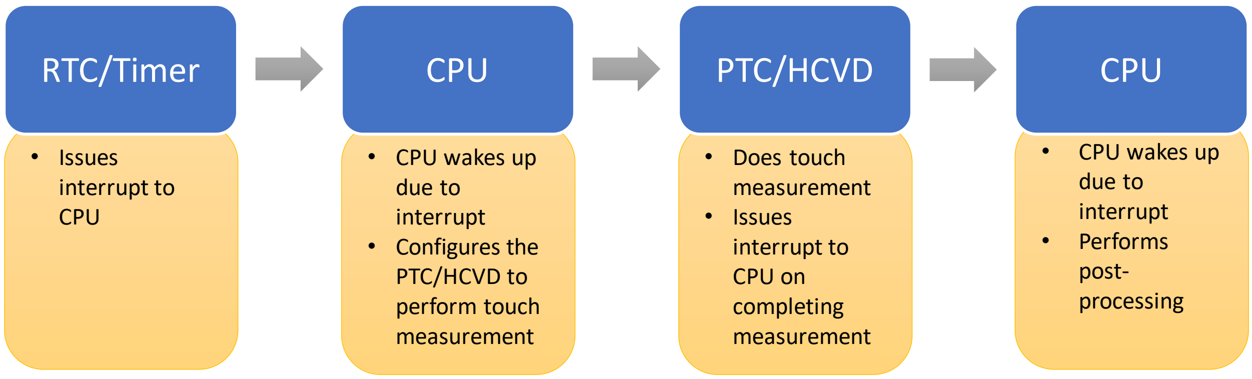
$$\text{Average Current} = \frac{A_{ACTIVE} * T_{ACTIVE} + A_{SLEEP} * (T_{TOTAL} - T_{SLEEP})}{T_{TOTAL}}$$

To reduce the current, the CPU Sleep time needs to be increased. In other words, the high-current consuming peripheral or computation unit of the MCU must be put in Sleep mode for a longer period of time.

1.2 Current Consumption in Active Touch Measurement

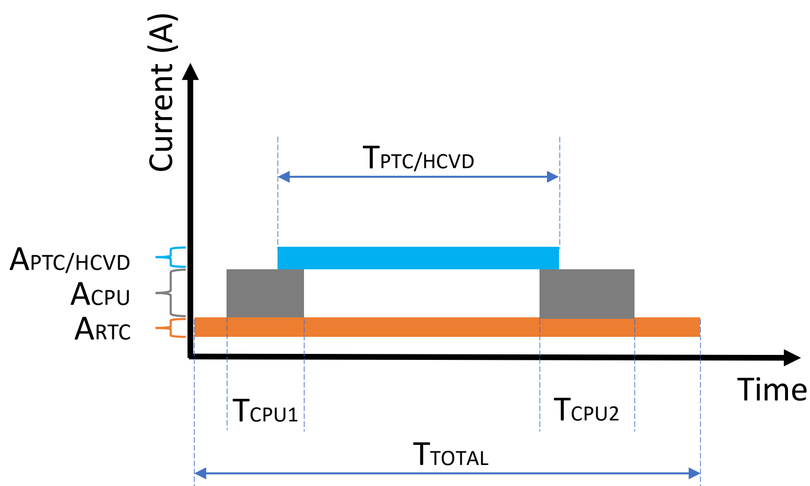
The active touch measurement process starts from the RTC in AVR/SAM devices, and Timer in PIC devices, by sending an interrupt to wake up the CPU. The CPU then configures the PTC in AVR/SAM devices, and HCVD in the ADC module of PIC devices, to perform a touch measurement, as shown in the figure below.

Figure 1-2. Peripheral Flow of Active Touch Measurement



For the given flow, the current consumption is as follows:

Figure 1-3. Current Consumption Based on Enabled Peripheral



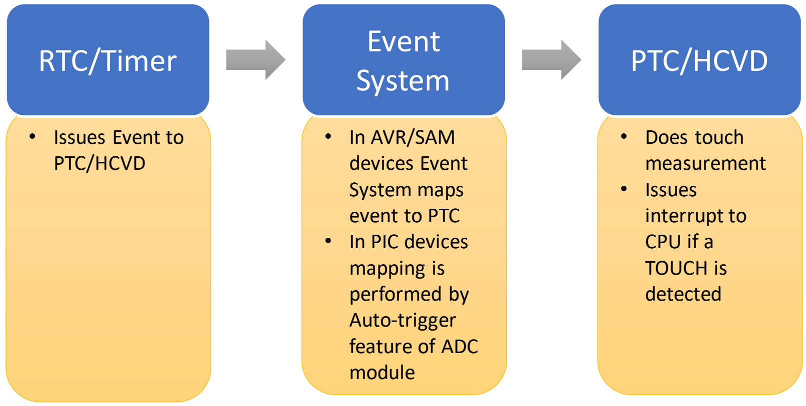
$$\text{Average Current} = \frac{A_{PTC/HCVD} * T_{PTC/HCVD} + A_{RTC} * T_{TOTAL} + A_{CPU} * (T_{CPU1}+T_{CPU2})}{T_{TOTAL}}$$

Here, the current consumed by the CPU is relatively higher compared to that of other peripherals.

