Projected Capacitive Touchscreens for Challenging Environments

Introduction

Projected Capacitive Touchscreen (PCT) technology where the sensor is located behind the front panel of the display stack is now the de-facto standard HMI technology for the vast majority of smartphone and PC Tablet applications. The feather light touch needed to register a position or trace a gesture into the device provides a very satisfying user experience.

One of the first mainstream applications of the technology was in the LG Prada Smartphone[i] back in December 2006, just before the first iPhone was unveiled in January 2007[ii]. Even before these iconic product introductions, one of the pioneers of Projected Capacitive Touchscreens, Quantum Research Group, since acquired by Atmel Corp, introduced projected capacitive touchscreens into home appliances in January 2006 in the Whirlpool Velos Oven[iii].

Back in these early days of PCT technology the touchscreens could be built around off the shelf microcontroller hardware and were fairly unsophisticated from an HMI point of view – rather low resolution typically, just driving fixed touch areas on the display. Much valuable insight was gained in these early implementations of the technology and now the rapidly commoditising mobile handset market is realising the improvements associated with this pioneering work.

All of the discussions below assume that the preferred technology will be a full multi-touch application. Most of the modern PCT controllers on the market implement full multi-touch, where typically 10 touch points are supported / reported. Although some operating systems / drivers and their associated applications do not fully support such a large number of touch points, the ability to use or selectively ignore the information associated with full multi-touch is key part of a high quality user experience.

Touchscreen Basics

In its most basic form, a PCT touchscreen consists of a front panel (usually glass) a sensor element (usually two layers of ITO on glass or PET) – this is then attached by a flex PCB circuit 'tail' which is electrically bonded to the sensor and which can either have the driver chip as part of the PCB (active tail) or which can route the sensor to a connector on the main board of the system where the driver IC may already be placed.

Front Lens - 0.7 to 5 mm
Optically Clear Adhesive - 0.05 to 0.1 mm
ITO on PET Receivers - 0.18mm
Optically Clear Adhesive - 0.05 to 0.1 mm
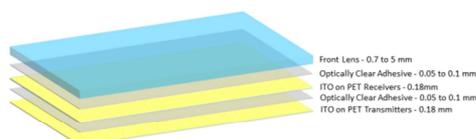ITO on PET Transmitters - 0.18 mm

Diagram 1 – typical construction of a film based touchscreen

The ultra-high volume product world is already moving down the path of further integration of sensors to drive out cost and to make products thinner and lighter. This is being achieved by simplifying / removing parts of the layer stack to produce 'window integrated' assemblies where the sensor is 'deposited' directly on the front panel or through integration of the PCT sensor either in the upper layers of the LCD (on-cell) or deeper in the LCD structure (in-cell). The highly custom nature of these innovations and the specialist construction techniques needed to integrate them with the mechanics of the end product limits their application.

There are two main ways to drive a PCT touchscreen and although there are many variants of these, the underlying technology is based on similar principles. The first way is to pulse 'packets' of charge into the transmitter lines and to measure the charge which is collected from each of these lines at the receiver line – this is a broadband measurement technique. The second technique is to use a fixed (or swept) frequency waveform to excite the transmitter lines and which then couple with the receivers to produce a fixed pattern of response according to the standing capacitance of each of the nodes – this is a narrowband technique.

These processes define the resting values of capacitance at each transmitter / receiver 'node' which is used as a reference. When a human finger or other conductive item is brought close to a node, the coupling between the transmitters and receivers is reduced and the change in coupling can be measured.

Sensor construction for full multi-touch requires an orthogonal grid 'matrix' approach to sensing where the 'image' of the surface is built up by interpolating between the nodes which are formed where the X drive lines and the Y sense lines intersect. This image of the touch points can subsequently be processed to provide positional touch data. The minimum resolvable adjacent finger distance is usually about 2x the pitch of the nodes.
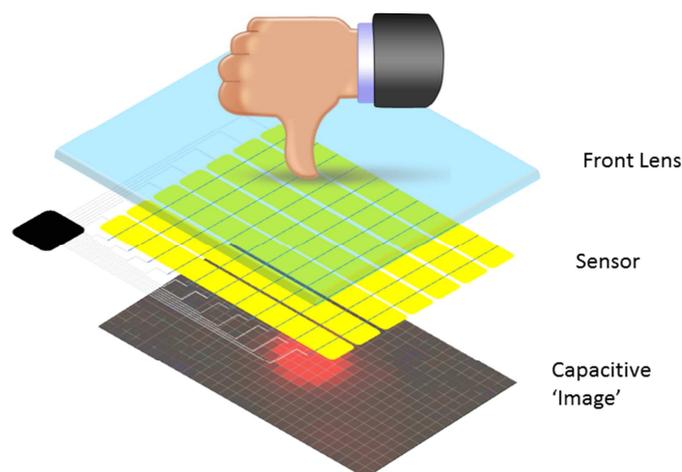

Diagram 2 - Orthogonal sensor arrangement and capacitive image

Noise requirements

One of the most important factors which has limited the performance and deployment of projected capacitive sensing and which still needs careful consideration is the impact of system noise on the stability and accuracy of the positional information generated by the driver IC.

