

Touch Technology for Design and Application



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TECHNICAL NOTE

INTRODUCTION

Touch technology goes back many years, but, it is the explosion of handheld display based devices that has been spawning renewed interest and development in this technology. Clever innovations and research have paid off and new classes of more advanced and intelligent user interfaces now include gestures as well as transparent and opaque zones.

A generation of gamers and phoners has created an expectation that any new devices in their lives will have sexy graphics and a killer user interface. People love their toys and touch interfaces are now more in demand than ever before.

While some companies have the deep pockets and engineering resources to be the pioneers of this evolving

technology, most are in the game but more on the sidelines watching and reacting to features that people must have. For time to market reasons, chip-makers are doing a lot of the heavy lifting by integrating well engineered solutions into their embedded systems offerings.

This article looks at touch technology and what options we designers have for integrating it into our designs and applications. It examines the underlying touch sensing technology choices we have and their strengths and weaknesses. It looks at sensing circuitry and algorithms to detect user intent. Finally it presents a well engineered and flexible example.

TOUCHSCREEN TECHNOLOGIES

Analog Resistive Touch Technology

The Technology

Analog resistive touchscreens are tough, durable, and can be used with a stylus or a glove. Overall, two types are most common and readily available, 4 wire and 5 wire.

With four wire, two closely spaced sheets are separated by fine spacers. The bottom rigid layer is typically glass while the upper resistive layer is a polymer based flexible sheet like Polyethylene (PET) that can non destructively deform to allow it to make contact with the lower layer when touched (See Figure 1).

Both the lower and upper layers are evenly coated with a resistive compound like Indium Tin Oxide through a deposition process. This creates a uniform resistive gradient across the touch area. When a touch occurs, it divides the resistors in both the X and Y axis into ratios corresponding to the location of the touch (See Figure 2). By alternatively driving X axis and Y axis through the use of bus bars, an analog voltage can be read into an A/D converter using a sense bar in the opposite axis.

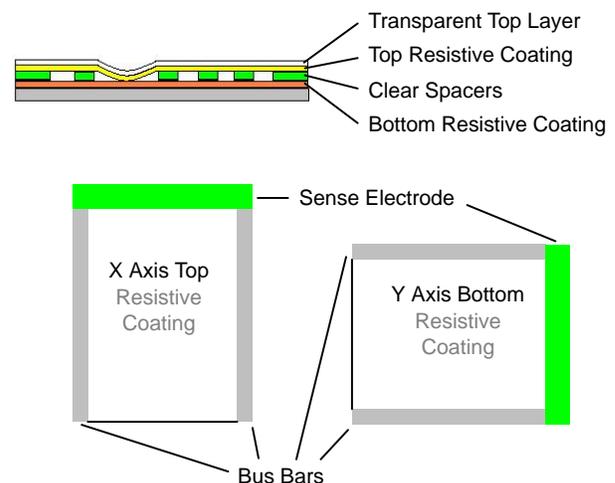


Figure 1. Resistive coatings deposited on transparent insulators creates resistive voltage dividers for each axis. Sense electrodes read the voltage and software triangulates position.

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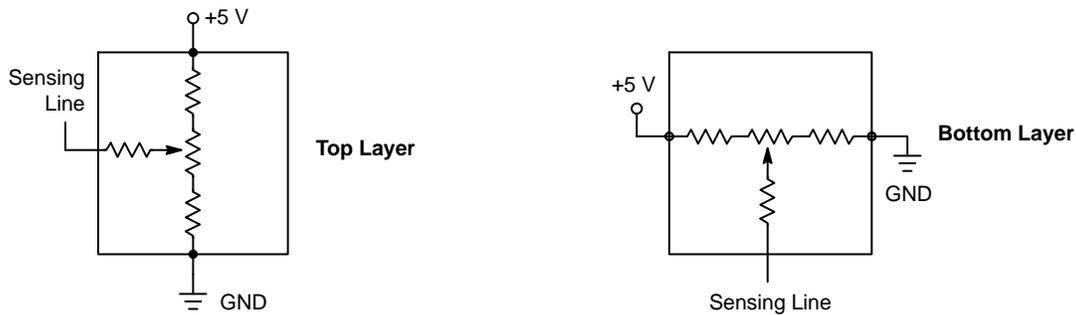


Figure 2. The sense electrode on the 4 wire analog resistive touch screen picks up the voltage formed by the position ratios in each axis. This allow this type of touch screen to be decoded directly by a microcontroller's A/D stage for small size and low cost applications.

