
AT13764: QTouch Scroll Sensor for Wearables

APPLICATION NOTE

Introduction

Smart wearable devices such as in-ear headphones, fitness bands, and watches incorporate capacitive touch interface for user interactions. These devices are small in size and allow only limited space to design a user interface. Wearable devices can include a single touch button to turn ON/OFF a display or multiple touch buttons for a detecting scroll or swipe gesture.

It is a challenge to design capacitive touch scroll sensor in a limited space with the desired tap and scroll functionality. This application note provides guidelines to design a capacitive touch based scroll sensor. The associated package includes hardware design files and demo firmware supporting tap and scroll detection using Atmel® | SMART SAM D10 MCU and PTC QTouch® Library.

Features

- Scroll sensor design
 - with four buttons
 - with five buttons
- Tap and scroll detection
- Design challenges

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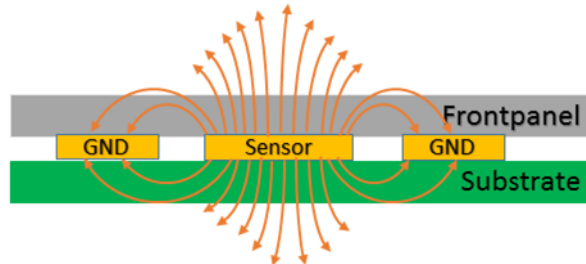
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1. Acquisition Method and Sensor Design

Atmel's Peripheral Touch Controller (PTC) supports both self-capacitance and mutual-capacitance sensors for Button, Slider, and Wheel design.

In self-capacitance method, the electric fields emit from sensor electrode in all directions. Any change in sensor electrode size impacts the coupling between electric fields and finger, affecting touch sensitivity.

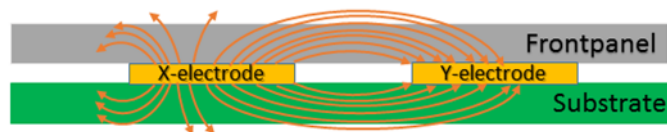
Figure 1-1. Field Penetration in Self-capacitance Sensor Design



In mutual-capacitance method, the electric field traverse from X electrode (transmitter) to Y electrode (receiver) of a sensor. The electric field is well organized and is confined within the sensor electrode.

In co-planar design, touch sensitive area is the gap between X-Y interlocking fingers of a sensor electrode. The number of X-Y fingers within a sensor electrode impacts field density. In turn, this affects mutual capacitance between X-transmitter and Y-receiver and touch sensitivity.

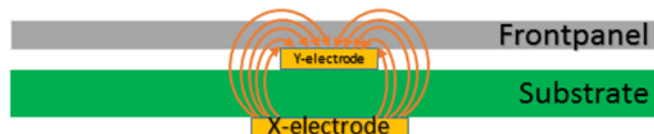
Figure 1-2. Field Penetration in Mutual-capacitance Coplanar Sensor Design



Co-planar design has better control over the electric field as field penetration can be controlled by adjusting the gap between XY fingers.

In mutual-capacitance, Flooded-X sensor design, X-electrode (on bottom layer) completely shields the Y-electrode (on top layer) from the back side. The electric field from X-electrode penetrate through PCB substrate and reach top surface of the front panel. Thickness of substrate and frontpanel impacts field penetration and touch sensitivity.

Figure 1-3. Field Penetration in Mutual-capacitance Flooded-X Sensor Design



The sensitivity factor estimation for specific front panel and substrate determines the projection of field penetration through front panel. To control the field penetration, thickness of front panel and substrate must be varied. The field penetration is better for front panels that use material with higher dielectric constant or have less thickness. In Flooded-X design, it is hard to control the field penetration as the thickness of PCB substrate must be varied.

Due to compact design of wearable devices, scroll sensor implementation requires smaller touch buttons that must be located very close to each other. The mutual-capacitance coplanar sensor design is more suitable for implementing a scroll sensor. Since the influence of approaching finger on adjacent touch buttons is very minimal. This helps to avoid false detections due to nearby finger interactions.

2. Design Guidelines

The scroll sensor in wearable devices typically performs the following scroll events:

- Left to right
- Right to left
- Up to down
- Down to up

The area available for scroll sensor depends on the product design. Typically 12 to 16sq.mm space is available for a scroll sensor on most wearable devices. To detect the direction of a scroll event, scroll sensor is designed with multiple discrete touch buttons.