There are two main noise conditions which are of concern when developing a robust PCT touchscreen which works well at the system level. It is possible to define various levels of degradation of the touch performance or behaviour which can be tolerated in different applications as follows:

Class A – the HMI system should continue to perform as intended (no false touches, touched or untouched) with no degradation of touch performance.

Class B – the HMI system can display a pre-defined level of degradation in touch (although no false touches, touched or untouched are allowed), possibly to gracefully stop reporting touch altogether. The equipment returns to normal operation as soon as the noise source is removed without needing user intervention to achieve this.

Class C – the HMI system can stop reporting touch position information or can report wrong, false or erratic touch position in the presence of the noise disturbance and may require a reset or power-cycle to recover once the noise is removed. Any effects are non-permanent.

Class D – the HMI system changes state permanently due to the noise (loss of settings, circuit damage etc.).

The noise conditions which are of primary concern in PCT touchscreens are defined in documents EN61000 4-3 and EN61000 4-6 and tests to determine the susceptibility of a system to these sources of noise can be carried out up to fairly extreme levels depending on the requirements for safety or usability in any particular application.

EN61000 4-3 relates to disturbances caused by fast transient noise of the sorts which can be generated by displays, fluorescent lighting and switched mode power supplies. In mobile handsets, where an aftermarket charger is often used to condition the battery, the unpredictable nature of these power supplies can lead to problems which manifest as class C performance or even unacceptable reporting of corrupted positional information. In applications where the touchscreen is to be used for more critical applications than in a mobile phone, this source of noise must be fully understood and mitigated.

EN61000 4-6 relates to noise disturbances where common mode noise is injected concurrently on all the terminals of the device. The injection voltage and frequencies of interest depend very much on the application and so for example, in a point of sale terminal, the operating frequencies and harmonics of the radio transmitters would need to be well understood. A common requirement is for class B operation over the broad spectrum but with class A operation at certain defined frequencies. It is worth noting that to make this test meaningful, it is essential to 'touch' the system to reveal the noise issue.

The more fully developed PCT driver IC's on the market today use a range of internal features to help mitigate the potential noise problems. These range from the use of high voltage drive, smart frequency hopping capabilities and extensive use of hardware and software noise filtering techniques. All of these and other techniques inside the IC can help to reduce the levels of system noise susceptibility to acceptable levels.

It is often not well understood that the sensor on a PCT touchscreen acts as an antenna to direct the noise into the driver IC and because of this, the sensor and IC need to be considered as part of a complete 'system'. There are many possible design and construction options for the sensor which and it is important to choose and implement a design which will work well in the specific application. A poor sensor implementation can lose as much as 80% of the SNR design margin in any particular system.

Multi-touch requirements & other HMI Considerations

Multi-touch is an often mis-understood part of projected capacitive sensing, there are few applications which meaningfully use more than a few touch points for input.

The most important part of multi touch is the ability to accept or reject the touch information in a smart way which enhances the user experience. This smart use of information can be handled at the driver IC level where only pre-qualified touch data is presented to the operating system or it can be handled in the operating system itself or even at the application level.

Handling the multi-touch information at the level of the driver IC can be problematic where several IC vendors provide a touch solution for a common platform as the lowest common denominator usually defines the capability. In a bespoke operating system however, presenting pre-qualified touch data can have significant advantages. For example, it may be appropriate to present only ONE touch to the OS and that any subsequent touches should be ignored, perhaps on an industrial weighing system for example. In touchscreen equipped cooking surface, it may be desirable to clean the surfacewithout generating unintended touch events, so in this case, a 'large' touch object would not be reported to the operating system.

Multi-touch capabilities which provide a good level of discrimination combined with the feather touch sensitivity of a PCT touchscreen appear to provide an optimal HMI for a broad range of applications.

Other areas of consideration in PCT systems are when the application calls for use of gloves or where some splashes of water on the surface are inevitable. The use of typical gloves found in many applications is entirely possible with a good design where noise issues have been properly mitigated, and the system set up correctly to be sensitive and stable. Although PCT technology is not well suited to full or partial immersion in liquid, the presence of modest amounts of water can still be tolerated to provide trouble free operation provided the sensor design and quite critically, the construction stack and materials are considered from the outset.