A five wire analog resistive touch screen is similar in that there are two sheets closely spaced that depend on touch to create a circuit closure. But, the top sheet is not resistive, it is a contact point.

With five wire technology, the bottom layer contains four electrodes that work together to frame an X axis sensor or

a Y axis sensor (See Figure 3). Charging A and C with 5 Volts while grounding B and D lets a contact point on the top measure the Y axis since the entire plane is the resistive voltage divider.

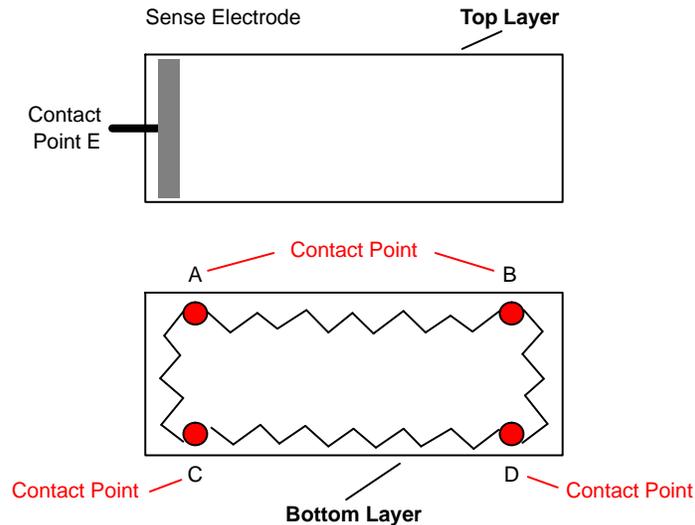


Figure 3. A 5 wire analog resistive touch screen uses a uniform conductor on the top layer for the contact point. This is more durable than a deposited resistive gradient.

Alternatively, applying 5 Volts to A and B while Grounding C and D lets the top contact point measure the position along the Y axis. The five wire is regarded as being more durable than the four wire since the top layer does not need to have and maintain uniform resistive gradients. It simply needs to be a contact point.

In either case pressure based contact actuates circuit closure through a resistor divided ratios to present an analog voltage relative to a driven X or driven Y axis. This lets a microcontroller read in voltages to determine touch location. Spatial resolution of up to 4096 DPI [1] is achievable with analog resistive touch technology making it an ideal solution to many of today's handheld touch devices.

Advantages

Analog resistive touch screens are relatively tough and durable. The use of a polymer sheet on top means it can be insensitive to various chemicals, compounds, and corrosives. It is also water tight and can be pressure sealed using gaskets as required by NEMA standards.

A big advantage is that analog resistive touch screens can be operate while using a gloves as well as with a bare finger or hard stylus or finger nail. The surface is also easy to clean.

Disadvantages

A disadvantage of analog resistive technology is that the plastics diffuse and attenuate the light. This means the vividness of a display will be diminished and the overall unit will not be as bright or as sharp. In time, it can yellow too.

Another disadvantage is that the surface can be scratched and damaged by sharp digging or slicing actions. It will most likely still work, but not in the damaged areas. Also, being a stretchy substance, in time, wear will deform the outer polymer layer like a wrinkled skin of a hippopotamus.

Surface Acoustic Wave Technology

The Technology

Surface Acoustic Waves (SAWs) are ultrasonic oscillations that ride on a clear glass surface like ripples on a pond. Each axis uses an emitter and a series of reflectors to direct the waves 90 degrees at different steps along the initial axis of propagation. This causes them to sweep out a plane in one axis (See Figure 4).

