The various types of display are now available like CRT display, plasma display, liquid crystal display (LCD), surface conduction electron emitter display (SED).

14.3. **RECORDER**

In any instrumentation system one of the important consideration is the method by which the data acquired is recorded. The recording method should be consistent with the typical system. If the signal is analogue and the analogue output is available for recording then we need an analogue recorder to record the event. On the other hand, if the system has a digital output then digital recording system to needed. Thus there are two types of recorders are used:

(a) Analogue Recorders.

(b) Digital Recorders.

Analogue Recorders are of various types. They can be broadly classified as under:

(i) Graphic Recorders.

(ii) Oscillographic Recorders.

(iii) Magnetic Tape Recorders.

The Graphic Recorders are devices which display and store a pen and ink record of some physical event. The basic element of a recorder include a chart for displaying and storing the recorded information, a chart drive for driving paper with known speed and a suitable coupling for connecting the source of information. The graphic recorders can be further classified as follows:

(a) Strip Chart Recorders:

A strip chart recorder records one or more variables with respect to time. Normally it is X verses time (t) recorder.

(b) X-Y Recorders:

An X-Y recorder records one or more dependent variables with respect to an independent variable.

14.3.1. **Strip Chart Recorder**

A basic strip chart recorder may be seen in figure 14.4. A strip chart recorder consists of:

(i) A long roll of graph paper which moves vertically.

(ii) A drive system for driving the paper at some selected speed. A speed selector switch is provided for chart speeds of 1 mm/sec to 100 mm/sec.

(iii) A stylus for making marks on the moving graph paper. The stylus moves horizontally in proportion to the quantity to be recorded.

(iv) A styles drive system to move proportional to the quantity to be recorded.

A range selector switch is used so that the recorder drive system is within the acceptable level.
Paper Drive System

The paper drive system moves the paper at a uniform speed. An electronic stepper motor, synchronous motor or spring wound mechanism is used for driving the paper.

Marking Mechanism

There are many types of mechanisms used for making marks on the paper. The most commonly used ones are as follows:

Marking with Ink filled Stylus

The stylus filled with ink by gravity or capillary action. This means that the pointer shall support an ink reservoir and a pen or contain a capillary connection between the pen and a pen reservoir. The stylus which moves over the paper traces the variation of the input signal normally on the graph paper. In this method ordinary ink and paper are used which is the cheapest method of recording. The advantage of this method is that this system can operate over a very wide range of recording speeds. The friction between the tip of the stylus and the paper is low. The disadvantages of this system are that ink splatters at high speeds, batches at low speeds and clogs when the stylus is at rest. The frequency of operation of this type of recorder is low.

Marking with Heated Stylus

Some recorders use a heated stylus which writes on a special paper. This method overcomes the difficulties encountered in the ink filled stylus system. The heated stylus melts a thin, white wax coating on a black paper base. This method is quite reliable and the frequency response is upto 40 Hz. The disadvantage of this system is high cost and requirement of special paper, need of power to heat the stylus.

The other methods of marketing are chopper bar, where the marking at the desired time is made on a pressure sensitive paper. This system is used where the continuous recording is not needed and the recording is done for some slowly varying quantity. The other method is electric
stylus marking in this method the paper with special coating which is sensitive to a current. When the current is passed from the stylus to the paper a trace appears on the paper. In electrostatic stylus method the stylus produces a high voltage discharge which produces a permanent trace on an electro-sensitive paper. The other method is optical marking method. This method uses a beam of light to write on a photosensitive paper. This method allows higher frequencies to be recorded and permits a relatively large chart speed with a good resolution. The disadvantage is the cost of paper which is very high and this is a photographic method and in this case the paper must be developed before a record is available. This method is not very suitable, where instantaneous monitoring is required.

**Tracing Systems**

There are two types of tracing systems used for producing graphic representations. In the curvilinear system the stylus is mounted on a central pivot and moves through an arc. In this system the time base is curved lines. The other system is rectilinear system of tracing. In the system a line of constant time is perpendicular to the time axis and therefore the system produces a straight line across the width of the chart.

