UNIT - IV

DISPLAY DEVICES
SPH 1102- PHYSICS OF ELECTRON DEVICES
TOPICS COVERED:

- Introduction
  - what is display devices?
  - Luminescence
  - Electroluminescence
- Active Display Devices
  - CRT – Cathode Ray Tube
  - LED – Light Emitting Diode
- Passive Display Devices
  - LCD – Liquid Crystal Display
  - Plasma Display
  - Dynamic Scattering Display
  - Touch screen
**INTRODUCTION**

- **Definition:**
  - A display device is an output device for presentation of information in visual or tactile form (the latter used for example in tactile electronic displays for blind people). When the input information is supplied as an electrical signal, the display is called an *electronic display*.
  - Display devices are used for the visual presentation of information.

- **Types of display devices:**
  - Electronic display devices based on various principles were developed.
    - Active display devices are based on luminescence.
    - Passive display devices reflect or modulate light.
Definition:
Luminescence is the general term used to describe the emission of electromagnetic radiation from a substance due to a non-thermal process. Luminescence occurs from a solid when it is supplied with some form of energy.

Types of Luminescence:
- Photoluminescence arises as a result of absorption of photons.
  - Fluorescence persists for a short lifetime of the transition between the two energy levels.
  - Phosphorescence persists for much longer time (more than $10^{-8}$ s).
- Cathodoluminescence - Excitation of electrons by bombardment with a beam of electrons.
- Electroluminescence - Excitation of electrons by application of an electric field.
- Thermoluminescence – Excitation of electrons by the application of High temperature.
- Chemiluminescence - Excitation of electrons due to chemical reaction.
Electronic visual displays present visual information according to the electrical input signal (analog or digital) by emitting light, they are called active displays.

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A cathode ray tube (CRT) is a specialized vacuum tube in which images are produced when an electron beam strikes a phosphorescent surface. Most desktop computer displays make use of CRTs. The CRT in a computer display is similar to the "picture tube" in a television receiver.

**A cathode ray tube consists of several basic components.**

**The four major components are:**

- The electron gun generates a narrow beam of electrons.
- The anodes accelerate the electrons.
- Deflecting coils produce an extremely low frequency electromagnetic field that allows for constant adjustment of the direction of the electron beam. There are two sets of deflecting coils: horizontal and vertical. (In the illustration, only one set of coils is shown for simplicity.) The intensity of the beam can be varied.
- The electron beam produces a tiny, bright visible spot when it strikes the phosphor-coated screen.
Working:

To produce an image on the screen, complex signals are applied to the deflecting coils, and also to the apparatus that controls the intensity of the electron beam. This causes the spot to race across the screen from right to left, and from top to bottom, in a sequence of horizontal lines called the raster. As viewed from the front of the CRT, the spot moves in a pattern similar to the way your eyes move when you read a single-column page of text. But the scanning takes place at such a rapid rate that your eye sees a constant image over the entire screen.

The illustration shows only one electron gun. This is typical of a monochrome, or single-color, CRT. However, virtually all CRTs today render color images. These devices have three electron guns, one for the primary color red, one for the primary color green, and one for the primary color blue. The CRT thus produces three overlapping images: one in red (R), one in green (G), and one in blue (B). This is the so-called RGB color model.

In computer systems, there are several display modes, or sets of specifications according to which the CRT operates. The most common specification for CRT displays is known as SVGA (Super Video Graphics Array). Notebook computers typically use liquid crystal display. The technology for these displays is much different than that for CRTs.
Applications of CRT:

- In cathode ray oscilloscope
- Used as a display device in RADAR
- In televisions
- In computer monitors
Light Emitting Diode (LED):

Definition:

A light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for other lighting. Introduced as a practical electronic component in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness.

Types of LED:

There are two of LED. namely,

i. Planar (or) Surface emitting LED
ii. Dome shaped LED.
Light Emitting Diode (LED)
Principle: 
Injection luminescence is the principle used in both the LEDs.

Working of LED:

- In LEDs the electrical energy is converted into optical energy. The main mechanism of working is injection electro luminescence. In injection electro luminescence, the carrier are injected across a p-n junction. Now the recombination of excess electrons and the holes can result photon emission if the semiconductor used, is a direct band gap semiconductor. In direct band gap semiconductor, transition between the two allowed bands can take place with no change in crystal momentum.

- When across the p-n junction, a voltage is applied then electrons and the holes are injected across the depletion region and they become excess minority carriers. These recombine with majority carriers when these minority carriers diffuse this in to neutral semiconductor region. This recombination process in direct band gap material results the emission of photons. The output photon intensity is directly proportional to the ideal diode diffusion current which is proportional to the recombination rate.

