Touchscreen

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A **touchscreen** is an input device normally layered on the top of an electronic visual display of an information processing system. A user can give input or control the information processing system through simple or multi-touch gestures by touching the screen with a special stylus/pen and-or one or more fingers.[1] Some touchscreens use an ordinary or specially coated gloves to work while others use a special stylus/pen only. The user can use the touchscreen to react to what is displayed and to control how it is displayed (for example by zooming the text size).

Interactive table, Ideen 2020 exposition, 2013

The touchscreen enables the user to interact directly with what is displayed, rather than using a mouse, touchpad, or any other intermediate device (other than a stylus, which is optional for most modern touchscreens).

HP Series 100 HP-150 c. 1983, the earliest commercial touchscreen computer

Touchscreens are common in devices such as game consoles, personal computers, tablet computers, and smartphones. They can also be attached to computers or, as terminals, to networks. They also play a prominent role in the design of digital appliances such as personal digital assistants (PDAs), GPS navigation devices, mobile phones, and video games and some books (E-books).

The popularity of smartphones, tablets, and many types of information appliances is driving the demand and acceptance of common touchscreens for portable and functional electronics. Touchscreens are found in the medical field and in heavy industry, as well as for automated teller machines (ATMs), and kiosks such as museum displays or room automation, where keyboard and mouse systems do not allow a suitably intuitive, rapid, or accurate interaction by the user with the display's content.

The IBM Simon Personal Communicator, c. 1993, the first touchscreen phone

Historically, the touchscreen sensor and its accompanying controller-based firmware have been made available by a wide array of after-market system integrators, and not by display, chip, or motherboard manufacturers. Display manufacturers and chip manufacturers worldwide have acknowledged the trend toward acceptance of touchscreens as a highly desirable user interface component and have begun to integrate touchscreens into the fundamental design of their products.

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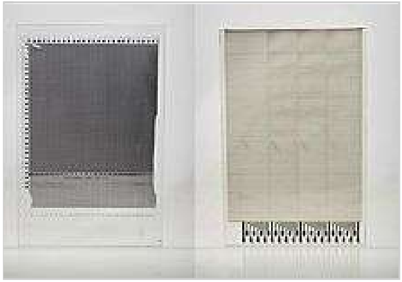
Apple iPad, a tablet computer with a touchscreen

History

E.A. Johnson described his work on capacitive touchscreens in a short article which is published in 1965[6] and then more fully—along with photographs and diagrams—in an article published in 1967.[7] A description of the applicability of the touch technology for air traffic control was described in an article published in 1968.[8] Frank Beck and Bent Stumpe, engineers from CERN, developed a transparent touchscreen in the early 1970s and it was manufactured by CERN and put to use in 1973.[9] This touchscreen was based on Bent Stumpe's work at a television factory in the early 1960s. A resistive touchscreen was developed by American inventor G. Samuel Hurst who received US patent #3,911,215 on October 7, 1975.[10] The first version was produced in 1982.[11]



The prototype[2] x-y mutual capacitance touchscreen (left) developed at CERN[3][4] in 1977 by Bent Stumpe, a Danish electronics engineer, for the control room of CERN's accelerator SPS (Super Proton Synchrotron). This was a further development of the self-capacitance screen (right), also developed by Stumpe at CERN[5] in 1972.

In 1972, a group at the University of Illinois filed for a patent on an optical touchscreen.[12] These touch screens became a standard part of the Magnavox Plato IV Student Terminal. Thousands of these were built for the PLATO IV system. These touchscreens had a crossed array of 16 by 16 infrared position sensors, each composed of an LED on one edge of the screen and a matched phototransistor on the other edge, all mounted in front of a monochrome plasma display panel. This arrangement can sense any fingertip-sized opaque object in close proximity to the screen. A similar touchscreen was used on the HP-150 starting in 1983; this was one of the world's earliest commercial touchscreen computers.[13] HP mounted their infrared transmitters and receivers around the bezel of a 9" Sony Cathode Ray Tube (CRT).