In the biomedical recorders the electrode picks up the bioelectrical potentials and transducer is used to convert the physiological signal to be measured into a usable electrical output. The signal conditioner converts the output of the electrode/transducer into an electrical quantity suitable for operating the writing system. The writing system provides a visible graphic representation of the input signal.

**14.3.2. Galvanometric Recorders**

The mechanism of Galvanometric recorder is a modified form of D’Arsonval meter movement. A cut-away view of the moving coil element is shown in figure 14.5. As the current flows through the coil it deflects. The deflection of the coil is proportional to the input quantity. The instrument requires an appreciable torque. For this a large moving coil in a strong magnetic field is needed. The instrument must be critically damped so there is no overshoot. But this results in slow response, which is being of the order of 0.75 to 1.5 sec. This type of recorder is not useful for recording fast variations in either current or voltage. This is suitable for recording average values.

A galvanometer type recorder is shown in figure 14.6. It is a modified version of PMMC (Permanent Magnet Moving Coil) instrument. the chart may be driven at a constant speed by a clockwork movement, an electrical motor or stepper motor. The recorder shown in fig. 14.6 uses a rectilinear system of tracing. The galvanometric recorders can work on range from a few mA to several mA or from a few mV to several mV it can work in a low frequency bandwidth of 0 to 10 Hz. It has a sensitivity of 0.4 mV/mm. For measurement of smaller voltages linear amplifier are used. In these recorder the bearing must be substantially larger than those used in indicator instruments because of the large mass of coil and stylus.
The ink recording method is very widely used. The trace should be thin, well defined and uninterrupted to allow best resolution of measurements. To achieve this a pressurised ink system is developed. The system uses high pressure, high viscosity ink to overcome inertial effects within the pen tube and give continuous flow of ink even at high pen velocities. Ink is supplied by a central ink reservoir that produces pressure of 15 to 20 psi and forces viscous ink into the microscopic pores on the chart paper surface. The other method of heated stylus writing system in which pointed stylus make a mark on the moving wax paper.

The usual paper drive is by a synchronous motor with a gear box for achieving different chart speeds. The other method of achieving variable speed by the use of different crystal frequency is also employed. Normally a time marker is produced before taking the ECG or other recording.

As already studied by the students in the course on measurement and Instruments the PMMC instrument using galvanometric principle
has three forces which act upon the moving system namely (i) the deflecting force (ii) the controlling force and (iii) the damping force. The deflection force results from the current which flows in the coil and is supplied to it from the driving amplifier. This force cause the pen to move from its zero position. A controlling force applied by the spring action will limit the otherwise indefinite movement of the pen and ensure that same movement of pen is always achieve by a given value quantity to be recorded. The damping force is necessary in order to bring the position of pen to rest quickly. In the absence of damping, owing to the inertia of the moving parts, the pen would oscillate about the final deflecting position for some time before coming to rest. The main function of damping is to absorb energy from the oscillating system and to bring it quickly in its equilibrium position. The amount of overshoot of pen depends upon the value of the damping factor. This is taken as unity when the galvanometer is critically damped. Under these conditions, the coil will deflect smoothly and take up its final position in the shortest possible time.
14.3.3. Ultraviolet Recorders

The galvanometric and potentiometric recorders due to the inertia of the writing system are not suitable to work when the signal is of higher frequency. Ultra-violet (UV) recorders record the events with frequencies from zero to several kHz. The writing system of an ultra-violet recorder consists of an ultra-violet light source and a photosensitive paper. The trace becomes variable in 30 sec after the exposure. If the recordings are required for permanent storage then after the exposure paper should be chemically treated.

The recorder consists of a number of galvanometer (moving coil) elements mounted in a single magnet block as shown in figure 14.8. A surface silvered mirror is attached to the galvanometer coil. A paper sensitive to ultraviolet light is used for producing a trace for the purpose of recording. The ultra-violet light is projected on the paper with the help or mirror’s attached to the galvanometer coil.

![Diagram of Ultraviolet Recorder](image)

**Fig. 14.8. Ultraviolet (u.v.) recorder**

The moving (galvanometer) coil is deflected if any current is passed through its coil, because the coils are under the influence of magnetic field. The ultra-violet light falling on it is deflected and is projected on the u.v. light sensitive paper through a lens and mirror system. The paper is driven past the moving light spot and thus a trace of variation in proportion to the current with respect to time is traced. In many u.v. recorders arrangement are provided to select a suitable paper driving speed out of as many as 12 difference speeds. Some u.v. recorders have an arrangement for controlling the speed of paper by applying external voltage.