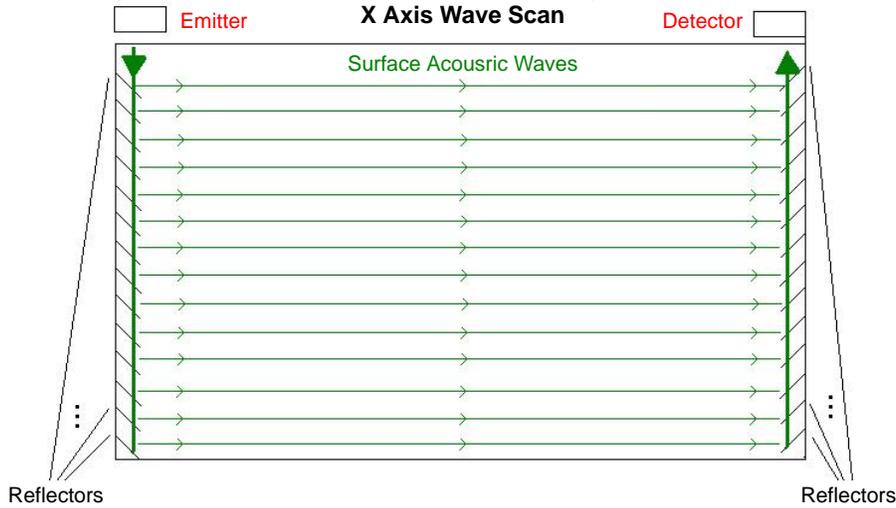


Figure 4. Surface Acoustic Wave technology uses corner emitters, detectors, and reflectors to guide ultrasonic sound wave streams into specific rows and columns. The time it takes to traverse each path is different, so a decoder can detect the missing sound energy in a specific timeslot to decode location.

Each wave has its own path with a different length. As a result, each will take a finite and discrete amount of time to traverse that path through a solid with a known modulus of elasticity. Therefore, when a soft surface (like a finger or a glove) is placed anywhere in the field of waves, the absorption of the sound waves is detected by the lack of energy in the timeslot that is blocked. This is done for the X and then the Y axis to triangulate a coordinate like is done with the analog resistive.

Advantages

An advantage of SAW technology is that panels are all glass meaning little attenuation of light from a backlit display. As a result, visibility of displays is excellent, vivid and bright, and they don't yellow like some plastics. SAW technology also boasts long term stability. It is virtually impossible to wear out a SAW panel so it is well suited for high levels of constant use. SAW panels don't require recalibration and are relatively unaffected by scratches or electric noise.

In addition, SAW panels have fast response and good resolutions like analog resistive and offer something other

technologies don't. Pressure sensitivity is the amount of absorption of the wave is dependant on how hard you are pressing. Like a tire low on air, with no weight it has a rather narrow profile but as weight is added, it flattens out. The flatter the touch, the more energy will be absorbed and SAW sensors can detect this. This allows a Z axis of control in addition to the standard X and Y.

Disadvantages

Some disadvantages are that panels may have to be a little larger (wider) because of the transducer locations. Also, hard surfaces like a stylus or pen tip will not work because they won't absorb the sound waves like soft surfaces. SAW technology cannot be used with NEMA environments since it cannot be gasket sealed.

Another possible issue is that SAW panels will malfunction when oil or water droplets get on the surface. Heavy amounts of dirt and dust can also affect performance. It is also more expensive compared to other readily available touch technologies.

Also, being glass based, SAW panels can be broken and shattered by violent shock forces.

Infrared Touch Technology

The Technology

Infrared touch screens have been around for a long time and have proven to be an effective and reliable technology. They are losing ground to other more modern touch technologies, but still have life for many applications.

With Infrared Touch Screens, a lattice of emitters and detectors are placed on a bezel surrounding the area designated to be touch sensitive. A curtain of invisible light beams travel across each axis to a corresponding array of infrared detectors (See Figure 5).

