KAPITEL 7 / *CHAPTER 7* [7]

ANALYSIS OF THE TECHNOLOGIES OF PRE-SCREEN TOUCH PANELS

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Introduction

In today's world, the technology of pre-screen touch panels has become an integral part of the user interface in a variety of electronic devices, from smartphones and tablets to ATMs and automotive control systems. This technology provides the ability to interact directly with electronic devices, allowing you to perform actions on the screen through simple gestures and touch.

A pre-screen touch panel [1] – is an electronic visual display capable of detecting and localizing touch in the display area. This technology simplifies the interaction between a person and a device by replacing most mouse and keyboard functions.

The development of modern screens requires constant improvement of these technologies. The details of the technical functionality of pre-screen touch panels include the ability to respond to different types of impact and provide advanced functions.

The analysis of the technologies of pre-screen touch panels is carried out to unlock the potential of these innovative solutions and improve their functionality, reliability and efficiency. Pre-screen touch panels are setting new standards for human interaction with electronic devices by enabling control and interaction through gestures, touch, and motion, making them essential for modern consumers and industrial applications. However, achieving optimum performance and quality requires a thorough understanding of technical specifications and functional features.

7.1. Technical features and principles of operation of the pre-screen touch panels

Pre-screen touch panels [2] – are an integral part of modern technology that allows users to interact with electronic devices using touches and gestures. For a detailed analysis of the technologies of pre-screen touch panels, let's look at their structure and principles of operation.

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The main components of pre-screen touch panels include [3]:

- touch sensor: a transparent glass panel with a touch-sensitive surface used to detect the very fact of touching the touch panel, which allows the pre-screen panel to respond to physical contact with the user;

- software driver: this is the operating system-level software that allows the on-screen touch panel and the computer to communicate. The software driver receives data from the controller and interprets it, converting the user's touches and gestures into commands that the operating system understands;

- controllers: a hardware chip that supplies power to the sensor panel and functions as an intermediary between the touch sensor and a computer or other device. The controller receives information from the sensor and converts it into signals that the computer can understand;

- tempered glass: special tempered glass that separates the user from the sensor itself and protects the touch sensor from scratches, shocks, and other mechanical damage.

The principle of a pre-screen touch panel is [4] to accurately detect the location of a touch or other interaction, such as swiping or gestures. The process of touch sensing is to accurately determine where the user touches the sensor panel on the pre-screen touch panel. This is achieved by measuring the difference in electric current, voltage, or other parameters that occur during physical contact.

The pre-screen sensor panel consists of two transparent dielectric materials separated by an insulated space. When a conductive object, such as a finger, touches the screen, it causes changes in the electric current. The sensor panel has two transparent grids printed on polyester with an optically transparent insulator in the middle. The conductive layer (often indium tin oxide or ITO) acts as a conductor and creates a capacitive capacitor. When an object touches the screen, this process disturbs the electric field, measuring the change in capacitance. The pre-screen touch panel system actively measures each column individually, using an electric field sweep along the rows and columns. This approach allows us to determine the exact place of touch and other characteristics of user interaction with the screen [5].

Different types of touch technologies, such as capacitive, resistive, optical, acoustic, and others, use different measurement methods, but the general principle is to accurately determine the location of a touch and other user interactions with the screen.

Pre-screen touch panels support various ways of user interaction, which makes them versatile and easy to use. Here are some of the basic principles of interaction [6]:

- one-touch: use a single touch to select an object or perform an action, such as opening an app or selecting an item;
- double-tap: double-tap is often used to perform various functions, such as zooming the display or selecting text;
- touch and hold: this option allows you to select objects for further dragging and other actions. This principle can also be used to unlock the screen or turn the device on/off;
- swipe: you can enter text or navigate pages and close apps by swiping your finger across the screen;
- finger swipe: you can zoom in and out of the display by swiping two fingers.

7.2. Technologies of pre-screen touch panels

7.2.1. Resistive pre-screen touch panels

The resistive pre-screen touch panel [7] – is a technology that has become widespread due to its simplicity and low production cost. This technology is used to determine the coordinates of the touch point on the screen, allowing users to interact with the device through physical contact. The principle of operation of a resistive touch panel is shown in Figure 1.

