Technology Brief 18
Touchscreens and Active Digitizers

Touchscreen is the common name given to a wide variety of technologies that allow computer displays to directly sense information from the user. In older systems, this usually meant the display could detect and pinpoint where a user touched the screen surface; newer systems can detect multiple touch locations as well as the associated touch pressures simultaneously, with very high resolution. This has led to a surge of applications in mobile computing, cell phones, personal digital assistants (PDA), and consumer appliances. Interactive touchscreens which detect multiple touches and interact with styli are now commonly used in phones, tablet computers and e-readers.

Numerous technologies have been developed since the invention of the electronic touch interface in 1971 by Samuel C. Hurst. Some of the earlier technologies were susceptible to dust, damage from repeat use, and poor transparency. These issues largely have been resolved over the years (even for older technologies) as experience and advanced material selection have led to improved devices. With the explosion of consumer interest in portable, interactive electronics, newer technologies have emerged that are more suitable for these applications. **Figure TF18-1** summarizes the general categories of touchscreens in use today. Historically, touchscreens were manufactured separately from displays and added as an extra layer of the display. More recently, display companies have begun to manufacture sensing technology directly into the displays; some of the newer technologies reflect this.

Resistive

Resistive touchscreens are perhaps the simplest to understand. A thin, flexible membrane is separated from a plastic base by insulating spacers. Both the thin membrane and the plastic base are coated on the inside with a transparent conductive film (indium tin oxide (ITO) often is used). When the membrane is touched, the two conductive surfaces come into contact. Detector circuits at the edges of the screen can detect this change in resistance between the two membranes and pinpoint the location on the *X–Y* plane. Older designs of this type were susceptible to membrane damage (from repeated flexing) and suffered from poor transparency.

Capacitive

Older capacitive touchscreens employ a single thin, transparent conductive film (usually indium tin oxide (ITO)) on a plastic or glass base. The conductive film is coated with another thin, transparent insulator for protection. Since the human body stores charge, a finger tip moved close to the surface of the film effectively forms a capacitor where the film acts as one of the plates and the finger as the other. The protective coating and the air form the intervening dielectric insulator. This capacitive coupling changes how a current flowing across the film surface is distributed; by placing electrodes at the screen corners and applying an ac electric signal, the location of the finger capacitance can be calculated precisely. One variant of this idea is to divide the sensing area into many smaller squares (just like pixels on the display) and to sense the change in capacitance across each of them continuously and independently; this is commonly known as ***self-capacitance sensing***. A newer development, found in many modern portable devices, is the use of ***mutual capacitance sensing*** touchscreens, which employ two sets of conductive lines, each on a different layer. On one layer, the lines might run horizontally, while on another layer below the first the lines run vertically. At each point of overlap between the lines on the two layers, a parallel plate capacitor is formed. If there are M lines on the top layer and N lines on the bottom, there will be $M \times N$ such nodes. Whenever a finger moves near a node, the capacitance of the node changes. By monitoring the capacitance of each node continuously, the touchscreen can detect when touches occur and where. The principal advantages of a touchscreen of this type are its ability to detect many simultaneous touches and its ability to detect very light ones. Capacitive technologies are much more resistant to wear and tear (since they are not flexed) than resistive touchscreen and are somewhat more transparent (> 85 percent transparency) since they can have fewer films and avoid air gaps. These types of screens can be used to detect metal objects as well, so pens with conductive tips can be used on writing interfaces.

Not all capacitive touch systems are integrated with screens; a number of interactive media technologies developed over the last 15 years integrate the touch sensing technology into furniture, household objects, or even countertops and overlay a display using nearby projection equipment. Some interactive tables operate this way. A completely different way to detect touch relies on the measurement of acoustic energy on or near the touchscreen. There are several ways to make use of