1.3 Current Consumption in Low-Power Touch Measurement

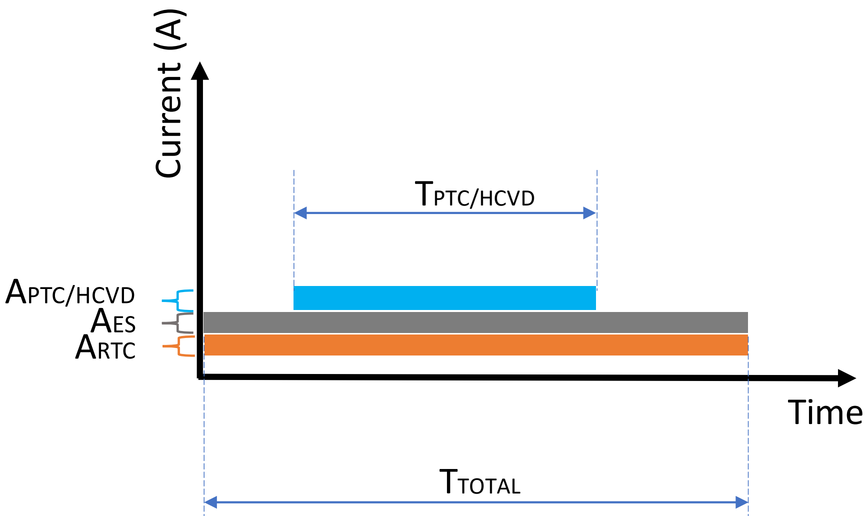
Low-power touch measurement starts from the RTC/Timer, the same as for the active touch measurement process, but, instead of the control being routed through the CPU, it is being handled by the Event System for AVR/SAM devices, and the auto-trigger feature of the ADC module for PIC devices, and finally the touch measurement is performed by the PTC/HCVD (see figure below).

Figure 1-4. Peripheral Flow for Low-Power Touch Measurement



For the given flow, the current consumption is as follows:

Figure 1-5. Current Consumption Based on Enabled Peripheral



$$\text{Average Current} = \frac{A_{PTC/HCVD} * T_{PTC/HCVD} + A_{RTC} * T_{TOTAL} + A_{ES} * T_{TOAL}}{T_{TOTAL}}$$

Here, the current consumed by the Event System is lower compared to that of the CPU, therefore, the average current will be lower as well.

Important: The current consumed by the Event System is constant and it consumes current throughout the device operation. Since the CPU is active for a shorter period of time, there are cases where the average current of the CPU is lower than the average current of the Event System. This occurs in ATtiny81x, ATiny161x and ATTiny321x devices when the low-power measurement interval is longer (64 ms). When the low-power interval is longer, it is better to use normal (active) measurement (with only one sensor enabled) compared to that of Event System-based measurement.

2. Implementing Low-power Touch Measurement

As seen in section 1. Current Consumption in Touch Project, the average current consumption varies between Event System- and CPU-based measurement.

Two types of low-power measurement are possible:

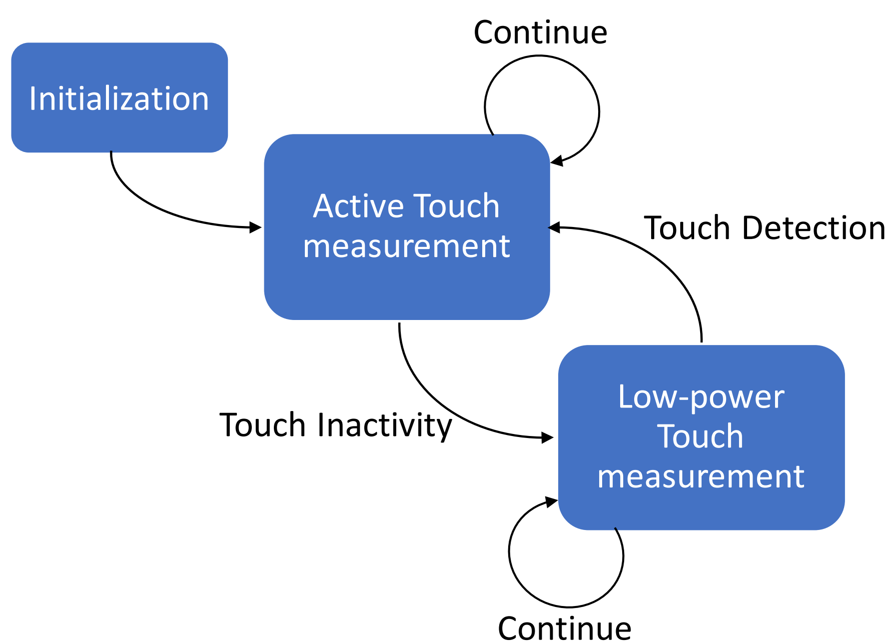
- Event-driven low-power touch measurement
- Software-driven low-power touch measurement

2.1 Event-Driven Low-Power Touch Measurement

Event-driven, low-power touch measurements are performed via the Event System. During inactive periods, when no touch is detected, the low-power touch measurements are started.