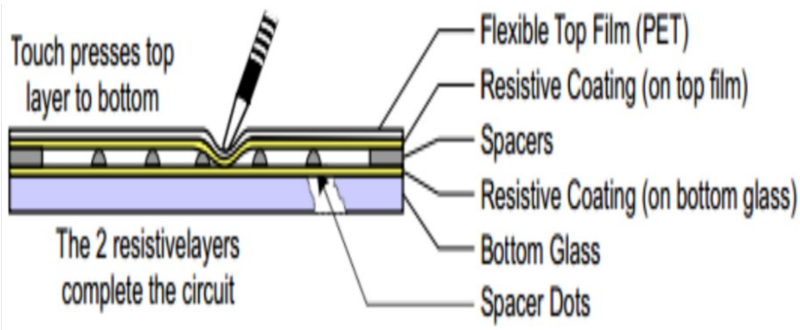

Figure 1 - Resistive touch panel in front of the screen

As can be seen from Figure 1, the resistive pre-screen touch panel is covered with two layers of resistive flexible sheets [8]. The first layer is of the digital matrix type, which forms a mechanical XY plane and has a flexible top surface and a conductive ITO surface below, which contact each other when an object is touched. The second layer is analogue, consisting of a flexible surface in contact with the user and a rigid

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part covered with ITO, which are separated by microdots. Thus, when the object is pressed, the resistive layers come into contact with each other, which leads to a circuit closure. The controller can notify of touch events and perform calculations that are sent to the software driver.

To determine the coordinates of the touch point, the resistive touch panel uses a special controller that monitors changes in resistance between the two layers. Below is the formula for calculating the coordinates of the touch point:

$$X = \left(\frac{R2_x}{(R1_y + R2_y)}\right) * \text{panel width},$$

$$Y = \left(\frac{R2_y}{(R1_y + R2_y)}\right) * \text{panel height}$$

where $R1_x$ and $R1_y$ – are the resistance of the first layer in the X and Y directions, respectively, $R2_x$ and $R2_y$ – are the resistance of the second layer in the X and Y directions respectively.

Resistive touch panels have several advantages [9]. Firstly, their low production cost makes them affordable for a wide range of devices. This makes them attractive to manufacturers seeking to reduce production costs while maintaining affordable prices for consumers. Secondly, resistive touch screens have a high sensitivity to touch, which allows users to interact with devices accurately and easily. This is especially useful for precision operations and handwriting recognition. Thirdly, these panels can be activated by various objects, including styluses, which expands their capabilities and use.

However, resistive touch panels also have some disadvantages. Firstly, poor light transmission leads to a limited transparent display on the screen and requires bright backlighting. Secondly, these panels usually do not support multi-touch, which limits their capabilities in gesture-based interfaces and multimedia applications. Third, they are unable to detect the force of pressure. Another disadvantage is that resistive touch panels are vulnerable to mechanical wear, which can lead to a shorter service life than the device itself.

7.2.2. Capacitive pre-screen touch panels

A capacitive pre-screen touch panel [10] – is a technology for interactive devices to interact with the user, based on the ability to detect the touch of a human finger or other conductive object on the surface of glass or another transparent insulator. It works through the formation of dynamic capacitors under the insulator, which allows determining the exact location of the touch and other user movements by responding to changes in capacitance between the conductive layer and the touch object (Figure 2).

