Atmel

APPLICATION NOTE

Atmel AT02259: QTouch Schematic and Layout Checklist

Atmel QTouch

Features

- Checklist for reviewing Atmel® QTouch® schematics and PCB layouts

Introduction

Designing a capacitive touch interface is an involved process that requires myriad factors to be considered. These interfaces frequently need to co-exist with other complex systems, which may affect its performance.

Since there are several considerations to be made while designing Atmel QTouch solutions it is important to know these for overall improvement of the design. The purpose of this document is to provide a checklist that can be used to review the schematic and PCB layout of these designs. This includes separate checklists for designs using Atmel QTouch, QTouchADC and QMatrix. This document only highlights the most important aspects and should not be considered as a substitute for QTAN0079 Buttons, Sliders and Wheels – Sensor Design Guide.

42094B–QTOUCH–07/2013

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1. Abbreviations and Definitions

The following is a list of terms, which will be used throughout the document.

- **Acquisition**: A single capacitive measurement process
- **Atmel QTouch Library**: The set of libraries for the touch sensing technologies offered by Atmel (*QTouch*, *QTouchADC* and *QMatrix*)
- **AVR®**: Refers to a device in the Atmel tinyAVR®, megaAVR®, XMEGA® and UC3 microcontroller (MCU) family
- **Button**: It is a zero dimensional sensor used to implement On/Off digital sensors, and is composed of a single channel. It is also known as a *Key*
- **Channel**: A channel is a logical group of pins used to perform the touch acquisition measurement. It can be composed of a single pin (QTouchADC), a pair of pins (QTouch) or a matrix of pins (QMatrix)
- **Charge Cycle Period**: It is the width of the charging pulse applied to the channel sampling capacitor
- **Charge Share Delay**: It is the duration when charge is shared between Cs and Cs in QTouchADC
- **Ct**: The capacitance caused by a finger touch over the Sense Electrode
- **Cx**: The self-capacitance or mutual-capacitance of the Sense Electrode
- **Dwell Cycle**: In a QMatrix acquisition method, the duration in which charge coupled from X to Y is captured
- **Port Pair**: A combination of SNS port and SNSK port to which sensors are connected in QTouch technology. The SNS and SNSK ports used in a port pair can be located in the same AVR Port (8 pins for 4 sensors), or they may be on two different AVR Ports (8+8 pins for 8 sensors)
- **QMatrix**: A type of capacitive touch sensing technology that uses the mutual capacitance between two electrodes. Each channel has a drive electrode (*X Electrode*) and a receive electrode (*Y Electrode*)
- **QTouch**: A type of capacitive touch sensing technology that uses the self capacitance of an electrode
- **QTouchADC**: A type of capacitive touch sensing technology that uses the self capacitance of an electrode connected to a single pin (ADC input)
- **Rs**: Series resistor on the sense line. This should be in the charging path of Cs
- **Sense Component**: The set of components connected to the MCU, which are used to perform a touch measurement
- **Sense Electrode**: Electrodes are typically areas of copper on a printed circuit board. An electrode or a pair of electrodes used to detect a finger touch
- **Sense Line**: Any track that connects the Sense Electrode to Sense Components
- **Sensor**: A channel or group of channels used to form a touch sensor. The three types of sensors are Buttons, Sliders and Wheels
- **Slider**: It is a one dimensional sensor used to implement linear position sensors. A group of channels forms a Slider, which is used to detect the linear position of touch. A QTouch Slider is composed of three channels. A QMatrix Slider can be composed of 3 to 8 channels
- **SNS Pin**: 'Sense' pin connected to the sampling capacitor (Cs) in QTouch technology
- **SNSK Pin**: 'Sense Key' pin connected to the electrode through a series resistor (Rs) in QTouch technology
- **Wheel**: It is a one dimensional sensor used to implement angular position controls. A QTouch Wheel is composed of 3 channels. A QMatrix Wheel can be composed of 3 to 8 channels. It is also know as a *Rotor*
- **X Line**: The Sense Line connected to the X Electrode in QMatrix Technology
- **Y Line**: The Sense Line connected to the Y Electrode used in QMatrix Technology

2. Schematic Review

This chapter consists of the checklists used for reviewing the schematics of Atmel QTouch, QTouchADC and QMatrix implementations. There are sections corresponding to each individual technology. Section 2.4 General is applicable to all technologies.

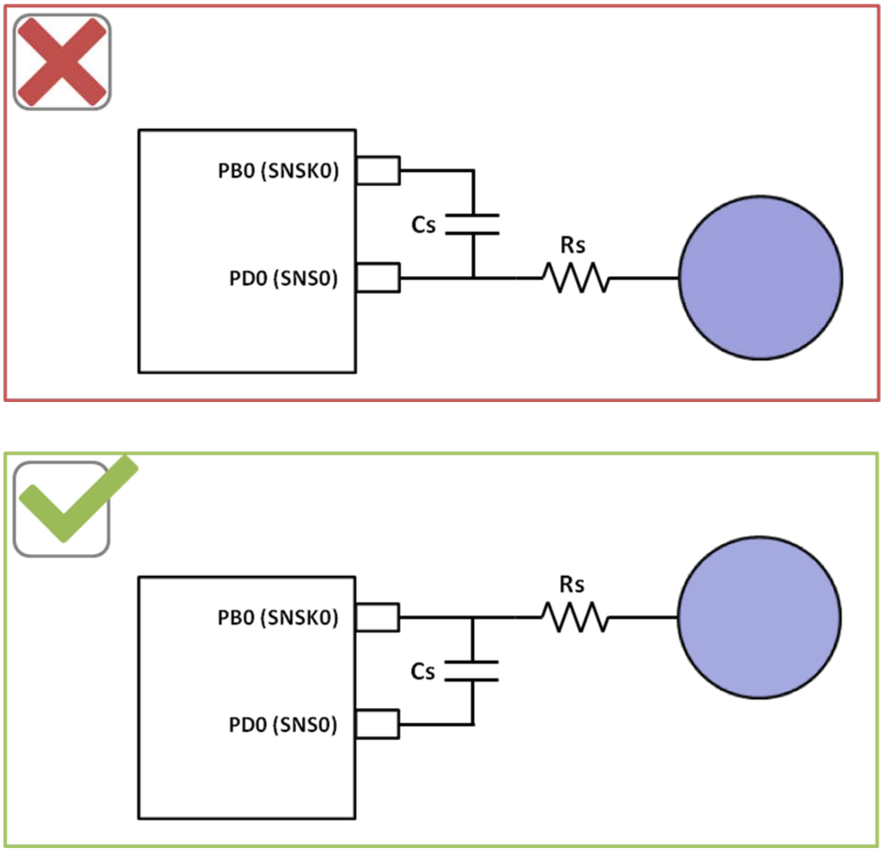
2.1 Atmel QTouch

This section consists of the checklist for reviewing a QTouch schematic.

✓ **Connect SNSK to the sensor electrode**

The sense electrode should be connected to the SNSK pin and not to the SNS pin. If the electrode is connected incorrectly, in some cases it may appear to work. This can happen due to parasitic capacitances providing an alternate path for charge transfer to occur. But the channel will have very poor sensitivity and will be very sensitive to temperature and humidity. Therefore it is important to verify the connections before attempting to improve sensitivity.

Figure 2-1. Typical QTouch circuit.



✓ **Rs = 1kΩ to 10kΩ**

The value of Rs should typically be within the range of 1kΩ to 10kΩ. If Rs is increased the value of Charge Cycle Period will need to be increased appropriately to ensure complete charging of Cx.

Tip

Increase Rs in steps up to 100kΩ to improve performance in noisy environments.
In extreme cases higher values of Rs, going up to 1MΩ may be required.

✓ **Cs = 1nF to 47nF**

The value of Cs should typically be within the range of 1nF to 47nF (not pF or µF). It is best to start with a nominal value of 10nF and fix the Cs values after tuning is done on a prototype.

Tip **Cs can be larger than 47nF for proximity sensors.**

✓ **Slider/Wheel uses only three channels**

A QTouch Slider/Wheel always uses only three channels. It is important to use channels with similar sensitivity. Using mismatched channels with significantly different sensitivities will lead to an unbalanced Slider/Wheel.

⚠ **Always split third channel (highest numbered channel) in a QTouch Slider.**

✓ **Sense pins selected for Slider/Wheel are not unbalanced**

Ensure that the sense pins selected for Slider/Wheel are not unbalanced. If loaded pins are combined with regular GPIOs, the linearity of the Slider/Wheel will be poor.

