NORITAKE CO., INC. WHITEPAPER

The Touch Screen Integration Problem

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Introduction

The purpose of this whitepaper is to address a common problem many engineering teams face when creating a new product: that the ubiquitous touchscreen is often overlooked in the initial design phase, in comparison to the application's core function, resulting in unwarranted costs down the line in development, production, sales, and maintenance.

In order to discuss the touchscreen integration problem, capacitive touchscreen construction and touch detection methods will be investigated. Common touchscreen integration pitfalls will be addressed and explained. Then, metallized projective capacitive touch (MPCT) screen technology will be explained and compared to common capacitive touchscreens. We will then dive deeper into MPCT technology and discover why it helps solve the touchscreen integration problem.

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Purpose of Touchscreens

Touchscreens are input devices positioned over liquid crystal panels that allow intuitive user input and functionality. Since touchscreens make it possible for someone to directly touch and control prompts such as “push” or “slide,” they are exceptionally user-friendly.

Compared to buttons, switches, and dials, capacitive touchscreens provide a more durable and user friendly surface to directly interface with integrated computers. Touchscreens do not succumb to wear-and-tear nearly as quickly and will respond just as quickly after 10,000 presses as they did with the first press. A physical button will have significant wear after 10,000 presses and may require maintenance. The only thing a touchscreen might need is to be wiped down and, if necessary, manually recalibrated.

Where are touchscreens used?

Touchscreens have become a part of our everyday lives. Smartphone, portable computer, and handheld device manufacturers use touchscreens for their display screens. Banks use touchscreens in their ATMs. We interact with touchscreens in tablet computers, portable game consoles, car navigation systems, multimedia stations, arcade games, information boards, restaurant order systems, and countless more places and industries. In just the last few years, they have become common in our daily lives and more desirable in new product/system designs.

The Touchscreen Integration Problem

When designing a system that requires touch input, an engineering team must consider numerous factors including: user interface control layouts, host system environment(s), and required screen protection. Design of user input control layouts are flexible and handled by software changes, placements of buttons, text, and image placement. However, host system environment(s) and screen protection design may not be as accommodating.

To be used in a system, a touchscreen must be reliable and maintain consistent touch input detection according to the system’s needs. For example, a system requiring only single button presses (or taps) has different touch sensitivity requirements compared to a system using a slider or using pinch-to-zoom.

Many touch display modules are designed for limited cover overlay configurations. This usually includes a pre-bonded cover overlay in a dry environment. This makes it difficult to select a touchscreen appropriate for unique aesthetic and environment needs. The current touch screen market is saturated with affordable displays designed for commercial use. The touch screen materials used are basic and the underlying touch controller firmware is set to detect bare hand touch input.

As touchscreen technology continues to be integrated into nearly every part of our lives, the demand for environmentally flexible systems is increasing. Touchscreen controlled showers, drink dispensers, ovens, etc., have unique environmental requirements. Surprisingly, the majority of touch screens on the market today have not added configurable touch sensitivity to their feature set. Touch controller manufacturers have moved forward in this realm, but many standard touch display modules do not take full advantage of the touch controller's capabilities.

How do we begin to approach a solution to this problem? Let's take a look at the construction of touchscreens, how metallized projective capacitive touch technology improves on this design, and how touch adjustment techniques can allow for a touchscreen function in various environmental conditions.

Ordinary Capacitive Touch Screen

Background

The first finger-driven touchscreen was invented by Eric A. Johnson in 1965 at the Royal Radar Establishment. The first application for capacitive touch was an air traffic control panel. The name "touch screen" wasn't used until 1977, when Elographics produced the first curved glass touch sensor interface.