In 1985, Sega released the Terebi Oekaki, also known as the Sega Graphic Board, for the SG-1000 video game console and SC-3000 home computer. It consisted of a plastic pen and a plastic board with a transparent window where the pen presses are detected. It was used primarily for a drawing software application.[14]

In the early 1980s, General Motors tasked its Delco Electronics division with a project aimed at replacing an automobile's non essential functions (i.e. other than throttle, transmission, braking and steering) from mechanical or electro-mechanical systems with solid state alternatives wherever possible. The finished device was dubbed the ECC for "Electronic Control Center", a digital computer and software control system hardwired to various peripheral sensors, servos, solenoids, antenna and a monochrome CRT touchscreen that functioned both as display and sole method of input.[15] The ECC replaced the traditional mechanical stereo, fan, heater and air conditioner controls and displays, and was capable of providing very detailed and specific information about the vehicle's cumulative and current operating status in real time. The ECC was standard equipment on the 1985–89 Buick Riviera and later the 1988–89 Buick Reatta, but was unpopular with consumers partly due to technophobia on behalf of some traditional Buick customers, but mostly because of costly to repair technical problems suffered by the ECC's touchscreen which being the sole access method, would render climate control or stereo operation impossible.[16]

Multi-touch technology began in 1982, when the University of Toronto's Input Research Group developed the first human-input multi-touch system, using a frosted-glass panel with a camera placed behind the glass. In 1985, the University of Toronto group including Bill Buxton developed a multi-touch tablet that used capacitance rather than bulky camera-based optical sensing systems (see History of multi-touch).

In 1986, the first graphical point of sale software was demonstrated on the 16-bit Atari 520ST color computer. It featured a color touchscreen widget-driven interface.[17] The ViewTouch[18] point of sale software was first shown by its developer, Gene Mosher, at Fall Comdex, 1986, in Las Vegas, Nevada to visitors at the Atari Computer demonstration area and was the first commercially available POS system with a widget-driven color graphic touchscreen interface.[19]

In 1987, Casio launched the Casio PB-1000 pocket computer with a touchscreen consisting of a 4x4 matrix, resulting in 16 touch areas in its small LCD graphic screen.

Sears et al. (1990)[20] gave a review of academic research on single and multi-touch human–computer interaction of the time, describing gestures such as rotating knobs, adjusting sliders, and swiping the screen to activate a switch (or a U-shaped gesture for a toggle switch). The University of Maryland Human – Computer Interaction Lab team developed and studied small touchscreen keyboards (including a study that showed that users could type at 25 wpm for a touchscreen keyboard compared with 58 wpm for a standard keyboard), thereby paving the way for the touchscreen keyboards on mobile devices. They also designed and implemented multitouch gestures such as selecting a range of a line, connecting objects, and a "tap-click" gesture to select while maintaining location with another finger.

In c. 1991–92, the Sun Star7 prototype PDA implemented a touchscreen with inertial scrolling.[21] In 1993, the IBM Simon—the first touchscreen phone—was released.

An early attempt at a handheld game console with touchscreen controls was Sega's intended successor to the Game Gear, though the device was ultimately shelved and never released due to the expensive cost of touchscreen technology in the early 1990s. Touchscreens would not be popularly used for video games until the release of the Nintendo DS in 2004.[22] Until recently, most consumer touchscreens could only sense one point of contact at a time, and few have had the capability to sense how hard one is touching. This has changed with the commercialization of multi-touch technology.

Technologies

There are a variety of touchscreen technologies that have different methods of sensing touch.[20]

Resistive

A resistive touchscreen panel comprises several layers, the most important of which are two thin, transparent electrically-resistive layers separated by a thin space. These layers face each other with a thin gap between. The top screen (the screen that is touched) has a coating on the underside surface of the screen. Just beneath it is a similar resistive layer on top of its substrate. One layer has conductive connections along its sides, the other along top and bottom. A voltage is applied to one layer, and sensed by the other. When an object, such as a fingertip or stylus tip, presses down onto the outer surface, the two layers touch to become connected at that point: The panel then behaves as a pair of voltage dividers, one axis at a time. By rapidly switching between each layer, the position of a pressure on the screen can be read.

Resistive touch is used in restaurants, factories and hospitals due to its high resistance to liquids and contaminants. A major benefit of resistive touch technology is its low cost. Additionally, as only sufficient pressure is necessary for the touch to be sensed, they may be used with gloves on, or by using anything rigid as a finger/stylus substitute. Disadvantages include the need to press down, and a risk of damage by sharp objects. Resistive touchscreens also suffer from poorer contrast, due to having additional reflections from the extra layers of material (separated by an air gap) placed over the screen.[23] This is the type of touchscreen used by Nintendo in DS consoles and the WiiU.[24]

Surface acoustic wave

Surface acoustic wave (SAW) technology also uses ultrasonic waves that pass over the touchscreen panel. When the panel is touched, a portion of the wave is absorbed. This change in the ultrasonic waves registers the position of the touch event and sends this information to the controller for processing. Surface acoustic wave touchscreen panels can be damaged by outside elements. Contaminants on the surface can also interfere with the functionality of the touchscreen.