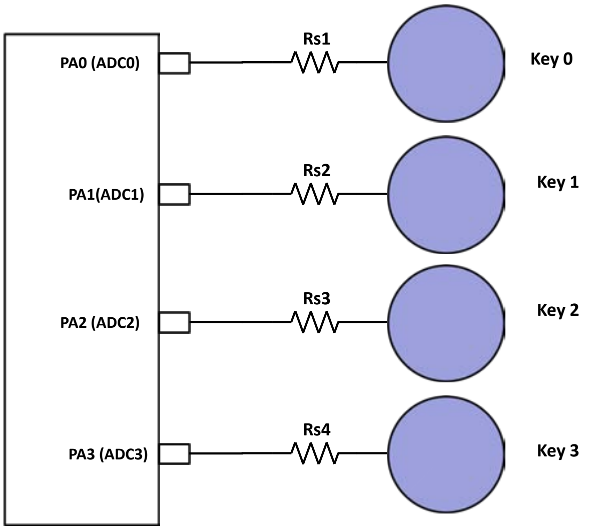
2.2 Atmel QTouchADC

This section consists of the checklist for reviewing a QTouchADC schematic.

✓ **Sense Electrode is connected to an ADC input pin**

The QTouchADC acquisition method uses the ADC module. Hence the sense channel needs to be configured on a port which has the ADC input pins.

Figure 2-2. Typical QTouchADC circuit.



✓ **Rs = 1kΩ to 10kΩ**

The value of Rs should typically be within the range of 1kΩ to 10kΩ. If Rs is increased the value of Charge Share Delay (CSD) will need to be increased appropriately to ensure complete charging of Cx.

Tip **Increase Rs in steps up to 100kΩ to improve performance in noisy environments.**
In extreme cases higher values of Rs, going up to 1MΩ may be required.

2.3 Atmel QMatrix

This section consists of the checklist for reviewing a QMatrix schematic.

✓ **For QMatrix designs V_{CC} is 4.5V or below**

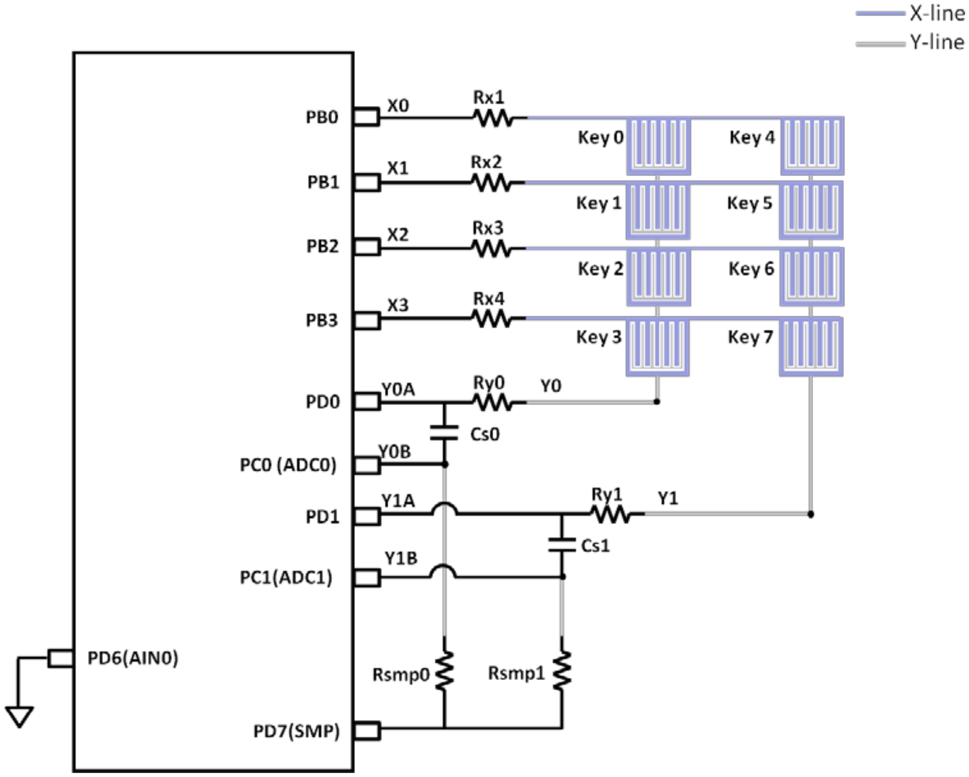
The supply voltage for QMatrix designs should be kept at 4.5V or below even if the device is capable of operating above 4.5V. This is required for reliable operation of the QMatrix sensors.

✓ **Pin selection is appropriate**

X pins, YA pins and SMP pin are configured on GPIOs. YB pins are configured on the ADC port. The AIN0 pin is fixed for the device and can be easily identified from the QTouch Library Selection Guide and the device datasheet. The AIN0 pin needs to be grounded.

⚠ **The AIN0 pin is not user configurable.**

Figure 2-3. Typical QMatrix circuit.



✓ **Cs = 1nF to 47nF**

The value of Cs should typically be within the range of 1nF to 47nF. In QMatrix acquisition technique a dual-slope approach is used to detect a touch. Hence Cs does not affect sensitivity. But if extreme values are used it can hinder the acquisition process. If the value of Cs is too low it is possible that the reverse charge build-up (V_{CS}) gets saturated. If it is set too high the V_{CS} may be too small.

Tip **Typical value Cs of is 4.7nF. Increase it to 10nF if saturated.**

- ✓ **Rx/Ry = 1kΩ to 10kΩ**

The value of Rx/Ry should typically be within the range of 1kΩ to 10kΩ. If Rx/Ry is increased the value of Dwell Time will need to be increased appropriately to ensure complete charging of Cx.

Tip **Increase Ry in steps up to 100kΩ to improve performance in noisy environments. In extreme cases higher values of Ry, going up to 1MΩ may be required.**

- ✓ **Rsmp = 220kΩ to 1MΩ**

Rsmp can be any value within the range of 220kΩ to 1MΩ. This value is used to tune the sensitivity of the channels sharing the corresponding Y-line.

Tip **Typically a 470kΩ resistor is used.**

- ✓ **Slider/Wheel uses four to eight channels**

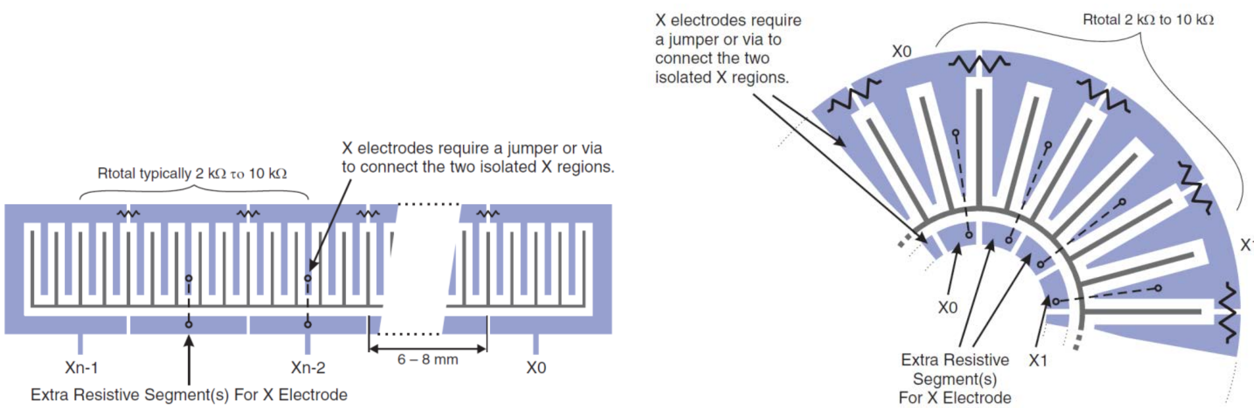
A QMatrix Slider/Wheel always uses a minimum of four channels. This can be increased up to eight channels for a bigger Slider/Wheel. It is important to use channels with similar sensitivity. Using mismatched channels with significantly different sensitivities will lead to an unbalanced Slider/Wheel.

- ✓ **Slider/Wheel resistive interpolation resistors are in range**

Total resistance between channels is 2kΩ to 10kΩ. The resistance between segments will depend on the number of segments used.

⚠ **There are no end resistors or split channels for a QMatrix Slider.**

Figure 2-4. Resistive interpolated QMatrix slider and wheel.



2.4 General

This section consists of the general checklist for reviewing a schematic. This is applicable to all implementations.

- ✓ **Sense pins are not loaded**

Ensure that the sense pins are not heavily multiplexed as this can cause increased loading. XTAL/OSC pins usually have high parasitic capacitance values and are not suitable. If loaded pins are used, the sensitivity of the channel will be poor.

- ✓ **Sampling Capacitor is X7R or better**

Stability of the Cs capacitor is important in achieving a consistent and repeatable measurement. A capacitor with X7R dielectric or better has a low temperature co-efficient and will be more stable.