Additional elements of HMI systems which are sometimes included in the designers wish list are the ability to use a small stylus, the ability to preview a touchdown position before the finger lands on the surface (hover function), sensing pressure on the screen as a secondary select (force sensing) and Haptic feedback to provide positive feedback of a successful touch event. All of these elements

can potentially be included in the final system architecture but they usually significantly add to the complexity and architecture and are only rarely currently implemented.

Good vs bad touchscreens

The definition of what is good and what is bad from a touchscreen point of view is quite dependent on the end application. The rapid demise of resistive touchscreens has primarily come from the poor usability and reliability and the relatively poor optical properties which restrict visibility of the display. PCT touchscreens overcome all of these issues but they do have some underlying potential weaknesses, some of which can be overcome by good design and implementation and other weaknesses which are harder to mitigate.

It is often not easy in a finished system or an evaluation module to determine what issues are due to the operating system or application software and which are due to the underlying reported data from the capacitive sensing IC. Despite this, there are some simple tests for touchscreens which can provide a rapid measure of their suitability for an end user application; two examples relating to noise are as follows:

For example in a mobile handset or tablet PC, you can plug onto an aftermarket charger (or charge directly from a laptop PC USB port) and then browse some fixed images. Initially, you should not notice anything abnormal, however, when you actually hold down a touch on the surface of the screen, in a poorly implemented system, you will notice that there is some jitter in the position of the picture as the noise influences the interpreted position. You might also note that using a bigger touch (eg a thumb) or several touches make the problem much worse.

The reason the noise only manifests when you touch is because the noise is 'earth referred' which means that your touch actually becomes the 'source' of the noise.

A second test worth carrying out is to bring a mains powered fluorescent lamp in proximity to the device you are evaluating – this is quite a stringent test and will often result in unstable operation.

These tests can indicate the overall stability of a projected capacitive touch system and while not qualitative tests, they do indicate areas for further investigation if your system is more mission critical than a typical mobile phone.

Standard Products

A few companies around the world have tried to introduce 'standard' PCT products which are aimed at simplifying the implementation of the technology in end user applications. Unfortunately, in most cases, the end users have found those standard products to be anything but simple to implement, with one of the biggest issues being false activation due to system noise.

Touchnetix has taken a more robust approach to introducing PCT standard products by designing specifically for the most challenging environments and ensuring that the product is very well characterised and stable. The first standard product introduced by Touchnetix as part of the *Brilliance* series is the 10.4" diagonal TNxBR-104A-A2-AB-001 which is known as "Attis". This module is tested to work with a range of LCD's and has also been evaluated to pass the stringent EN61000 tests described earlier in this document. The unit tracks up to 16 touch points and is designed to

interface over I^{2}C or it can work directly over USB as a native digitiser device on Windows XP and higher.

Because the Touchnetix PCT modules are designed to be very robust, when the module is used with the Touchnetix evaluation, tuning and testing software suite, the system integrator has all the tools needed to quickly set up and integrate the unit even in the most demanding operating environment.
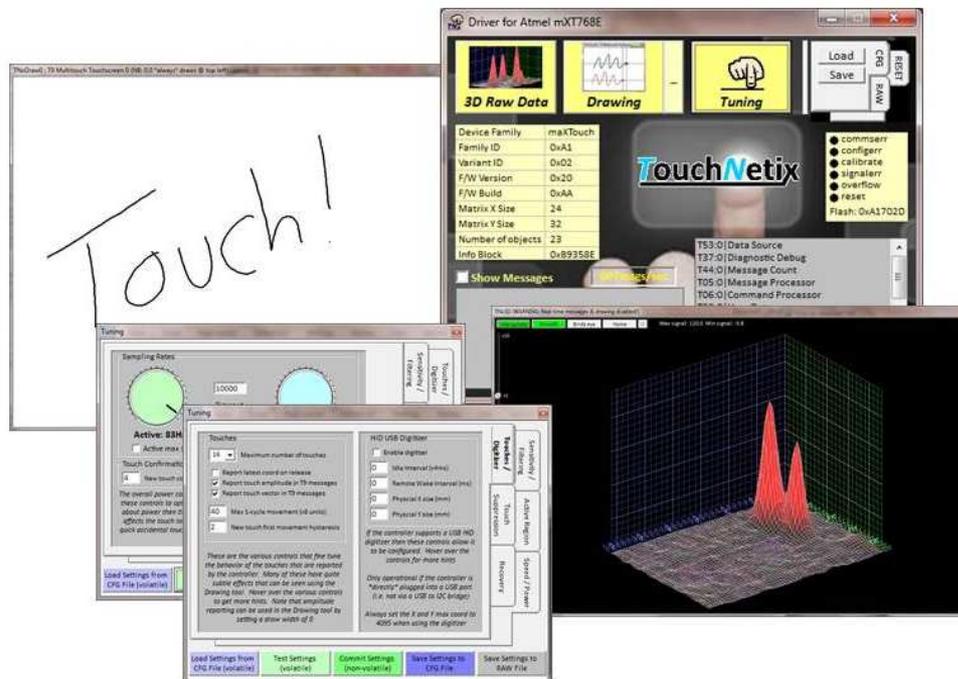