- The wave length of output optical signals depends upon the band gap energy. The output wave length can be engineered within certain limits by using compound semiconductors, so that a particular color can be observed, provided the output is in visible range.
Application of LED:

- In motorcycle and bicycle lights.
- In traffic lights and signals.
- In message displaying boards.
- In light bulbs and many more.
- Indicators and signs:- these are mainly used in traffic signals, exit signs, light weight message, displaying box etc
- Light Emitting Diode lamps have become highly popular and as the energy consumption is very low for them, they are also being made by LED s.
- In television and computer/laptop displaying, LEDs are used.
- Non visual application:- Communication, sensor are the main area of non visual application of LEDs.

Advantages of LED:

- Smaller in size
- cost is very low
- it has long life time
- it operates even at very low voltage
- response time of LED is very fast (10^{-9} secs).

Disadvantages of LED:

- Power output is low
- intensity is less than laser
- the light cannot travel through longer distance
- the light output is incoherent and are not in phase
- the light will not have directionality
Main LED materials

The main semiconductor materials used to manufacture LEDs are:

- **Indium gallium nitride (InGaN):** blue, green and ultraviolet high-brightness LEDs
- **Aluminum gallium indium phosphide (AlGaInP):** yellow, orange and red high-brightness LEDs
- **Aluminum gallium arsenide (AlGaAs):** red and infrared LEDs
- **Gallium phosphide (GaP):** yellow and green LEDs
Electronic visual displays present visual information according to the electrical input signal (analog or digital) by modulating available light during the process of reflection or transmission then the light modulators are called *passive displays*.

### Passive displays

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What is LCD (Liquid Crystal Display)?

A liquid crystal display or LCD draws its definition from its name itself. It is combination of two states of matter, the solid and the liquid. LCD uses a liquid crystal to produce a visible image. Liquid crystal displays are super-thin technology display screens that are generally used in laptop computer screen, TVs, cell phones and portable video games. LCD’s technologies allow displays to be much thinner when compared to cathode ray tube (CRT) technology.

Liquid crystal display is composed of several layers which include two polarized panel filters and electrodes. LCD technology is used for displaying the image in notebook or some other electronic devices like mini computers. Light is projected from a lens on a layer of liquid crystal. This combination of colored light with the grayscale image of the crystal (formed as electric current flows through the crystal) forms the colored image. This image is then displayed on the screen.
An LCD is either made up of an active matrix display grid or a passive display grid. Most of the Smartphone's with LCD display technology uses active matrix display, but some of the older displays still make use of the passive display grid designs. Most of the electronic devices mainly depend on liquid crystal display technology for their display. The liquid has a unique advantage of having low power consumption than the LED or cathode ray tube.

Liquid crystal display screen works on the principle of blocking light rather than emitting light. LCD’s requires backlight as they do not emits light by them. We always use devices which are made up of LCD’s displays which are replacing the use of cathode ray tube. Cathode ray tube draws more power compared to LCD’s and are also heavier and bigger.
How LCDs are Constructed?

Simple facts that should be considered while making an LCD:
- The basic structure of LCD should be controlled by changing the applied current.
- We must use a polarized light.
- Liquid crystal should able be to control both of the operation to transmit or can also able to change the polarized light.

As mentioned above that we need to take two polarized glass pieces filter in the making of the liquid crystal. The glass which does not have a polarized film on the surface of it must be rubbed with a special polymer which will create microscopic grooves on the surface of the polarized glass filter. The grooves must be in the same direction of the polarized film. Now we have to add a coating of pneumatic liquid phase crystal on one of the polarized filter of the polarized glass. The microscopic channel cause the first layer molecule to align with filter orientation. When the right angle appears at the first layer piece, we should add a second piece of glass with the polarized film. The first filter will be naturally polarized as the light strikes it at the starting stage.

Thus the light travels through each layer and guided on the next with the help of molecule. The molecule tends to change its plane of vibration of the light in order to match their angle. When the light reaches to the far end of the liquid crystal substance, it vibrates at the same angle as that of the final layer of the molecule vibrates. The light is allowed to enter into the device only if the second layer of the polarized glass matches with the final layer of the molecule.
How LCDs Work

- Mirror (A)
- Glass Filter (B)
- Negative Electrode (C)
- Liquid Crystal Layer (D)
- Positive Electrode
- Glass Filter (E)
- Polarizing Film
- Polarizing Film (F)
- Cover Glass
- Displayed Image
How LCDs Work?

- The principle behind the LCD’s is that when an electrical current is applied to the liquid crystal molecule, the molecule tends to untwist. This causes the angle of light which is passing through the molecule of the polarized glass and also cause a change in the angle of the top polarizing filter. As a result a little light is allowed to pass the polarized glass through a particular area of the LCD. Thus that particular area will become dark compared to other.

- The LCD works on the principle of blocking light. While constructing the LCD’s, a reflected mirror is arranged at the back. An electrode plane is made of indium-tin oxide which is kept on top and a polarized glass with a polarizing film is also added on the bottom of the device. The complete region of the LCD has to be enclosed by a common electrode and above it should be the liquid crystal matter.