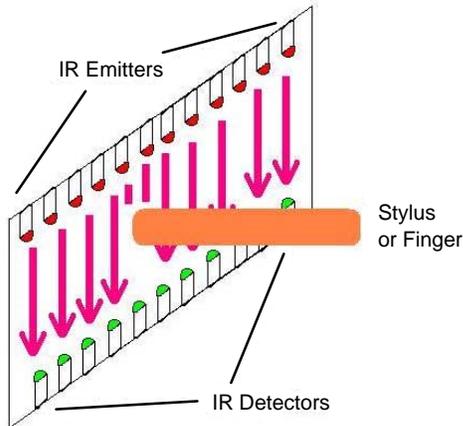


Figure 5. Interrupting the light beam in an array lets the detector inform the controller the location in each axis. LEDs can be turned on sequentially and detectors read in adjacent locations allowing interpolation to increase accuracy.

When there is no finger, glove, stylus, or beam interrupting object, every detector will detect the infrared light. When anything interrupts the light, its position along each axis is noted and thus the location has been detected.

Since LEDs have a divergence angle, more than one adjacent detectors can be tripped by a single emitter. This lets the controller turn on the emitters in sequential and in staggered patterns. This not only detects blockage of line of site, it also lets the controller perform interpolation of position giving a pretty good resolution.

Advantages

Advantages of Infrared Touch Screens is that there is no stacked layer on top of the display. This means absolutely no light is lost and no dispersion takes place by any micro coated sheets. The displays are crystal clear and as bright as they can be. In addition, the touch area will always perform because it cannot be scratched or damaged.

Disadvantages

Disadvantages of the Infrared Touch screen technology is that LED emitters use more power than high impedance

resistive dividers of Analog Resistive touchscreens and the low power oscillators used in SAW touchscreens. Overall power can be reduced by activation only one emitter at a time like a circular raster scan, but LEDs can use 10's of milliamps compared to micro amps used by other technologies. As a result, Infrared Touch screens are mostly used by line powered equipment.

Another potential disadvantage is that there is nothing protecting the LCD display. Typically, the touch screens are the first line of defense and are either tough, or sacrificial since displays are more costly. Without the layers imposed by the stacked touch screens, you may need to include a protective glass layer for the display.

Another potential disadvantage is that the size of the bezel that holds the emitters and detectors can impose mechanical constraints on the enclosure and physical design.

Other Touch Technologies

Optical Imaging

With the flourishing of cell phone cameras comes very low cost image sensors. Image sensors with advanced processing engines can detect and decode complex movements and gestures in 2 and 3 dimensions.

At some point in time, this technology may supplant analog, capacitive, SAW, and other types of touch screens. For now though, it is not cost effective, requires a lot of code and a high performance processor with a lot of memory.

Dispersive Signal

Dispersive Signal is similar to a 5 wire analog resistive but with piezo transducers mounted in every corner instead or resistor contact points. A dedicated and sophisticated controller determines the touch position by pinpointing the source of the bending wave created by the finger or stylus touching the glass substrate.

It offers fast and accurate repeatable touch with excellent light transmission. The higher end dedicated controller and piezo transducers may make it cost prohibitive compared to other technologies.

Acoustic Pulse

A similar technology to Dispersive Signal is Acoustic Pulse, which uses a table lookup instead of a streaming signal processing engine. Also based on corner placed piezo transducers, the technique is based on the principle that every location that can be touched generates a unique sound. Sound profiles of the glass are store in a lookup table to determine to exact position of touch.

Objects can be at rest on the screen and not affect the ability to detect touches elsewhere making it an ideal solution for tabletop touch sensitive areas. The downside to this is that this technology cannot detect a still finger after it has been touched and remains in place.

CAPACITIVE TOUCHSCREENS

Surface Capacitance

The Technology

Surface Capacitance Touch screens use the property of charge conduction through a capacitive junction created by the touch of a bare finger or capacitive stylus. A glass surface is coated with a transparent metal oxide along the borders. The controller applies voltages to the corner of the touch screen creating a small electric field (See Figure 6). By measuring the current pulse that flows from each corner to the capacitively conductive finger contact point, the controller can calculate the location of the touch on the surface of the glass.

