10 Output Devices

10.1 INTRODUCTION

The data presentation devices are termed as output devices. The output devices not only limited to display devices for indicating the output but it also used as control devices. The control of process get accomplished via inverse transducers. In fact in this chapter, we deals with devices that represent the output of a measurement system. The devices discussed here pertain to electrical and electronics devices which are most commonly used for display and record the output data of a measurement system.

The choice between the display recorder devices mainly depends upon two parameters:

1. The expected use of output.
2. The information content of output.

The first parameter mainly concern whether output is meant for human observation or the output is to be stored or the output is going to be an input to a digital computer. Similarly the second parameter is get influenced by wheather a single value is desired or the output is required as a function of time and also by frequency content of the output.

1. Single Number output devices: It is designed to indicate the value of some particular quantity under conditions such that the value to be measured can be regarded as time invariant over the time interval during which the measurement is made. Hence a single number used to represent the measurement and the time required to represent a value becomes short thus readings have to be taken at certain interval of times.

Eq. indicating instruments digital display units.

2. Time Domain output Devices: When the value of quantity taken as function of time, the indicating instrument or digital display units are no longer satisfactory except for applications where output get varies at a very slow rate. For fast changing output, usually CRT is used. For permanent record of variation of output with time is to be kept cathode ray tube photographs, direct writing recorders, magnetic tape recorders etc are used.

3. Machine interpretable output: In modern applications, it becomes necessary that the output data should be in such a form that can by

"Read" by a machine. These machine interpretable 'output' can be had from-Magnetic tapes, punched paper tapes, punched cards and teletype writer etc.

The "Machine interpretable output" can either be in analog form or in digital form. A single recorded on a magnetic tape in analog form becomes useful in activating output devices like CRT, recorder, or an indicating instrument.

Similarly, a single recorded in digital format on a magnetic tape, punched cards, a floppy disc or a hard disc may be used as an input for output devices like digital display units, a printer, or a digital computer.

10.2 RECORDER

It is often becomes necessary to have a permanent record of measurement being carried out by the instruments discussed so far. In many of the industrial and research process, it becomes necessary to monitor continuously the condition, state, or value of process variable such as flow, force, pressure, temperature, current, voltage, electrical power etc. Thus A recorder is a device that records both electrical and non-electrical quantities as a function of time. This record may be written or printed so that it can analyzed as well as examined later on to achieve a better understanding and the control of the processes. One could record current and voltage directly while non-electrical quantities are recorded indirectly by first converting them to equivalent currents and voltage with the help of sensors and transducers already described.

In an instrumentation system, one of important consideration is the technique by which the data acquired is recorded. The recording technique must require to consistent with the type of the system. If one is dealing with analog system, then analog recording techniques should be used. If the systems have digital output, then digital recording devices are used. Thus, recorders are classified as:

1) Analog recorder
2) Digital recorder

Analog recorders: There are various types of analog recorder that broadly classified into.

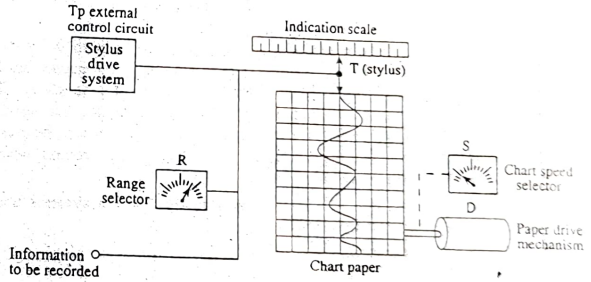
a) Graphic recorder.
b) Magnetic tape recorder.
c) Oscilloscope recorder.

a) Graphic recorder: It is devices that display and store a pen and ink record of history of some physical event. The typical basic elements of a recorder include chart for displaying and storing the recorded information, a stylus moving in a proper relationship to the paper and suitable means of interconnection to the couple the stylus to the source of information. The most commonly used two types of graphic recorders are:

(i) Strip chart recorder
(ii) X-Y recorder

(i) Strip chart recorder

A basic features of strip chart recorder is illustrated in diag. 110.1. It consists of A long roll of graph moving vertically. This paper is driven by a drive system D and the speed of this drive system get controlled by chart speed selector S. chart speed of 1-100 mm/sec is usually used. A stylus T is used for marking on the moving graph paper and this stylus moves horizontally in proportional to the quantity being recorded. A stylus driving system moves the stylus in a nearly exact replica or analog of the quantity being recorded. A range selector switch "R" is used so that input to the recorder drive system is within the acceptable level. Most recorder use a pointer attached to the stylus. This pointer moves over a calibrated scale thus showing the instantaneous value of the quantity being recorded. An external control circuit for the stylus can also be used as indicated in diag. 110.1.



Diag. 110.1. Strip Chart Recorder

1. Paper Drive Systems: It's main function is to move the paper at a uniform speed one may use a spring wound mechanism but in most of the recorders a synchronous motor is used to drive the paper.

2. Marking Mechanism: There are various types of mechanisms used for marking marks on the paper but most commonly used ones are:

a) Making with Ink Filled Stylus: The stylus is filled with Ink by gravity or capillary actions. The stylus moving over the paper with printed scales traces the variations of the input signal. This mechanism is most commonly used as ordinary can be used and hence the cost becomes low. In addition, operation over a wide range of recording speed is possible and

hence there is a little friction between the stylus tip and the paper. However this mechanism has drawback that Ink splatter at high speed, batches at low speeds and clogs when stylus is at rest.

b) Marking with Heated Stylus: some recorders use a heated stylus which writes on a special paper. This technique overcomes the difficulties encountered in ink writing systems. The heated stylus melts a thin white wax like coating on a black paper base, since the paper uses a special one, the cost becomes high. However this technique cannot be used for recording certain prosses that produce heat which indirectly effect the recordings. But this method is quite reliable and yields high contrast traces.

c) Electric Stylus Marking: It employs a paper with a special coating which is sensitive to current. In this method, when current is conducted from stylus to the paper, a trace appears on the paper. This method has wide range of marking speeds, has low stylus friction and a long stylus life. The drawback is that the paper cost is high.

d) Electrostatic Stylus: It produces a high voltage discharge thereby producing a permanent trace on an electrosensitive paper. This arrangement has been incorporated in a recorder having a 50mm wide charge nine voltage ranges from 10mv/mm to 5v/mm. Eight chart speeds from 300mm/S to 10mm/min and a frequency response of 60 Hz at a maximum amplitude of 1 db.

e) Optical Marking Stylus: It uses a beam of light to write on a photosensitive paper. This mechanism allows higher frequencies to be recorded and permits a relatively large charts with good resolution. The drawback of this technique is that paper cost becomes high, the writing process is photographic and thus require developing before it becomes available for analysis. This method is not appropriate for process where instantaneous monitoring is required.

3) Tracing Systems: There are two types of tracing systems used for producing graphic representations.

i) Curvilinear system.

ii) Rectilinear system.

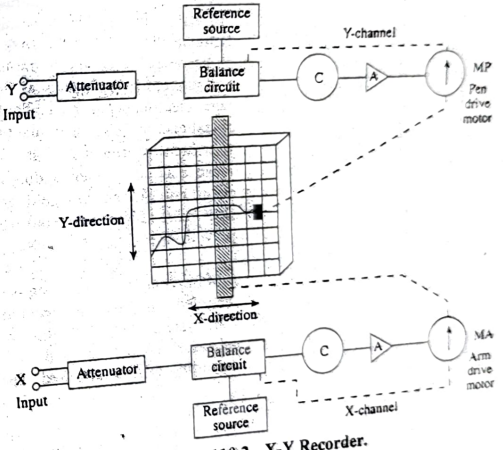
a) Curvilinear System: It uses stylus mounted on a central pivot and moves via an arc that allows a full width chart marking. If the stylus makes a full range recording, the line drown across the chart will be curved and the time intervals will be along this curved segments. This type of system is used on many records with PMMC galvanometers actuating the stylus filled with ink. This method has drawback that the charts are difficult to Analyses because of curved time base lines.