- Next comes to the second piece of glass with an electrode in the form of the rectangle on the bottom and, on top, another polarizing film. It must be considered that both the pieces are kept at right angles. When there is no current, the light passes through the front of the LCD it will be reflected by the mirror and bounced back. As the electrode is connected to a battery the current from it will cause the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle to untwist. Thus the light is blocked from passing through. That particular rectangular area appears blank.
Advantages of an LCD’s:

• LCD’s consumes less amount of power compared to CRT and LED
• LCD’s are consist of some microwatts for display in comparison to some mill watts for LED’s
• LCDs are of low cost
• Provides excellent contrast
• LCD’s are thinner and lighter when compared to cathode ray tube and LED

Disadvantages of an LCD’s:

• Require additional light sources
• Range of temperature is limited for operation
• Low reliability
• Speed is very low
• LCD’s need an AC drive

Applications of Liquid Crystal Display:

• Liquid crystal thermometer
• Optical imaging
• The liquid crystal display technique is also applicable in visualization of the radio frequency waves in the waveguide
• Used in the medical applications
What is the difference between LCD and LED?

- LCD is a device, which consists of several parts whereas an LED is a single component device.
- LCD is only used as a display device, whereas LEDs are used in various other applications such as flashlights and indicators. LEDs are capable of producing light whereas liquid crystals cannot produce light. LED displays consume less power in general than the same sized LCDs.
- In recently produced displays, LEDs are used as the backlight to LCDs.
- LED displays can produce more brightness and contrast than the counterpart LC displays.
Plasma is referred to be the main element of a fluorescent light. It is actually a gas including ions and electrons. Under normal conditions, the gas has only uncharged particles. That is, the number of positive charged particles [protons] will be equal to the number of negative charged particles [electrons]. This gives the gas a balanced position. Suppose you apply a voltage onto the gas, the number of electrons increases and causes an unbalance. These free electrons hit the atoms, knocking loose other electrons. Thus, with the missing electron, the component gets a more positive charge and so becomes an ion.

In plasma, photons of energy are released, if an electrical current is allowed to pass through it. Both the electrons and ions get attracted to each other causing intercollision. This collision causes the energy to be produced. Take a look at the figure illustrated below.
Plasma displays mostly make use of the Xenon and neon atoms. When the energy is liberated during collision, light is produced by them. These light photons are mostly ultraviolet in nature. Though they are not visible to us, they play a very important factor in exciting the photons that are visible to us.

In an ordinary TV, high beams of electrons are shot from an electron gun. These electrons hit the screen and cause the pixels to light up. The TV has three types of composite pixel colours which are distributed throughout the screen in the same manner. They are red, green and blue. These colours when mixed in different proportions can form the other colours. Thus the TV produces all the colours needed.

A plasma display consists of fluorescent lights which causes the formation of an image on screen. Like a CRT TV, each pixel has the three composite fluorescent colour lights. These fluorescent lights are illuminated and the different colours are formed by combining the composite colours.
Working of Plasma Display:

Two plates of glass are taken between which millions of tiny cells containing gases like xenon and neon are filled. Electrodes are also placed inside the glass plates in such a way that they are positioned in front and behind each cell. The rear glass plate has with it the address electrodes in such a position that they sit behind the cells. The front glass plate has with it the transparent display electrodes, which are surrounded on all sides by a magnesium oxide layer and also a dielectric material. They are kept in front of the cell. As told earlier when a voltage is applied, the electrodes get charged and cause the ionization of the gas resulting in plasma. This also includes the collision between the ions and electrons resulting in the emission of photon light. The state of ionization varies in accordance to colour plasma and monochrome plasma. For the latter a low voltage is applied between the electrodes. To obtain colour plasma, the back of each cell has to be coated with phosphor. When the photon light is emitted they are ultraviolet in nature. These UV rays react with phosphor to give a coloured light. Take a look at the diagram given below. The working of the pixels has been explained earlier. Each pixel has three composite coloured sub-pixels. When they are mixed proportionally, the correct colour is obtained. There are thousands of colours depending on the brightness and contrast of each. This brightness is controlled with the pulse-width modulation technique. With this technique, it controls the pulse of the current that flows through all the cells at a rate of thousands of times per seconds.
Characteristics of Plasma Display:

- Plasma displays can be made up to large sizes like 150 inches diagonal.
- Very low-luminance “dark-room” black level.
- Very high contrast.
- The plasma display panel has a thickness of about 2.5 inches, which makes the total thickness not more than 4 inches.
- For a 50 inch display, the power consumption increases from (50-400) watts in accordance with images having darker colours.
- All displays are sold out in shop mode which consumes more power than the above described. It can be changed to home mode.
- Has a life-time of almost 100,000 hours. After this period, the brightness of the TV reduces to half.