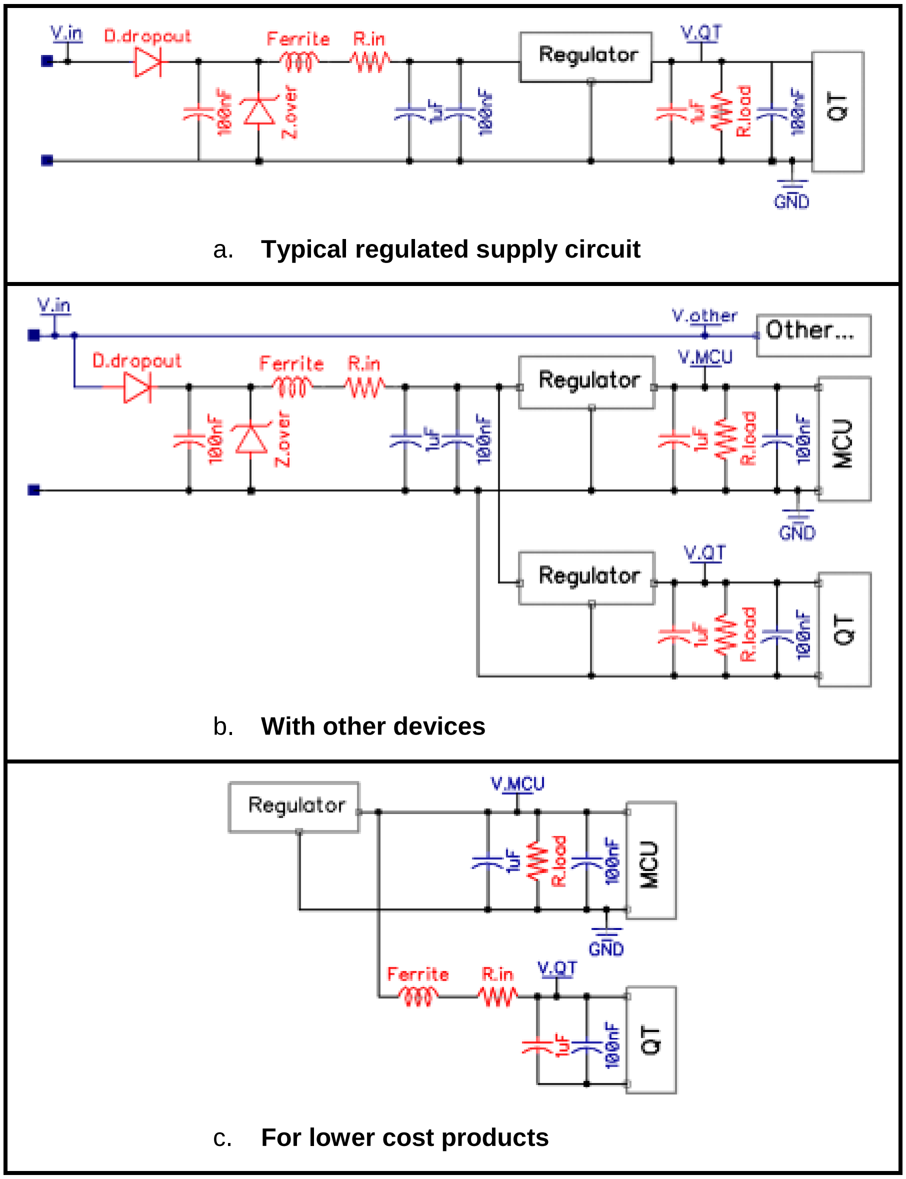
Quality of series resistor Rs is not critical.

✓ **Dedicated voltage regulator is used**

It is recommended to use a dedicated voltage regulator for a QTouch application. If the voltage regulator is shared with other components it is important to ensure that the power supply is clean.

The ripple on the supply voltage needs to be within ±10mV.

Figure 2-5. Regulated supply circuit configurations (optional components are highlighted in red).



a. **Typical regulated supply circuit**

b. **With other devices**

c. **For lower cost products**

✓ **Any load on GPIO pins does not source or sink more than ~1mA**

If there is any load on a discrete out pin of the microcontroller, ensure that the load does not sink or source too much current directly from chip. This can cause ground bounce which would in turn affect QTouch measurements. Typically the current should be limited to ~1mA, but this can vary depending on the part and sensitivity of channels. If required use transistors etc. to lower load current.

✓ **No additional circuitry on sense lines**

Placing ESD protection circuitry, MUX, etc are not recommended since they add parasitic capacitance and may introduce noise. Placing option resistors on the sense lines to connect the pins to different circuitry is acceptable. But the sensitivity of the channel needs to be re-tuned if options change.

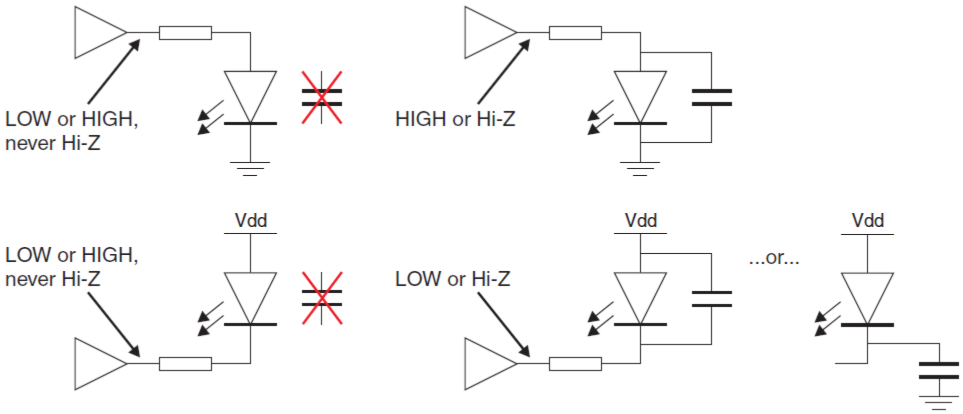
✓ **Nearby LEDs have a bypass capacitor**

The changing capacitance from switching LEDs can cause detection instability and stuck-on state in nearby sensors. This is particularly true if LEDs are pulled down or up to switch on, but are allowed to float when off.

If such LEDs are less than 4mm away from capacitive sensors, they must be bypassed with a capacitor that has a typical value of 1nF.

Tip **Bypass capacitor does not need to be physically close to the LED.**

Figure 2-6. Bypass capacitors on nearby LEDs.



✓ **LEDs and sense lines do not share the same port**

Avoid placing LEDs on the same port as the sense lines, since switching LEDs can cause the touch measurement to be noisy. If they are required to be on the same port it is recommended to increase the value of the LED series resistor to minimize the impact.

3. PCB Review

This chapter consists of the checklists used for reviewing the PCB layout of Atmel QTouch, QTouchADC and QMatrix implementations. There are sections corresponding to each individual technology.

Tip **For general PCB design considerations please refer to AVR042: AVR Hardware Design Considerations.**

3.1 QTouch and QTouchADC

This section consists of the checklist for reviewing the PCB layout for both QTouch and QTouchADC designs.

3.1.1 Components

✓ **Sense components are placed close to microcontroller pins**

The sense components (Cs and Rs for QTouch; only Rs for QTouchADC) should be placed close to the microcontroller sense pins. If they are placed too far from the pin, there will be increased noise pick-up from nearby sources.

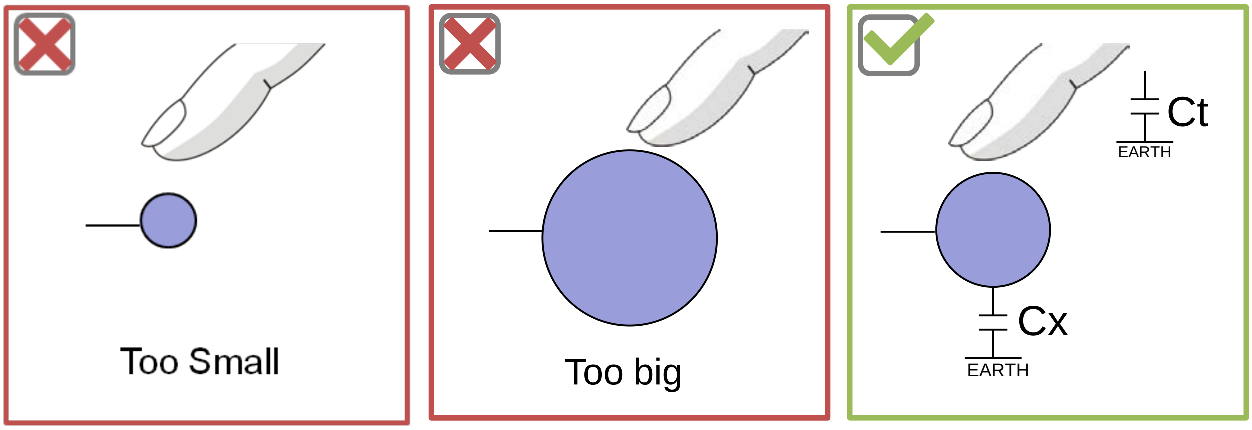
3.1.2 Sensors

✓ **Electrode size is slightly larger than a normal finger**

It is recommended to have a key size that is slightly larger than the item to be sensed (finger, thumb etc). In general larger keys are more sensitive, but avoid oversized keys as they may have a prox effect.