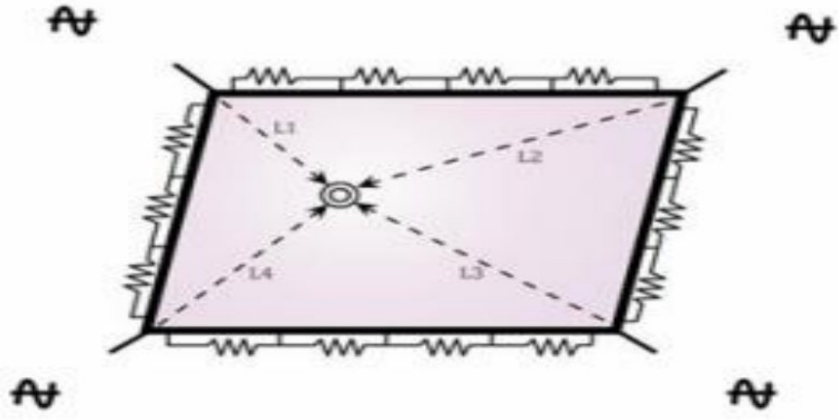

Figure 2 - Capacitive pre-screen touch panel

As you can see in Figure 2, a capacitive touch panel works by changing the capacitance when an object touches the screen. As long as nothing is touched, a small amount of current flows through the display. However, every time an object (e.g., a user's finger) touches it, it causes a voltage drop at the point of contact [11]. When an object touches the screen, it creates some interference effect, which leads to a voltage drop at the point of contact. This is created by the interaction between the insulating layer and the conductive panel, where the conductivity changes due to the touch. Oscillators are placed at each corner of the touch panel to determine the exact point of contact. The capacitance can be calculated using the oscillator capacitance formula:

$$C = \frac{e_0 * e_r * A}{d}$$

, where *C* - is the oscillator capacitance, e_0 - is the dielectric constant, e_r - is the dielectric constant of the material between the conductive layer and the object of contact, *A* - is the oscillator area that changes during contact, and *d* - is the distance between the conductive layers.

Touching an object affects the capacitance at each of these angles. After the object is touched, the capacitance changes. The controller system measures the change in capacitance at each corner. Using differential changes in the frequency of the oscillators determines the location where the touch occurred. Oscillators are located at each corner of the touch panel. Information about the point of contact and coordinates is sent to the controller for further processing. This allows you to determine exactly where the object was touched and respond accordingly.

Capacitive touch panels have two main modes of operation that affect their ability to register touches [12]:

1. Surface capacitive technology: in this mode, only one side of the insulator is covered with a conductive layer. Each time the user's finger touches the screen, a dynamic capacitor is created. The controller then detects the position of the touch by measuring the change in capacitance at the four corners of the screen.

2. Design-capacitance technology: in this technology, the conductive layer is etched to create a grid of electrodes in the horizontal and vertical directions. Each cross-point of the grid functions as a separate capacitor. This system can provide greater accuracy and the ability to detect multiple touches simultaneously.

Capacitive touch panels differ from other technologies in their ability to respond to physical contact. Capacitive sensors require electrical contact with a conductive object, usually a finger. They do not respond to non-conductive objects, such as ordinary styluses. An important feature of capacitive touch panels is their fast response time and ability to display clear images without the need for strong pressure on the screen. Also, capacitive touch panels support multi-touch gestures, which allow users to interact with the device through gestures such as pinching, swiping, rotating, and other similar movements.

Despite their many advantages, capacitive touch panels have their limitations. First of all, capacitive panels do not respond to non-conductive objects, which can limit their use in various situations. Also, electromagnetic bands can affect the operation of capacitive touch panels, which can lead to incorrect touch response. In addition, capacitive touch panels require physical touch to interact with, which limits their use in environments where touch is not appropriate or desired.

7.2.3 Acoustic surface wave (SAW) type

Acoustic surface wave (SAW) [13] – is a touch panel technology that uses the effect of acoustic waves to determine the coordinates of a touch point on the screen.

This technology involves applying glass with transmitting and receiving transducers to a surface located on both sides of the X and Y axes. When an object touches the surface, electrical signals are generated, which are converted into ultrasonic waves that are transmitted through the screen using reflectors. The other end of the sensor receives the reflected waves, forming the X-Y coordinate plane (Figure 3).

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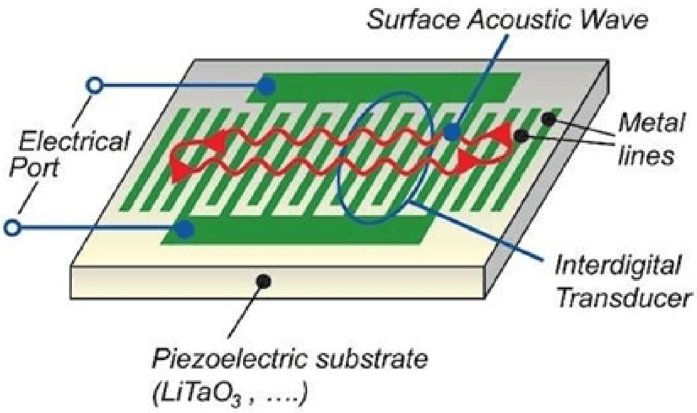