b) Rectilinear System: A chart in which a line of constant time is perpendicular to the time axis and therefore this system produces a straight line across the width of chart. Here the stylus is actuated by a drive cord

over pulleys to produce the forward and reverse motion as determined by the drive mechanism. The stylus may get activated by self balancing potentiometer system, a photo electric deflection system, a photo electric potentiometer, or a bridge balance system. The mechanism is usually used with a thermal or electric writing.

(ii) X-Y Recorder

A typical basic configuration of X-Y recorder is illustrated in diag. 110.2. It provides. a graphic record of relationship between two variables. In X-Y recorder an emf is plotted as a function of another emf and this task is get accomplished by having one self-balancing potentiometer control the position of the rolls (i.e. paper) while another self balancing potentiometer controls the position of the recording pen (stylus).



Diag. 110.2. X-Y Recorder.

There are various types of X-Y recorders and in some of them, one self balancing potentiometer circuit moves a recording pen (stylus) in X-direction while another self-balancing potentiometer circuit moves the recording pen (Stylus) in X-direction while another self balancing potentiometer circuit moves the recording pen (styles) in the Y-direction at right angles to the X-direction. But paper remains stationary". The emf used for operation of this recorder may not be necessarily measure only voltage. The measured emf may be the output of a transducer that may measure

displacement, force, pressure, strain, light intensity or any other physical quantity. Thus with the help of X-Y recorders and appropriate transducers, a physical quantity may be plotted against another physical quantity.

Here, the main function of attenuator is to bring the input signals to the levels acceptable by the recorder. The signals enters each of the two channels and signals are get attenuated to the inherent full scale range of the recorder. The signal then passes to balance circuit where it is compared with an internal reference voltage. The error signal (i.e. difference between the input signal voltage and the reference voltage) is fed to a chopper circuit "C" which converts D.C. signal to an A.C. signal. The signal is then amplified by amplifies "A" in order to actuate servomotors MP and MA which is used to balance the system and hold it in balance as the value of quantity being recorded changes.

The action mentioned above Takes place in both axes simultaneously and hence one can get a record of one quantity with respect to another.

An X-Y recorder may have a sensitivity of 10 μv/mm, A slewing speed of 15m/S and frequency response of about 6HZ for both the axes. The chart size is 250 X 180mm. The accuracy of X-y recorder about ± 0.3%.

Typical uses of X-Y recorders are:

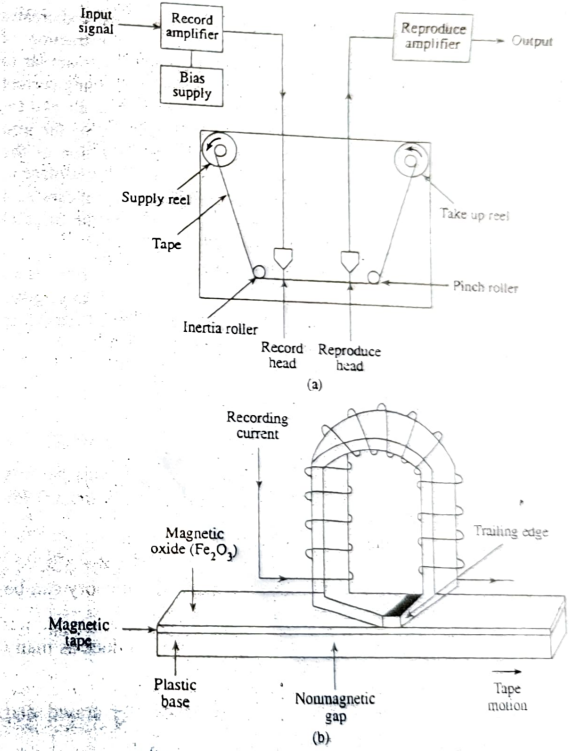
1. To record speed/torque characteristics of motors.
2. To lift/drag wind tunnel test.
3. To plot the characteristics of vacuum tubes, zener diodes, rectifiers and transistors etc.
4. In regulation curve of power supplies.
5. To plot stress-strain curves, hysteresis curve and vibration amplitude against swept frequency.
6. In electrical characteristics of materials such as resistance versus and temperature plotting the output from electronic calculators and computers.
7. It is widely used for measurement of physical quantity like force, temperature, pressure, stress, strain and light intensity etc.

