A Primer on Popular Touch Screen Types

White Paper

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Table of Contents

Technologies 2

Resistive 2

1) 4 Wire 2

2) 5 Wire 4

3) ULTRA 5

Capacitive 7

Projected Capacitive 8

Surface Acoustic Wave 9

Infrared Matrix 10

Technologies

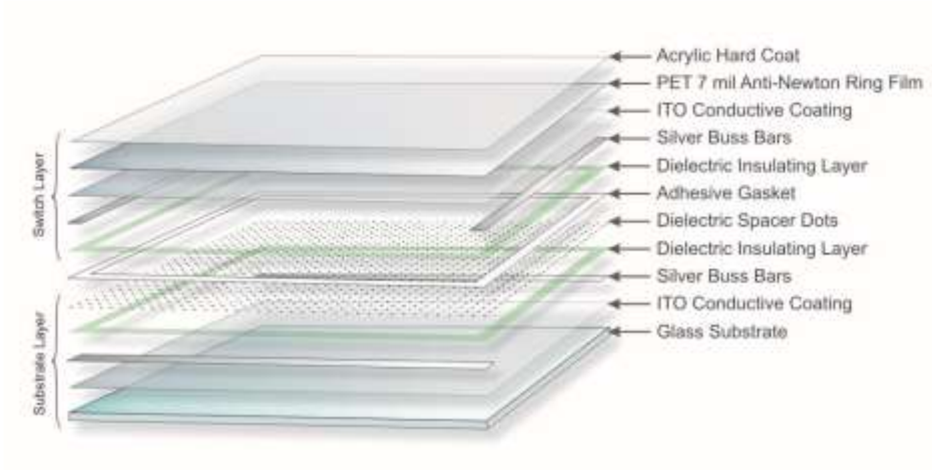
Touch screen technologies all provide the same function yet are considerably varied in types and method of operation. Each type has specific benefits and deficiencies, thus choosing the right type of touch screen for a specific application may be difficult and requires a comprehensive knowledge of the different types of technologies and their operational considerations.

The purpose of this paper is to provide an overview of the common types of touch screen technologies and explore their benefits and weaknesses.

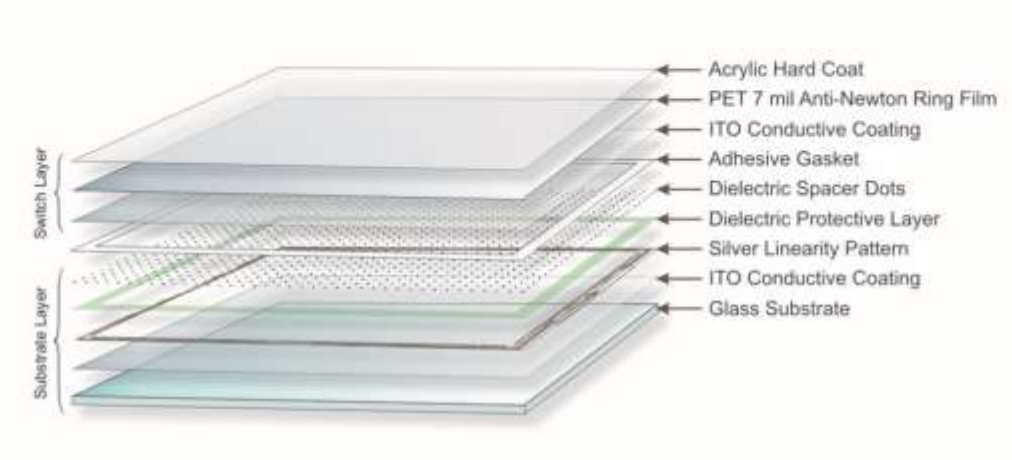
Resistive: This is the most common type of touch screen in use today largely because it has good operational characteristics and is inexpensive. Resistive touch is available in 4, 5, and 8 wire variations. The term "wire" is used to indicate how many circuit elements are terminated to the cable for connection to the interface electronics. 4 and 8 wire resistive is similar in operation. All resistive technologies have similar constructions. That is to say they are analogue switches. They are constructed of a transparent substrate – usually glass with a conductive coating overtop of which is affixed a flexible transparent switch layer – usually a polyester film with a similar conductive coating. This perimeter affixed switch layer is physically held away from the substrate with very small "spacer dots". If you hold a resistive touch sensor up to the light, you can usually see them. To activate the sensor, you apply pressure to the switch layer with a finger or stylus to force the flexible polyester in between the spacer dots to make contact with the substrate. On the 4 wire technology, the position of the touch is obtained by way of voltage drop measurement. The substrate layer and the switch layer both have a transparent conductive sputtered coating which is usually Indium Tin Oxide (ITO) which is preferred because it is quite transparent while offering low sheet resistances typically from 15 – 1000 ohm/square. Most resistive touch screens use ITO coatings around 300 ohms/square as it is a good trade-off between durability and optical transparency. Applied on top of each of these two layers are conductive buss bars at the edge usually screened on with conductive silver ink. One layer has these bars positioned vertically left and right for the X-Plane element and the other has them positioned top and bottom for the Y-Plane element. Thus 4 bars connected by 4 wires. The controller interface will apply a current through the bars of one of these planes – say the X-Plane in through the left bar and out the right. With this current flowing through the 300 ohm/square sheet resistance of the ITO coating on the X-Plane substrate, there will be a voltage drop between the 2 bars. When pressure is applied to short the X and Y layers together, a voltage is picked up by the Y-Plane and measured by the controller interface. The closer you get to one bar or the other on the X-Plane, the higher or lower the voltage will be thus determining an X coordinate. To get a Y coordinate, the same operation is done in turn but this time powering the Y-Plane with the X-Plane picking up the voltage measurement.