As time went on, touch technology became more common and was finally used in a home computer in 1983 on the HP-150. This device used a grid of infrared beams to detect finger movements. IBM's Simon smartphone was created in 1993 and had an integrated touch screen. The era of Palm Pilots followed shortly afterwards in 1996. In 2002, Apple introduced its 2nd generation iPod controlled by a touch-sensitive scroll wheel. This helped consumers become more comfortable with touch-based device control. This evolved into full touch screen operation and resulted in tablets and smart phones entering the consumer market. This dramatically increased the popularity of touch screens, effectively removing keyboards and buttons from handheld devices over the course of a decade.

Electrostatic capacitive touchscreens are used in numerous smartphones such as Apple iPhones and Android devices. Unlike resistive type touchscreens, electrostatic capacitive touchscreens are highly responsive yet cannot react to glove touch, or fingernails. The disadvantages of capacitive touchscreens are they only react to a conductive material, and they may not work correctly if wet.

Mechanics

When a fingertip comes into contact with a capacitive touchscreen, the conductivity of the human body will interact with the touchscreen's circuitry as a means for detecting input.

For the purposes of this whitepaper, we will dive into two types of capacitive touch screens: surface capacitive and projected capacitive.

Surface Capacitive Touch Screen

A surface capacitive touch screen uses a transparent layer of conductive film overlaid onto a glass sublayer. Typically, the conductive film contains indium tin oxide (ITO). ITO is a ternary composition of indium, tin, and oxygen. Indium oxide is transparent, so when it is doped with Tin, it conducts electricity while staying transparent. This allows it to be used in touch screen applications.

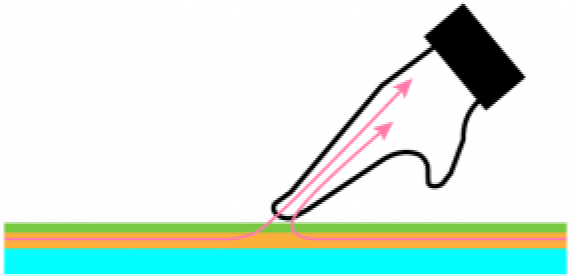

Figure 1: Surface Capacitive Diagram

A protective layer is applied to the conductive film. Voltage is applied to the electrodes on the four corners of the glass sublayer to generate a uniform electric field. When a conductor touches the screen, current flows from the electrodes to the conductor. The location of the conductor is then calculated based on electrode current activity. Surface capacitive touchscreens are often used for large screen panels.

Projected Capacitive Touch Screen

Projected capacitive touchscreens are extremely precise and quick responding. This technology is typically found on smaller devices such as iPhones, iPod touches or iPads.

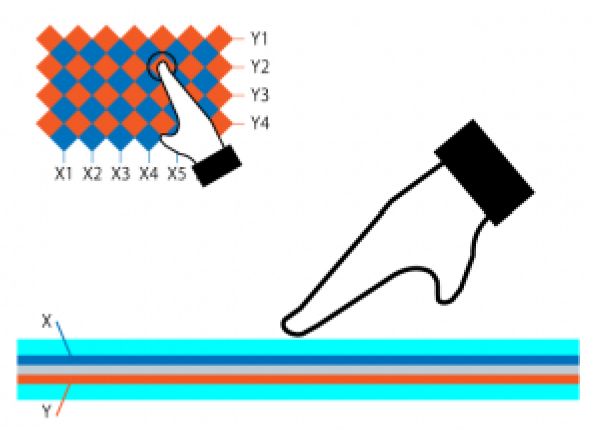

Figure 2: Projected Capacitive Diagram

Unlike surface capacitive touchscreens, which use four electrodes and a transparent conductive film, projected capacitive touchscreens use a vast amount of transparent electrodes arranged in a specific pattern on two separate layers, similar to Figure 2. When a conductor moves near the screen, the electrical field between the electrodes changes and the sensors can instantly identify the location on the screen. This is seen in Figure 3.