During low-power touch measurement, the Event System routes the trigger from RTC to PTC. When a touch is detected, the PTC issues an interrupt to wake up the CPU, as shown in Figure 2-1. The same principle is applicable for PIC devices that have ADC with HCVD. The timer auto-triggers the HCVD and wakes up the CPU upon touch detection.

Figure 2-1. Event-Driven State Machine



During active measurements, the PTC/HCVD performs touch measurement on multiple channels sequentially. The CPU is required in order to configure the touch channels and to retrieve the previous touch results. Also, the library applies a drifting algorithm on the measured data to keep track of the capacitance changes due to variations in the environment (e.g., temperature, humidity etc). CPU is required to run this algorithm.

Since the CPU is not involved in the Event System measurement, configuration of multiple channels and drifting is not possible. To overcome the drifting issue, the state machine of the event-driven touch measurement is modified to accommodate an active measurement that temporarily interrupts the low-power measurement (see Figure 2-2).

During low-power measurement, the timer is configured to trigger an interrupt at intervals of at least two seconds, or more. When this interrupt occurs, the CPU wakes up from Sleep and performs an active measurement. After completing the active measurement, post-processing is performed (drifting too, if required) and the low-power measurement is resumed.

Figure 2-2. Modified Event-Driven State Machine (with drift)

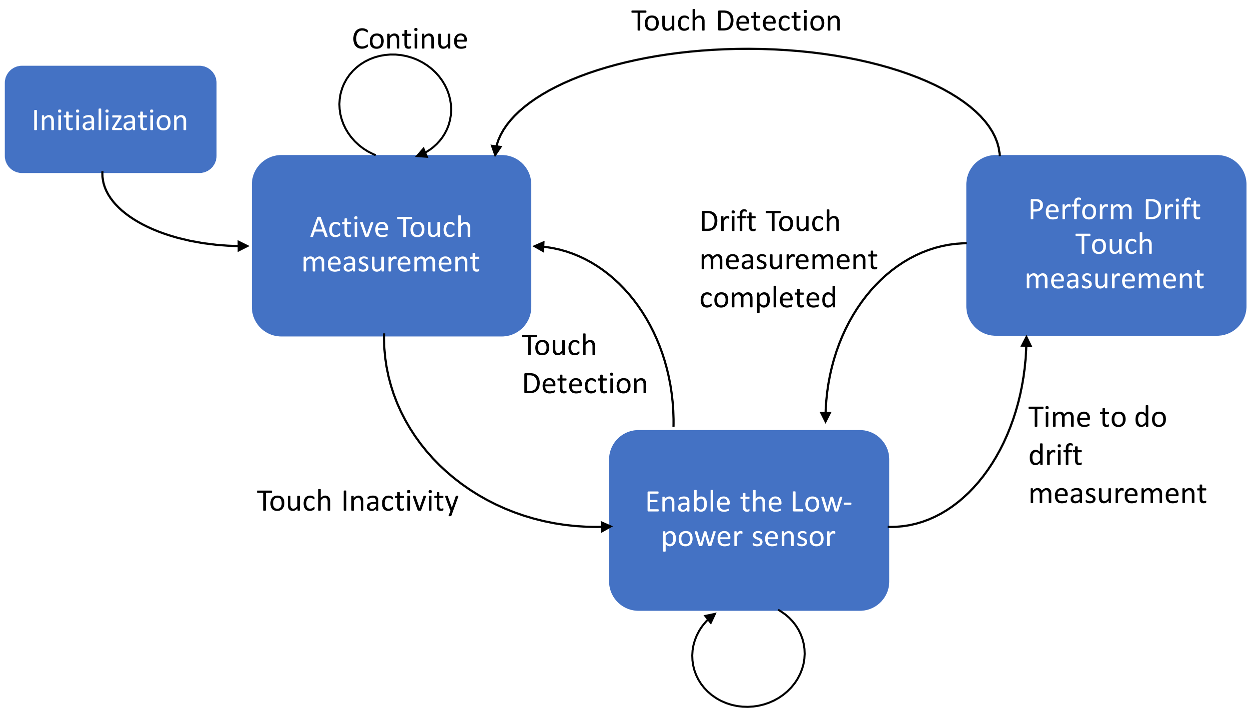
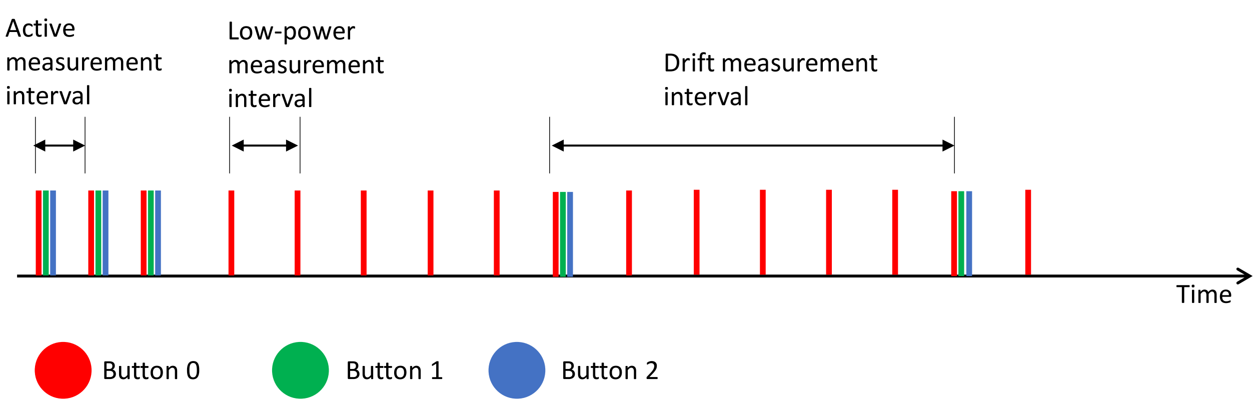