The standard recommendation is to design the touch button slightly larger than size of a normal finger i.e. approximately 12mm. Since the available area on wearables for scroll sensor is very less, touch buttons must be smaller than a typical touch button.

Depending on the available area, the scroll sensor can be constructed. The following section describes two approaches using either four touch buttons or five touch buttons.

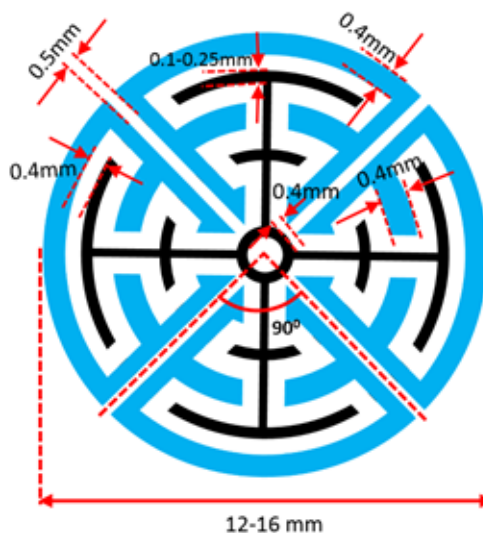
2.1. Scroll Sensor with Four Buttons

This design allows construction of larger touch buttons within the available area for scroll sensor. This design uses four coplanar touch buttons with four X-lines and one Y-line. These buttons are designed in the form of a quadrant and arranged together in circular shape.

For smaller touch buttons, less number of XY fingers can be implemented using the T/2 (T is front panel thickness) guideline provided in [Buttons, Sliders and Wheels Sensor Design Guide](#). The buttons must have more XY fingers to achieve good sensitivity. In such cases, adjust the design guidelines by reducing the separation between XY fingers, X-finger thickness and thickness of X-border.

The dimension and separation guidelines for a scroll sensor implementation with four buttons are specified in the following figure.

Figure 2-1. Dimensions of Scroll Sensor Design with Four Buttons



- Thickness of Y-finger should be between 0.1mm and 0.25mm

- Thickness of X-finger should be 0.4mm
- XY finger separation should be 0.4mm
- Thickness of X-border should be 0.4mm
- Separation between two touch buttons should be 0.5mm
- Diameter of scroll sensor should be in the range of 12 to 16mm

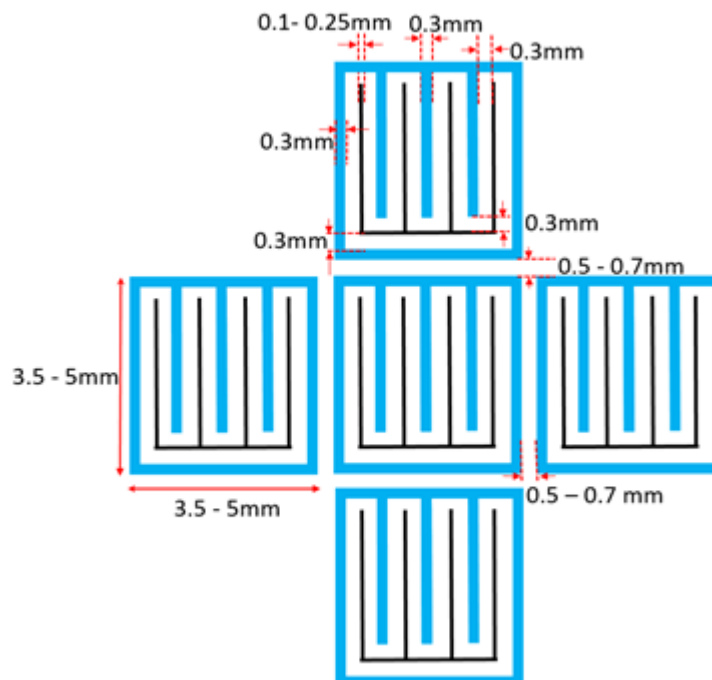
Note:

1. The scroll sensor designs with diameter higher than 16mm, allows to extend dimension of each touch button. This allows to add additional XY fingers within each touch button.
2. For extremely large scroll sensor designs (i.e. diameter higher than 25mm), the typical touch button design guidelines are applicable.