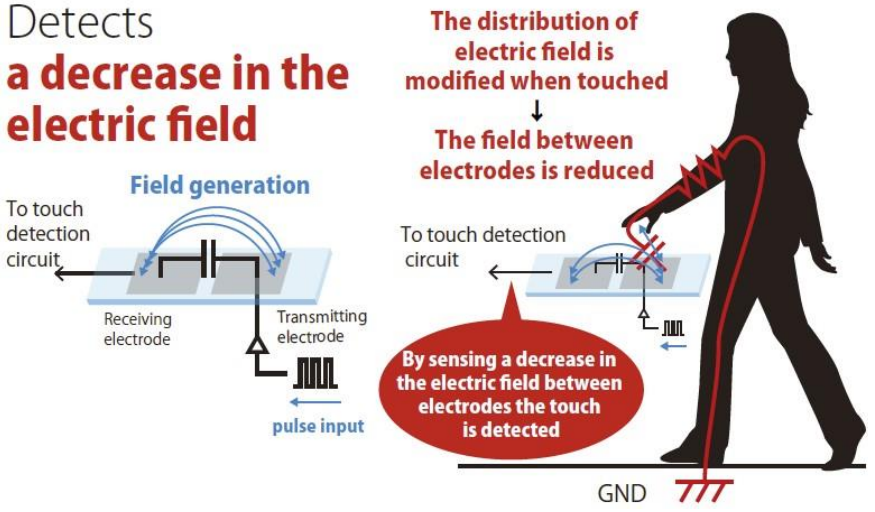

Figure 3: Electric Field Touch Detection

Projected capacitive touchscreens can accurately register single and multi-touch events. Every electrode produces an electrical field relative to another electrode, so multiple fields can change and be detected by the touch controller. However, these electrical fields are very sensitive and susceptible to noise. Electromagnetic interference, water, and static electricity are a few possible noise sources.

Sensitivity Adjustment

This depends on screen/module manufacturer, the touch IC's capabilities, and system firmware.

A simple technique is to let the user adjust the touch input gain. Increasing gain increases the touch panel's sensitivity to changes in the electrical field between electrodes. This helps the touch screen detect objects that cause a small electrical field change or detect a touch input through thick glass. The drawback to changing gain is that it makes the touch screen even more susceptible to false readings due to noise.

Integration Difficulties

Challenges arise with touch screens whenever an obstacle is introduced between the sensors and touch input. Common obstacles are gloves, water, overlay, and air.

Gloves are typically worn in medical and industrial environments and add an extra layer of material between the touch sensor and finger. Depending on the type of glove, it may create a large distance between the finger and touch sensor. For example, leather gloves add an extra layer between the user's finger and touch sensor, thus reducing the electrical field change between electrodes and in turn, reducing the perceived touch levels.

Water is a conductive liquid capable of producing noise on the touch screen surface. The noise it can create varies depending on the amount of water and composition. It can very easily cause the touch screen to detect a touch input where there is only water on the screen. For example, salt water is more conductive compared to normal tap water and will cause a greater disturbance. So a salt water spill on the touch screen would cause many touch inputs to occur, potentially pressing buttons and triggering system commands that may cause damage. Also, note that tap water composition varies geographically as it is dependent on the water source and filtering provided by local water supply systems.

Overlays are used to protect the touch screen from breaking during a normal day of operation in the associated working environment. For example, ATMs and vending machines need a very thick overlay to protect the money/product stored in the machine. Typically, there is another protective structure after the touchscreen to protect the goods, but the exterior will be more prone to attack if it appears as a weak point. Overlays are normally made of glass, acrylic, or polycarbonate and reduce the touch level, similar to a glove, but across the entire display. Acrylic overlays cause a higher touch level reduction than glass, so thicker glass can be used compared to acrylic.

Metallized Projected Capacitive Touch Screen

Noritake understands the many touch screen integration challenges that engineering teams face. This drove the development of metallized projective capacitive touch (MPCT) technology and continues to push the improvement of touch screen sensitivity flexibility in firmware and tools.