Capacitive

A capacitive touchscreen panel consists of an insulator such as glass, coated with a transparent conductor such as indium tin oxide (ITO).[25] As the human body is also an electrical conductor, touching the surface of the screen results in a distortion of the screen's electrostatic field, measurable as a change in capacitance. Different technologies may be used to determine the location of the touch. The location is then sent to the controller for processing.


Capacitive touchscreen of a mobile phone

Unlike a resistive touchscreen, one cannot use a capacitive touchscreen through most types of electrically insulating material, such as gloves. This disadvantage especially affects usability in consumer electronics, such as touch tablet PCs and capacitive smartphones in cold weather. It can be overcome with a special capacitive stylus, or a special-application glove with an embroidered patch of conductive thread passing through it and contacting the user's fingertip.

The largest capacitive display manufacturers continue to develop thinner and more accurate touchscreens, with touchscreens for mobile devices now being produced with 'in-cell' technology that eliminates a layer, such as Samsung's Super AMOLED screens, by building the capacitors inside the display itself. This type of touchscreen reduces the visible distance (within millimetres) between the user's finger and what the user is touching on the screen, creating a more direct contact with the content displayed and enabling taps and gestures to be more responsive.

A simple parallel plate capacitor has two conductors separated by a dielectric layer. Most of the energy in this system is concentrated directly between the plates. Some of the energy spills over into the area outside the plates, and the electric field lines associated with this effect are called fringing fields. Part of the challenge of making a practical capacitive sensor is to design a set of printed circuit traces which direct fringing fields into an active sensing area accessible to a user. A parallel plate capacitor is not a good choice for such a sensor pattern. Placing a finger near fringing electric fields adds conductive surface area to the capacitive system. The additional charge storage capacity added by the finger is known as finger capacitance, CF. The capacitance of the sensor without a finger present is denoted as CP in this article, which stands for parasitic capacitance.

Surface capacitance

In this basic technology, only one side of the insulator is coated with a conductive layer. A small voltage is applied to the layer, resulting in a uniform electrostatic field. When a conductor, such as a human finger, touches the uncoated surface, a capacitor is dynamically formed. The sensor's controller can determine the location of the touch indirectly from the change in the capacitance as measured from the four corners of the panel. As it has no moving parts, it is moderately durable but has limited resolution, is prone to false signals from parasitic capacitive coupling, and needs calibration during manufacture. It is therefore most often used in simple applications such as industrial controls and kiosks.[26]

Projected capacitance


Back side of a Multitouch Globe, based on Projected Capacitive Touch (PCT) technology

Projected Capacitive Touch (PCT; also PCAP) technology is a variant of capacitive touch technology. All PCT touch screens are made up of a matrix of rows and columns of conductive material, layered on sheets of glass. This can be done either by etching a single conductive layer to form a grid pattern of electrodes, or by etching two separate, perpendicular layers of conductive material with parallel lines or tracks to form a grid. Voltage applied to this grid creates a uniform electrostatic field, which can be measured. When a conductive object, such as a finger, comes into contact with a PCT panel, it distorts the local electrostatic field at that point. This is measurable as a change in capacitance. If a finger bridges the gap between two of the "tracks", the charge field is further interrupted and detected by the controller. The capacitance can be changed and measured at every individual point on the grid (intersection). Therefore, this system is able to accurately track touches.[27] Due to the top layer of a PCT being glass, it is a more robust solution than less costly resistive touch technology. Additionally, unlike traditional capacitive touch technology, it is possible for a PCT system to sense a passive stylus or gloved fingers. However, moisture on the surface of the panel, high humidity, or collected dust can interfere with the performance of a PCT system. There are two types of PCT: mutual capacitance and self-capacitance.

Mutual capacitance

This is a common PCT approach, which makes use of the fact that most conductive objects are able to hold a charge if they are very close together. In mutual capacitive sensors, a capacitor is inherently formed by the row trace and column trace at each intersection of the grid. A 16-by-14 array, for example, would have 224 independent capacitors. A voltage is applied to the rows or columns. Bringing a finger or conductive stylus close to the surface

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