10.3 MAGNETIC TAPE RECORDERS

It is used to record analog data in such a way that they can be retrieved or reproduced in electrical form again. The most common and most useful way of achieving this is via the use of magnetic tape recording.

The basic components of a tape recorders are:

i) Tape Transport Mechanism: A simple arrangement of tape transport mechanism is illustrated in diag. 110.3 (a). The main function of this mechanism is to move the tape along the recording head or reproduce head at constant speed and also the mechanism must be capable of handling the tape during various modes of operation without straining, distortion or wearing the tape. This require that the mechanism must use an arrangement to guide the tape past the magnetic heads with great precision, maintain proper tension and obtain sufficient tape to magnetic head contact.



Diag. 110.3. (a) Tape Transport Mechanism and (b) Recording Head.

A provision of having fast winding and reversing are available. A simple tape transport mechanism consists supply real, record head, tape, roller, reproduce head, take up real etc. as illustrated in diag. 110.3a.

ii) Magnetic Tape: It is composed to a coating of fine magnetic iron oxide particles [Fe_2o_3] on a plastic ribbon. A typical size of tape is 12.7 mm wide and 25.4 μm thick. The magnetic particles conform to magnetic pattern get induced in them and retain it.

iii) Conditioning Device: It includes amplifiers and filters that needed for modifying the signal to a format which can be properly recorded on a tape.

iv) Recording Head: It responds to an electrical signal and creates magnetic pattern on a magnetizable medium. The basic construction of recording head is illustrated in diag.110.3b, which is very much similar to that of transformer having toroidal core with a coil. When recording current passed via coil, magnetic fluxes created which allow to pas via air gap (5-15μm) to come in contact with magnetic tape, thereby magnetizing the iron oxide particles as they passes the gap. The state of magnetization of the oxide as it leaves the gap is retained, thus the actual recording takes place at the trailing edge of the gap. Any signal recorded on the tape appears as a magnetic pattern dispersed in space along the tape, similar to the original coil current variation with time.

v) Reproduce Head: The main function of reproduce head is to detects the magnetic pattern stored in them and converts it back to original electrical signal. In appearance, it is very much similar to that of recording head.

Advantages of Magnetic Tape Recorders

It includes following important advantages:

1. It has a wide frequency range from D.C. to several MHZ.
2. It has wide dynamic range that exceeds 50 db. This permits the linear recording from full scale signal level to about 0.3% of full scale.
3. It has low distortion.
4. The electrical input signal stored in magnetic Memory can be reproduced whenever desired.
5. The recorded signal can be played back or reproduce as many times as desired without loss of signal.
6. To processed the information, the tape can be erased and reused to record a new set of data.

10.4 RECORDING METHODS

They are three methods of magnetic tape recording that meets various requirements:

1. Direct Recording
2. Frequency Modulation Recording.
3. Pulse Duration Modulation Recording.

1) Direct Recording: The recording head used in magnetic tape recorder is similar to a toroidal transformer with signal winding. The signal current in the winding put around the core, produces a magnetic flux in air gap. Magnetic tape is simply a ribbon of plastic with tiny particles of magnetic materials deposited on it. When tape moved across recording head gap the magnetic material subjected to flux pattern proportional to the signal current that is current in the head winding. As the tape leaves the gap, each tiny particles retains the state of magnetization that was fast imposed upon it by the flux. Thus, the actual recording takes place at the trailing edge of the recording head gap.

