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# Atmel AVR3000: QTouch Conducted Immunity



## 1 Introduction

EMC compliance testing requirements include a check of the susceptibility of a product to RF interference coupled through cables that may normally be connected to the system. Since all cables carry conducted RF voltages and currents, and since these voltages and currents can interfere with electronic devices, it makes good sense to test products to ensure that they will work reliably in their intended operating environment.

Although most applications do not require a high level of immunity to conducted noise, certain industry sectors (for example Automotive, industrial and white goods, to name a few) have defined standards for EMC compliance.

When using capacitive touch interfaces in such environments, it is important to understand the implications of conducted noise and how to mitigate the effects through careful design.

With some basic hardware modifications, Atmel® touch applications can be designed to meet the highest industry standards for CI testing.

This application note provides a basic overview of conducted immunity testing and describes in detail the techniques employed to improve noise immunity for Atmel's capacitive touch applications.

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## 8-bit Atmel Microcontrollers

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## Application Note

Rev. 8425A-AVR-08/11





## 2 Conducted immunity

Conducted RF immunity simply refers to a product's immunity to unwanted 'noisy' RF voltages and currents carried by its 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 appropriate apply suitable techniques to address the effects of unwanted noise disturbances.

## **3 Testing requirements**

### **3.1 EMC standards**

The immunity test for conducted disturbances induced by radio-frequency fields is defined by standard IEC/EN 61000-4-6 and is often called up as the basic test method by immunity standards listed under the Electromagnetic Compatibility (EMC) directive. The standard establishes a common reference and a set of testing methods for evaluating the functional immunity of electrical and electronic equipment to conducted noise.

### **3.2 Test criteria**

CI testing involves injecting RF voltages or currents into each of the cables associated with the equipment under test. The basic requirement for the test system is to generate a modulated RF signal of sufficient amplitude, stepped over the frequency range from 150kHz to 80MHz. The upper frequency range may be extended by some product standards or customer specific requirements.

The tested frequency range is covered in number of small steps. At each step there is a 'dwell period' whilst the EUT (Equipment Under Test) is checked for performance degradation.

According to Table 1 of IEC/EN 61000-4-6, the standard test levels are:

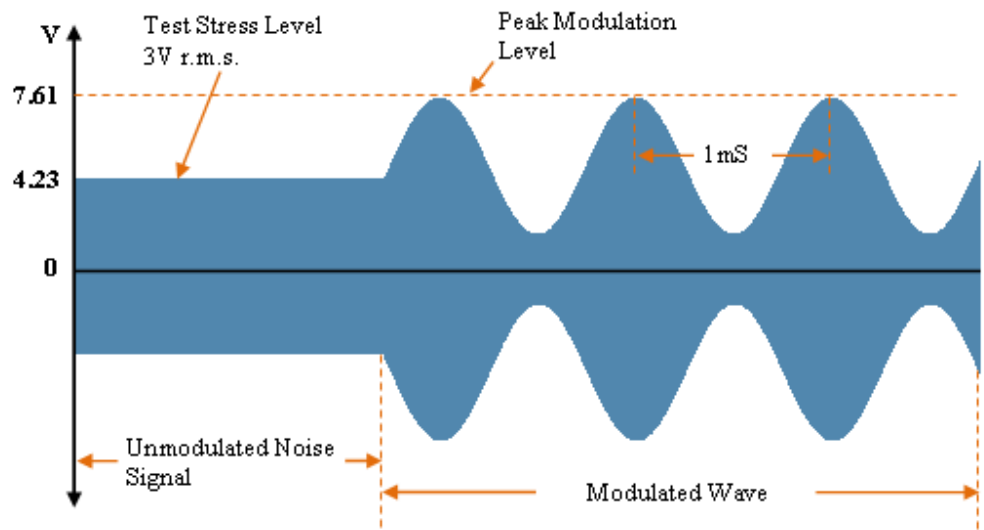
Test Level 1	1V rms
Test Level 2	3V rms
Test Level 3	10V rms
Test Level X	User specified

Test Level X is called an 'open' specification and is included to provide the flexibility for a specification to be set by a product or generic standard committee if they feel it is more appropriate for the type of equipment covered by their standard.

Test levels 1 and 2 are generally considered the minimum stress levels required for conformance testing of products intended for domestic and commercial environments. Test level 3 normally applies to industrial applications.

The above table values refer to the open-circuit test levels (e.m.f) of the unmodulated noise signal, expressed in r.m.s. When applying the test, this signal is 80% amplitude modulated with a 1kHz sine wave to simulate real-world environments.