Tip **Area of contact from a normal finger is 8mm to 10mm in diameter.**

Figure 3-1. Appropriate sensor size.



✓ **Sense Electrodes are located on the top layer**

The sense electrodes should be located on the layer closest to touch in order to maximize the sensitivity.

⚠ **Do not place the MCU or any other components directly under the Sense Electrodes.**

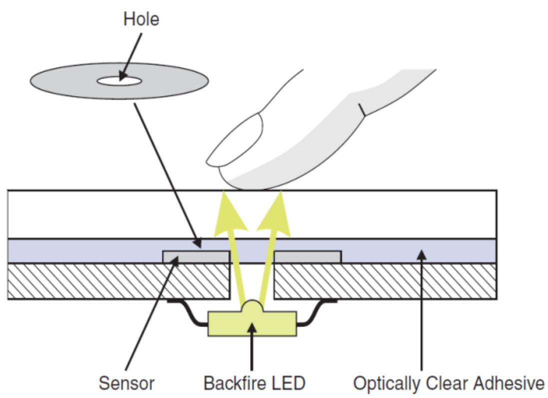
✓ **Spacing between adjacent Sense Electrodes is at least T/2**

The separation between keys should be at least half of T (front panel thickness), to prevent cross-coupling and unintentionally touching a neighbouring key. The probability of an unintentional touch from the palm or hand-shadow should be minimal.

✓ **LED holes have diameter less than 4mm**

Led holes that are too large can lead to poor sensitivity or cause the key to have a dead spot in the middle.

Figure 3-2. Hole for backlighting LED.



3.1.3 Routing

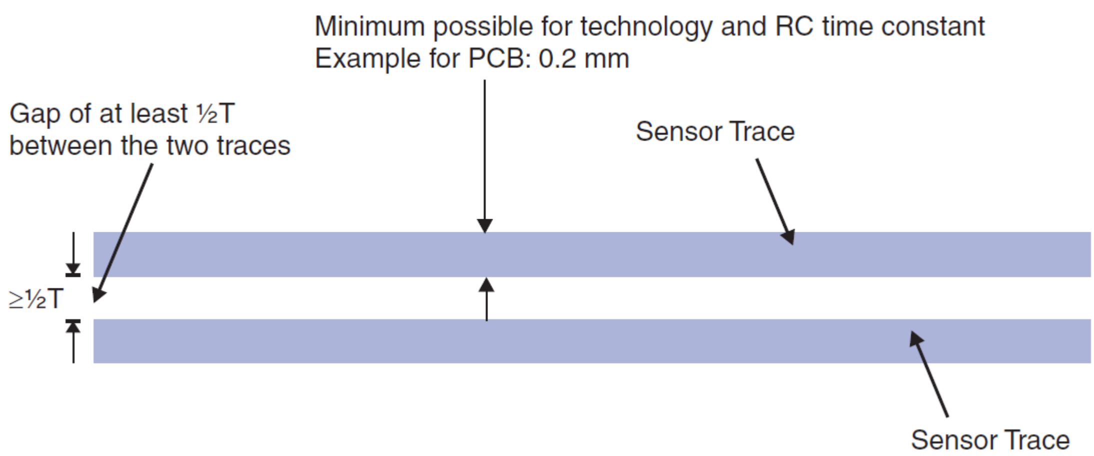
✓ **Sense Lines are routed on the bottom layer**

Sense tracks are sensitive to touch and wherever possible they must be routed on the bottom layer to prevent false keys on the touch surface.

✓ **Spacing between adjacent Sense Lines is at least T/2**

If Sense Lines are placed close to each other, it can cause cross-bleed and increase noise on the channels. It will also load both channels and decrease their sensitivity.

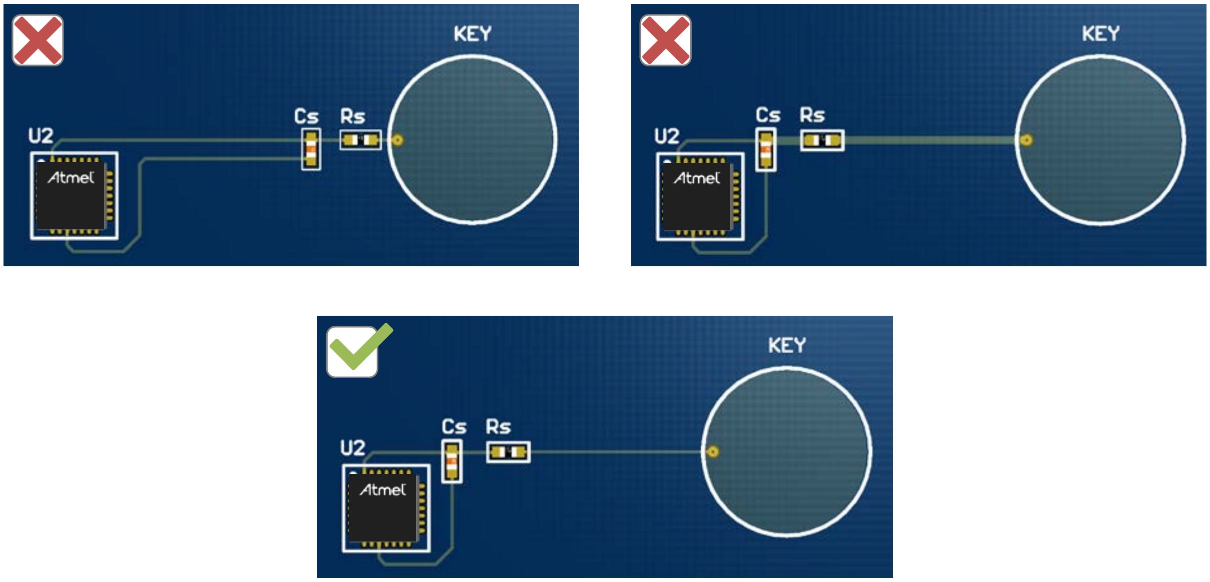
Figure 3-3. Spacing between two sense lines.



✓ **Sense Line thickness should be between 0.1mm to 0.5mm**

To prevent false detect over electrode traces keep them thin. The Electrodes drive very small loads so minimum metal trace widths may be used.

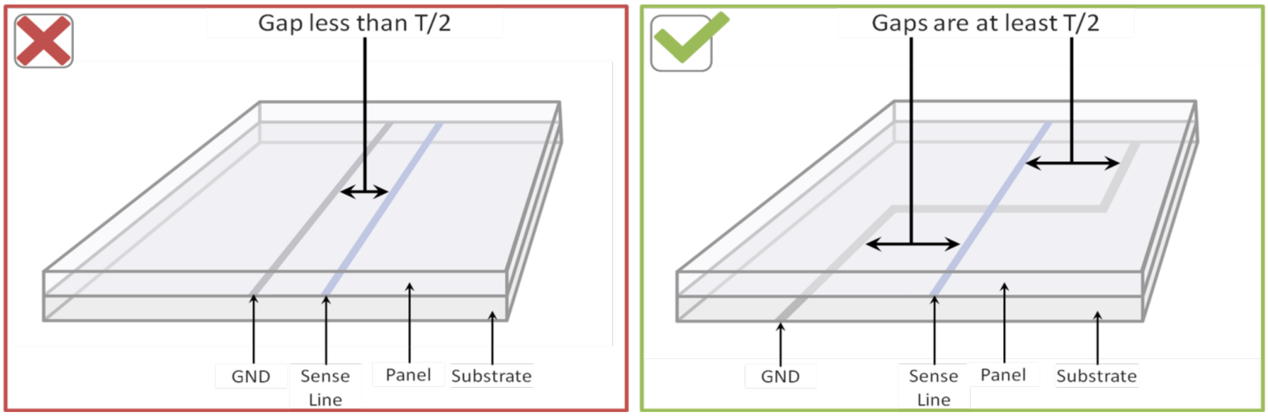
Figure 3-4. Typical QTouch button layout.