Figure 3 - SAW technology for front-of-screen touch panels

Touching an object interrupts the invisible waves, causing a touch event [14]. The controller is responsible for sending electrical energy to the transducer and processing the signals received from the receiving sensor.

$$X = \frac{V_p * t}{2}$$

$$Y = \frac{V_s * t}{2}$$

, where V_p - is the velocity of acoustic waves in the X direction, V_s - is the velocity of acoustic waves in the X direction. t - is the delay between sending an acoustic wave and receiving it at the receiving sensor.

The velocity of acoustic waves usually depends on the material of the touch panels and can be measured experimentally for a particular panel. Latency can be measured electronically and represents the time between the sending of an acoustic wave and its reception at the receiving sensor. This delay helps determine the travel time of the acoustic waves from the transmitting sensor to the receiving sensor.

7.2.4. Infrared pre-screen touch panels

Infrared touch panels [15] – are touch devices that detect user touch on a surface using infrared light and photo sensors (Figure 4).

The technology of infrared touch panels is based on the use of infrared light and photo sensors to detect user touch on the screen. The main components of this technology are LEDs, which emit infrared rays, and phototransistors, which receive infrared light. The LEDs are arranged along two adjacent sides of the touch screen, creating an invisible grid of infrared rays that intersect in vertical and horizontal

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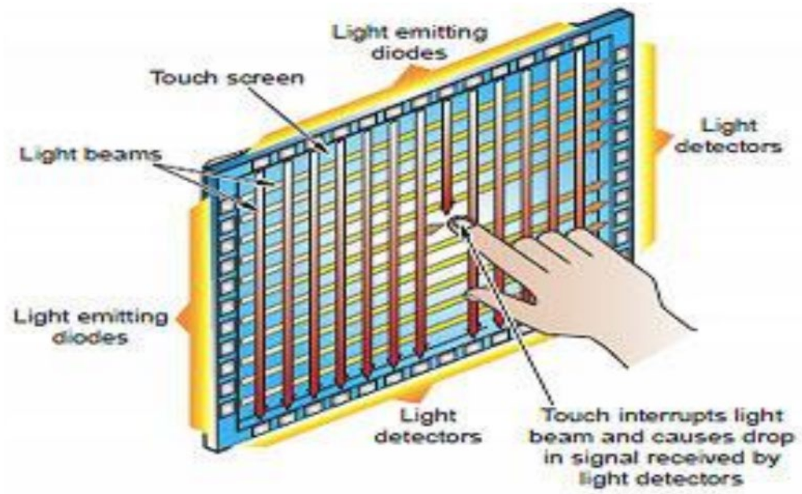

Figure 4 - Infrared grid technology for touch panels

patterns. When a user touches the screen with a finger or other object, it interrupts the infrared rays at a specific point on the screen. This interruption results in a lack of infrared light on the phototransistors, and this information is immediately transmitted to the touch panel controller. The controller processes the ray interruption information and determines the exact coordinates of the touch on the screen. This information is then used to interact with the device and perform various actions, including moving the cursor, selecting objects, and performing gestures [16].

The advantages of infrared touch panels include their high quality: infrared touch panels provide high image quality and clarity because they do not require additional layers on the screen; and their ability to register opaque objects: infrared touch panels can register almost any opaque object, such as a finger, gloved finger, stylus, or pen.

The main disadvantages of infrared touch panels include the sensitivity to dirt and dust of touch panels like other types of touch panels, infrared panels are exposed to dirt and dust, which can lead to incorrect operation; the inability to determine the force of pressing. The main disadvantage is the accuracy of coordinate determination: compared to other touch technologies, infrared touch panels have lower accuracy in determining the coordinates of touch, which can affect the accuracy of interaction with the device.