Mechanics

Noritake's metallized projective capacitive touch screen utilizes the construction and mechanics described in the projected capacitive touch screen mechanics section, but with a fine mesh made out of an aluminum base alloy. Noritake's experience with detailed ceramic art and VFD manufacturing allows for very fine pitch aluminum pitch creation on a glass substrate.

Compared to a common projected capacitive touch screen using ITO, the aluminum mesh has lower electrical resistance and outputs a stronger touch signal. This gives the associated touch peaks a higher touch value with a thinner overall shape, thus improving the signal-to-noise ratio. This means there is a larger difference between a touch input and the surrounding noise on the touch screen. This difference is seen in Figure 4. The touch peak is much higher than the "ordinary" touch screen's touch peak and the surrounding noise is less prominent on the Noritake touch panel.

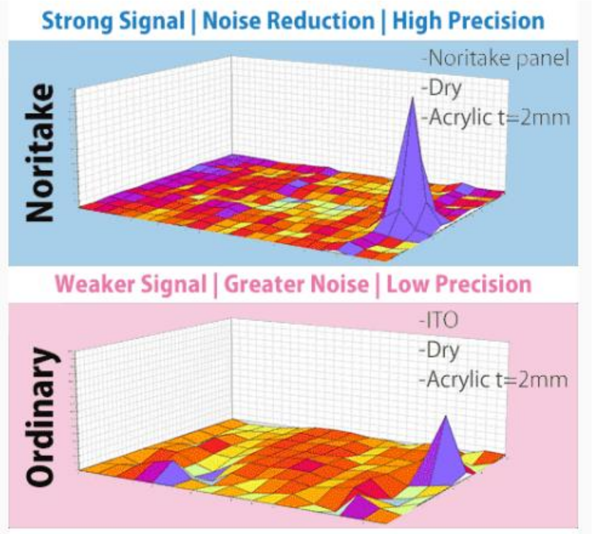

Figure 4: Signal-to-noise Ratio Comparison

MPCT's high signal-to-noise ratio allows developers to counteract integration difficulties that touch screens face. The touch sensitivity techniques described later in this whitepaper will further reduce other associated design concerns. Figure 5 shows a touch comparison between a common touch screen and an MPCT screen.

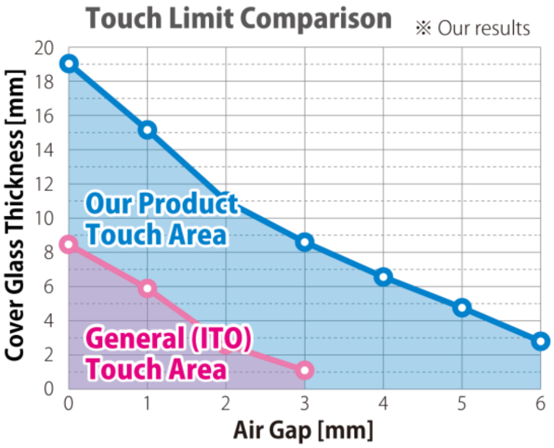

Figure 5: Touch Limit Comparison

The colored areas show where the touch screen works based on the cover glass thickness and air-gap distance applied during the touch test. Both of these physical integration constraints limit the common touch screen between an 8mm thick cover glass and 3mm thick air-gap. This might look like it covers enough ground (1mm air-gap and 3mm cover glass), but this is the absolute maximum that an input can be read. In application, where there is noise from the environment, stray capacitance from the enclosure, gloved users, or moisture, the pink area covered my ITO will not be able to filter out a human interaction from false inputs.

The MPCT screen can handle a 19mm thick cover glass or at least a 6mm thick air-gap. Figure 6 illustrates the touch limitation differences by taking data points from the touch limit comparison graph and comparing both scenarios.

