Touch Screen Technology Primer

Introduction

Touch screens best suit applications that require frequent interaction with non-technical users or must work in dirty environments. The devices are easy to use and can tolerate dirt and moisture that would quickly disable a keyboard or a mouse. Some Touch screens can work through a 2-inch thick barrier. This feature can protect both the system from user abuse and the user from the system's environment. Compact designs can also benefit from touch screen technology. Because Touch screens are integral to the display device, the screens eliminate the need for a separate keypad. You can make hand-held devices with Touch screens as small as the display itself.

Touch screen technology comprises a variety of options that let you match the technology to your application. For example, a touch screen's sensor uses one of five mechanisms; resistance, capacitance, acoustics, optics, and mechanical force. The first step in successfully applying Touch screens, therefore, is to understand these options.

The Types

Resistive Touch Screens use a thin, flexible membrane, usually polyester film (Mylar), separated from a glass or plastic substrate by insulating spacers. The substrate surface and the facing membrane surface have transparent metallic coatings that meet between the insulating spacers when the user’s finger or a stylus presses on the screen, thus closing an electrical circuit. Four and five wire designs are available for sensing the position of the touch.

In a four wire resistive touch screen, electrode arrays at opposite sides of the substrate can establish a one dimensional voltage gradient across the substrate’s resistive indium-tin-oxide (ITO) coating. Similar electrodes can establish an orthogonal gradient across the membrane’s ITO coating. Both sets of electrodes also allow the ITO coatings to act as high-impedance probes. When a user touches a four wire system screen, the controller establishes a gradient across the substrate. The controller then measures the voltage at the point of touch using the membrane as a probe. Similarly, the controller establishes a gradient across the membrane and uses the substrate as a probe. The two voltages provide the x and y coordinates of the touch point. The 4 wire type has the advantage of being able to produce very small and simple construction touch panels ideally suited for hand-held devices. They do not have a very long life span - usually 1 to 4 million touches.

In a five wire system, the substrate (usually glass) has a resistive ITO coating and electrodes on all four corners. The membrane has a single electrode and a similar ITO conductive coating. When a user touches the screen, the membrane, which is typically grounded, draws off current from the corner electrodes of the substrate. The further the touch is from a corner, the lower the current draw will be from that corner. The controller then calculates the touch coordinates from the ratio of the four currents. This is the resistive technology most used in full size displays. It needs more room around the edge of the sensor for what is called a linearity pattern which is used to correct a pincushion deformation of corner electrode technologies. The same pattern is required for capacitive touch screens. The 5 wire types have a high life span of 35 million touches or more.

Capacitive Touch Screens use resistive ITO or TAO (Tin Arsenic Oxide) sensor coatings but have no membrane. The resistive coating lies below a very thin protective layer of glass. With analog capacitive screens, electrodes at the four corners establish an small AC field on the coating, while the controller monitors the current flow through each electrode. When a user touches the screen with his or her bare finger or a conductive stylus, a capacitive coupling between the coating and the finger or stylus draws a small current from the screen. The controller then calculates the touch coordinates from the ratio of the four currents. This type of technology provides a hard glass surface which is preferred in operating environments such as kiosks because it is much more vandal proof than the resistive type. It requires the use of a bare finger or tethered conductive stylus, however, and also has a lower life span - usually 7 million touches.
Surface Acoustic Wave Touch Screens rely on absorption of sound energy by the finger or stylus touching the screen. Such touch screens operate by launching bursts of high-frequency (5-MHz) acoustic energy along two edges of the screen. Reflector arrays along the edges divert the acoustic energy across the screen and redirect the energy to sensors. Because the speed of sound in the glass is constant, the energy’s arrival time identifies its path. A touch causes a dip in the received energy waveform for both axes. A firmer touch causes a greater dip, providing acoustic systems with a third (z) measurement axis which is pressure. The timing of the dips indicates the x and y touch-point coordinates. Again, this technology provides a hard glass surface which is preferred in operating environments that need to be vandal proof. It is, however susceptible to dust, dirt and moisture which can falsely absorb the sound energy. Also, it cannot be sealed into the monitor display with a gasket or the sound energy will be blocked from moving onto the surface of the glass. And finally, if the scratch on the sensor glass is deep enough, the sound energy will fall into the scratch groove. The life span is excellent - infinity.

Infra Red Matrix Touch Screens use an array of photodiodes on two adjacent screen edges with corresponding photo sensors on the opposite edges. These diode/sensor pairs establish an optical grid across the screen. Any object that touches the screen breaks the optical-grid lines that cross the touch point, causing drops in the corresponding photo sensor output signals. These drops indicate the touch point coordinates. Rather than simultaneously establishing all grid lines, IR screen controllers typically scan through the array. This type has no glass panel construction that may reduce visibility of the display. It also has no tactile sense so the user may falsely activate a touch since the activation will happen before the user actually feels the touch of the display with their finger. The life span is excellent - infinity.

The Strain-gauge Touch Screen have pressure sensors that measure at each corner the stresses that a touch to the screen produces. The ratio of the four readings indicates the touch point coordinates. The platform touch screen doesn’t use a screen. Instead, the monitor or display device rests on a platform with force measurement sensors at the corners of the base. A touch to the display device translates to forces at the platform’s base corners. The platform’s controller performs the vector calculations that determine the touch point from the four force measurements through rigid body mechanics. The controller tracks out static forces, such as gravity, and repetitive forces, such as vibration. This type also has no glass panel construction that may reduce visibility of the display. The platform type is a good concept in theory because there is no integration of touch components into the display. You need only set the display on the touch base, calibrate and go. Practically, problems occur when the display is moved only a very small amount on the platform base or if even the display is tipped up or down for different heights of viewing. This throws off the base vector values as initially calibrated and therefore the calibration. The life span is excellent - infinity.