2.2. Scroll Sensor with Five Buttons

In this design the scroll sensor requires five coplanar touch buttons. To implement five buttons, the design can use either five X-lines and one Y-line or three X-lines and two Y-lines. These buttons are arranged in form of a right angle cross. To increase XY interdigitation within the button, reduce the gap between XY fingers, X-finger thickness, and X-border thickness. The dimension and separation guidelines for a scroll sensor implementation with five buttons are specified in the following figure.

Figure 2-2. Dimensions of Scroll Sensor Design with Five Buttons



- Thickness of Y-finger should be between 0.1mm and 0.25mm
- Thickness of X-finger should be 0.3mm
- XY finger separation should be 0.3mm
- Thickness of X-border should be 0.3mm
- Separation between two touch buttons should be 0.5 - 0.7mm
- Dimension of each button should in the range of 3.5mm to 5mm

Note:

1. The larger scroll sensor designs allows to extend dimensions of each touch button. This allows to add additional XY fingers within each touch button.
2. For extremely large scroll sensor designs (i.e. dimension higher than 30mm), the typical touch button design guidelines are applicable.

2.3. Front Panel Thickness

Touch buttons in the scroll sensor are usually smaller than 5mm and can support up to 2mm thick front panel. The recommendation is to choose a thinner front panel. The front panel material must have good dielectric properties. Typically, the dielectric constant must be greater than 3. Refer Section 2.3.3 of [Buttons, Sliders and Wheels Sensor Design Guide](#) for more information on recommended front panel materials.

3. Demo Firmware

The demo firmware is based on the Atmel ATSAM D10 Microcontroller using PTC QTouch Library. The firmware is tested with ATSAM D10 Xplained Mini evaluation kit and an externally connected scroll sensor.

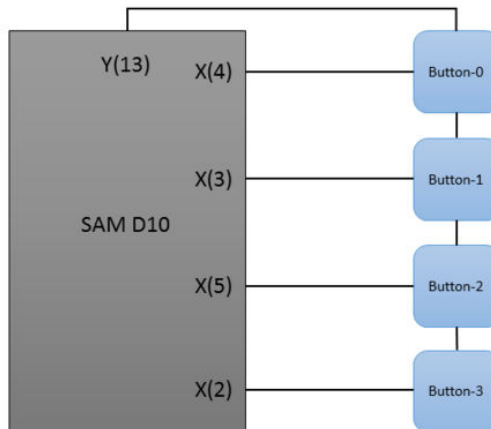
It consists of:

1. Mutual capacitance sensor configuration.
2. Tap and scroll detection.
3. Low power operation with lumped configuration.
4. Application Flow.
5. QDebug communication for analyzing touch data using the Atmel QTouch Analyzer tool.

3.1. Sensor Configuration

In the demo firmware, four discrete mutual capacitance buttons are configured for the scroll sensor implementation. The following figure shows X- and Y-line combination.

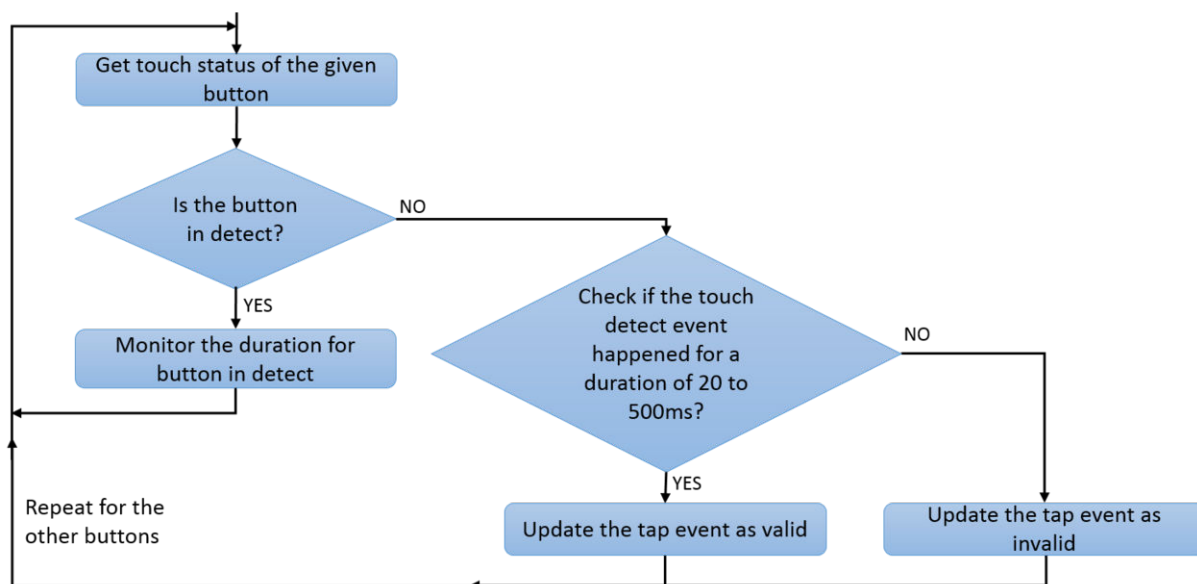
Figure 3-1. PTC Configuration for the Buttons