Figure 2-3 presents how the acquisition occurs during the event-driven measurement (with drift).

Figure 2-3. Event-Driven Sensor Measurement



While in Active mode, three sensors are scanned at a short interval. In Low-Power mode, only one sensor is being scanned, but at a longer interval. In addition to the low-power measurement of one channel, one active measurement is performed every drift interval.

Important: The drift measurement scanning interval should be set longer than the scanning interval of the low-power measurement to reduce the average current consumption. Frequent wake-up (less than 2s) to perform drifting is not required for many applications.

2.2 Software-Driven Low-Power Touch Measurement

Software-driven, low-power touch measurements are started by the CPU. If no touch is detected for a certain period of time, low-power measurements are started. During these low-power measurements, each low-power node is configured in a round-robin method. When one node is measured, all other nodes are disabled. Also, these measurements are performed at a longer interval than that of active measurements, to save power.

Figure 2-4. Software-Driven State Machine

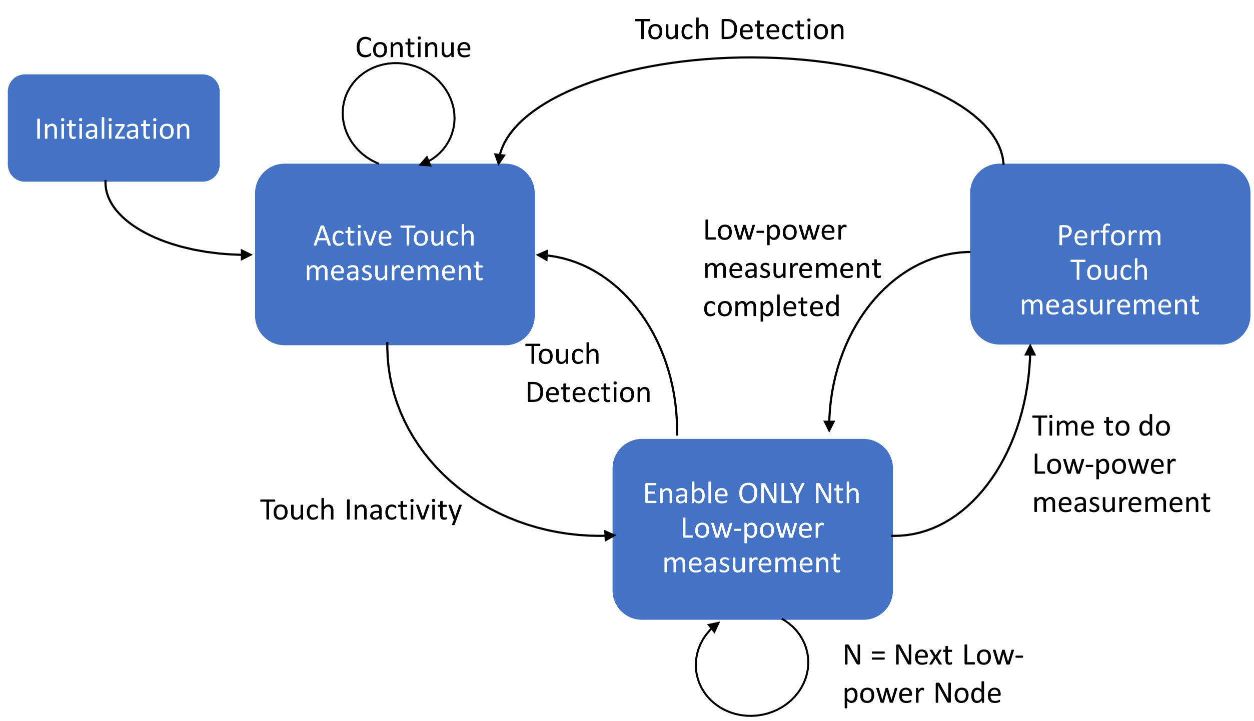
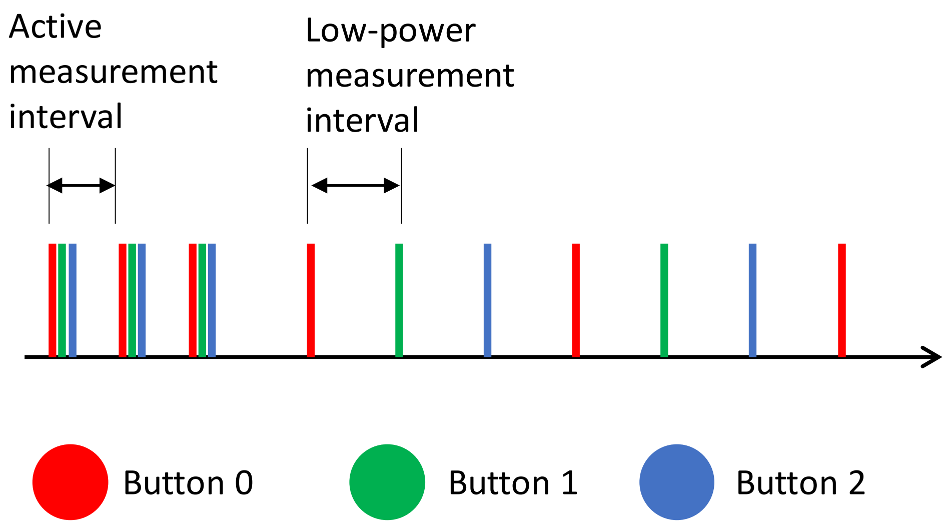