Figure 3-1.



The IEC/EN 61000-4-6 test level is always specified for the unmodulated wave. For example, a 3V r.m.s. test has a peak-to-peak voltage of 15.22V as shown in [Figure 3-1](#).

### 3.3 Compliance criteria

The pass/fail criteria depend on the purpose and function of the product. It may also be defined by customer expectations.

IEC/EN 61000-4-6 recommends four general classifications for evaluating the performance of the equipment under test.

Class A – No significant degradation in operation or functionality is allowed.

Class B – Some degradation in operation may occur, but the product recovers once the stress is removed without any operator intervention. No change in operating state or loss of data occurs.

Class C – Operation of the EUT is affected and operator intervention is required to recover normal operation. Again, no loss of data is permitted.

Class D – Unrecoverable loss of function or degradation of performance. Loss of data may occur.

### 3.4 Noise injection methods

There are a number of alternative test transducers, described in IEC/EN 61000-4-6, which can be used for inducing the RF noise signal into connected cables.

According to the standard the preferred approach is to use Coupling-Decoupling Networks (CDN's) to directly inject RF voltages into the cables under test. A CDN requires the least power of all transducers and automatically and accurately controls the injected source impedance, maintaining a reasonably accurate RF voltage into the EUT's cables.

Alternative methods such as Bulk Current Injection (BCI) and the Electromagnetic Clamp (EM-Clamp) are also described, although it is important when using either of

these methods to closely follow the instructions set out in the standard. **Incorrect application of either technique can create a severe over-test situation which would be unrealistic of most real life electromagnetic environments.**

## 4 Improving noise immunity

With careful attention to sensor layout and some basic circuit modifications it is possible to realize a touch solution using Atmel's capacitive sense technologies that meet the highest CI conformance requirements as specified in IEC/EN 61000-4-6.

### 4.1 Signal path impedance

Increasing the impedance of the signal path from the sense electrode to the touch controller input can significantly improve immunity to conducted noise in applications using Atmel AVR<sup>®</sup> QTouch<sup>®</sup>, Atmel AVR QMatrix and Atmel AVR QTouch-ADC sensing methods. A larger series resistor in the 'charge transfer' path provides high impedance to noise while maintaining the overall signal integrity.

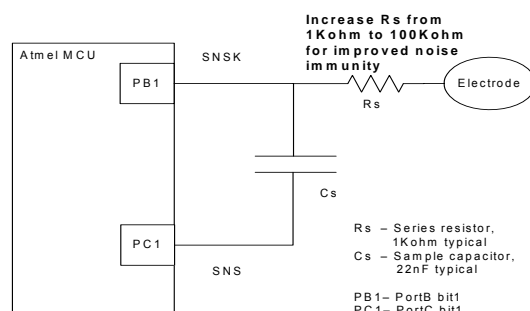
Increasing the series resistor from a typical value of 1K $\Omega$  to about 100K $\Omega$  and ensuring complete 'charge transfer' can typically improve noise immunity by a factor of two or more. Depending on the noise disturbance in a given application an optimal intermediate resistor value can be chosen to achieve the required level of noise suppression while meeting other system design requirements such as power consumption and response time.

QTouch, QMatrix and QTouch-ADC sensing methods are optimized for minimum power. Adding a high value of series resistor will require an increased 'charge transfer' time that increases capacitance measurement time, thereby increasing the response time and power consumption. However, with a small increase in power consumption, considerable improvement in Conducted Noise immunity can be achieved. Refer to Section 4.1.4 in order to ensure proper tuning of the charge transfer pulse when the series resistor is increased.

#### 4.1.1 QTouch

In the case of QTouch, using a larger value of series resistor on the SNSK Port pin as indicated in Figure 4-1 results in improved noise immunity.

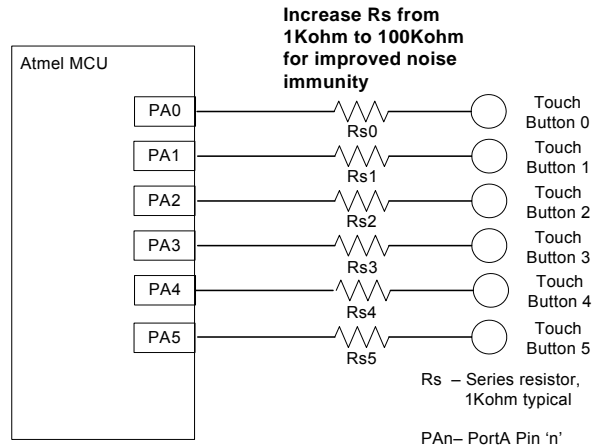
**Figure 4-1.** Increasing series resistor for QTouch method.