1) **4 Wire:** technologies can operate on very low power since they are voltage operated and do not require a lot of current so they are desirable for use in portable battery operated devices. They also have the benefit of being able to use most of the sensor's surface as the active area where touches can be sensed. The silver buss bars can be very narrow so as not to take up much space at the edges. Also, the

connecting trace ways of silver ink can be layered overtop separated by UV dielectric making for a very compact construction. This is also an important consideration in applications such as hand-held devices where size is very limited. Since 4 wire is voltage operated, there can be no variance in the electrical properties of the conductive layers or the voltage reading from these X and Y layers will change causing a positional drift in the touch point. Several factors can cause this with the most common one being heating and cooling of the sensor from environmental conditions. This only becomes a noticeable problem with extreme temperature variations and on large format sizes such as 12.1" sensors and larger. It is really not noticeable on small format such as 6.4" and smaller. The real problem with 4 wire is sensor life. It is not that good. Typically you can expect 4 million touches or less on the same spot with finger operation. With a stylus, it is much worse. A 4 wire sensor can be destroyed by only a few hard strokes of a fine point stylus. This is because the ITO of the polyester switch layer is brittle. ITO is a ceramic and is cracked or "fractured" easily when it is bent too much. This cracking usually happens on the polyester switch layer as it is repeatedly flexed into the substrate layer between the spacer dots to make electrical contact. With the repeated bending especially in a highly used spot such as an enter button on an application, the ITO will fracture in that area and will not conduct current as well causing the sheet resistance of that spot to increase. This damage happens much faster if a stylus is used as the bending of the switch layer by the small point of the stylus is much sharper. If this happens, the voltage measurement of the X and Y plane over or around this spot will be higher than it should be making the touch point appear as though it is further away from a buss bar than it really is. This loss of accuracy is non linear and can't be restored with recalibration as you could a drift problem. New techniques such as Pen Based ITO Polyester Film apply ITO on an irregular surface coated onto the polyester first to avoid a smooth flat ITO coating that can be cracked easier. This improves the problem but does not fix it. A variation of the 4 wire is the 8 wire which claims "is based on the 4-wire resistive technology with each edge providing one more sensing line as a stable voltage gradient for the touch screen controller. The functionality of additional 4 lines is to obtain the actual voltage generated by the drive voltage, so the touch screen controller can automatically correct the drift issue resulted from the harsh environment exposure or long time usage". I must admit to being a little unsure as to how this theory of operation works. It has never been explained to me in a manner that makes any sense but I'm sure it does work.