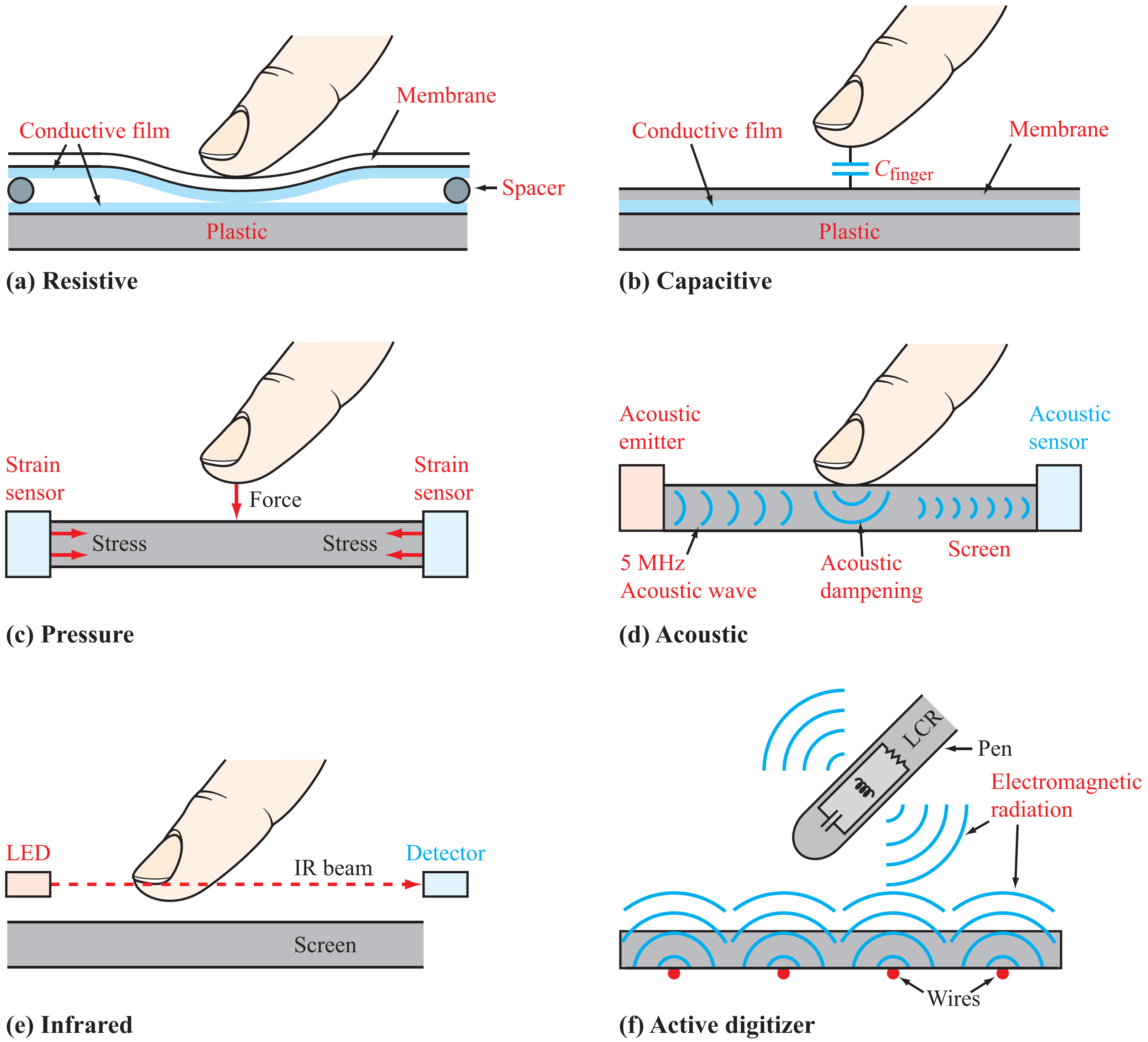

Figure TF18-1: Touchscreen technologies: (a) resistive, (b) capacitive, (c) pressure/strain sensor, (d) acoustic, (e) infrared, and (f) active digitizer.

acoustic energy to measure touch. One implementation relies on transmission of high-frequency acoustic energy across the surface of the display material.