✓ **Sense Lines are separated from GND tracks by at least T/2**

GND tracks should not be placed near Sense Lines. This will load the Sense Lines and reduce the sensitivity of the channel. To reduce loading the Sense Lines and GND track should cross at 90° on separate layers.

Figure 3-5. Typical QTouch button layout.



✓ **Sense Lines are as short as possible**

Having long Sense Lines will worsen any loading and interference from nearby tracks and components.

⚠ **Sense Lines should not be longer than 150mm.**

✓ **Sense Lines are separated from all other tracks and components by at least T/2**

Sense Lines should not be placed near other tracks and components, as this may cause loading and interference. These will load the Sense Lines and reduce the sensitivity of the channel. Tracks with switching signals can cause noise in the Sense Lines if they are placed too close.

✓ **There is no GND plane behind components, tracks and electrodes**

Keep solid Ground Plane or Fill away from the Sensor Signals. If shielding from noise sources is necessary a thin meshed ground may be used behind electrodes (<40% copper). Meshed ground can also be helpful in increasing SNR and stability when conducted noise is present.

Figure 3-6. No ground flood under sense components, tracks and electrodes.

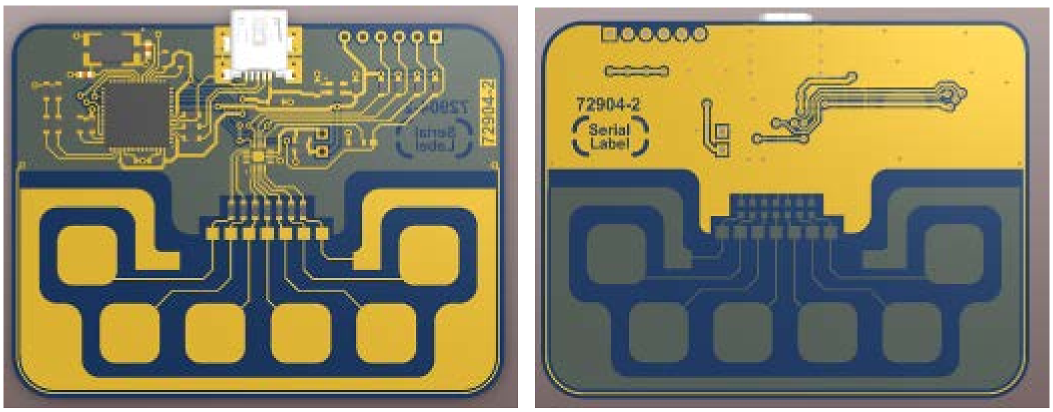
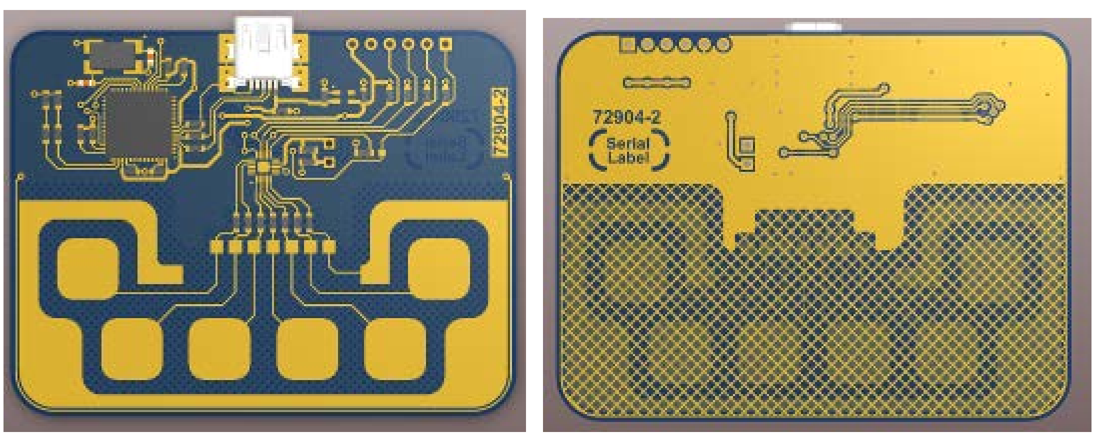


Figure 3-7. Meshed ground to provide shielding from noise sources behind the board.



3.1.4 QTouch slider or wheel

The checklist in this section is applicable only to QTouch designs.

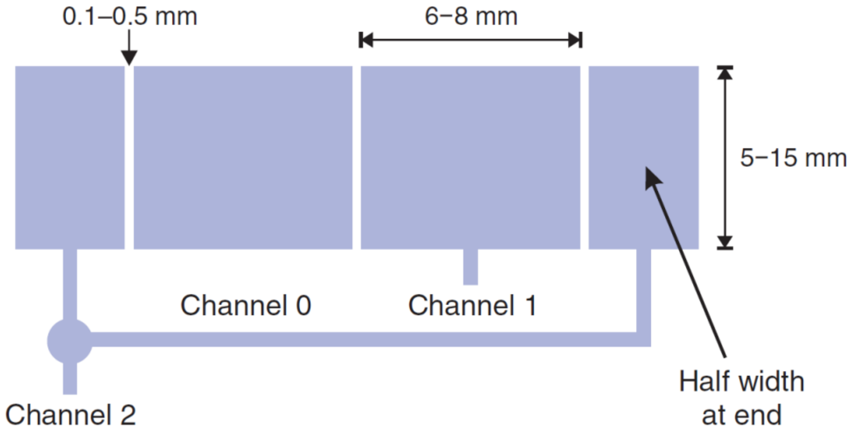
✓ **Small Slider/Wheel has a segment size of 6mm to 8mm**

Segment size should be comparable to the diameter of a standard finger touch. Segments that are too large will lead to poor linearity. In case of Wheel the outer arc of the segment should of length 6mm to 8mm. This is applicable to small spatially interpolated Slider/Wheel which uses simple rectangular or wedge shaped segments.

✓ **For a small spatially interpolated Slider the end segments are half the width of the middle two segments**

The end segments, which are connected to the same channel, need to be narrower to ensure linearity near the ends of the Slider.

Figure 3-8. Small spatially interpolated – length 21mm to 26mm.



✓ **The first and last segments of the Slider are connected to the same channel**

This needs to be ensured for both spatially and resistively interpolated QTouch Sliders.

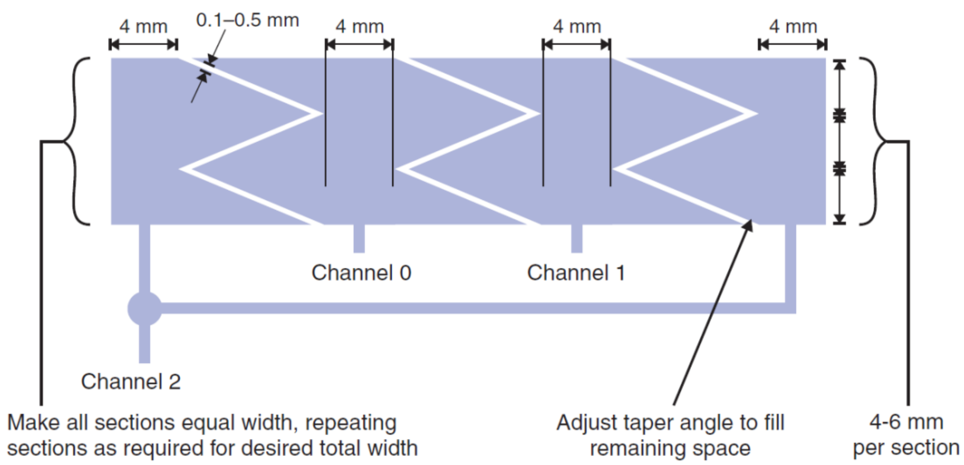
✓ **The track connecting end segments is placed away from the Slider**

The track needs to be placed away from the Slider to prevent accidentally touching it while sliding the finger. This can lead to incorrect position being reported.

✓ **Medium/large spatially interpolated Sliders have segment width of 4mm or less**

The segments need to be narrow to ensure that the finger interacts with more than one segment when touching the slider. The regions between the segments must have interleaving teeth.

Figure 3-9. Medium/large spatially interpolated QTouch slider – length 26mm to 60mm.



To increase the height of the Slider increase the number of interleaving teeth (don't stretch the same pattern).

Figure 3-10. Repeat interleaving pattern to add height to slider.