Things to Consider

Once you understand the touch screen mechanisms, your next step is to consider the conditions under which your system must work. Moisture, grease, dust, and other contaminants that have no effect on some touch screens but can cripple others. You need to know if a bare finger, a gloved finger, a stylus, or any combination will activate your system. Keep in mind also, the type of handling the system will receive. A system in a hospital will receive more reasonable care than a public information kiosk, which is more susceptible to vandalism. Other factors may also have a bearing on your applications.

By understanding basic touch screen technology and your operating environment, you can begin to evaluate the range of choices. The comparison chart shows some of the tradeoffs for various touch screen options. Although most of the technologies are comparable in price, Resistive touch screens are typically the least expensive option. Four wire resistive Touch screens, however, are highly susceptible to wear out and all Resistive types are susceptible to surface damage because of their flexible outer layer.
Touch screen vendors, such as Elo Touchsystems and MicroTouch, have addressed the damage and wear out problems of Resistive touch screens with the creation of tougher outer coatings and the adoption of the five wire approach. Resistive touch screens wear out because repeated flexing of the membrane can crack its resistive coating. Four wire touch screen membranes need uniform surface resistivity for the sensor to accurately determine touch points. Cracks quickly ruin that uniformity. Five wire screens, in contrast, require only that the membrane be somewhat conductive. Cracking must be severe to affect the five wire system’s membrane. The five wire screens, therefore, have 35 million touches per point, whereas four wire systems offer only 1 to 4 million touches per point.

Five wire screens are also less affected by surface damage, such as cuts, than are four wire screens. A cut in a four wire screen’s membrane compromises the membrane’s ability to establish a uniform voltage gradient, making accurate touch point determination impossible. The five-wire system’s membrane, however, is merely a probe, so cuts, and even holes, do not affect its accuracy. Cuts and holes may create dead spots on the screen but don’t totally disable the system.

Unlike Resistive touch screens, Capacitive touch screens are all glass and have no flexing parts. As a result, Capacitive touch screens are highly resistant to physical surface damage. Despite the overcoat of a protective thin layer of glass, the conductive coating will eventually wear off through repeated touches. This is accelerated when used in dirty environments where the dirt has abrasive properties. Their main drawback is that the screens depend upon the user’s conductivity for operation and typically don’t work if the user is wearing gloves. Vendors have developed some Capacitive systems, however, that work with gloves and other insulating barriers.

Capacitive touch screens had other drawbacks, such as accuracy limits and drift (the change of sensor calibration over time). Vendors have corrected both limitations such as improving the accuracy of capacitive screens using a multi-point calibration procedure built into the controller and software. The calibration procedure prompts the user to touch a series of points on the display screen. The controller then calculates correction factors that accommodate irregularities in both the touch screen and the display. The correction factors improve position accuracy to within 1%.

In settings in which the system must be water and contamination resistant, Acoustic touch screens prove troublesome. Dust, grease and water drops on the screen’s surface can disturb the acoustic signal enough to degrade accuracy or even generate false touch indications. Unless you apply it carefully, any sealant that you use to make the touch screen water resistant dampens the acoustic signal. The sealant may also make the screen inoperable. Vendors of the SAW type have come up with a gasket material which has open pores and allows the sound energy to pass through but this may not be enough as the open pores collect dust and dirt and in time cause the same problems of degraded accuracy.

The Strain-gauge Platform Touch Bases are the simplest to install in the field. You simply set the display on the pedestal. Their drawback is the need for frequent calibration. When you place the display on the platform, you must then calibrate the sensors. The sensors need recalibration whenever the display changes position on the pedestal. The sensors are also subject to false readings based on shock and vibration to the pedestal.

One technology that appears to be declining is the Infra Red Matrix touch screen. IR screens are susceptible to dust and other contaminants, need special bezels for daylight use, have more possible points of failure, and cost in scale with the array size. IR screens also suffer from parallax problems when used with curved screens. Because the light must travel in a straight line from source to sensor, the optical grid that forms the touch-sensing surface must be flat. If used with CRT displays having curved faces, the optical grid floats above the screen. This displacement causes parallax between the display and the optical grid, resulting in possible misalignment between the measured and intended touch points if the user views the screen from an angle. The effect is most pronounced at the corners. Having the optical sensor grid float above the screen also causes the touch sensor to register a touch before the user’s finger reaches the display screen. This feature deprives the user of tactile feedback and could result in unintended activation of the screen.
The primary advantages of IR Touch screens are their clarity and immunity to drift. The LED and sensor arrays of an IR touch screen need no substrate, so the touch screen doesn’t place anything between the display and the user that might reduce the display’s brightness. Further, because the array forms a stationary optical grid, the touch point positioning cannot drift. These advantages may outweigh IR’s limitations in many applications.

The many tradeoffs between touch screen technology options are subject to change. Vendors are constantly improving their technology to reduce or eliminate the drawbacks inherent in each choice. Vendors are also creating packaging that extends the utility of their Touch screens.

Conclusion

Touch screen technology will increase in significance as an I/O technique for user oriented embedded systems. Vendors have been steadily reducing or eliminating the weaknesses in touch sensors as well as adding new capabilities. This combination of steady improvement punctuated by innovation will continue to broaden the range of applications that touch screens can serve.

With these improvements, touch screen technology has become a viable user interface for many embedded systems. The inclusion of electronic ink services in Windows 9x indicates that touch screens will become a dominant interface. You need only to carefully match the technology to the application environment.