#### 4.1.2 QTouch-ADC

For QTouch-ADC, using a larger value of series resistor on the port pin connected to the sensor as indicated in Figure 4-2 results in improved noise immunity.

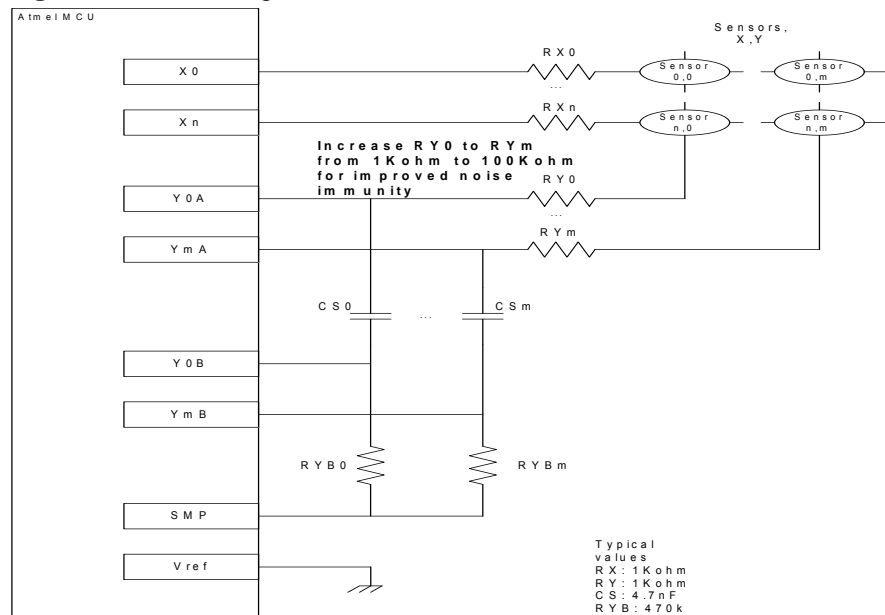
**Figure 4-2.** Increasing series resistor for Atmel AVR QTouch-ADC method.



#### 4.1.3 QMatrix

In the case of QMatrix, using a larger value of the RY series resistor on the YA Port pins as indicated in Figure 4-3 results in improved noise immunity.

**Figure 4-3.** Increasing series resistor for QMatrix method.



#### 4.1.4 Tuning for proper charge transfer pulses

With the increased series resistor, the RC time constant formed in combination with sensor capacitance will slow down the charge transfer settling process. In order to obtain stable and repeatable results, it is important to ensure proper settling process. For an overview of charge transfer pulses and method to observe good and bad charge pulses using an oscilloscope, refer to the 'Charge transfer' section in Atmel's

[Touch Sensor Design Guide](#). In order to achieve good charge pulses, the firmware parameter to control the charge transfer time should be increased.

For application specific devices this parameter will be identified in the relevant datasheet.

When using the Atmel AVR QTouch Library, the QT\_DELAY\_CYCLES parameter should be used so as to increase the 'Charge cycle' time for QTouch method. For the case of Atmel AVR QMatrix, the QT\_DELAY\_CYCLES parameter should be used so as to increase the 'Dwell time'. For the case of QTouch-ADC for tiny40 device, the library with a higher 'csd' value should be used. With QTouch-ADC for tiny20 device, higher value of the DEF\_QT\_DELAY\_CYCLES parameter should be used. For additional information on these parameters, refer to [QTouch Library User Guide](#). Also refer to [QTAN0062: QTouch and QMatrix Sensitivity Tuning for Keys, Sliders and Wheels](#) for Sensitivity tuning.

With a series resistor of 100K $\Omega$ , a 'charge transfer' time of 4 $\mu$ s or higher is recommended.

## 4.2 Sensor design considerations

Excellent immunity to CI noise can be achieved by having a good layout for capacitive sense applications. Traces from the microcontroller input pins to the sense electrodes should be kept as short as possible and electrode designs should be consistent with the recommendations in Atmel [Touch Sensor Design Guide](#).

For self-capacitance electrode configurations using QTouch and QTouch-ADC sensing methods, additional improvements in noise immunity can be achieved by adding ground loading, either in a planar way or by having a hatch ground plane behind the sensor. The ground loading provides a low impedance noise path, directing coupled noise away from the touch controllers input pins. Although this approach is not recommended under the general sensor design guidelines because of the effect on sensor gain, the SNR improvements achieved from ground loading can far outweigh any reduction in touch sensitivity when operating in noisy environments.