3.2. Tap and Scroll Detection

The demo firmware detects single tap event on the configured buttons. The tap detect flag is set to a valid tap event. The following diagram shows application flow of the tap logic implementation.

Figure 3-2. Single Tap Code Flow



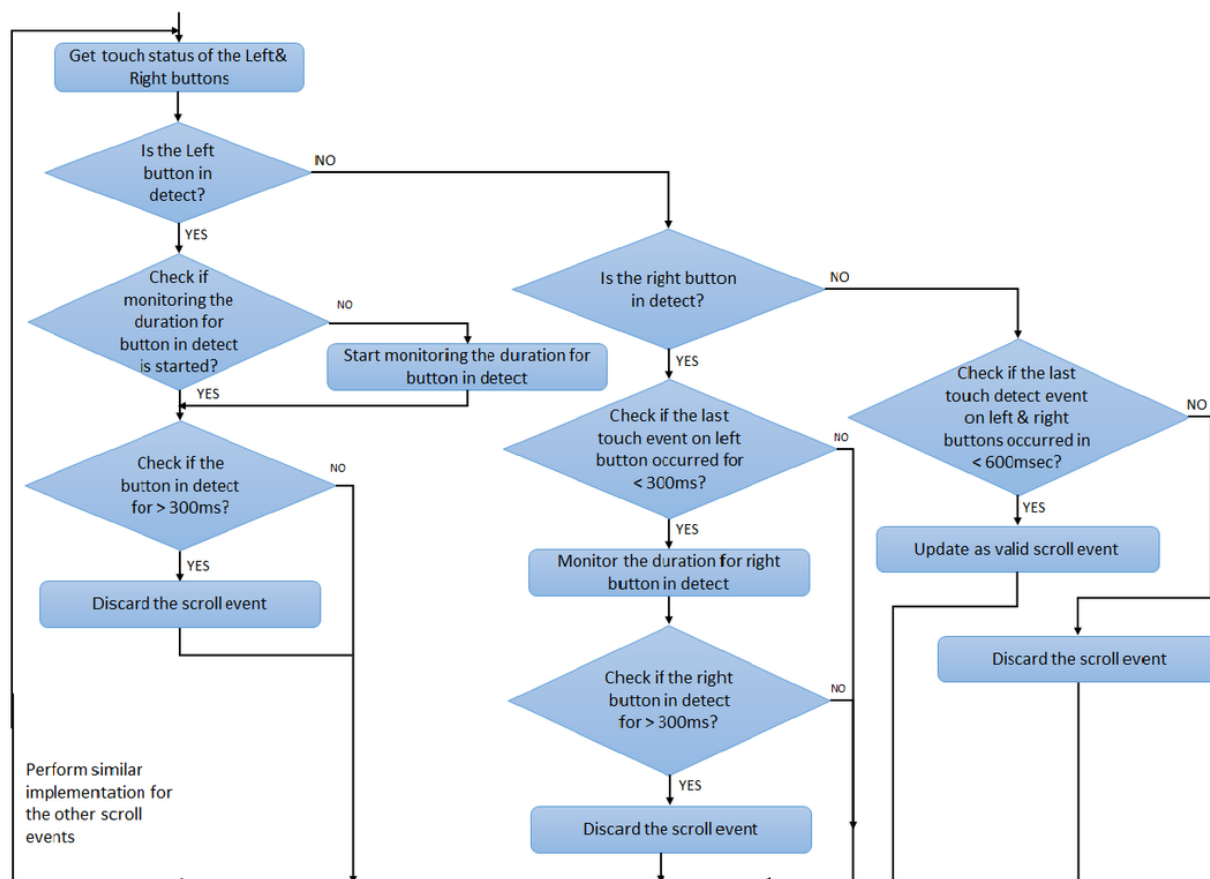
After completion of touch measurement, the application verifies if any touch button is in detect. If the button is in detect state continuously for a duration of 20 to 500 milliseconds, then the tap event is considered as valid. After a successful tap event detection, tap detect flag is set by the application.