Figure 2-5 represents how the acquisition occurs during software-driven measurement (with drift).

Figure 2-5. Software-Driven Sensor Measurement

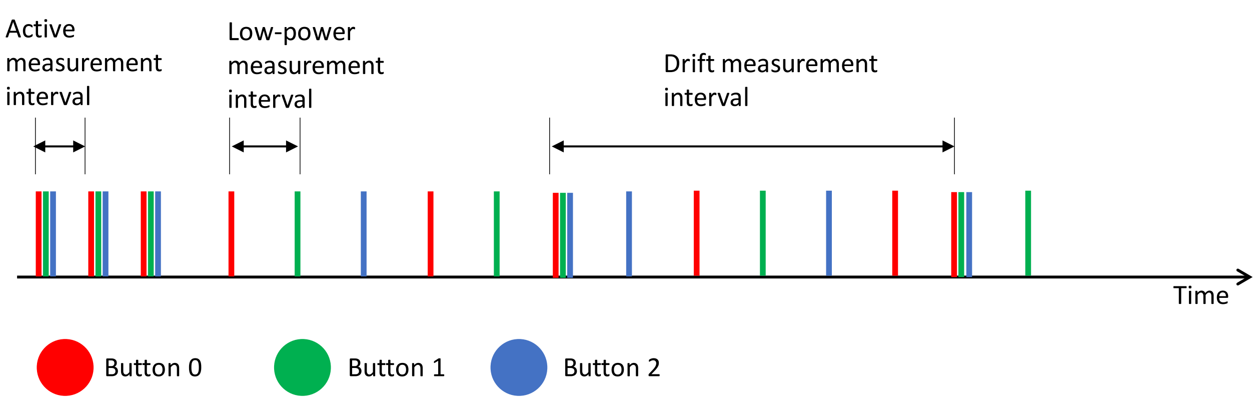


While in Active mode, three sensors are scanned at a short interval. In Low-Power mode, only one sensor is being scanned, but at a longer interval. Since the CPU is involved in touch measurements, no special care is needed to perform drift measurement.

It is possible to configure all the nodes as low-power nodes. However, the number of nodes configured as low-power nodes and the low-power measurement interval will decide the measurement interval for each node. For example, if the low-power measurement interval is 100 ms, and if five nodes are configured as low-power node, then each node is scanned at every 500 ms.

There is the possibility for only a few of the sensors to be configured as low-power sensors in Software-Driven mode. During this condition, the drifting is performed the same as in Event-Driven mode, as shown in the following figure:

Figure 2-6. Software-Driven Sensor Measurement (with drift)



3. Low-Power Sensor Configuration

Any sensor can be configured as a low-power sensor. The following subsections cover the typical application scenarios for a low-power sensor.

3.1 Power-on Key

This is the most basic configuration for a low-power sensor implementation. One key out of all the available keys in a touch panel is configured as the low-power sensor. This acts as a power-on key for the entire touch panel.

Figure 3-1. One Button as the Low-Power Sensor

3.2 Lumped Mode

PTC features Lumped mode configuration that allows the combining of multiple Y-lines (Self Capacitance) or multiple X- and Y-lines (Mutual Capacitance) to form a single sensor. This feature allows combining multiple physical sensors and configures them as a single sensor, called Lumped Sensor.