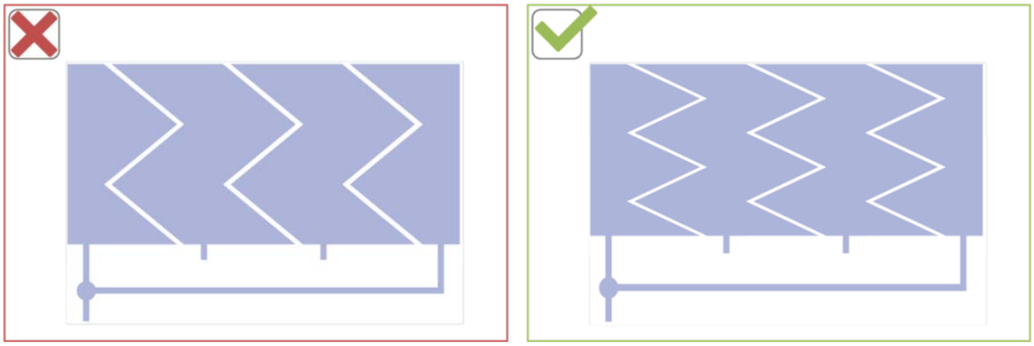
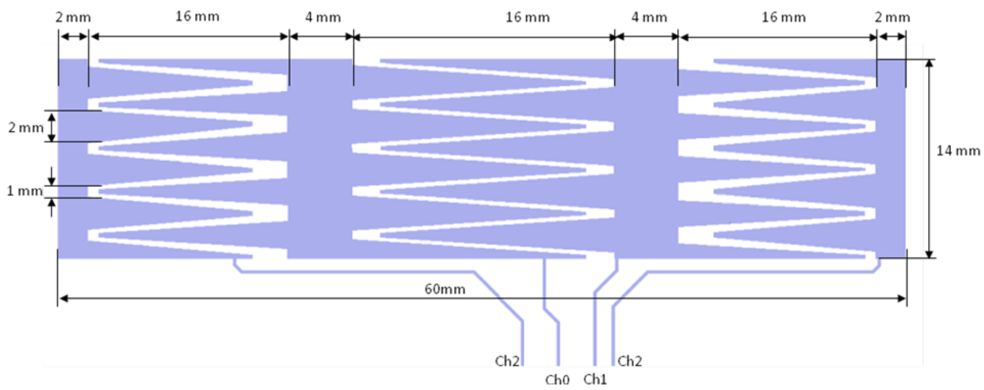


Figure 3-11. Repeat interleaving pattern to add height to slider.



✓ **There are no switching traces/components under the Slider/Wheel**

These can degrade the SNR and compromise the achievable resolution. This can manifest itself as jitter in the reported touch co-ordinate and is not desirable.

✓ **There are no ground planes under the Slider/Wheel**

Ground planes under the Slider/Wheel will load the sensor and make it less sensitive. Ground planes that unevenly load some of the channels are worse than all the channels being equally loaded.

Although GND loading decreases sensitivity, it increases SNR and Signal stability which can be useful in noisy environments.

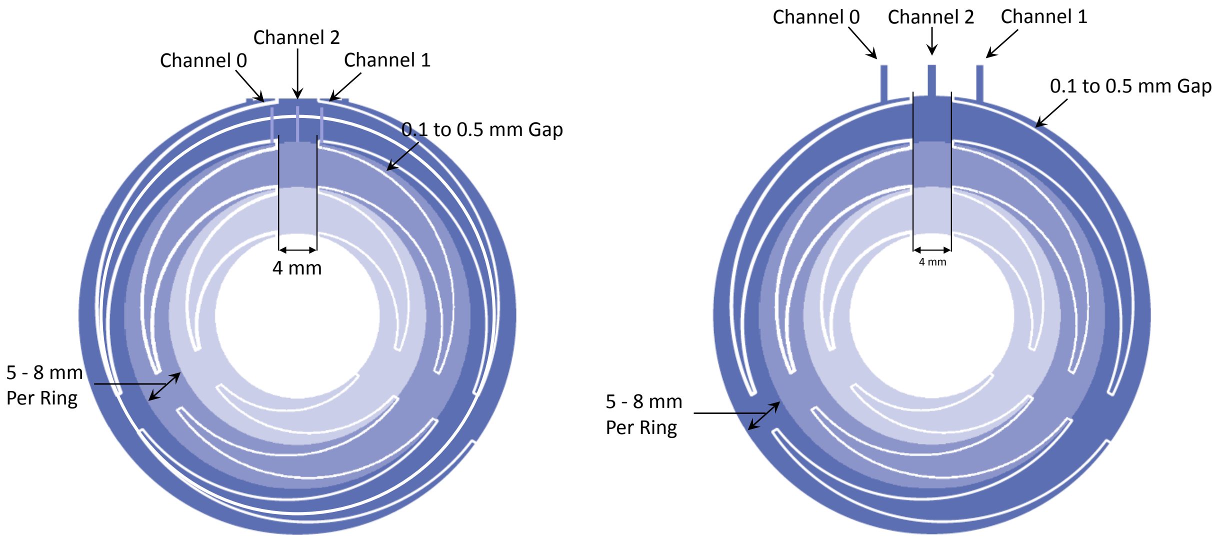
✓ **Medium/large spatially interpolated Wheels have segment width of 4mm or less**

The segments need to be narrow to ensure that the finger interacts with more than one segment when touching the slider. The regions between the segments must have curved interleaving teeth.

✓ **In a medium/large spatially interpolated Wheel the width of each interleaving ring is 5mm to 8mm**

For increasing the diameter of the Wheel increase the number of interleaving rings rather than increasing the width of the ring.

Figure 3-12. Larger spatially interpolated QTouch wheel with an additional ring of interleaving teeth.



3.2 QMatrix

This section consists of the checklist for reviewing the PCB layout for QMatrix designs.

3.2.1 Components

✓ **Sense components are close to the microcontroller**

The sense components (Sampling Capacitor Cs, Series Resistor Rx/Ry) should be placed close to the microcontroller sense pins. The Cs and Rx/Ry components form an RC filter and if they are placed too far from the pin the filtering effect is diminished.

The Rsmp (sampling resistor) should be placed closer to Y sense pin. It is OK to place the Rsmp resistor further from SMP pin since it is always driven.

3.2.2 Sensors

✓ **There are no ground planes directly under co-planar Buttons**

These will load the sensor and decrease the sensitivity. But the effect is not as dramatic as in the case of QTouch Sensors.

✓ **Y Electrodes are located on the top layer**

The Y electrodes should be located on the layer closest to touch in order to maximize the sensitivity.

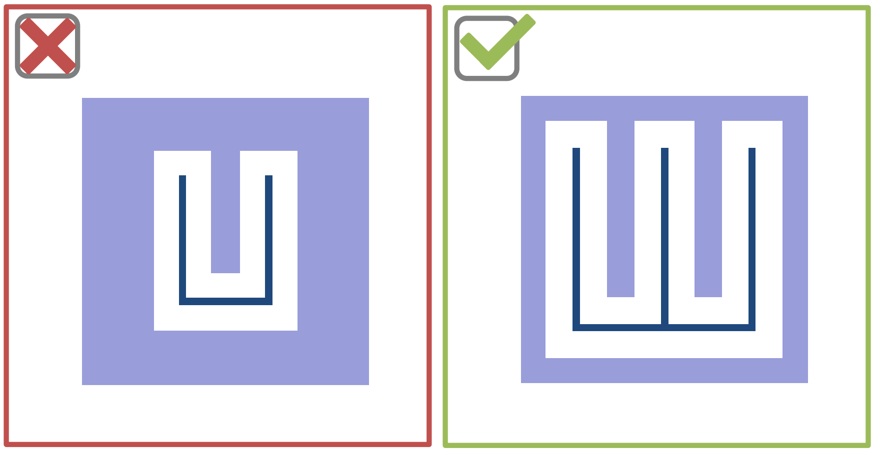
✓ **X Electrodes completely surround the Y Electrodes**

In QMatrix sensors the field only exists in the gap between the X Electrode and Y Electrode. Surrounding the Y Electrode with the X Electrode will keep the field contained and the touch sensitive area can be precisely defined.

✓ **The X-Y interdigitation is maximized**

Designs that result in very small X-Y inter-digitation should be avoided as such designs result in poor sensitivity.

Figure 3-13. Typical QMatrix co-planar (single layer) button.