The following scroll events are implemented in the demo firmware:

- Left to right
- Right to left
- Up to down
- Down to up

The scroll detect flag is set on detection of a valid scroll event. The following figure shows application flow of left to right scroll detection. After completing the touch measurement, the application verifies if the left and right buttons are sequentially detected within a time frame of 600 milliseconds. On successful detection of scroll event, the application sets the left to right scroll flag.

Figure 3-3. Left to Right Scroll Code Flow

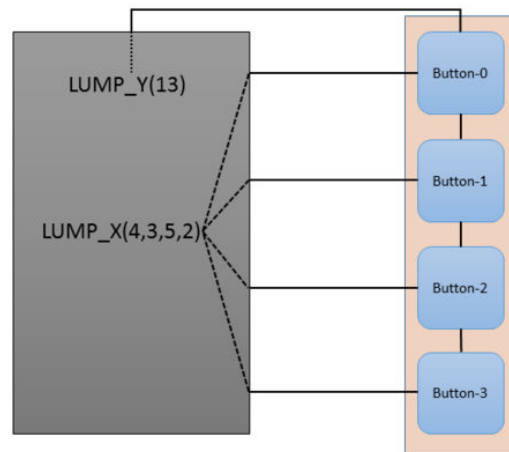


For detecting the other scroll event, similar implementation can be used with the corresponding button combinations.

3.3. Low Power Operation

Firmware configures the four touch buttons as a lumped sensor. The lumped configuration feature of PTC QTouch Library allows to combine multiple X- and Y-lines to form a single lumped sensor. The following figure shows the lumped configuration. For more details on lumped configuration, refer to application note [QTouch Smart Scan with Lumped Mode](#).

