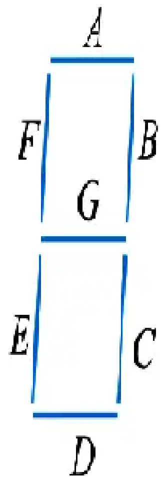
Module 5

DISPLAY DEVICES AND RECORDERS

Seven Segment Display Working Principle

Typically, a seven-segment display is made up of several LEDs. An illustration of a seven-segment display's front is provided below. Seven LEDs in the shape of an eight are present in it: A, B, C, D, E, F, and G. A segment refers to each LED. One or more LEDs will light up and emit a bar of light if they are forward biased. One can display any number between 0 and 9 by forward biasing different combinations of seven LEDs. By forward biasing LEDs A, B, C, D, and G, for instance, to light up, the display will show the number 3. In a same vein, the display will display the number 6 if LEDs C, D, E, F, A, and G are lit. In order to obtain. All but G are lit in order to obtain the number 0.



In the field of electronics, we refer to the process of allowing current to flow across a diode junction of a 7-segment display to trigger the emission of photons as electroluminescence.

The mixture of different impurities added to the semiconductor materials used to produce the light determines the spectral wavelength of the visible light emitted by an LED, which can range in color from blue to red to orange. The primary benefits of light emitting diodes over conventional bulbs and lamps are their small size, extended lifespan, availability, affordability, and ease of integrating with other electronic parts and digital circuits. Some other advantages are their availability in a variety of colors. But light emitting diodes' primary benefit is that, due to their small die size, multiple of them can be connected together to form what is commonly referred to as a 7-segment display inside of a single, tiny package.

Seven LEDs are arranged in a rectangular pattern as indicated by the 7-segment display, also known as the "seven segment display," hence its name. As a portion of a decimal or hexadecimal number that is to be displayed, each of the seven LEDs is referred to as a segment when it is lit. Sometimes, to display numbers larger than ten, two or more 7-segment displays are connected together, and an extra 8th LED is used within the same package to allow the indication of a decimal point (DP).

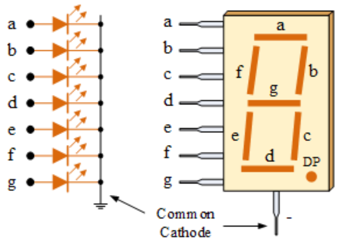
With one of its connection pins taken straight out of the rectangular plastic package, each of the seven LEDs in the display is assigned a positional segment. Each individual LED is represented by a through g on these pins that are designated for individual LEDs. A common pin is formed by connecting and wiring the other LED pins together.

Thus, the desired character pattern of the number can be generated on the display by forward biasing the appropriate pins of the LED segments in a specific order, causing some segments to be light and others to be dark. The ten decimal digits, 0 through 9, can now all be seen on the same 7-segment display thanks to this.The common pin on the display is typically used to determine the kind of 7-segment display. Common Cathode (CC) and Common Anode (CA) are the two types of LED 7-segment displays because each LED has two connecting pins, one of which is referred to as the "Anode" and the other as the "Cathode."

The difference between the two displays, as their name suggests, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows.

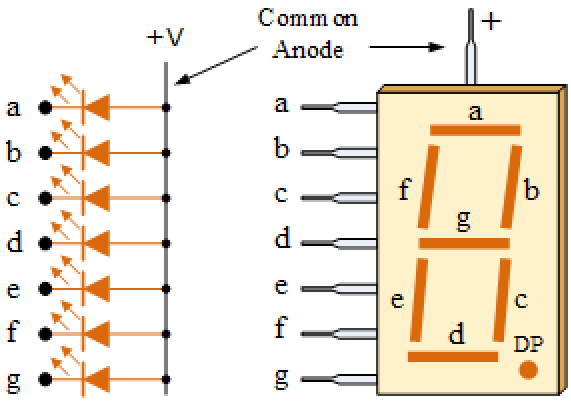
1. **The term "Common Cathode" (CC)** refers to a display where all of the LED segment cathode connections are collectively connected to ground or logic "0." A "HIGH" or logic "1" signal is applied to each individual segment to forward bias the individual anode terminals (a-g) and illuminate them through a current limiting resistor.

Common Cathode Configuration



The common anode (CA) display is made up of all the anode connections from the LED segments connected to logic "1". Through the use of an appropriate current limiting resistor, a ground, logic "0," or "LOW" signal is applied to each segment's cathode (a–g) to illuminate it.

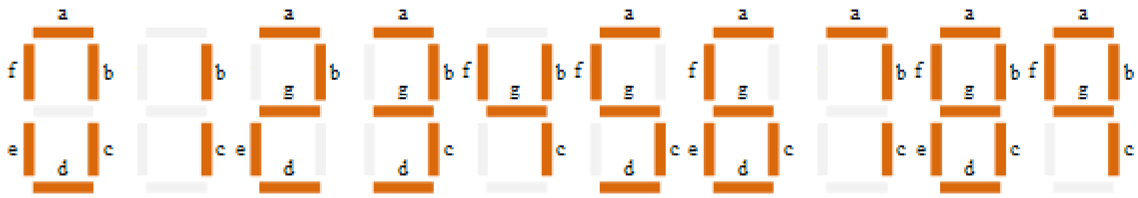
Common Anode Configuration



Since many logic circuits are able to sink more current than source, common anode displays are generally more widely used. Additionally, keep in mind that connecting common cathode displays to common anode displays and vice versa in a circuit is equivalent to connecting LEDs in reverse, which prevents light emission.

This specific set of LEDs is forward biased based on the decimal digit to be displayed. For example, we will need to turn on six of the LED segments that correspond to a, b, c, d, e, and f in order to display the number 0. A 7-segment display can thus be used to display the different digits from 0 through 9 as shown.

Digital Segments for all Numbers



The individual segments that must be illuminated in order to produce the necessary decimal digit from 0 to 9 can then be found in the truth table that we can create for a 7-segment display, as shown below.