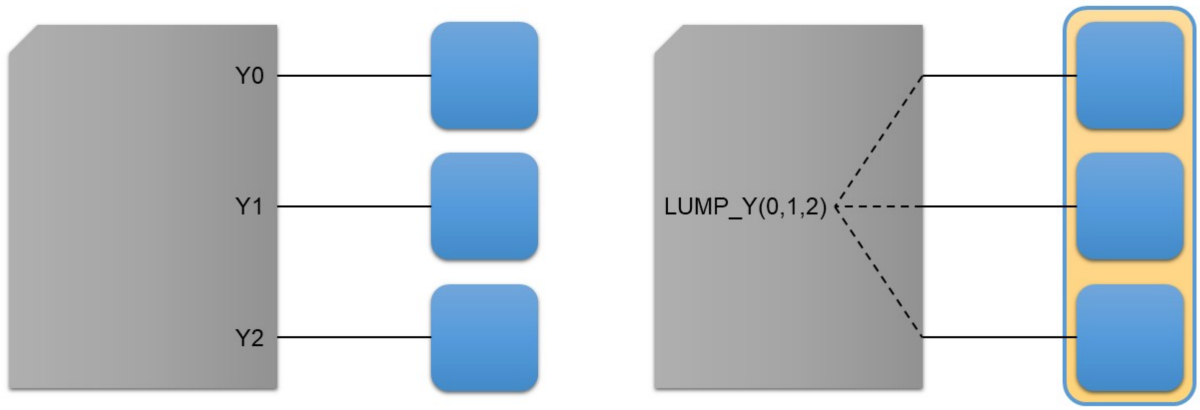
The use of Lumped mode improves power consumption and response time. In applications with a large number of keys, the sensors can be arranged in groups to form multiple lumped sensors. Scanning can be performed only on the lumped sensors. When one of the lumped sensors shows touch detection, only the keys within that lumped sensor are individually measured to determine which key is actually touched, thus improving the efficiency of the system, since fewer measurement cycles are needed, compared to the number of cycles it takes to scan all the keys.

Important: PTC has restrictions on the total sensor capacitance that it can handle. If the sensor capacitance is more than the allowed limits, it would saturate the measurement and the sensor might not work as expected. In general, lump sensor capacitance would be closer to the sum of individual buttons capacitance. Therefore, lumping a large number of buttons might result in saturation. The user may need to try different combinations to find the optimum lump configuration.

3.2.1 Lumped Sensor in Self Capacitance

In a self-capacitance design, the user needs to configure the Y-lines that are combined together to form a lumped sensor. In this example, three Y-lines are combined in a system to create one lumped sensor.

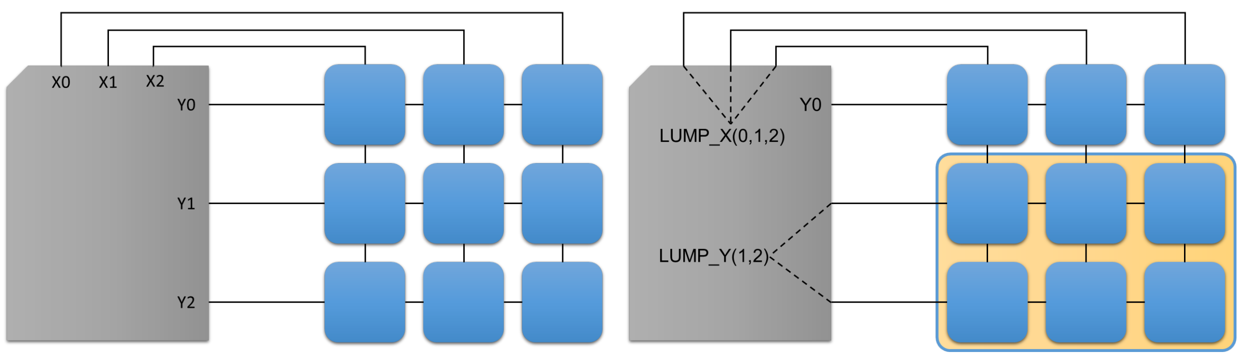
Figure 3-2. Self-Capacitance Lumped Mode



3.2.2 Lumped Sensor in Mutual Capacitance

In a mutual capacitance design, the user needs to configure the X-lines and the Y-lines that are combined together to form a lumped sensor. In this example, the system has 3X and 3Y lines, but only 3X and 2Y lines are combined to create one lumped sensor.