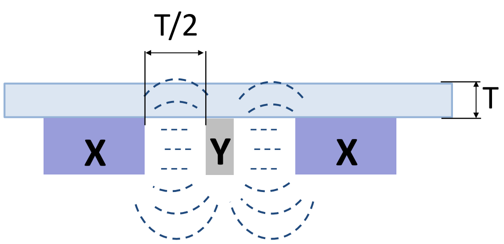
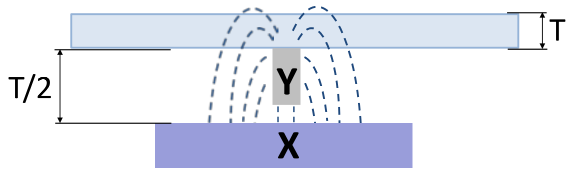
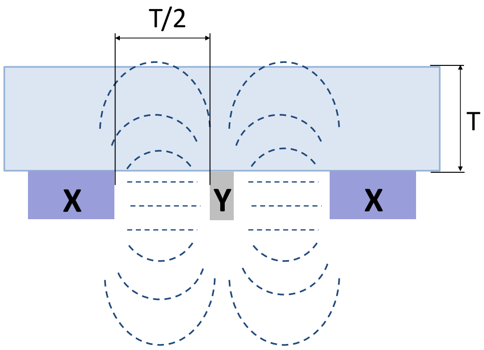
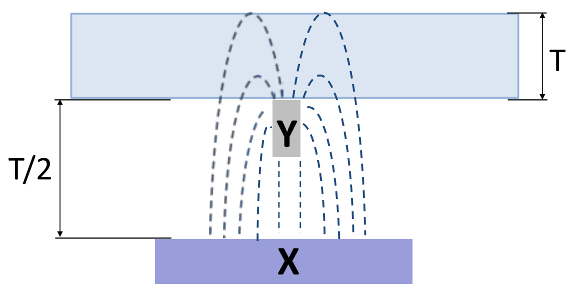


✓ **Spacing between X and Y Electrodes is at least T/2**

The spacing between the X and Y electrode needs to be at least half the front panel thickness. If the front panel thickness is T then the X-Y gap should be at least T/2. There should be no other tracks running below the X-Y gap as this can desensitize the key.

⚠ **In flooded-X designs X-Y separation is determined by the PCB thickness. Therefore the acceptable front panel thickness is constrained by the thickness of the PCB used.**

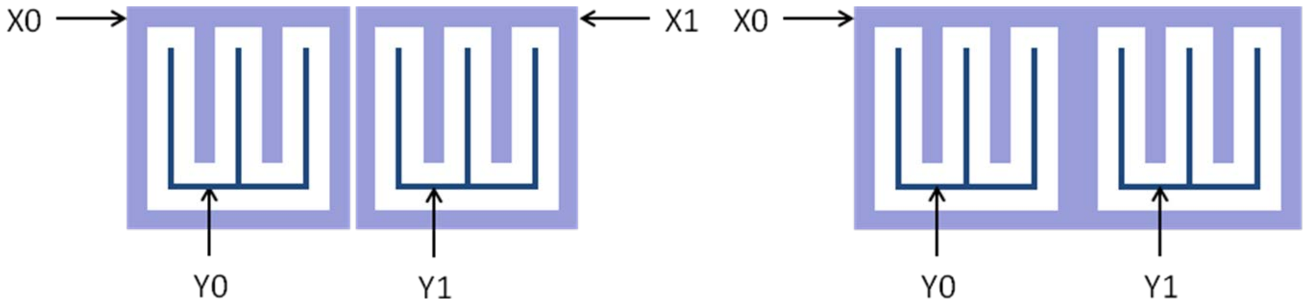
Figure 3-14. X-Y separation and front panel thickness.

Single Layer Planar Electrode Layout	**Double Layer Flooded-X Electrode Layout** (the field only extends towards touch)
	
	
Small X-Y separation = Thin Panel **Large X-Y Separation = Thicker Panel**	

✓ **Spacing between X Electrodes is not critical**

The X Electrodes are not susceptible to loading. They can be placed with minimal separation without affecting neighbouring keys. Keys that share the same X Line, the X electrodes can be merged.

Figure 3-15. Keys that share the same X Line, the X Electrodes can be merged.

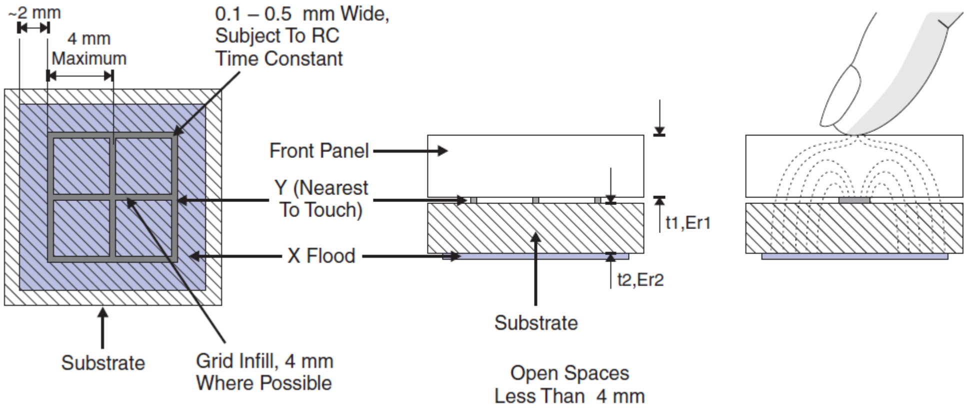


✓ **In two layer design Y Electrodes are on the top layer (closest to touch)**

The Y Electrode should be on the top layer in order to maximize the interaction of the finger with the X-Y electric field, thus maximizing the sensitivity of the sensor.

X Electrode on the bottom layer can provide shielding from noise sources behind the board.

Figure 3-16. QMatrix flooded-X (two layer) design.



3.2.3 Routing

✓ **Y Lines are as thin and short as possible**

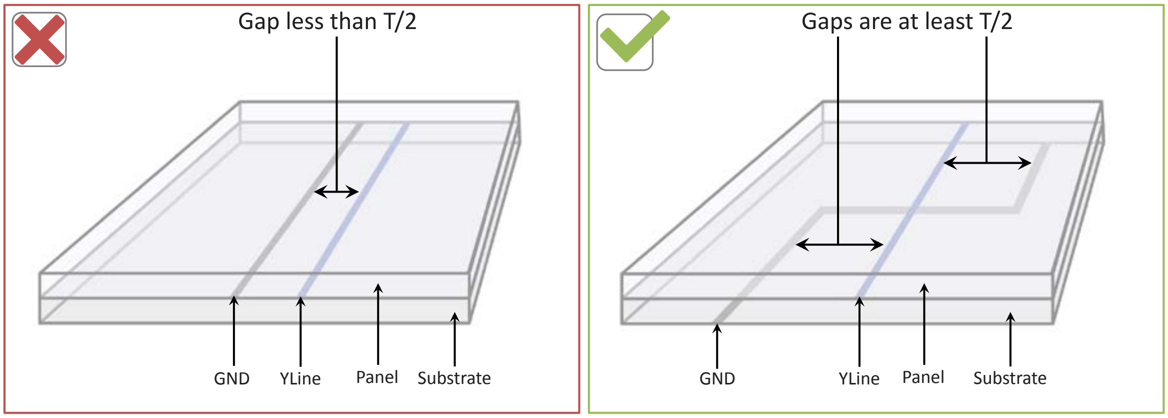
Having long Sense Lines will worsen any loading and interference from nearby tracks and components. The thickness of the Y electrode should be kept as low as possible (0.1mm to 0.5mm) to minimize noise pickup when touched.

⚠ **The Y Lines should not be longer than 150mm.**

✓ **Y Lines are separated from GND tracks by at least T/2**

GND tracks should not be placed near Y Lines. This will load the Sense Lines and reduce the sensitivity of the channel. If absolutely necessary the Y Lines and GND track should cross at 90° on separate layers. Y Lines and GND tracks running parallel to each other for long distances should absolutely be avoided.

Figure 3-17. Y Line separation from GND.



✓ **Y Lines are separated from all other tracks and components by at least T/2**

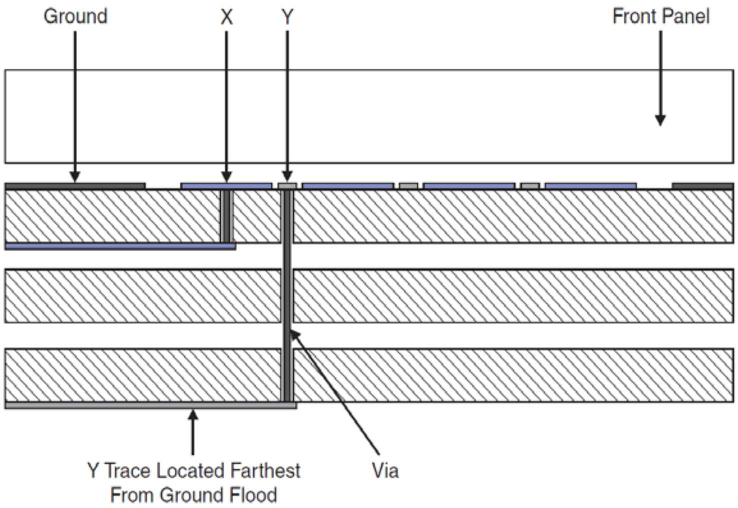
Y Lines should not be placed near other tracks and components, as this may cause loading and interference. These will load the Y Lines and reduce the sensitivity of the channel. Tracks with switching signals can cause noise in the Y Lines if they are placed too close.