7-segment Display Truth Table

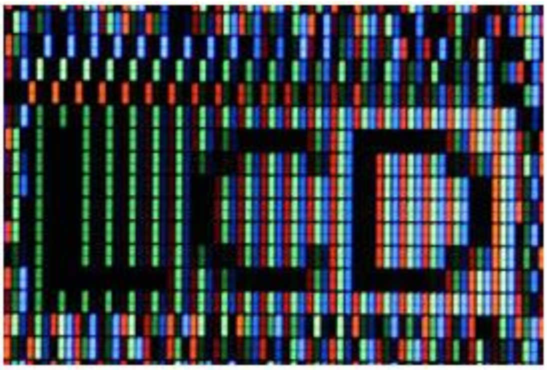
Segments (✓= ON)							Display	Segments (✓= ON)							Display
a	b	c	d	e	f	g		a	b	c	d	e	f	g	
✓	✓	✓	✓	✓	✓		0	✓	✓	✓	✓	✓	✓	✓	8
	✓	✓					1	✓	✓	✓			✓	✓	9
✓	✓		✓	✓		✓	2	✓	✓	✓		✓	✓	✓	A
✓	✓	✓	✓			✓	3			✓	✓	✓	✓	✓	b
	✓	✓			✓	✓	4	✓			✓	✓	✓		C
✓		✓	✓		✓	✓	5		✓	✓	✓	✓		✓	d
✓		✓	✓	✓	✓	✓	6	✓			✓	✓	✓	✓	E
✓	✓	✓					7	✓				✓	✓	✓	F

LCD Display

Though they didn't develop right away, liquid crystal displays (LCDs) are ubiquitous today. The development of the liquid crystal and the numerous LCD applications came about over a very long period of time. A botanist from Austria named Friedrich Reinitzer created the first liquid crystals in 1888. A substance similar to cholesterol benzoate dissolved in it, and he saw that the fluid initially became hazy before clearing up as the temperature increased. Before finally crystallizing, the fluid turned blue after cooling down. Hence, the RCA Corporation created the first experimental liquid crystal display in 1968. Following then, the LCD manufacturers have progressively created clever modifications and advancements on the technology, expanding the capabilities of this display device to an amazing extent. Therefore, the LCD has finally advanced in terms of development.

An LCD is defined by its own name: liquid crystal display. The two states of matter—solid and liquid—combine to form it. A visible image is produced by LCD using a liquid crystal. Cell phones, laptop computers, TVs, and portable video games are common devices that use liquid crystal displays, which are incredibly thin technological display screens. Displays made with LCD technologies can be significantly thinner than those made with cathode ray tube (CRT) technology.

One layer of a liquid crystal display is composed of two polarized panel filters and an electrode sheet. Using LCD technology, images can be displayed in notebooks and other electronic devices like mini computers. Light is projected via a lens onto a layer of liquid crystal. Combining colored light with the grayscale image of the crystal produced when an electric current flows through it yields the colored image of the crystal. This image appears on the screen thereafter.



An active matrix display grid or a passive display grid make up an LCD. While some older smartphones still use passive display grid designs, the majority of smartphones with LCD technology use active matrix displays. Liquid crystal display technology is the mainstay of most electronic devices' displays. The liquid has the distinct benefit of using less power than an LED or cathode ray tube.

Instead of producing light, the liquid crystal display screen blocks light in order to function. Since LCDs don't produce light, they need a backlight. Our gadgets are all composed of LCD displays, which have taken the place of cathode ray tubes in many applications. In comparison to LCDs, cathode ray tubes are larger, heavier, and require more power.

Two pieces of polarized glass act as the filter that we need to create the liquid crystal, as was previously mentioned. To create microscopic grooves on the surface of the polarized glass filter, a particular polymer must be rubbed on glass that is not coated in a polarized film. The grooves and the polarized film must face one another.

Two pieces of polarized glass are the filter we need to make the liquid crystal. It is necessary to rub a specific polymer on glass that isn't covered in a polarized film in order to create tiny grooves on the polarized glass filter's surface. It is necessary to face the polarized film and the grooves in the same direction.

Light is therefore directed by a molecule to the next layer after passing through each layer. The molecule tends to modify its plane of vibration as the angle of the light varies. The final layer of the molecule vibrates at an angle that coincides with the angle at which light vibrates at the distant end of the liquid crystal substance. The device only lets light in when the second layer of polarized glass lines up with the last layer of the molecule.

LCD Working principle:

The basic principle behind LCDs is that when an electrical current is applied to a liquid crystal molecule, it has a tendency to untwist. This alters the light's path through the polarized glass molecule as well as the angle of the top polarizing filter. In that particular region of the LCD, this results in a tiny amount of light passing through the polarized glass.

LCDs are based on the fundamental principle that a liquid crystal molecule tends to untwist when an electrical current is applied to it. Both the angle of the top polarizing filter and the angle at which light passes through the polarized glass molecule are altered by this. This results in a tiny amount of light entering that particular region of the LCD through the polarized glass.

The next glass piece has an electrode shaped like a rectangle on the bottom and a second polarizing film on top. It is important to remember that both pieces are kept at right angles. Light enters the LCD through the front, reflects off the mirror, and then bounces back when there is no current. The liquid crystals that are sandwiched between the common-plane electrode and the rectangular electrode will untwist when the electrode is powered by a battery. Light cannot flow through as a result. That particular rectangle appears to have empty space in it.

Different Types of LCD

There are the various LCD types:

Twisted Nematic Display

All industries use TN (Twisted Nematic) LCDs, which are manufactured fairly regularly, as the most prevalent type of display. Gamers are most likely to use these screens because of their inexpensive price and quick response time in comparison to other displays. These displays' main shortcomings are poor quality, viewing angles, and color reproduction, in addition to partial contrast ratios. These devices are sufficient for daily tasks, though.

With these screens, quick refresh rates and quick response times are both achievable. Hence, these are the only gaming monitors with 240 hertz (Hz). These displays have low color and contrast due to the highly inaccurate otherwise precise twist device.