Figure 3-3. Mutual-Capacitance Lumped Mode



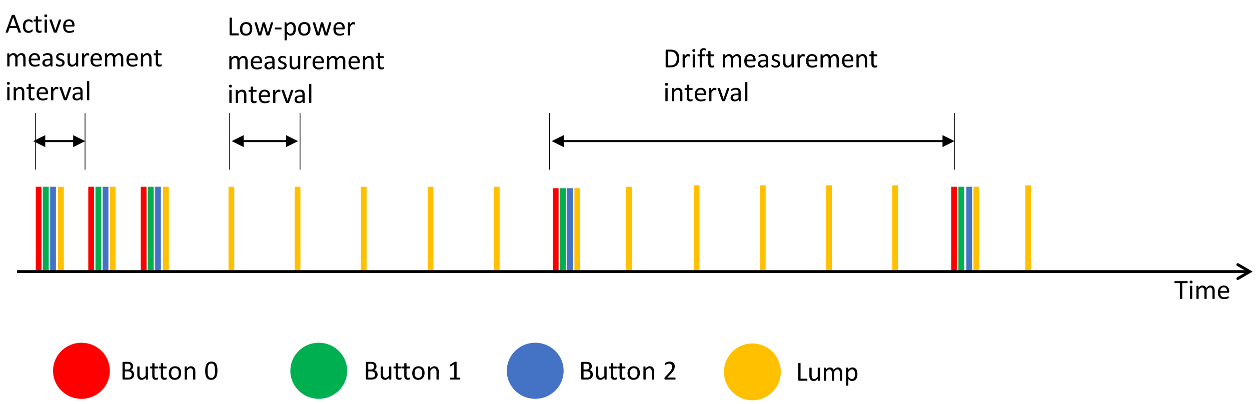
3.2.3 All Keys Lumped Together

Lumped mode configuration in the PTC allows to combine multiple sensors as one. By using this feature, all the sensor electrodes can be combined together to form a big sensor. This lumped sensor can be configured as a low-power sensor. Touching any key in the panel would wake up the device.

Figure 3-4. All Buttons Lumped and Configured as Low-Power Sensor

Touch measurement would happen as shown in Figure 3-5. The measurement of the lump sensor during Active mode is optional. If the lump sensor is not measured during Active mode, it should be calibrated properly before being configured as a low-power sensor.

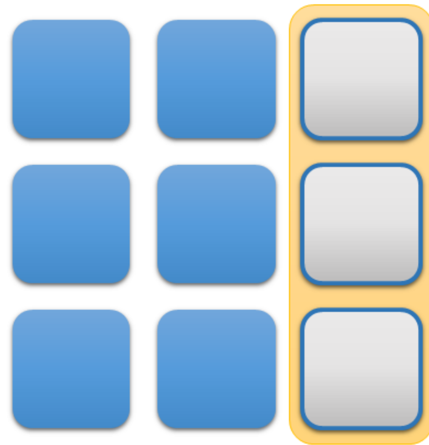
Figure 3-5. Lumped Sensor Configured as Low-Power Sensor



3.2.4 Some Keys Lumped Together

Instead of all keys being configured as one lumped sensor, only some of the keys can be configured as a lumped sensor. This allows the user to limit the wake-up region on the touch panel to a few sensors.

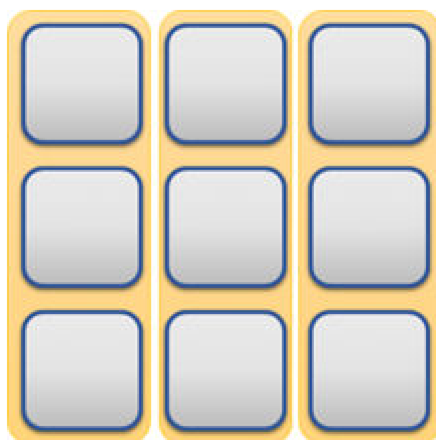
Figure 3-6. Custom Group of Keys Lumped and Configured as Low-Power Sensor



3.2.5 Group of Lumped Keys

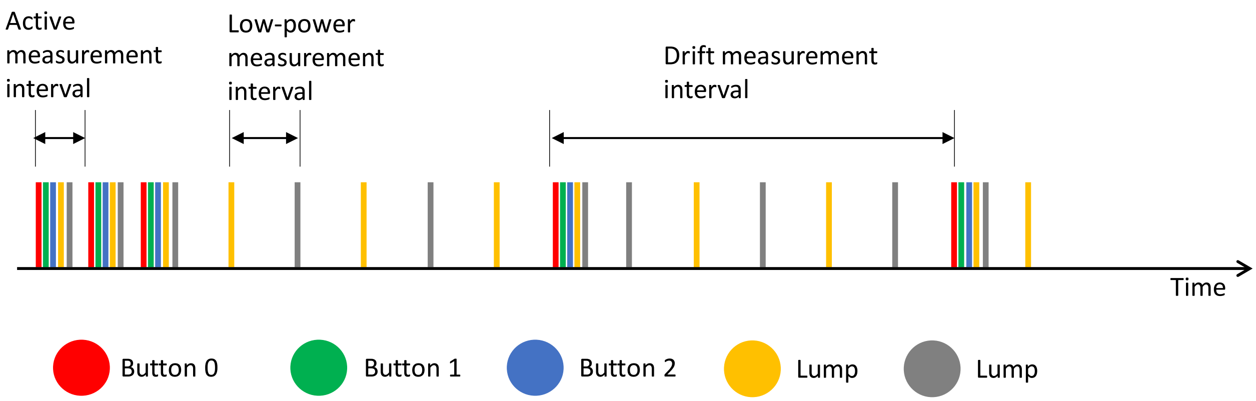
Instead of all the keys being configured as one lumped sensor, multiple lumped sensors can be formed. This allows the user to limit the lumped sensor capacitance, and also allow the touch of multiple keys. This is possible only with software-driven touch measurement.