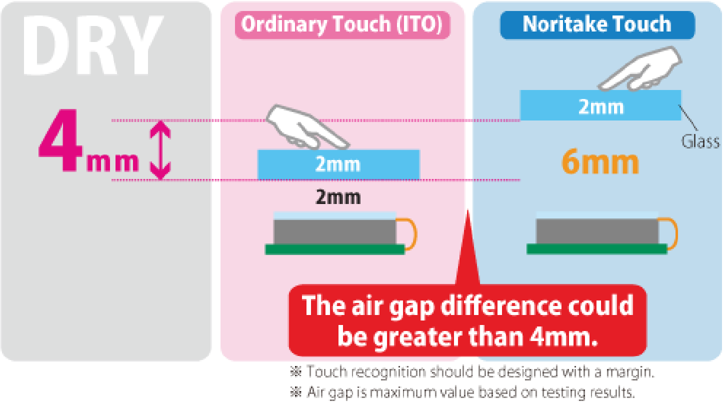

Figure 6: Overlay and Air-Gap Comparison

NOTE: Figure 5 and Figure 6 show testing results performed via Noritake internal testing. These results are not guaranteed on all touch products.

Touch Detection

The touch sensors quantify the electric field strength between electrodes. A touch input/release is determined based on electric field strength changes. Within a Noritake GT series display module, the firmware implements more stipulations and logic before a touch is finally recognized as valid. Figure 7 simplifies this processing into a graph. Basically, when the red line dips below the blue dotted line, a touch is seen as ON for that duration. Otherwise, no touch is triggered.

Touch Detection Flow

1. If there is no human finger (or equivalent conductor) near the touch panel, no touch input is triggered.
2. Count Value decreases as a finger approaches the touch panel.
3. When Count Value falls below the threshold, a touch input is triggered.
4. Count Value increases as a finger gets further away from the touch panel.
5. When Count Value exceeds the threshold, no touch input is triggered.

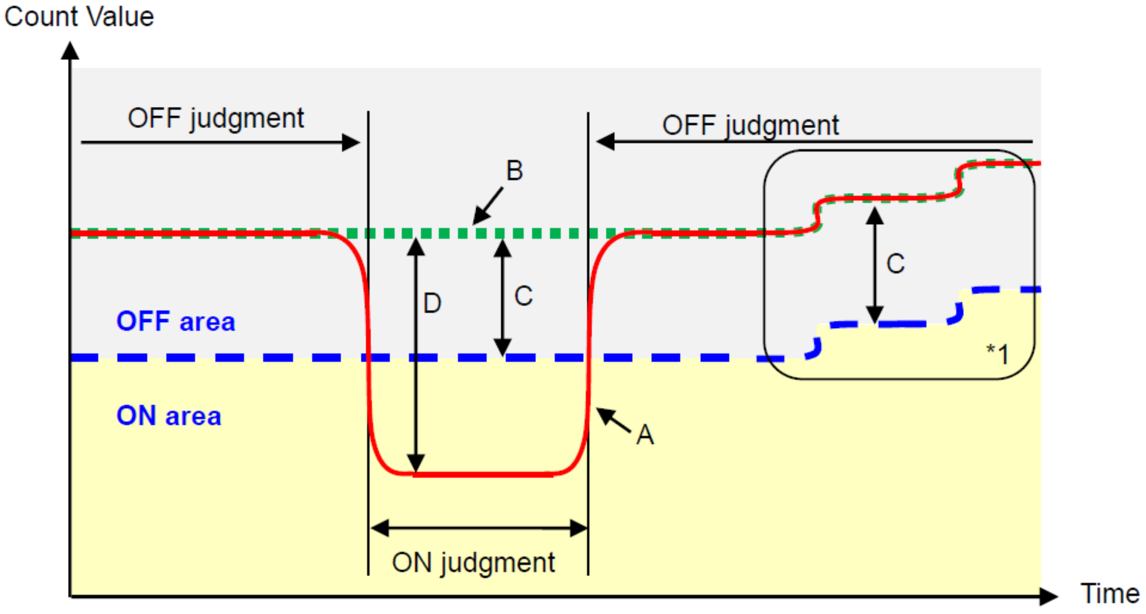

Figure 7: Touch Detection Graph

A. **Count Value:** A numerical value of the electrical field strength between the electrodes.
B. **Touch Reference:** Count Value when no touch input is triggered.
C. **Threshold:** The touch input judgement value (a constant value from the touch reference)
D. **Touch Level =** Touch Reference - Count Value