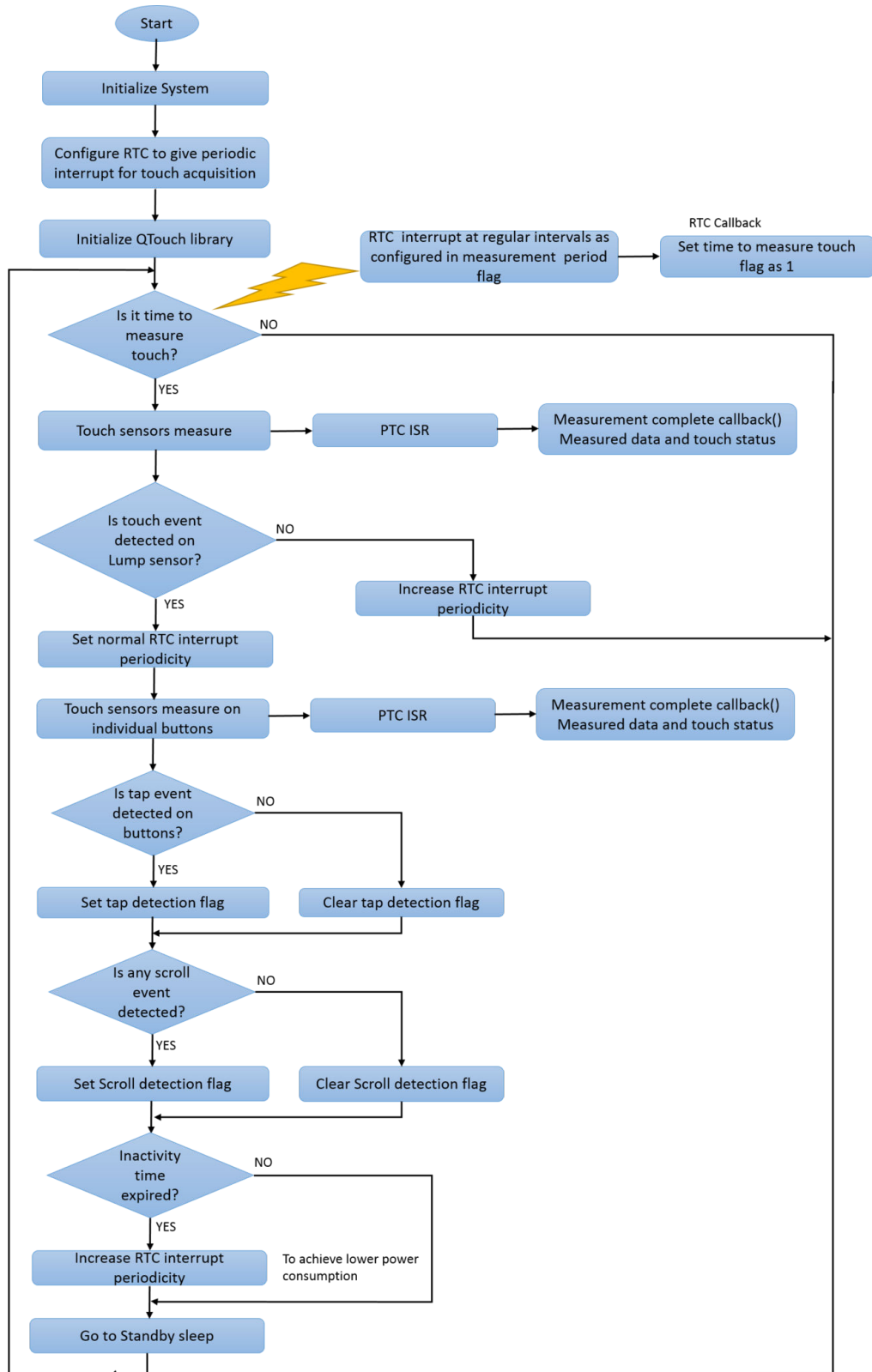
Figure 3-4. Lump Configuration



The MCU device periodically performs touch measurement on the lumped sensor. If touch is detected on the lumped sensor, the firmware will reconfigure the lumped sensor as four buttons and start detecting tap and scroll events. The touch measurement is now performed at a faster scan rate of 20 milliseconds. When there is no activity for 5 seconds, the MCU enters standby sleep mode. It wakes up periodically on a RTC event and performs a touch measurement. Higher scan rate (approximately 250 milliseconds) is set to reduce power consumption.

3.4. Application Flow

Figure 3-5. Application Flow



4. Design Challenges

Scroll sensor for wearable applications requires careful design, placement of touch buttons. The firmware must incorporate the desired functionality for scroll events. The scroll sensor design should address the following challenges.

- **Limited space** - Use small mutual capacitance buttons with appropriate number of X-Y fingers to achieve optimal touch sensitivity.
- **Sensor placement** - Strategic placement of buttons to achieve appropriate scroll operation and minimize the impact of finger interactions over adjacent buttons.
- **Scroll speed** - Time frame set to identify a valid scroll event from the reported touch is important for reliable scroll sensor operation. This time period can be set in the firmware and tuned for the desired scroll speed.
- **Finger orientation and fat finger operation** - The finger can be swiped in any orientation. A vertical finger swipe creates smaller area of contact, whereas a horizontal thumb swipe creates larger area of contact. In this scheme, if the area of contact is higher then it could lead to simultaneous touch of multiple buttons, preventing the firmware to detect the correct scroll event. This can be mitigated by applying an intelligent overlay design for scroll sensor as per the desired finger orientation.

5. Reference

[1]. QTAN0079 Buttons, Sliders and Wheels - Sensor Design Guide - www.atmel.com/images/doc10752.pdf

[2]. AT13323 QTouch Smart Scan with Lumped Mode - http://www.atmel.com/images/atmel-42533-qtouch-smart-scan-with-lumped-mode_applicationnote_at13323.pdf

6. Revision History

Doc Rev.	Date	Comments
42593A	01/2016	Initial document release.



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