Pressure

Touch also can be detected mechanically. Pressure sensors can be placed at the corners of the display screen or even the entire display assembly, so whenever the screen is depressed, the four corners will experience different stresses depending on the (X, Y) position of the pressure point. Pressure screens benefit from high resistance to wear and tear and no losses in transparency (since there is no need to add layers over the display screen).

Acoustic

A completely different way to detect touch relies on the transmission of high-frequency acoustic energy across the surface of the display material. Bursts of 5 MHz tones are launched by acoustic actuators from two corners of the screen. Acoustic reflectors all along the edges of the screen re-direct the incoming waves to the sensors. Any time an object comes into contact with the screen, it dampens or absorbs some fraction of the energy traveling across the material. The exact (X, Y) position can be calculated from the energy hitting the acoustic sensors. The contact force can be calculated as well, because the acoustic energy is dampened more or less depending on how hard the screen is pressed.

Another approach is to listen, with very sensitive acoustic transducers (i.e., microphones) to the characteristic pressure signal (e.g., sound) made in the touchscreen material when it is touched. By placing several transducers around the edge of the screen, the system can determine if a touch occurred and where. One drawback is that motionless fingers cannot be detected. However, this does provide an advantage in that resting objects (i.e., your cheek) do not trigger the screen. This method is sometimes known as ***acoustic pulse recognition***.

Infrared

One of the oldest and least used technologies is the infrared touchscreen. This technology relies on infrared emitters (usually infrared diodes) aligned along two adjoining edges of the screen and infrared detectors aligned across from the emitters at the other two edges. The position of a touch event can be determined through a process based on which light paths are interrupted. The detection of multiple simultaneous touch events is possible. Infrared screens are somewhat bulky, prone to damage or interference from dust and debris, and need special modifications to work in daylight. They largely have been displaced by newer technologies.

Electromagnetic Resonance

Another technology in widespread use is the electromagnetic resonance detection scheme used by many tablet PCs. Strictly speaking, many tablet PC screens are not touchscreens; they are called ***active digitizers*** because they can detect the presence and location of the tablet pen as it approaches the screen (even without contact). In this scheme, a very thin wire grid is integrated within the display screen (which usually is a flat-profile LCD display). The pen itself contains a simple RLC resonator (see Section 6-1) with no power supply. The wire grid alternates between two modes (transmit and receive) every ~ 20 milliseconds. The grid essentially acts as an antenna. During the transmit mode, an ac signal is applied to the grid and part of that signal is emitted into the air around the display. As the pen approaches the grid, some energy from the grid travels across to the pen's resonator which begins to oscillate. In receive mode, the grid is used to "listen" for ac signals at the resonator frequency; if those signals are present, the grid can pinpoint where they are across the screen. A tuning fork provides a good analogy. Imagine a surface vibrating at a musical note; if a tuning fork designed to vibrate at that note comes very close to that surface, it will begin to oscillate at the same frequency. Even if we were to stop the surface vibrations, the tuning fork will continue to make a sound for a little while longer (as the resonance dies down). In a similar way, the laptop screen continuously transmits a signal and listens for the pen's electromagnetic resonance. Functions (such as buttons and pressure information) can be added to the pen by having the buttons change the capacitance value of the LCR when pressed; in this way, the resonance frequency will shift (see Section 6-2), and the shift can be detected by the grid and interpreted as a button press.

Increased Integration

Mobile devices have largely driven the development of advanced touch technologies in the last few years. Given the constant pressure to miniaturize and integrate, a number of companies have or are developing integrated touch and display systems. Unlike the earlier-generation technologies, the display and the touch sensor are not manufactured separately and then integrated during assembly. Rather, the touch sensor conductors (in the case of capacitive sensing) are designed into the very display itself, either into the conductive traces in/on the pixels of the display or immediately over them. In other designs, light-sensing pixels are manufactured into each display pixel of a display, giving the display not only the ability to produce images but also to sense nearby objects that occlude light landing on the sensing pixels. Even the integrated circuits are increasingly being integrated; earlier-generation systems relied on stand-alone ***touch controller IC*** chips that managed the sensor information and communicated it to the application processor in the mobile devices. There is a push to integrate this functionality into some phone processors directly.