In-Plane Switching Display

Because they offer superior color accuracy, sharpness, and contrast, as well as superior image quality, IPS displays are regarded as the best LCD. Most graphic designers use these displays, and in some other applications, LCDs must be able to reproduce images and colors to the highest possible standards.

Vertical Alignment Panel

The Twisted Nematic and in-plane switching panel technologies are centered around the vertical alignment (VA) panels. These panels have better features, as well as the best color reproduction and viewing angles when compared to TN type displays. These panels have a quick response time. However, these are more sensible and appropriate for daily use.

Comparing this panel's structure to the twisted nematic display, the former produces better colors and deeper blacks. Additionally, compared to TN type displays, multiple crystal alignments may allow for better viewing angles.

Advanced Fringe Field Switching (AFFS)

When it comes to performance and color reproduction, AFFS LCDs outperform IPS displays. AFFS's applications are very complex because it can reduce color distortion without compromising a wide viewing angle. Most sophisticated and professional settings, like operational airplane cockpits, are where one can find this kind of display.

Passive and Active Matrix Displays

In order to provide charge to a particular pixel on the LCD, passive-matrix type LCDs use a straightforward grid. Starting with two substrates known as glass layers, the grid's design can be completed silently. A transparent conductive substance such as indium-tin oxide is used to design rows, while one glass layer produces columns.

The rows and columns of this display are connected to integrated circuits (ICs) to control when a charge is transmitted in the direction of a particular row or column. The liquid crystal material is positioned between the two glass layers in areas where a polarizing film can be applied to the substrate's exterior. An IC can turn on the ground in the precise row of one substrate and transmit a charge down the precise column of the other substrate to activate a pixel.

The slow response time and imprecise voltage control are two of the passive-matrix system's main shortcomings. The display's ability to update the displayed image is primarily indicated by its response time. The easiest method for determining a display type's slow response time is to quickly move the mouse pointer from one side of the screen to the other.

The main component of active-matrix LCDs is TFT (thin-film transistors). These transistors are small switching transistors and capacitors arranged in a matrix on top of a glass substrate. When the corresponding row is turned on, a charge can be sent down the precise column to a particular pixel. The capacitor next to the designated pixel is the only one that receives a single charge because all other rows that the column intersects are turned off, making this possible.

How Colored Pixels Works in LCDs?

How the Pixels of LCD Switched OFF

- ✓ Light flows through the LCD from the back to the front.
- ✓ When a horizontal polarizing filter is positioned in front of a light, only horizontally vibrating light signals will be blocked. A transistor allows current to flow through its liquid crystals, causing the crystals to sort out and maintaining the constant light supply through them, thereby turning off a pixel in the display.
- ✓ Horizontal vibrations of light signals emanate from the liquid crystals.
- ✓ Only vertically vibrating light signals are blocked when a vertical type polarizing filter is placed in front of liquid crystals. The light vibrating horizontally will pass through the liquid crystals, blocking their passage through the vertical filter.
- ✓ The LCD screen is dark at this position, making light impossible to reach.

How the Pixels of LCD Switched ON

- ✓ The backlight of the display stays bright as it did previously.
- ✓ The horizontal polarizing filter in front of the light blocks all light signals, with the exception of those that vibrate horizontally.

- ✓ To enable pixel activation, a transistor interrupts the liquid crystals' electrical current, allowing the crystals to rotate. As the light passes through these crystals, it is turned ninety degrees.
- ✓ Light signals that enter the liquid crystals that vibrate horizontally will exit them and vibrate vertically.
- ✓ Any light signal that isn't vibrating horizontally is blocked by the horizontal polarizing filter that is placed in front of the light. The light that emerges from the liquid crystals will now be vibrating vertically, and it can pass through the vertical filter.
- ✓ After the pixel is turned on, it starts to take on color.

Difference between Plasma & LCD

Only light signals that vibrate vertically will pass through the vertical polarizing filter placed in front of the liquid crystals. This causes the light to vibrate vertically, allowing it to pass through the vertical filter as it emerges from the liquid crystals. Upon activation, the pixel begins to acquire color.

Advantages

Liquid crystal displays have the following benefits.

- Compared to CRT and LED, LCDs require less power to operate.
- Compared to mill watts for LEDs, microwatts are used in the display of LCDs.
- When compared to cathode-ray tubes and LEDs, LCDs are less expensive, offer superior contrast, and are lighter and thinner.

Disadvantages

These are some of the drawbacks of liquid crystal displays.

- Need extra sources of light.
- LCDs require an AC drive because their operating temperature range is limited, their reliability is low, and their speed is extremely low.

Applications

Below are some examples of how liquid crystal displays are used.

- ✓ Scientific and engineering fields, as well as the electronics industry, have significant uses for liquid crystal technology.
- ✓ This liquid crystal display technology can also be used to visualize radio frequency waves in a waveguide and is utilized in medical applications. It is also applicable to liquid crystal thermometers and optical imaging.

BCD to Seven Segment Display

Binary or digital decoders are digital combinational logic circuits that can translate one type of digital code into another.