**1: If the surrounding environment changes while no touch inputs are detected, the Count Value may change accordingly. The built-in calibration function averages previous Count Values to achieve stable touch detection in the changed environment. This calibration function can be turned off as well.*

**2: If a touch is triggered for more than ten seconds, Touch Reference is set as the Count Value and the touch input is released. This is done to prevent any unexpected conductors and objects from continually triggering touch inputs. This feature can be turned off with help from Noritake.*

Sensitivity Adjustment Techniques

The sensitivity of Noritake metallized projected capacitive touch screens can be adjusted in a few ways. Two of which are: threshold value adjustment and uploading a touch setting package file (pre-configured and custom). These techniques help the touch screen achieve stable sensitivity in challenging environments. (For example, thick glove operation, an enclosure with a thick overlay, or a wet environment)

Threshold Value

MPCT screens rely on a threshold value to determine if a touch input is valid. If a touch input value is greater than the threshold value, then the input is registered as a touch (either press or release). If a touch input value is below the threshold value, then the input is ignored. Figure 8 shows three simultaneous touch inputs on an MPCT screen:

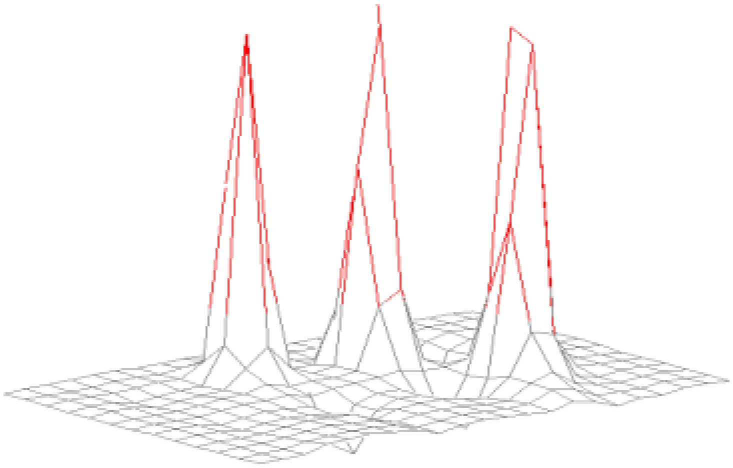

Figure 8: MPCT Screen | Three Inputs

The red area is the touch input portion that meets or exceeds the threshold value. The grey area is the portion under the threshold value. About 75% of these touch peaks exceed the threshold value, that means there is some room for touch inputs at a lower touch value to trigger. This is not good, as stray noise like water may trigger a touch input. To fix this, the touch threshold value needs to be adjusted so that only 25-50% of the peak breaks past the touch threshold value. This is considered the threshold sweet-spot. Figure 9 shows an improved set of touches:

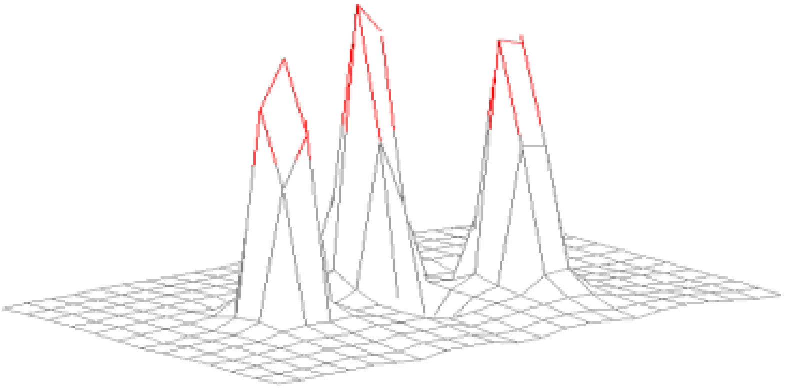

Figure 9: MPCT Screen | Improved Threshold

The threshold value has increased, so other noise that causes smaller touch peaks will get ignored. This increases the confidence rate that the touch screen is detecting proper input.