Plasma TV Resolutions:

The resolution of a plasma display varies from the early enhanced definition [ED], to the modern high-definition displays. The most common ED resolutions were 840*480 and 853*480.

With the emergence of HDTV’s the resolution also became higher. The modern plasma TV’s have a resolution of 1,024*1,024, 1,024*768, 1,280*768, 1,366*768, 1,280*1080, and also 1,920*1,080.
Advantages of Plasma Display:

• The slimmest of all displays
• Very high contrast ratios [1:2,000,000]
• Weighs less and is less bulky than CTR’s.
• Higher viewing angles compared to other displays [178 degrees].
• Can be placed even on walls.
• High clarity and hence better colour reproduction. [68 billion/236 vs 16.7 million/224]
• Very little motion blur due to high refresh rates and response time.
• Has a life span of about 100,000 hours.

Disadvantages of Plasma Display:

• Cost is much higher compared to other displays.
• Energy consumption is more.
• Produces glares due to reflection.
• These displays are not available in smaller sizes than 32 inches.
• Though the display doesn’t weigh much, when the glass screen, which is needed to protect the display, is included, weighs more.
• Cannot be used in high altitudes. The pressure difference between the gas and the air may cause a temporary damage or a buzzing noise.
• Area flickering is possible.
A touch screen is a two dimensional sensing device display that can detect the presence and location of a touch within the display area. The term generally refers to touching the display of the device with a finger or hand. Touch screens can also sense other passive objects, such as a stylus. Touch screens are common in devices such as game consoles, all-in-one computers, tablet computers and Smart phones.

Basically there are Five important elements in the touch screen:

1. **Bezel or Front panel**
   Bezel forms the outermost skin of the touch screen system. It is the protective covering of the screen that resists scratching to the underlying touch sensor.

2. **Touch controller**
   This is the Microcontroller based Integrated circuit(IC) present between the touch sensor and the embedded system controller. It is meant for transferring the informations from the touch sensor to the embedded system.
3. Touch Sensor

It is the clear glass panel sensitive to touch. The touch sensor layer is placed over the LCD (Liquid Crystal Display). The touch sensor layer covers the whole screen area. When the touch sensor senses the pressure from the finger, a voltage or signal change occurs which is then sensed by the touch controller and determines the location of touch on the screen.

4. Liquid Crystal Display

Most touch screens use LCD technology. It is based on the principle that, a small electrical change takes place in the crystal array of LCD where it gets pressure from touch.

5. System software

The software in the touch screen system allows the touch screen and the system controller to work together and tells how to interpret the touch information send to the controller. The touch screen driver works just like the mouse of PC.
Types of Touch screens:

There are two common types of touch screens. These are Resistive type and Capacitive types. Projected capacitive touch screen is the latest introduction.

Resistive touch screen:
It is the most commonly used type of touch screen in high traffic applications. It is immune to moisture and debris on the screen. It can be activated through finger or pencil like objects.

Capacitive type:
In surface capacitive touch screen, sensors are placed at the four corners of the screen. These sensors detect the capacitance change caused by the touch. This type of touch screen can be activated only by fingers.

Projected Capacitive touch screen:
This is the latest technology that gives superior quality and optical clarity. It can senses multiple touches at the same time and do not require positional calibration. These are used in Mobile phones, Music players etc.
How it works?
The most commonly used touch screen system is Resistive type generally used in ATMs, Railway stations etc. Both Resistive and Capacitive types use the electrical conductor called Indium Tin Oxide (ITO).

Resistive touch screen

The resistive touch screen has a flexible top layer called X layer formed of Indium Tin Oxide. Below the X layer is an Air gap. Below this is the Y layer formed of Indium Tin Oxide. So it is just like a sandwich arrangement of X layer-Air gap – Y layer. Four wires are connected to the Indium Tin Oxide layers. In the X layer, the wires are connected at the left and right sides while in the Y layer the wires are connected at the top and bottom sides.

When the finger touches the flexible X layer, the finger pressure presses the X layer to the Y layer through the Air gap. The X layer then makes contact with the Y layer. The location of touch is sensed in two steps.

1. Right part of the X layer is driven to a known voltage.
2. The left part of X layer is driven to ground.

This voltage level is detected by the underlying Y layer. This process repeats for the other axis also to detect the exact position of the finger.
In some resistive touch screens, the X layer Indium Tin Oxide is replaced with a conductive material for durability. In such screens there are Five wires connected.
Capacitive touch screen
In this type a capacitance of about 15 PF is created on the screen when the finger touches. The capacitance between the finger and screen is measured by the sensor layer in the screen. The most common method of capacitance measurement is the Sigma-Delta Modulator (CSD) technique. In this method, the discharge time of current through a bleeder resistor is measured.