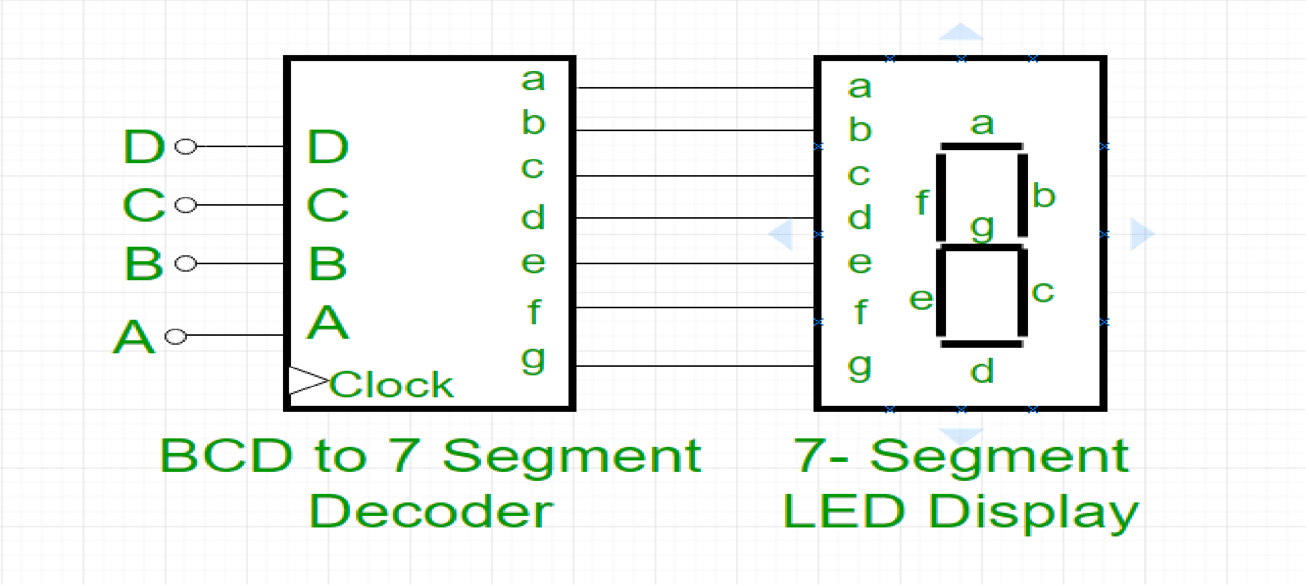
Binary coded decimals can be converted into a format that is easily readable by a 7-segment display using a special decoder called a BCD to 7-segment display decoder.

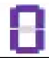
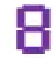
Binary Coded Decimal is referred to as BCD. Four bits of binary numbers can be used to represent each decimal number in this digital numbering system.

In a decimal system, there are ten numbers. We require 10 pairings of 4 binary bits to represent all 10 digits.

Digits	A	B	C	D
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

Large numbers in binary format are easily understood and readable by digital systems such as computers. But big binary numbers are not readable by humans. In order to solve this problem, we must use a 7-segment display to display it as a decimal digit.



Decimal Digit	Input lines				Output lines							Display pattern
	A	B	C	D	a	b	c	d	e	f	g	
0	0	0	0	0	1	1	1	1	1	1	0	
1	0	0	0	1	0	1	1	0	0	0	0	
2	0	0	1	0	1	1	0	1	1	0	1	
3	0	0	1	1	1	1	1	1	0	0	1	
4	0	1	0	0	0	1	1	0	0	1	1	
5	0	1	0	1	1	0	1	1	0	1	1	
6	0	1	1	0	1	0	1	1	1	1	1	
7	0	1	1	1	1	1	1	0	0	0	0	
8	1	0	0	0	1	1	1	1	1	1	1	
9	1	0	0	1	1	1	1	1	0	1	1	

Plasma-Display

A television's fundamental component is the cathode ray tube (CRT). For the past 75 years, we have been utilizing this technology.

However, there are numerous drawbacks to a CRT. The screen is enormous, and the display is not very clear. The size of them increases as the screen width increases because the tube's length must also increase. Thus, the weight is increased.The best solution for this is a plasma display. Their main benefits are their compact size, wide screen display, and high definition clarity.

Plasma

One term for a fluorescent light's primary component is plasma. With ions and electrons, it is actually a gas. The galaxies only contains uncharged particles under typical circumstances. Stated differently, the quantity of positively charged protons and negatively charged electrons will be equal. The gas is now balanced as a result. If a voltage is applied to the gas, it could lead to an imbalance because there would be more electrons. As these liberated electrons collided with the atoms, additional electrons were released. Since the component now has a greater positive charge due to the missing electron, it turns into an ion.

Encouraging an electrical current to flow through plasma releases energy in the form of photons. Interaction results from the attraction of the ions and electrons to one another. Energy is created as a result of this collision. Henon and xenon atoms are primarily used in plasma displays. They produce light as a result of the energy released during collision. UV photons make up the majority of these light particles. They are crucial in stimulating the photons that are visible to us even though they are invisible to us.

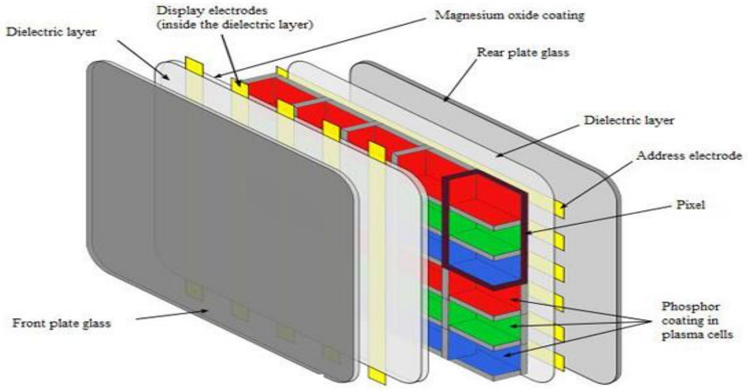
Electron beams are fired from an electron cannon into a standard television. The pixels light up when these electrons strike the screen. The composite pixel colors on the TV come in three different varieties, and they are all evenly spaced across the screen. The colors are blue, green, and red. These colors can be combined in various ratios to create other colors. Thus, all the necessary colors are produced by the TV.

The fluorescent lights in a plasma display create the image that is seen on the screen. There are three composite fluorescent color lights in each pixel, just like in a CRT TV. When these fluorescent lights are turned on, a variety of colors are created by mixing the composite colors.

Working of Plasma Display

Between two glass plates, millions of microscopic cells containing gases like xenon and neon are positioned. Additionally, electrodes are arranged inside the glass plates so that they are behind and in front of every cell. The address electrodes on the back glass plate are positioned so that they are behind the cells. Enclosed by a dielectric material and a layer of magnesium oxide on all sides, the transparent display electrodes are attached to the front glass plate. They're held in front of the enclosure.

As previously explained, the electrodes become charged when a voltage is applied, which ionizes the gas and produces plasma. This also includes the photon light that is released when ions and electrons collide.