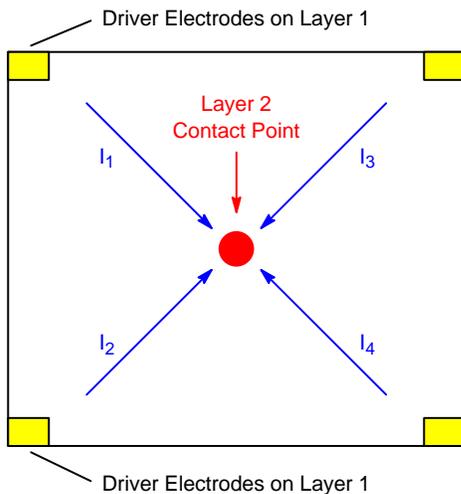


Figure 6. Surface capacitance types of touch screens use corner drivers which each supply impulses of current when a capacitively coupled finger or stylus is placed on the screen.

Advantages

Advantages of Surface Capacitive touch screens is that they are very durable and reliable. They are hard to wear out through high use. They also offer good optical characteristics with the clarity and strength of glass.

Dirt and dust typically don't affect performance and the surfaces clean up well and are resistant to cleaning chemicals. This technology also offers fast response times and good resolutions.

Disadvantages

Disadvantages of Surface Capacitance touch screens is that they require a finger or capacitive stylus to work. Severe scratches can affect performance. Typically, a gloved operation or even a conductive wand won't absorb enough charge unless you select a capacitive touch screen interface device with high sensitivity and accuracy. They also require either a dedicated controller or a processor with the bandwidth to handle the main tasks at hand along with touch stimulus and decoding.

Projected Capacitance

The Technology

Projected Capacitance is fairly new compared to the older more established touch technologies. While generally not supported or used before 2009, the iPhone really propelled this technology into the forefront and is still the most widely used touch technology for relatively small (around 10 inch diameter or less) handheld designs.

Instead of making electrical contact through conduction, Projected Capacitance touch screens rely on mutual or self capacitance. The water rich conductive human body capacitively couples the two layers when in close proximity. The result is a detectable signal between layers (See Figure 7).

Capacitive Coupling between Adjacent Cells

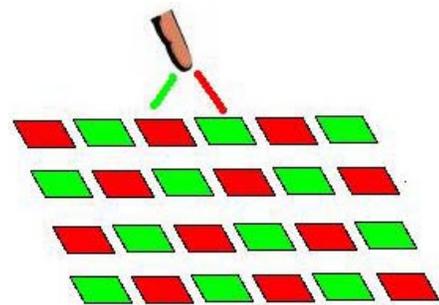


Figure 7. Projected Capacitance technology can rely on mutual or self capacitance which couple the adjacent pads with the bare or gloved finger above the surface. Sensitivity can be adjusted to be able to use thick covers.

Screen Construction:

Like other touch technologies, Projected Capacitance uses two electrode layers in a structured matrix type array. Different implementations include X-Y electrode layers 'Piled' in a single sheet with insulation separating them. Another structure of the Projected Capacitance touch screen uses one sheet with electrodes on different sides. Yet another approach is to use two sheets facing each other.

In any case, the X and Y electrodes are formed on the different surfaces in a perpendicular matrix similar to an X-Y keyboard matrix. This creates a series of intersection wire or diamond shaped intersection points.

Unlike other technologies though, the Projected Capacitance touch screen can also detect gloved fingers because its sensitivity can be adjusted to not only detect a gloved finger, but also detect touch through a glass protective top sheet.

Signal Processing:

Signal processing for Projected Capacitance touch screens can take place at the controller level or at the applications level. At the controller level, location detection,

multi touch detect, and a series of pre programmed gestures can be decoded with higher level commands issued to the host processor running the main applications.

Conversely, the entire scan, detect, and decode function can be performed as a task on a main CPU if sufficient bandwidth and resources are available. There are advantages and disadvantages to both approaches.

A dedicated controller can let the main CPU remain asleep and use less overall power in most cases. It also unburdens the main CPU from this real time task.