Ultra-violet recorders may be single channel or multichannel. The dynamic performance of a ultraviolet recorder is determined by chart drive characteristic, its overall frequency response depends on galvanometer performance and its maximum writing speed. The u.v. recorders with frequency response upto 2000 Hz are commercially available.
14.3.6. Colour Printer

Inkjet printers were introduced in the market in 1980. An inkjet printer places extremely small droplets of ink onto paper to create an image. The dots are extremely small usually between 50 and 60 microns in diameter. The dots are thinner than the diameter of human hair (70 microns). The dots are positioned on the paper very precisely, with a resolution of up to 1440 x 720 dots per inch (dpi).

There are several major printer technologies available. These technologies can be broken down into two main categories with several types in each.

A. Impact

These printers have a mechanism that touches the paper in order to create an image. There are two main technologies.

- Dot matrix printers use a series of small pins to strike a ribbon coated with ink, causing the ink to transfer to the paper at the point of impact.
- Character printers are basically computerised typewriters. They have a ball or series of bars with actual characters (letters or numbers) embossed on the surface. The appropriate character is struck against the ink ribbon, transferring the character’s image onto the paper.

B. Non-Impact

These printers do not touch the paper when creating an image, inkjet printers are part of this group and includes.

- Inkjet printers which use a series of nozzles to spray drops of ink directly on the paper.
- Laser printers use dry ink (toner), static electricity and heat to place and bond the ink onto the paper.

Print Head Assembly

Print head is the core of an inkjet printer. The print head contains a series of nozzles that are used to spray drops of ink.
Ink Cartridge

In colour printer the cartridge has three primary colours cyan, magenta, yellow and black (CMYK).

Print Head Stepper Motor

A stepper motor moves the print head assembly (print head and ink cartridges) back and forth across the paper. A belt is used to attach the print head assembly to the stepper motors. Most of the inkjet printers have a tray that is loaded. A set of rollers pull the paper in from the tray or feeder and advance the paper when the print head assembly is ready for another pass. The paper feed stepper motor powers the rollers to move the paper in the exact increment needed to ensure a continuous image is printed. A small but sophisticated amount of circuit is built into the printers to control all the mechanical aspect of operation, as well as decode the information sent to the printer from the microprocessor based instrument.

Fig. 14.9. A thermal bubble print head

There are various methods of ink to be put on the paper. The important methods are heating or vibration. A thermal bubble method is used by the manufacturer Canon and Hewlett Packard as shown in figure 14.9. In this tiny resistor create heat, and this heat vaporizes ink to create a bubble. As the bubble expands, some of the ink is pushed out of a nozzle onto the paper. When the bubble collapses, a vacuum is created. This pulls more ink into the print head from the cartridge. A typical bubble jet print head has 300 on 600 tiny nozzles and all of them can fire a droplet simultaneously.

A piezoelectric print head is patented by Epson as shown in figure 14.10. A crystal is located at the back of the ink reservoir of each nozzle. The crystal receivers a tiny electric charge that causes it to vibrate. When the crystal vibrates inward, it forces a tiny amount of ink out of the nozzle. When it vibrates out, it pulls some more ink into the reservoir to replace the ink sprayed out.
Colour Laser Printers

Colour laser printers work the same way as monochrome printers, except they go through the entire printing process four times, one pass each for cyan (blue), magenta (red), yellow and black. By combining these four colours of toner in varying proportions one can generate the full spectrum of colour.

There are several different ways of doing this. Some printers have four toner and developer units on a rotating wheel. The printer lays down the electrostatic image of one colour and puts that toner unit in position, it then applies this colour to the paper and goes through the process again for the next colour. Some printers add all the four colours to a plate before placing the image on the paper.

Some expensive printers actually have a complete printer unit such as a laser assembly, a drum and a toner system, for each colour. The paper simply moves past the different drum heads, collecting all colours similar to an assembly line.