Differentiating between color and monochrome plasma determines the ionization state. An insignificant voltage is inserted between the electrodes for the latter. Each cell must have phosphor coated on the back in order to produce color plasma. Photons are ultraviolet particles that emit light when they do. These UV rays cause phosphor to react, producing colored light. It has already been explained how pixels function. There are three composite colored sub-pixels for every pixel. The right color is produced when they are combined proportionately. Depending on each color's brightness and contrast, thousands of colors exist. The pulse-width modulation method is used to control this brightness. Thousands of times per second, the current pulse that passes through every cell is controlled using this technique.

Characteristics of Plasma Display

- It is possible to create large-scale plasma displays up to 150 inches diagonal.

- Extremely high contrast and low illumination, akin to a "dark room"
- The thickness of the plasma display panel is approximately 2.5 inches, resulting in a maximum total thickness of 4 inches.
- Darker-colored images require a 50-inch display to have a power consumption of between 50 and 400 watts.
- In shop mode, all displays are sold out and use more energy than what is mentioned above. It has a home mode setting.
- Has nearly 100,000 hours in its lifetime. Following this time, the TV's brightness drops to half.

Advantages of Plasma Display

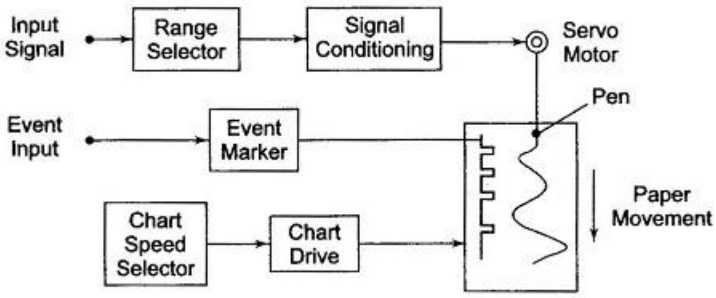
- The thinnest display of them all
- Extremely elevated contrast ratios [1:2,000,000]
- Compared to CTRs, it is lighter and less bulky.
- Greater viewing angles [178 degrees] in comparison to other displays.
- Suitable for mounting on walls.
- Superior color reproduction due to high clarity. [16.7 million/224 as opposed to 68 billion/236]
- Exceptionally low motion blur because of fast refresh rates and reaction times.
- Contains roughly 100,000 hours of life left in it.

Disadvantages of Plasma Display

- ✓ Cost is significantly higher than that of other displays, and energy consumption is higher.
- ✓ Causes reflections to create glares.
- ✓ There are no displays available in sizes smaller than 32 inches.
- ✓ The glass screen that is included to protect the display weighs more even though the display itself doesn't weigh much.
- ✓ ☐ Unsuitable for use at high elevations. A buzzing sound or transient damage could result from the pressure differential between the gas and the air.
- ✓ Flickering may occur in the area.

Strip Chart Recorder Working Principle:

A continuous roll of chart paper that moves at a constant speed is used to record data in a strip chart recorder according to its basic operating principles. The recorder captures the variation of one or more variables over time. A long roll of vertically moving chart paper, a pen (stylus) for marking on movable paper, a pen (stylus) driving system, a chart paper drive mechanism, and a chart speed selector switch are the essential parts of a strip chart recorder working principle.



Basic Strip Chart Recorder

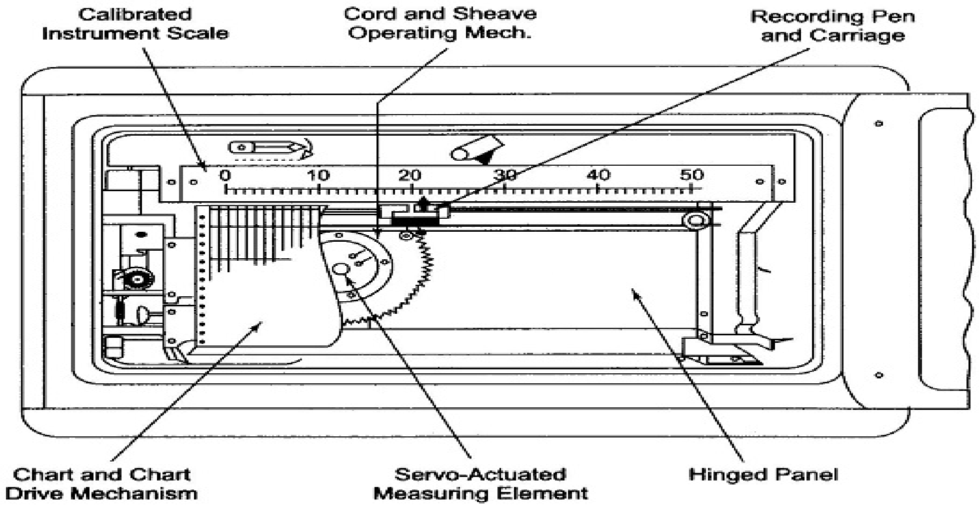
A pointer attached to the stylus is used by most recorders to measure the instantaneous value of the quantity being recorded directly on a calibrated scale. Figure depicts the assembly of a working principle for a strip chart recorder. Servo driven, this recorder only needs one pen.

For the purpose of ensuring that the movement of the pen (or stylus) across the paper matches the input voltage within the required frequency range, most strip chart recorders employ a servo feedback mechanism.

The position of the writing head (stylus) is typically measured using a potentiometer system.

Typically, a chart paper drive system consists of a stepping motor that maintains a steady pace for the movement of the paper.

There are several ways to record the data on the strip chart paper.



Assembly of a Single Pen Servo Operated Strip Chart Recorder

Pen and Ink Stylus:

Through capillary action, the stylus receives ink from a refillable reservoir. Disposable fiber tip pens have supplanted these with modern technology. Moreover, multichannel operation is possible, meaning that up to six pens can be used simultaneously to record data. To prevent mechanical interference when using multiple pens, the pens must be spaced out.