TouchHub – Evaluation, Tuning & Test Suite

Conclusions

Projected Capacitive Touchscreen technology is currently the standard for high volume applications where finger input is considered essential. Many of the problems associated with deployment of this technology have been reduced in magnitude or solved as the commoditisation for mobile handsets has driven the investment over the past few years.

A generation of touch enabled device users are now looking forward to similar functionality in user Interfaces becoming available on things as diverse as home appliances and security systems and also in a broad range of infotainment systems in cars and in many commercial applications.

These screens which are often larger than the consumer electronics applications and which are usually in more demanding environments mean that careful design and implementation of the projected capacitive touch technology is needed to be sure that the end user applications work well.
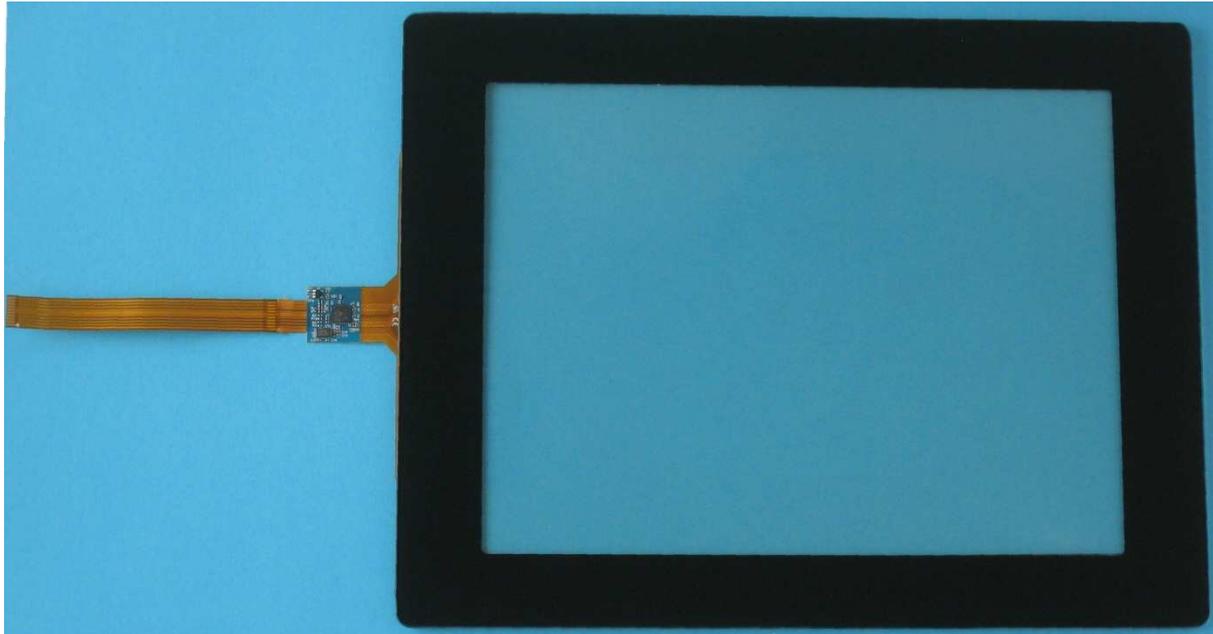
Picture 1 – Standard 10.4" projected capacitive touchscreen module with chemically strengthened front panel, active tail and 2 layer ITO on PET film sensor.

About the Author

Chris Ard is Managing Director for TouchNetix Ltd., a company dedicated to the design and supply of high performance Capacitive Touchscreen and other HMI technology for specialist applications. Before founding TouchNetix, the author, along with his the three co-founders comprised the management team of the Touch Technology group in Atmel Corporation which was established when Quantum Research Group, one of the pioneers of Touch Technology, was acquired by Atmel in March 2008.

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