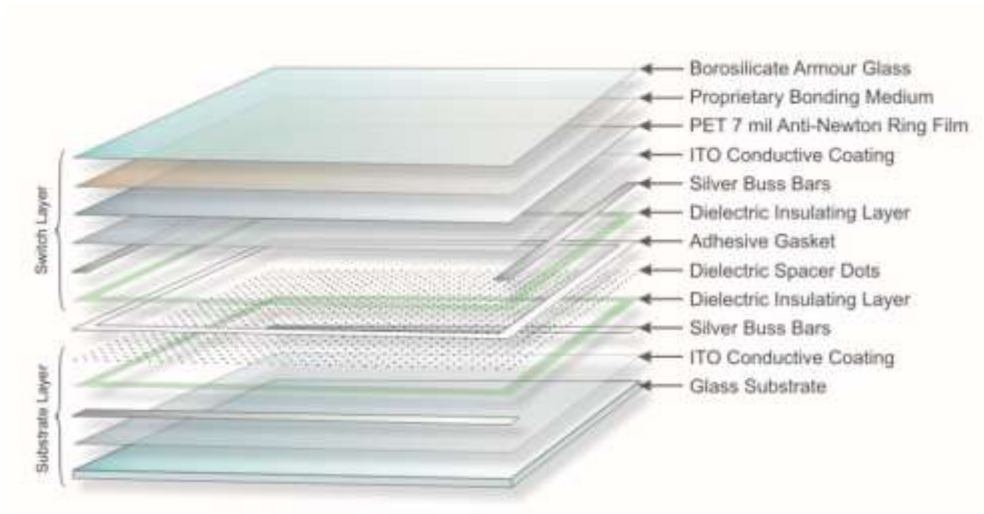


2) **5 Wire:** touch screens is in my mind the real solution to the ITO fracture problem. It does not rely on voltage to obtain it's X and Y position, but rather current flow. A 5 wire is constructed of the same switch layers of the 4 wire but instead of opposing pairs of X and Y buss bars, a 5 wire utilizes electrodes that are placed on the four corners of the substrate layer representing 4 of the 5 wires. The top ITO polyester switch layer is a single ground plane representing the 5th wire – thus *5 wires*. The controller interface applies a low voltage to the 4 corner electrodes. Nothing happens until the grounded switch layer is depressed into the substrate then current starts to flow from the 4 corners. If you were to touch directly in the middle of the sensor, you would get identical current flow from each corner as the touch point is the same distance away from each corner and therefore the resistance across the ITO coating from the corner to the touch point would be the same. The closer you get to a corner, the higher the current flow becomes as the distance and the resistance from the touch point to the corner decreases. The distance and resistance from the other three corners increase causing the current flow to decrease as the touch point moves away. Depending on the current flowing from each corner, the controller interface can determine where the touch point is. The 5 wire is not affected nearly as much by ITO fracturing because it does not need to maintain actual values of current flow to remain linear. For instance, if our touch point is directly in the middle of the screen, we may see current flows of say 50 mA through each corner electrode. That's a total of 200 mA with each corner representing 25% of the total. If the current flow is equal at all four corners than the touch point must be in the middle. What if the ITO fractures in the middle of the screen and looses 90% of its ability to conduct current. Well then only 20 mA of current will be flowing through the four corners with 5 mA through each corner which is still a 25% representation of the total current flow through each corner so the linearity stays the same. The 5 wire looks at the corner current flow values as relational to one another and not literal values as the voltage readings in a 4 wire so ITO can fracture but it won't make any difference to linearity on a 5 wire. The ITO would have to fracture to a point where the controller interface could not detect a current flow when the switch layer was depressed. A typical 5 wire resistive can achieve 35 million touches at the same point with finger activation. Again, less with a stylus.