Impact Printing:

When the impact system was first introduced, the data recording ink was supplied by a carbon ribbon that was positioned between the paper and pointer mechanism. Using the pointer mechanism, the mark was made on the paper. Up to 20 variables can be recorded simultaneously with impact printing, which gives it an advantage over pen and ink methods. A wheel and matching ink pad that supplies the ink for the wheel's symbol are used to accomplish this. With each variable that is recorded, the wheel is moved across the paper.

Pressure-sensitive paper is utilized in certain mechanisms. The chopper bar is used to mark the paper by applying pressure to the surface. A single chopper bar occurs once every second.

Thermal Writing:

A unique movable pen that receives thermal heating from an electric current is employed in this system. For this system, thermally sensitive paper that changes color when heated is needed. A unique movable pen that receives thermal heating from an electric current is employed in this system. For this system, thermally sensitive paper that changes color when heated is needed.

Electric Writing:

The basis of this method is the electrostatics principle.

An unique chart paper is needed for this method. This paper is made up of a thin layer of aluminum coated on a paper base that has been colored (black, blue, or red) with dye.

A tungsten wire that moves across an aluminum surface makes up the stylus, or pen. Marks can be made on paper by providing the stylus with a potential of 35 V. The aluminum is removed by an electric discharge that results from this, exposing the colored dye.

Optical Writing:

A unique type of photo-sensitive chart paper that is susceptible to ultraviolet light is used for this writing technique. Galvanometer systems are the main application for this technique.

The use of ultraviolet light helps mitigate the negative effects of ambient light. In contrast to ordinary light, which cannot be developed under artificial or daylight lighting, the paper can be developed without the need for specialized chemicals.

The pointer on most recorders is fastened to the stylus. The value of the quantity being recorded is displayed by this pointer as it moves along a calibrated scale.

Paper drive system: The paper drive system should provide consistent speed for the paper. Most systems can make use of a spring wound mechanism. To drive the paper, a synchronous motor is employed.

Chart speed: Chart speed is the unit of measurement used to describe how the recording paper moves in a strip chart recorder. It depends on mechanical gear trains and is expressed in in/s or mm/s. If one knows the chart speed, one can calculate the recorded signal's period as follows:

$$\text{Period} = \frac{\text{time}}{\text{cycle}} = \frac{\text{time base}}{\text{chart speed}}$$

and the formula for frequency is f = 1/period.

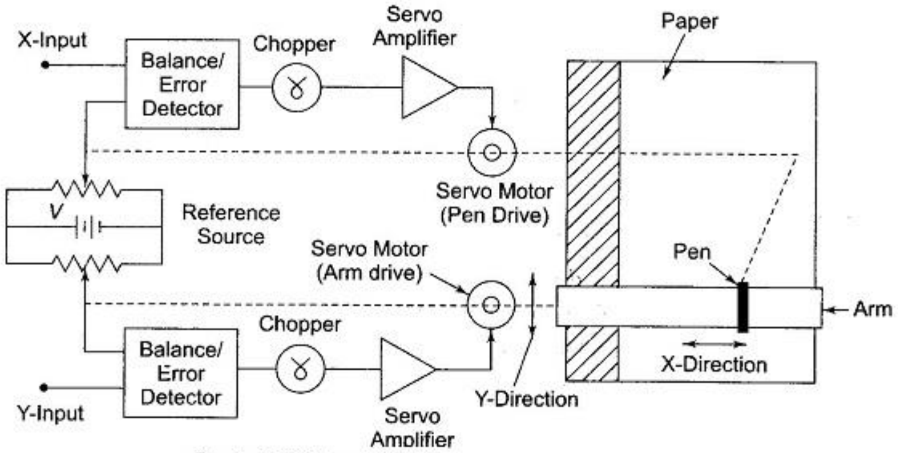
XY Recorder Working – In most research fields, it is often more convenient to plot the instantaneous relationship between two variables [Y = f(x)] rather than plotting each variable separately as a function of time. When this occurs, one variable is plotted against another using the X-Y recorder. An analog X-Y recorder deflects its writing head in either the x or y direction on a fixed graph chart paper. Typically, the graph paper is square in shape and is secured in place either by vacuum or electrostatic attraction.

To control the writing head, either a self-balancing potentiometer or a servo feedback system is employed. Depending on the use, the writing head has one or two pens in it. In an X-Y recorder, one emf is plotted as a function of another emf in real life.

X-Y recorders can also be used to plot one physical quantity (displacement, force, strain, pressure, etc.) as a function of another physical quantity. By utilizing a suitable transducer, which produces an output (EMF) proportionate to the physical quantity, this is achieved.

Utilizing a stationary chart paper as a reference, the servo system drives the motion of the recording pen in both axes. Using a sliding pen and moving arm arrangement, movement in the x and y directions is obtained.

Figure shows an example of a block diagram showing how an XY recorder works.



Basic X–Y Recorder

To enable it to function within the recorder's dynamic range, each input signal is attenuated between 0 and 5 mV. This is followed by a comparison of the attenuated signal with a fixed internal reference voltage by the balancing circuit. The difference between the reference voltage and the attenuated signal generates a dc error signal, which is the output of the balancing circuit. An ac signal is subsequently produced from this dc error signal with the aid of a chopper circuit.

An ac amplifier amplifies this ac signal since it is insufficient to operate the pen/arm drive motor. The servo motor is then activated by this amplified signal, also known as the error signal, causing the pen/arm mechanism to move in the proper direction, thereby reducing the error and bringing the system to balance. Therefore, the pen/arm attempts to maintain system balance as the input signal being recorded varies, creating a record on the paper.The aforementioned action occurs simultaneously in both axes. As a result, a record of one physical quantity relative to another is acquired.

With an accuracy of ± 0.1% of the full scale, certain X-Y recorders offer continuously variable x and y input ranges between 0.25 mV/cm and 10 V/cm. There are additional adjustments for zero offset.