On the downside, it is another micro to code and maintain, If new gestures need to be learned, a means of updated its firmware has to be built in. When the main CPU performs these tasks, any new features can just be part of the application software.

Advantages

A key advantage of Projected Capacitance touchscreens is the ability to detect a bare finger or a gloved finger based on its sensitivity setting. The adjustable sensitivity is a key feature since software controlled sensitivity levels can dynamically adjust to conditions.

The other key feature is its ability to do multiple touches and elaborate gestures. Both features make them ideal for the smart phones and tablets that count on these abilities.

Another advantage is the high durability and long life because of the glass sheet and lack of moving or deforming parts.

The fact that a separate top glass sheet can act as a protection layer means that a scratched top sheet can be replaced without damaging the rest of the touch assembly and display.

Other nice features include clear optical properties, relatively fast response times, and low power use.

Challenges

There are a few challenges that Projected Capacitance technology carries along with it as well. First is the coupling of the touch screen with the controller design. With Projected Capacitance touch screens, the characteristics of the electrostatic capacitance need to be part of the controller design. With simpler technologies like analog resistive, you can just plug in a touch screen with a controller, run through a brief calibration routine, and you are up and running.

The algorithm for achieving precise location is much more complex so both screen and controller need to be designed together. A phenomena called Ghost Points can be formed when more than one location is touched and processing must be done to eliminate the false touch from the real touch (similar to sneak paths on older matrix scanned keyboards).

Another issue is that fine patterning of the matrix electrodes may introduce some higher manufacturing costs.

Patterns must be formed on the sheets, not just deposited. The simplest are just X-Y lines, but more complex crosshatch and diamond pattern etchings may also be used. This may easily be offset by the high volumes this technology is enjoying.

Noise

The Projected Capacitance technology may also be susceptible to electronic noise. This can be tricky when it is so closely coupled to a display. As long as good grounding and filtering is used, this can be overcome.

Ambient noise can also be a factor. High static and RF fields can cause erroneous readings unless filtered. Surge suppression should also be used because high voltage spikes can traverse capacitive junctions.

Calibration

The detection, decoding, and calibration of Projected Capacitance types of touch screens can be a challenge. The variations in sensed capacitance is typically in the 10 to 15 femto Farads meaning controllers need to amplify, condition, measure, and filter the signal.

Because the capacitors on a Projected Capacitance touch screen are always in the same place, the screen itself will not ever need to be recalibrated. Although bias components and conductivity of exposed electrodes and wires can change characteristics, this is typically negligible, especially in a row and column based scan.

As a result, typically the upper level applications layers may include a routine to define the limits of usable touch as a calibration setup. But after that, once established, the Projected Capacitance touch screen should not need to be recalibrated.

Sensitivity

Unless the controller you plan on using has an adaptable and dynamic sensitivity adjustment (similar to an Automatic Gain Control), you may have issues with different types of gloves. A finger will most always have the same characteristics since it is mostly water. But, gloves come in a variety of materials with differing characteristics.

For example, a finger and a surgical glove will typically trip a Projected Capacitance touch screen setup with the same calibration and sensitivity setting. But, a heavy winter glove with thick insulative properties may not.

While some designs like an iPod can be used indoors and outdoors from the tropics to the arctic, you may have trouble using a thick glove in the arctic. But an application like a piece of equipment used in an operating room will always be used within a known temperature range with or without a thin surgical glove. Sensitivity should not be an issue here.

ON Semiconductor Capacitive Sensing Solutions

The LC717A00 AR/AJ is a single chip Projected Capacitance touch screen interface device from ON Semiconductor (See Figure 8). The LC717A00 AR/AJ is an 8 input channel device while its sister chip, the LC717A10 AR/AJ has 16 channels.

Both have built in multiplexers and they both detect proximity and touch using the Differential capacitance detection technique and are sensitive to changes in capacitance in the Femto Farad range. They operate from 2.6 to 5.5 V drawing less than 1 mA.