Figure 3-7. Multiple Buttons Lumped as Groups and Configured as Low-Power Sensors



It is possible to form multiple lump sensors to avoid saturation and perform low-power measurement using multiple lumps, as shown in Figure 3-8.

Figure 3-8. Multiple Lumped Groups Configured as Low-Power Sensors



3.2.6 Slider and Wheel as Low-Power Sensors

Low-power sensor configuration only allows the use of one X- and Y-channel. Thus, in principle, a slider or a rotor cannot be configured as a low-power sensor, as they are composed of multiple sensor channels. However, all the channels of a slider or rotor can be configured as a single lumped sensor, which can then be configured as a low-power sensor.

4. Optimizing Low-Power Measurement

Table 4-1. Software Driven or Event Driven

Parameter	Should Event Driven Be Used?	Should Software Driven Be Used?
Short Low-Power Interval?	Yes	No
Multiple Sensor Measurement	No	Yes
Low-Power Measurement Interval Longer than 64 ms in ATtiny?	No	Yes

Table 4-2. Optimizing the Parameters that Affect Low-Power Measurements

Parameter	Description
`QTM_LOWPOWER_TRIGGER_PERIOD`	Low-power measurement interval. • Higher the period, lower the power consumption. • Higher period results in slower response.
`DEF_TOUCH_TIMEOUT`	Touch inactivity time. • This time defines the waiting time to switch from Active mode to Low-Power mode.
`DEF_TOUCH_DRIFT_PERIOD_MS`	Drift measurement period. • Higher the period, lower the power consumption. • Higher period can be used where the change in environmental conditions occurs less often.

5. Application Consideration

It is recommended to take in consideration the low-power requirements during the initial state of the project - even before finalizing the MCU. There are various factors that affect low-power measurement, as described in Table 5-1 .

Table 5-1. Factors That May Affect Low-Power Measurement

Factors	How Do They Impact Current Consumption?
MCU	In traditional MCUs, the clock for the CPU and peripherals is shared. MCUs provide the option to control the clock of the device as well as peripherals. Advanced MCU provides the option to control the clock for each peripheral and the option to provide a separate clock for the CPU and peripherals. If current consumption is a critical requirement, the user may choose the one where the clock can be optimized at the peripheral level.
Operating Voltage	Higher voltage consumes more current and vice-versa. So, operate the device at the lowest possible voltage to achieve low-power numbers.
Clock Frequency	Using a higher clock frequency for the CPU and peripherals consumes more current. It is not ideal to operate the CPU at the lowest possible clock frequency. This will increase the code execution time and consequently the post-processing time (for touch applications). Therefore, optimum clock frequency must be chosen to achieve low-power.
Unused Peripherals	Configure the unused peripherals in Low-Power mode. If possible, disable the clock for peripherals before going to Sleep (if they do not need to be active during Sleep). Advanced MCUs provide the option to automatically disable the clock for peripherals during Sleep.
Unused Pins	Do not connect anything to unused pins in hardware. Connecting to a ground or pull-up resistor can lead to leakage through that path. If it is not connected in the hardware, configure the unused pins as output-low in the firmware.
Debug Information	Debug information keeps the CPU and peripherals active for a considerable amount of time. Disable debug information when not required.

6. Current Consumption

Table 6-1. ATtiny3217 Power Numbers

1 Key/3.3V/CPU @ 8 MHz/PTC @ 4 MHz/CSD = 4, Drift wake-up = 2s, Driven shield = Disabled			
Low-Power Scan Rate (ms)	Filter Level		
	x4	x16	x64
256	1.9	3.64	11.9
128	2.46	5.56	20.6
64	3.65	7.48	44.5
32	6.02	16.2	74.5
16	10.6	30.5	167.2
4	37.8	114.9	573

Table 6-2. SAML10 Power Numbers

1 Key/3.3V/CPU @ 12 MHz/PTC @ 4 MHz/CSD = 4, Drift wake-up = 2s, Driven shield = Disabled	
Low-Power Scan Rate (ms)	Filter Level
	x16
256	2.373
128	2.983
64	4.063
32	5.96
16	9.59
8	16.8

7. Using START to Configure Low-Power Sensors

Refer to the following link for help in configuring low-power sensors:

- http://www.microchipdeveloper.com

8. Revision History

Doc Rev.	Date	Comments
B	2/2019	Updated document title
A	10/2018	Initial document release. Microchip DS00002812A replaces Atmel 42441A (AT12405-042015).

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	T	= Tape & Reel
Temperature Range:	I	= -40°C to +85°C (Industrial)
	E	= -40°C to +125°C (Extended)
Package:	AA	= Package AA
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