X-Y recorders' acceleration and slewing rate define their dynamic performance. With a peak acceleration of 7620 cm/s and a slewing rate of 97 cm/s, an extremely fast X-Y recorder with a signal up to 10 Hz and an amplitude of 2 cm peak to peak could record signals.

The sensitivity of an XY recorder working can be as high as 10 μV/mm, its slewing speed can reach 1.5 ms, and its frequency response can reach approximately 6 Hz on both axes. About 250 by 180 mm is the size of the chart. An X-Y recorder's accuracy is within ± 0.3%.

Utilization of X-Y Recorders:

The following parameters are measured using these recorders.

- Motor speed-torque characteristics.
- Power supply regulation curves.
- Plotting the properties of active components, like transistors, rectifier diodes, zener diodes, and vacuum tubes, among others.
- Plotting curves such as hysteresis and stress-strain.
- Electrical properties of materials, like resistance against temperature.

Potentiometric Recorder Working Principle

Null Type Recorder:

The principle of self-balancing or null conditions underlies these null type recorders. A sensor or transducer provides an input to the recorder's measuring circuit, upsetting its equilibrium and generating an error voltage that drives another device to either reset the system's balance or bring it to zero.

The error signal's magnitude and direction correspond to the movement of the balance restoring device and the quantity being measured, respectively.

The different types of Null Type Recorder are as follows:

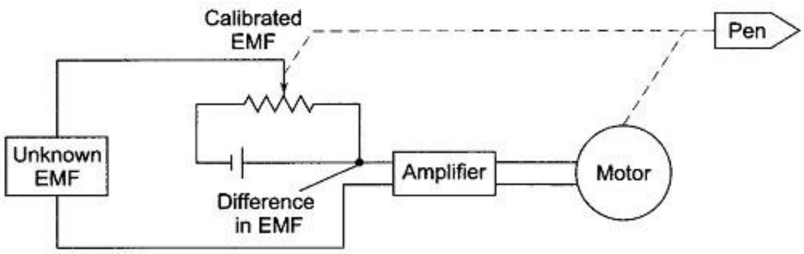
- Potentiometric recorders
- Bridge recorders
- LVDT recorders (Linear Variable Differential Transformer)

Potentiometric recorders

A galvanometer-style recorder's primary drawbacks are its low input impedance and restricted sensitivity. This disadvantage can be overcome by putting an amplifier in between the input terminals and the display or indicating devices. Low accuracy is exchanged for increased sensitivity and a high input impedance in this amplifier. Using a potentiometer circuit, the input signal is compared with a reference voltage to increase the instrument's accuracy.

A servo motor, whose rotational speed and direction are determined by the output of an amplifier, is used to achieve the self-balancing function. All this is in a dc system is a reversible motor, like the kind that has a permanent magnet for a field. It appears as a two-phase motor in the alternating current system.

A potentiometric or self-balancing recorder's basic circuit is shown in Figure.

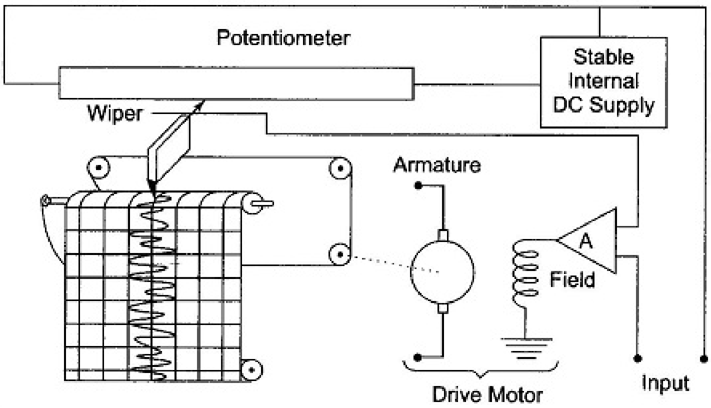


Basic Circuit of a Self-Balancing or Potentiometric Recorder

The error signal is the difference between the potentiometer voltage and the input signal. A DC motor's field coil is energized by means of an amplified error signal. Instead of rotating the voltage divider's arm to achieve a balance between the two opposing voltages in this circuit, an error current is permitted to flow in either a clockwise or counterclockwise direction, depending on which voltage is higher. The electronic detector uses this error as its input, amplifying it before feeding it to the balancing motor. This motor is configured so that its rotation reduces error by rotating the voltage divider arm, which is geared to it. The null balance is produced when the motor slows down and eventually stops at the point where the error is zero as the error decreases.

This is accomplished by mechanically attaching the wiper/variable arm to the DC motor's armature. Additionally, the wiper and pen are mechanically linked. As a result, the pen moves synchronously in the same direction as the wiper does, recording the input waveform. When the voltage of the potentiometer is balanced against the voltage of the unknown signal, the wiper comes to rest. The outcome of this method is very high input impedance graphical recorders.

Using 0.8 Hz as the bandwidth, 4 V/mm of sensitivity is achieved with an error of less than ± 0.25%. For potentiometer recorders, the chart drive is typically driven by a motor synchronized to the power line frequency. So, a gear train with varying gear ratios can be used to alter the chart drive's speeds. The main applications of potentiometer recorders are in process temperature monitoring and recording. A dc self-balancing system's basic block diagram is depicted in the figure below. Single point recorders are instruments that track variations in just one measured variable.



Block Diagram of Self-Balancing Potentiometer Recorder

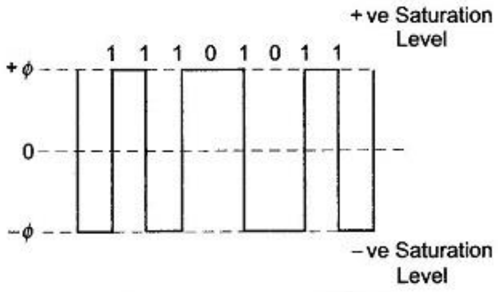
Recorders with multiple inputs recorded on one recorder are known as multipoint recorders. They can have up to 24 inputs and display traces in six different colors. Data is recorded at frequencies ranging from DC to 5 kHz on an 8-inch chart; models with up to 36 channels are also offered.