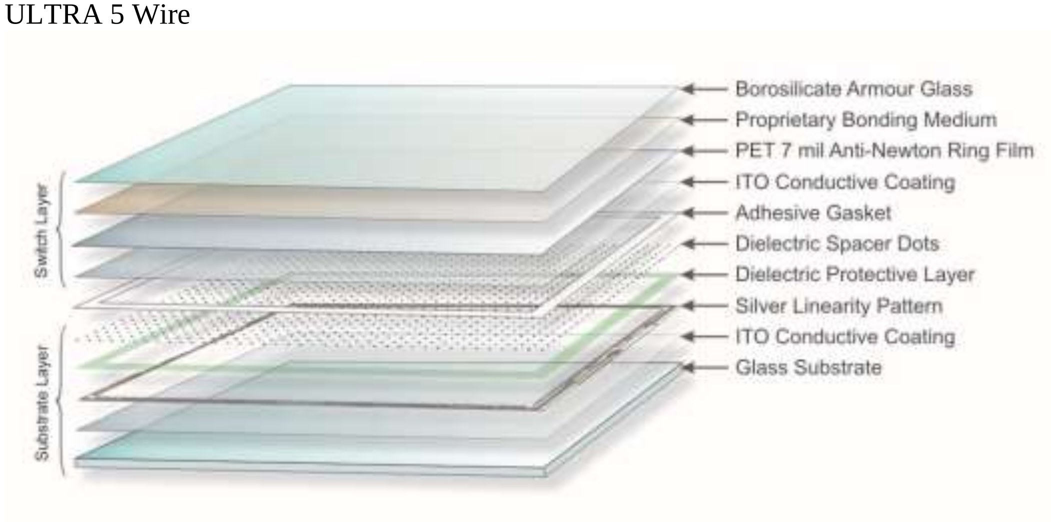


3) **ULTRA:** A D Metro in Canada offers an Armored resistive technology which replaces the polyester switch layer with a glass / polyester laminated switch layer which is stiffer than polyester. Apart from the obvious surface durability, the stiffer glass / poly switch layer can not bend sharply enough to cause ITO fracturing of the switch layer allowing this type to last 10 times longer than regular 5 wire types. Because of the two layers of ITO required in the resistive technology, transparency is not as good as in other kinds of touch screens. Optical transmission is normally around 82% for resistive. Resistive may not be suited for some hostile environments as the polyester switch layer can be damaged by sharp objects. Also, the polyester switch layer is not moisture proof but moisture resistant which means that in high humidity with repeated heating and cooling, moisture can move through the polyester switch layer and condense inside the airspace between the switch and substrate layers causing a failure. Some large format resistive sensors have a problem with “pillowing”. This is when the polyester switch layer expands in relation to the glass substrate and either deforms or puffs up and does not lie flat on the glass substrate. This quite often is just a cosmetic defect but can cause false activation if the switch layer is deformed enough. This problem is typically due to heating and cooling where the polyester has a higher expansion and contraction coefficient compared to the glass substrate and will expand in size more than the glass when heated. Apart from lower light transmission, the armored resistive technology, ULTRA, from A D Metro addresses all the above deficiencies making the ULTRA:
   - Abrasion and scratch resistant
   - More durable, water proof and impervious to flames, chemicals, solvents etc.
   - Operational in expanded environmental window
   - Lasts longer due to the stiffer glass/polyester top layer which reduces ITO fracturing failures including damage from stylus use
   - Has reduced possibility of top layer pillowing as glass/polyester lamination has a closer expansion/contraction coefficient to the substrate glass
   - Shatter free: the glass/polyester top layer does not shatter and allows the sensor to continue to operate even after extreme abuse such as deep scoring, repeated impact trauma and other vandalism

ULTRA 4 Wire:



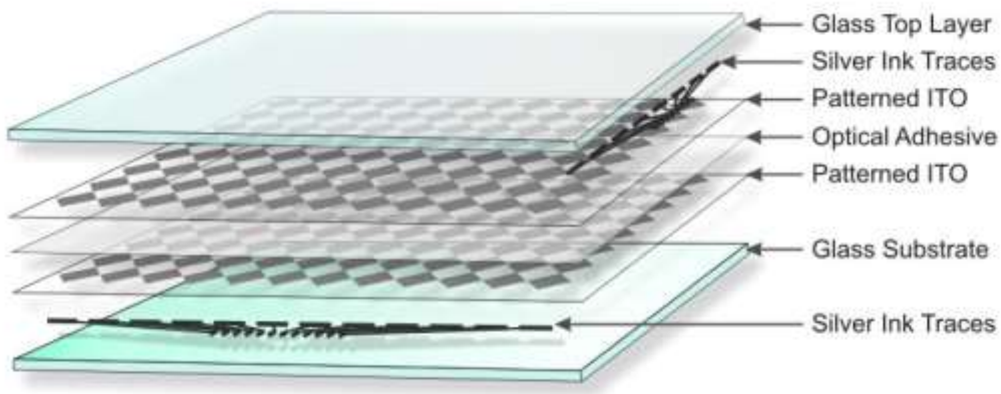
ULTRA 5 Wire



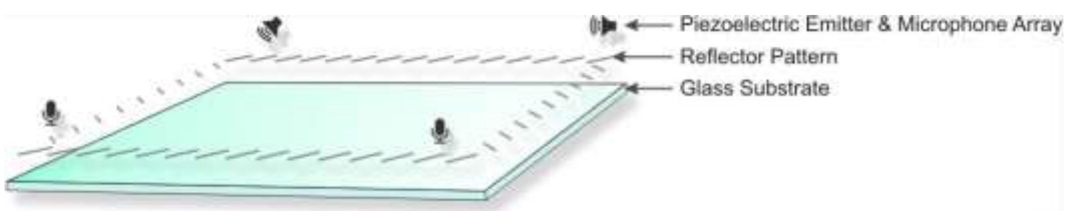
Resistive technology is pressure activated which means it can be used with a finger, heavy glove, stylus, or any other implement which is a highly desirable feature. It requires very little power and is highly reliable and fast. It is Z axis capable which means it can detect when you apply various amounts of pressure to a touch point which is handy if you have an application where you would like to accelerate an operation by just applying more pressure to a touch button like opening a valve quickly or slowly in a process control application for instance. It is not affected by dirt any contaminates and it has stealthy electric operational characteristics which makes it a favorite with military applications.

Capacitive: The construction of a capacitive is somewhat similar to a 5 wire resistive but it has no switch layer. There is only a conductive coated substrate with 4 corner electrodes similar to the 5 wire. The conductive coating used is not typically ITO but rather Antimony Tin Oxide (ATO) which has a higher sheet resistance of about 2,000 ohms/square which is better suited for capacitive technology. The ATO coating usually has a silicate overcoat about 50 angstroms thick fired on to protect it from rubbing off during use. The controller electronics apply an RF frequency to the four corner electrodes. Activation is achieved by touching your finger to the surface of the screen with the coupling of your finger surface with the ATO surface underneath creating a capacitive coupling with which the radio frequency can flow through. Your body dissipates the RF into the atmosphere like an antenna. The closer you get to a corner, the more radio frequency will flow through it. By looking at the radio activity from each corner, the controller can calculate where your finger is touching. Because of surrounding electromagnetic interference (EMI) and radio frequency interference (RFI) from other radio and electrical devices in the area, a lot of signal processing has to be done to filter out surrounding RF noise making the controller interface more complex requiring more power consumption. Despite this, capacitive is still relatively fast. It has a very light touch and is ideally suited for drag and drop applications. Since the surface is glass it is vandal resistant and is used broadly in kiosk applications including gaming machines. It has a good optical transmission of about 90%. It is not affected by dirt or contamination unless bad enough that it interferes with the capacitive coupling of your finger. It can not be used with heavy gloves or any stylus or pointing implement unless tethered and electrically connected to the controller. If your finger is too dry, it may not work as skin moisture is needed for a good capacitive coupling. If the surface is scratched it can cause the sensor to fail in the scratched area or fail completely if the scratch is long enough. EMI and RFI can cause it to go out of calibration. It is not Z-axis capable. It is not suited for mobile operation as the ambient surrounding EMI and RFI changes too frequently which would confuse the controller interface. It is not suited for military applications requiring stealthy operation because it emits RF. It requires specific mounting considerations as housings and metal bezels can interfere with its operation.

Projected Capacitive: Projected capacitive including Near Field Imaging (NFI) is constructed from a glass substrate with an ITO or ATO coating that is etched away to leave a grid pattern consisting of X and Y line elements. Some designs use imbedded metal filaments which are not visibly noticeable to obtain the same grid. The grid patterned substrate has a protective glass plate bonded to the face of the grid substrate. An AC field applied to the grid. When a finger or conductive stylus touches the sensor surface, it disturbs the field allowing the controller interface to pinpoint where on the grid the field is disturbed the most. The controller interface can then calculate the position of the touch. This technology is highly durable and can not be damaged to the point where it will not function unless the substrate grid is broken. It can sense touches through a window. It can operate out of doors. It is not affected by dirt. It can be used with gloved hands. It is, however, expensive. It has a comparatively low resolution. It can be zapped easily by electrostatic discharge. It has no real tactile sense meaning it can activate before you touch it. It is sensitive to EMI and RFI interference making its reliability problematic.