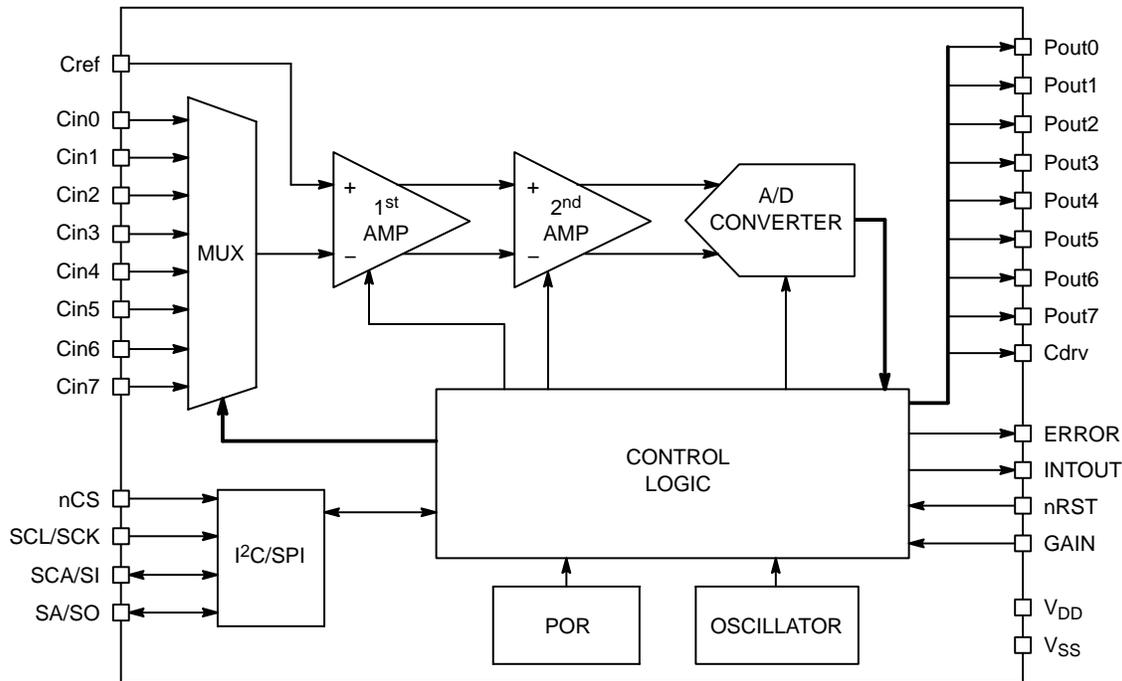


Figure 8. The 8 channel LC717A00 AR/AJ has a power up sequence that allows it to operate in a stand alone mode. Pout outputs can drive verification LEDs as well as feed logic inputs to a microcontroller.

LC717A00 Series Description and Operation

Both the 8 channel and 16 channel parts use a patented input stage which performs environmental calibration and noise cancellation. Functioning basically as a capacitance to digital converter, they use a sensor driver frequency of 143 kHz using an internal 8 bit A/D converter to generate values representing the capacitance at the sensor point.

A particularly nice feature is it auto calibrates upon power up to compensate for environmental variations. Another key benefit is that it uses differential sensing method to eliminate the problems associated with common mode noise. Since common mode can be discriminated against in its dual stage amplifier, the LC717A00 series can significantly reduce the interference based on local sources of noise (See Figure 9).

The LC717A00AR/AJ can operate in a stand-alone mode with initial gain settings for specific sense trace patterns. In this mode, when any of the input sensors detects touch, a corresponding driver output is activated. This can drive LEDs for touch verification while also sending logic signals to a remote micro allowing a lower cost satellite user interface board.

For communications an IIC and SPI port are also built in. This permits a local or remote micro the ability to change

gain and threshold settings to compensate for noisy conditions.