Digital Data Recorders

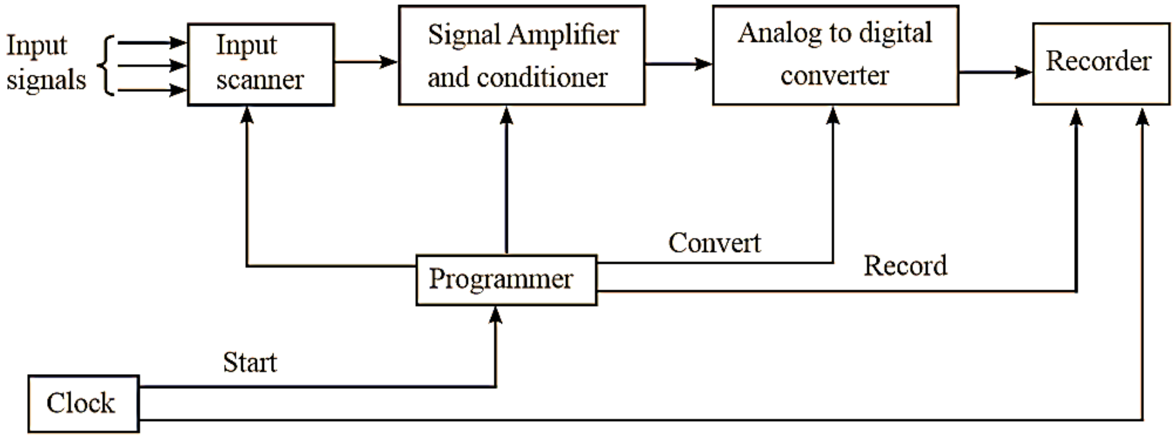
Digital Data Recording: Digital data processing applications frequently use digital magnetic tapes as storage devices. Incremental and synchronous digital tape units are the two types available. Digital recorders that are designed to record digital characters are instructed to advance (increment) with each digital character. There could be a noticeable lag or even discontinuity in the input data flow. Each character is positioned exactly and equally along the tape in this manner.

In a synchronous digital recorder, a lot of data characters are recorded while the tape advances at a steady pace of roughly 75 cm/s. Up to tens of thousands of characters per second of precise data are fed in. The tape is accelerated quickly, recording occurs, and the tape is quickly stopped. This method allows for the writing of a record, or block of characters, with each character evenly spaced along the tape. The record gap, a blank space on the tape, is typically used to divide data blocks apart from one another. The tape is started and stopped by the synchronous tape unit for every block of data that needs to be recorded.

On magnetic tape, characters are represented by a coded combination of one bit placed in the proper tracks throughout the width of the tape. The IBM format of Non-Return Zero (NRZ) recording, which is widely accepted in the industry, is the recording method used in the majority of instrumentation tape recorders.



NRZ Method of Digital Recording

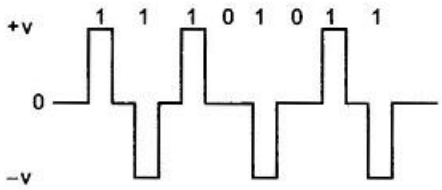


The tape is always magnetically saturated in this system, either in the positive or negative direction. The NRZ method uses a change in flux direction on the tape to represent a 1 bit and a zero bit to be indicated by no change in flux direction. Fig. provides an illustration of this method using a flux pattern in the NRZ system to represent the binary number 11101011. Reversing the recording head field's direction is the most straightforward way to code it.When recording digital data, an amplitude recording field that is big enough to create magnetic saturation across the entire thickness of the tape layer is reversed to record a 1 signal and maintained constant to record a 0 signal. Using a timing signal from a different clock track that represents the moment a 1 or 0 is recorded, this recording can be replicated.There are also self-clocking systems, in which the recording field is periodically reversed and 1 or 0 signals are recorded in between clock signals. It is clear that adjusting the field amplitude to cause the maximum longitudinal decrement to occur in the tape's surface layer yields the best resolution in NRZ recording. To guarantee more dependable recordings on a coated thicker tape, larger fields are typically used in practice. Big recording fields are used, sacrificing resolution for increased reliability in order to reduce the effects of dropouts.

Currently, there are 1500–2000 flux reversals per inch of high density data recorded on oxide powder tape. In the future, extensions up to 10,000 reversals per inch may be achievable by employing thin metallic coatings with strong coercive force.

The typical issues of non-linearity and distortion present in direct and FM recordings do not arise because magnetization is independent of frequency and amplitude and depends only on the polarity of the recording current. Only enough current with the appropriate polarity is needed for the write coils in the tape head to saturate the tape. Signal drop out and spurious pulses (losing or adding data) are two issues that arise in digital recording. When the packing density rises (a lot of bits per unit tape length), there is a significant risk of signal dropout or pulse loss.

Most tape systems have a parity check to detect dropout errors. Using an additional tape track to write a parity check pulse, this check counts the number of 1 bits of information that were originally recorded on the tape. An even parity check is one in which the number of 1s recorded is even; an odd parity check is one in which the number of 1s recorded is odd. A parity error is found when there is a dropout because the parity check does not match the real data that was recorded.



Bipolar (Alternate
Mark Inversion) NRZ

In addition to signaling that a parity error has occurred, some systems use the parity error system to correctly insert missing bits.

Fig. presents an alternate mark inversion scheme, also known as bipolar. Figure illustrates this format, which has zero power in the spectrum at zero frequency and no residual dc component. These pulses are created by inverting the polarity of alternate 1 bits and have a 50% duty cycle, meaning they are only half as wide as the pulse interval permits. A three state signal (+ V, 0 – V) is actually what the bipolar format represents.

Advantages of Digital Data Recording:

Using basic conditioning equipment, high accuracy, insensitivity to tape speed, and direct feeding of data to a digital computer for processing

Disadvantages of Digital Data Recording:

- The transducers provide analog information, so an A/D converter is needed. Poor tape economy.
- An excellent tape and a mechanism for transporting it are needed.