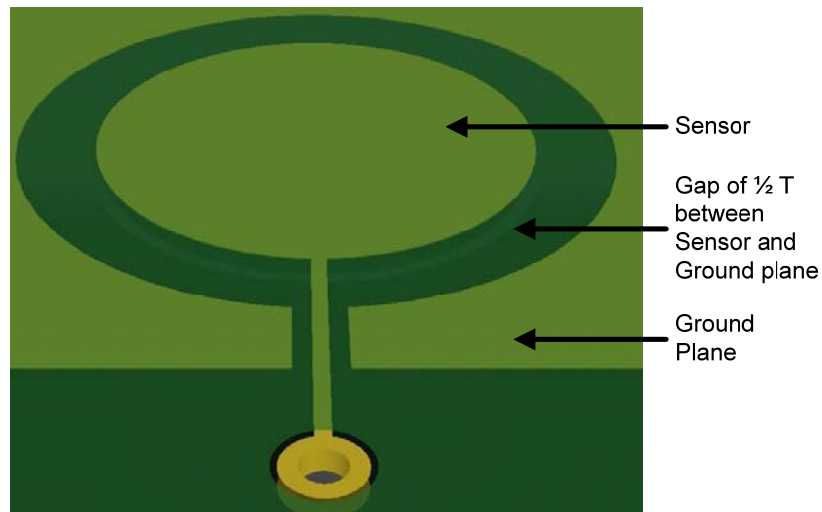
In most cases, loss of sensor gain due to the introduction of ground loading can be compensated by careful sensitivity tuning.

For mutual-capacitance electrode configuration using QMatrix, ground loading does not result in any additional improvement to noise immunity.

### 4.2.1 Ground loading planar construction

Ground loading for self-capacitance sensors is indicated in the [Figure 4-4](#). The gap between sensor and ground plane should be half the thickness of the overlying panel T. This method is useful for single-sided PCB's.

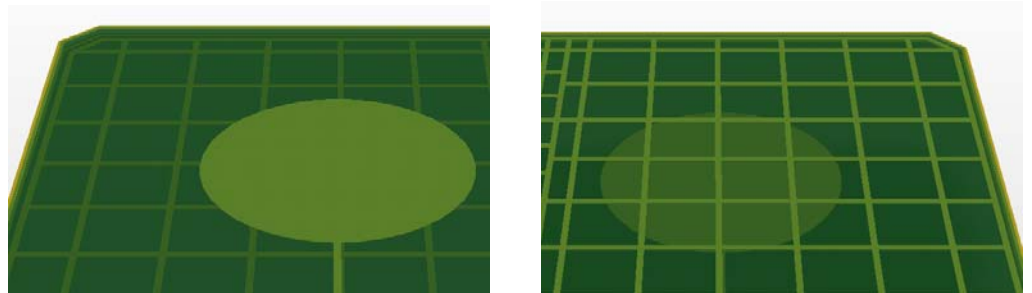
**Figure 4-4.** Ground flood, near to a sensor.



#### 4.2.2 Ground loading, hatched ground plane behind the sensor

Figure 4-5 shows the arrangement of a hatched ground plane behind the sensor. The left side image indicates the top side view and the right side image indicates the bottom side view.

**Figure 4-5.** Hatched ground plane behind the sensor.



To balance the tradeoff between sensor gain reduction and noise suppression a 50% mesh flood is recommended for most applications.



## 5 Conclusion

For the case of Atmel AVR QTouch, Atmel AVR QTouch-ADC and Atmel AVR QMatrix methods, increased series resistor along with 'charge pulse' tuning provides improved protection against conducted immunity noise. In the case of QTouch and QTouch-ADC methods, additional improvement can be achieved by using ground loading.

## 6 References

1. Touch Sensors Design Guide.  
[www.atmel.com/dyn/resources/prod\\_documents/doc10620.pdf](http://www.atmel.com/dyn/resources/prod_documents/doc10620.pdf).
2. Atmel AVR QTouch Library User Guide.  
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3. QTAN0062: QTouch and QMatrix Sensitivity Tuning for Keys, Sliders and Wheels.  
[www.atmel.com/dyn/resources/prod\\_documents/QTAN0062.pdf](http://www.atmel.com/dyn/resources/prod_documents/QTAN0062.pdf).

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