Tip: **X Lines and X Electrodes are not sensitive to loading from ground planes and foreign tracks/components.**

✓ **Y Lines are routed on the bottom layer**

Y Lines are sensitive to touch and wherever possible they must be routed on the bottom layer to prevent false keys on the touch surface.

Figure 3-18. Cross-section of a multi-layer PCB.



✓ **Spacing between adjacent Y Lines is at least T/2**

If Y Lines are placed close to each other, it can cause cross-bleed and increase noise on the channels. It will also load both Y Lines and decrease their sensitivity.

✓ **X Lines and Y Lines are not routed near each other**

The X-lines are not touch sensitive and hence their routing is not as critical. But it is important to ensure that they are not routed near Y-lines as this may create false keys (Figure 3-19). If the lines need to run together or cross then extra care needs to be taken to avoid false keys. Some routing suggestions are illustrated in Figure 3-20.

Figure 3-19. X and Y Lines placed close to each other can behave like a button.

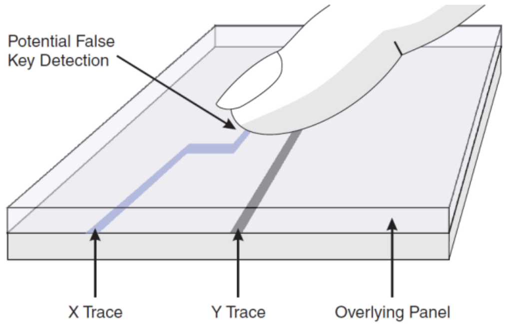
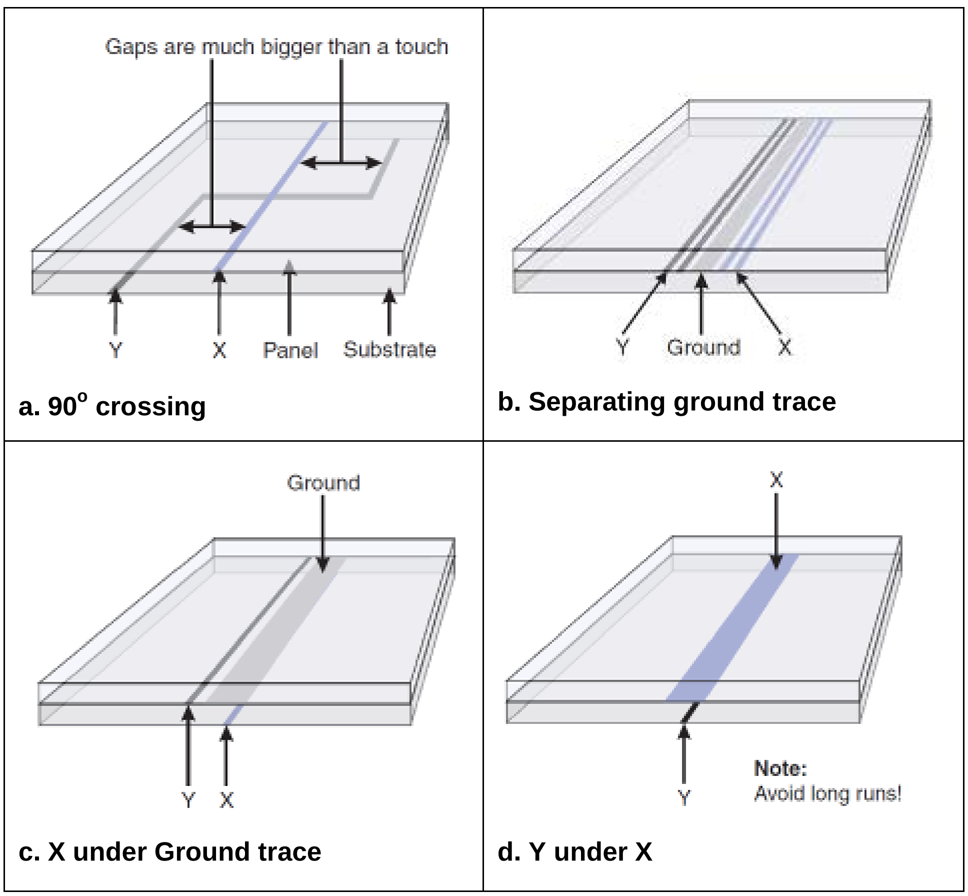


Figure 3-20. Tips for minimizing interaction between X and Y routing.



3.2.4 Sliders and wheels

✓ **There are no ground planes or foreign traces/components under the Slider/Wheel**

These can degrade the SNR and compromise the achievable resolution. This can manifest itself as jitter in the reported touch co-ordinate and is not desirable.

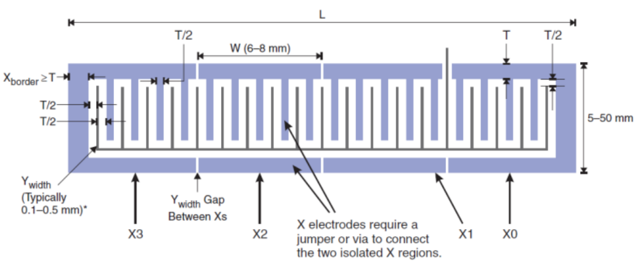
✓ **Slider/Wheel has a segment size of 6mm to 8mm**

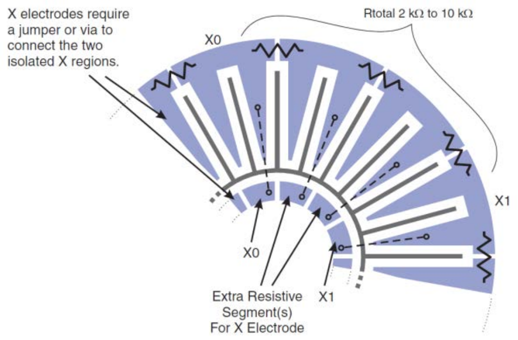
Segment size should be comparable to the diameter of a standard finger touch. Segments that are too large will lead to poor linearity. In case of Wheels the outer arc of the segment should be 6mmto 8mm long.

✓ **In single layer Slider/Wheel, isolated X regions are connected using vias**

Since the Slider segments are on the same layer, the Y Electrode cuts through the X Electrode. This causes the X Electrodes to be split. These isolated regions need to be connected on the bottom layer using jumpers or vias.

Figure 3-21. Single layer slider/wheel with X electrodes split by the Y electrode.

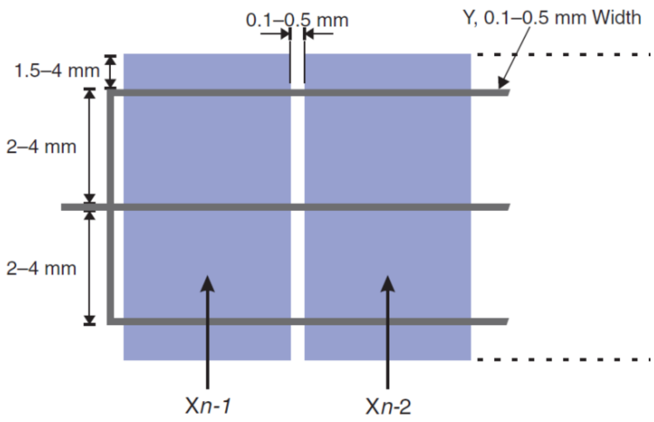


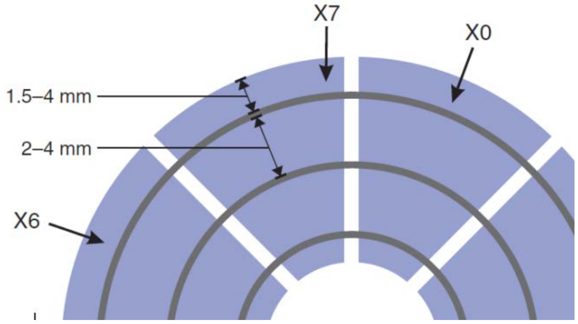


✓ **In two layer Slider/Wheel the gap between Y Electrode traces is less than 4mm**

Gaps that are larger than 4mm can lead to an insensitive region on the Slider/Wheel.

Figure 3-22. Two layer QMatrix slider/wheel.





4. Revision History

Doc. Rev.	Date	Comments
42094B	07/2013	Atmel QMatrix section updated: • Figure 2-3. Y-line connection in Typical QMatrix Circuit updated. • Added tip to check list item "Rx/Ry = 1kΩ to 10kΩ".
42094A	03/2013	Initial document release

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