Surface Acoustic Wave: This technology requires no electrical signal processing on the sensor surface and uses no conductive coatings. It utilizes ultrasonic sound to sense touches. A SAW sensor is comprised of a sensor substrate which has affixed to it's perimeter a piezoelectric emitter along with 2 or 3 receivers. Also running along the entire perimeter of the sensor edges are reflection ridges used to bounce ultrasonic sound back and forth across the surface of the sensor face. To detect touches, the piezoelectric transducer sends out bursts of ultrasonic sound which is reflected by the perimeter ridges back and forth across the entire face of the sensor. Because the speed of sound is somewhat constant, it is known when the originate burst of sound along with all the reflected bursts from the perimeter ridges should arrive at each receiver. If a finger or other sound absorbing stylus comes in contact with the sensor face, some of that sound originate or reflected will be absorbed and will be missing when the controller expects to hear them arrive at the receivers. Those missing incidents are what allow the controller interface to determine where the touch would have to be positioned on the sensor face in order to block those sound incidents from arriving at the receivers when expected. This technology offers 97% light transmission since the sensor substrate is just bare glass. It also offers a very light touch and works well for drag and drop functions. It has a glass surface which is highly durable and is not easily vandalized. It will operate with heavily gloved hands but not with a hard stylus or any implement that can't absorb sound. If you scratch it deeply enough though, the ultrasonic waves can fall into the valley of the gouge and bounce off into space causing a dead spot on one side of the scratch. It is susceptible to dirt and dust which slow down or block the ultrasonic sound. Water droplets interfere with it's operation – so can insects attracted to the light of the display. It can not be effectively sealed from dirt or moisture as such gasketing would block the ultrasonic sound. Open cell foam gasketing can't seal from moisture and will still eventually clog with dirt causing a blockage of the ultrasonic sound. Changes in humidity and temperature will cause a change in air density affecting the speed in which the ultrasonic sound can travel which can cause problems with accuracy.



Infrared Matrix: This is one of the first touch technologies ever developed. It is very simple in operation and has been returning as a viable solution for touch as it is better suited for flat panel displays. IR Matrix is made up of a frame in which is mounted a row of 30 to 40 IR photo emitters along one side and either top or bottom matched with IR photo receivers aligned along the opposing side and top or bottom. The controller interface strobes the IR emitters both in the X and Y plane to provide a grid of light beams that can be broken by a finger or any touch implement. When a touch is made by a finger or touch implement, one or more beams of light in the matrix will be broken and the controller interface can tell where the touch is positioned to block those particular beams. Also, partial blockage of light beams to one side or the other of the touch allow the controller interface to resolve to a fairly high resolution but the stylus diameter must be large enough to block at least one photo emitter light beam as well as part of an adjacent one in order for the controller interface to see a change in position. The technology fell out of favor as other technology types came online because displays years ago were spherical CRTs with radius curvatures of 22.5" or less. There was a considerable parallax problem when trying to use IR matrix with straight and flat light beams on a curved CRT display. The IR matrix touch screen would activate well before your finger reached the surface of the CRT especially in the corners making it cumbersome to use. This of course is no longer an issue with the universality of flat panel displays today and is why IR matrix is making somewhat of a comeback. It offers a very light touch and is suited for drag and drop applications. If a frame version is used with no protective glass substrate, then the optical transmission is 100% which is desirable in any application. It has good resolution and is very fast. It is not affected by rapid changes in temperature or humidity. It is very linear and accurate. The technology has no tactile sense, however, and will activate before your finger contacts the screen surface. It needs a lot of space to reside both in thickness and in frame width so special housing design of the display may be necessary to accommodate the frame. It has many component elements that pose a higher risk of component failure. It is affected by dirt that can block the light beams. Flying insects attracted to the display light can false activate the sensor.