On the other hand, the threshold value should not be set so that less than 25% of the correct touch peaks break through. This introduces the possibility that the touchscreen may not detect a proper touch from the user. Touch inputs have a degree of variability and a "tight" touch threshold value does not allow for this. The previous diagrams show this. Both diagrams show three fingers touching the screen at the same time. However, the peaks of all three are not equal. If the touch threshold was set higher, only one out of the three touches may get seen as a valid touch, even though three fingers are legitimately touching the screen.

Touch Setting Package File

If adjusting the touch threshold value does not meet desired touch sensitivity requirements, a touch setting package file can access the module's touch controller and fine tune its touch settings. In conjunction with a recommended touch threshold value, touch can be adjusted to work in a plethora of environments.

Touch setting package files contain numerous parameters that help improve touch detection, ignore noise, and adapt the touch screen to unique circumstances. Some settings limit certain touch events. For example, the screen can be configured to ignore any touch movement after the screen has been touched. This limits graphical user interface functionality to only use buttons with a hard, deliberate touch, which stabilizes the touch experience if the display is in a turbulent environment.

Water interference can be dealt with using a couple of parameters: maximum touch inputs and maximum touch area. If the maximum number of touch inputs is limited to 1, then numerous water droplets are easily ignored. Large amounts of water can be ignored if the maximum touch area is adjusted properly. Bare hand touch input generates a much smaller touch area compared to a large water droplet. Setting the maximum touch area to the average touch area from a bare will help the touch screen ignore large water droplets and even water flowing right over the screen.

Numerous pre-configured touch setting package files are available from Noritake. These pre-configured files were created and tested for common environmental and enclosure parameters. For example, a 3.0mm acrylic overlay with a 0.5mm air-gap being used with bare hands.

Customized touch setting package files can be created as well. If no pre-configured touch file can meet the desired touch sensitivity requirements, Noritake engineers are open to collaborate and create a custom touch package file.

Conclusion

In conclusion, the aluminum touch screen electrode material and flexible firmware found in Noritake MPCT screens can help solve the touchscreen integration problem. The high signal-to-noise ratio improves touch signal strength, precision, and noise reduction. Compared to common ITO touch screens, MPCT screens have a wider range of adaptive sensitivity. Design challenges concerning cover overlays, gloved touch, and wet environments turn into manageable system parameters when touch sensitivity settings can be customized to meet user interaction and product aesthetic needs. Noritake touchscreen solutions become secondary to the vision of your core product instead of its form and function being designed around the limited capacity of standard touchscreens. MPCT screens are included in all Noritake GT series display modules: serial command-controlled, digital video input, and embedded host board types.

References

Bellis, Mary. "The Inventor of Touch Screen Technology." ThoughtCo, Feb. 11, 2020, thoughtco.com/who-invented-touch-screen-technology-1992535.

Mazur, Michal et al. “Influence of thickness on transparency and sheet resistance of ITO thin films.” 11/17. Wroclaw, Poland.

Appendix

Eric A. Johnson: An engineer at the Royal Radar Establishment with an interest in developing a touchscreen for air traffic control.

Royal Radar Establishment: A scientific research establishment in the United Kingdom’s Ministry of Defense.

Elographics (now Elo Touch Solutions): An electronics company focused on the engineering and production of touch screen technology.

Disclaimer

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