7.2.5. Optical pre-screen touch panels

Optical technology of pre-screen touch panels [17] – is a technology that uses optical sensors to register touch. They are based on the principle of using infrared light to determine where an object touches the screen surface.

$$X = \frac{(\text{Horizontal resolution}) * (\text{Interrupt column number})}{(\text{Total number of columns})}$$

$$Y = \frac{(\text{Vertical resolution}) * (\text{Interrupt line number})}{(\text{Total number of rows})}$$

Optical touchscreens are a modern touch panel technology that uses two or more image sensors, usually CMOS sensors, positioned along the edges or corners of the screen. This technology is also known as "optical touch technology". Optical touch panels can detect touch by relying on an infrared light that is located on the opposite side of the screen. When an object touches the screen, some infrared rays are blocked, and the location and size of the object that made the touch are immediately calculated [18].

Optical touchscreen imaging technology is based on the use of optical sensors and infrared light. Typically, there are two infrared image sensors on top of the screen, which are used not only as sensors but also as sources of infrared light. The infrared light is emitted from these sensors and reflected by reflective tapes placed around the screen. When an object touches the touch panel, some of the rays are blocked, and this shadow is created on the image sensors, indicating the place of contact. The touch panel controller processes the information provided by the image sensors and determines the coordinates of the exact touch on the screen.

Optical touch panels have several important advantages. First, they are scalable, making them ideal for large touch panels. Second, this technology is versatile because it can respond to a variety of objects, including fingers, styluses, and other opaque objects[19].

Optical touch panels also have some disadvantages. First, they are highly sensitive to dirt and dust, which can interfere with the proper operation of the sensors. This can lead to instability of the touch panel and requires regular cleaning. Secondly, optical touch panel technology requires light to function properly, which can create limitations in low-light conditions.

7.2.6. PCAP technology

PCAP (Projected Capacitive Touch Screen) technology [20] – is a modern touch panel technology that uses the capacitive principle to determine the position and interaction of a user's finger or other conductive objects on multimedia devices such as smartphones, tablets, and other touch devices. They are characterized by multi-touch capabilities and high scratch resistance.

PCAP touch panels work based on the capacitance principle. They contain an electrode network that creates an electromagnetic field under the screen's protective glass. The basic principle is that when the user's finger or other conductive object touches the glass surface of the screen, it changes the capacitance of this field in a specific area.

PCAP (Projected Capacitive Touch Screen) touch panels have several important advantages. First of all, they provide multi-touch interaction, which allows users to interact with the screen using up to ten touches simultaneously [21].

The main disadvantage of this technology is the lack of the ability to measure the force of pressure, which can be important in some applications where the reaction to a forceful touch is important.

7.2.7. Acoustic Pulse Recognition Technology

Acoustic impulse recognition technology [22] – is an innovative method of interacting with a touch panel based on the analysis of sound waves that arise as a result of a user touching the panel surface.

When the user touches the surface of the touch panel, it creates a sound wave in the substrate that propagates through the screen material. A touch screen is equipped with several tiny sound transducers that are attached to the edges of the screen. These transducers register sound waves that travel across their surfaces. The sound signal registered by the transducers is converted to a digital signal and digitized. This signal is compared to a list of pre-saved sound profiles, each of which corresponds to a specific position on the screen surface. By comparing the sound signal with the list of sound profiles, the technology determines the user's touch point. The speed of the technology's response allows it to track the user's finger movements on the screen. The technology ignores extraneous and ambient sounds, as they do not match any of the stored sound profiles. This allows for an increase in the accuracy of touch recognition and avoids accidental interference [23].

The advantages of acoustic pulse recognition technology include high durability and optical clarity. Touch panels using this technology typically have a glass surface, which makes them extremely durable and ensures high display quality. Scratch and dust resistance is another advantage of this technology. Even if there are scratches and dust on the surface of the screen, it can maintain its accuracy. The ability to recognize the touch of any object, including gloved fingers, makes this technology very versatile and user-friendly. In addition, the technology is ideal for large touchscreen displays, such as TVs or interactive whiteboards, due to its ability to work with different display sizes [24].

The disadvantage of this technology is the inability to detect a user's fixed finger after the first touch. This can limit the ability to interact with some applications and interfaces that require steady contact with the screen.

Conclusion

The presented work investigated the modern technologies of pre-screen touch panels used in various electronic devices and interactive systems.

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