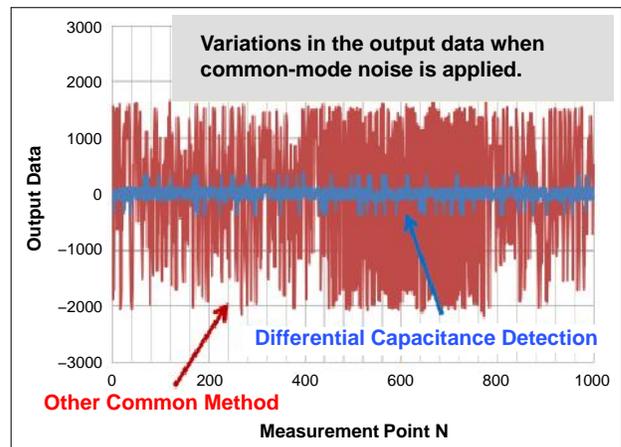


Figure 9. The differential capacitance detection stages greatly reduces common mode noise effects that can be introduced by an LCD or LED backlight in close proximity.

How It Addresses Touch Screen Challenges

Both parts can be used with opaque types of printed circuit board trace patterns that function as touch sensitive zones. These replace bulky, costly, failure prone mechanical switches of yesteryear.

In this manner, it is easy to create low cost user interfaces as part of your PCB including sliders and touch rings. Because of the projected capacitance feature, decorative plastic or glass overlays can protect the PCB while creating the sexy user interface.

As a matter of fact, because of the noise cancellation and environmental compensation, thick sheets up to 3 mm wide can be overlaid on top of a printed circuit board or LCD (See Figure 10).

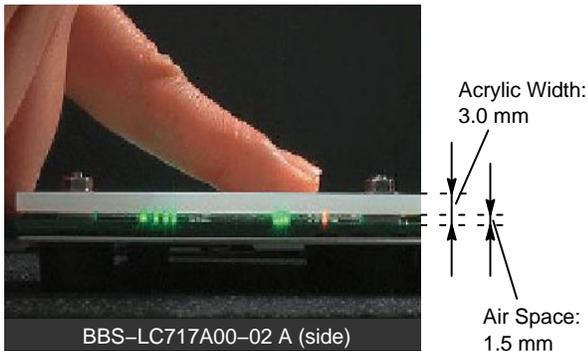


Figure 10. Because of the noise cancellation and adjustable sensitivity, thick surfaces can be used to protect the display and PCB from external shock and force. A top surface can be replaced if damaged and extend the life of the unit.

TOUCH SCREEN TRENDS

The use of touch with equipment is not going away. Consumers demand highly graphic displays and easy to use interfaces. Touch provides this at a reasonable cost and allows highly decorative and ergonomic designs to perform with high reliability and good durabilities.

As Projected Capacitance technology becomes more widespread, older more costly and feature limited single point only sensing technologies will fall along the wayside.

We should see smaller touch screen controllers with more inputs as well as higher temperature parts coming down the

For use with larger LCD based transparent touch screens, external multiplexing can be used to expand the number of channels when coordinated with a local microcontroller. In addition, since the A/D data is directly available to the host micro, interpolated values can synthesize higher levels of accuracy and multipoint and multi touch operations can be supported.

Note, because the noise thresholds and sensitivities can be adjusted by the LC717A00 series controllers on the fly, ambient noise levels can be sensed and compensated for dynamically. Knowing the noise levels lets you adjust the gains (over the serial interface) of the 2 stage amplifier section. This allows the LC717A00 series to become a true projected capacitance sensor.

This means that a physical touch may not be needed at all. Instead, the proximity is detected which is projected above the actual touch surface. This is sometimes called hover technology. Not only does this allow a gloved finger to work, but double gloved fingers also work because the mutual capacitance is still present and can affect the internal oscillator of the controller to react.

The granularity of the data read out of the LC717A00 series is in 8 bit chunks to allow any processor to easily handle the sensor's inputs. When used as a wake up detection switch, the fast response time and measurements intervals (down to 3 ms), can let the processors wake up, perform tasks and go back to sleep to save energy in a low power application.

pipeline. We should also see more algorithms and gesture decoding tricks from suppliers in their reference designs and development kits.

So, it's OK to touch that dial...

For more details regarding ON Semiconductor's Capacitive Sensing solution, please visit us at www.onsemi.com.

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REFERENCES

[1] Analog Resolution – http://en.wikipedia.org/wiki/Resistive_touchscreen

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