The magnetic pattern on the tape is reproduced by moving the tape across a reproducing head. The induced voltage in recording head winding is proportional to the rate of change of flux, and hence the reproduce signal becomes the replica of the recorded signal.

Advantages of Direct Recording

1. It has wide frequency response ranging from 50 HZ to 0.3 MHZ.
2. It has good dynamic response and takes overloads without increase in distortion.
3. It requires only simple, moderately priced electronic circuitry.
4. For recording signals where information is contained in the relation between frequency and amplitude such as spectrum analysis of noise.
5. For recording voice and in multiplexing a number of channels of information into one channel of tape recording.

Disadvantages of direct Recording

1. Some portions of the tape may not be recorded perfectly due to dirt or poor manufacture which is termed as drop out.
2. At long wavelengths (low frequencies) the amplitude variations result by in homogeneities may be only few percent, however for frequency near the upper bandwidth limit, for given tape speed, amplitude variation can exceed 10% and momentary decrease of over 50% due to drop out may occur.

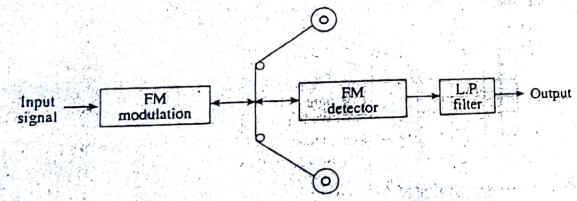
recording is used only when maximum bandwidth is required and when variations in amplitude are acceptable.

4. The direct recording, no doubt, can be used for instrumentation purposes but is mainly used for recording of speech and music.

In sound recording, the ear averages the amplitude variation errors. While the audio tape recording utilizes the direct recording process. It is seldom satisfactory to use an audio recorder for instrumentation purposes. The audio tape recorder is designed to take an advantages of rather peculiar spectral energy characteristics of speed and music, where as the requirement of instrumentation recorder are uniform response over its entire range.

10.5 FREQUENCY MODULATION RECORDING

The block diagram of FM recording system is illustrated in diag. 110.4. It uses the variation of frequency to carry desired information instead of amplitude. The modulation contains an oscillation with a centre or carrier frequency when the input is zero. The variation of this frequency becomes directly proportional to the input signal. The signal is applied to the tape with no further conditioning as the signal is independent of the amplitude. The FM detector converts the difference between centre frequency and the frequency on the tape to a voltage proportional to the difference in frequencies. Thus this process can record D.C. voltages to several thousands HZ.



Diag. 110.4. Block diagram of FM recording system.

There are two important factors in FM recording.

1. Percentage deviation m that defined as the carries deviation (Δf) to centre frequency (fc). Therefore, m can be written as:

$$m = \frac{\Delta f}{fc} \times 100 \quad \ldots\ldots(i)$$

2. Deviation ratio δ that is defined as the ratio of carrier deviation from centre frequency to the signal of modulating frequency fm, therefore δ can be written as

$$\delta = \frac{\Delta f}{fm} \quad \ldots\ldots(ii)$$

A system with high deviation ratio generally has low noise figure. However, Δf is limited by recorder bandwidth and fm must kept high to accommodate all the data signals.

Advantages of FM Recording

1. It becomes useful when D.C. component of input signal preserved or when amplitude variation of direct recording process cannot be tolerated.
2. This system has wide frequency range and can record from D.C. voltage to several KHZ.
3. It is free form dropout effects.
4. It is independent of amplitude variations and accurately reproduce waveform of input signal.
5. It is extremely useful for multiplexing in instrumentation system.
6. It is extensively used for recording the voltages from the force, pressure, and acceleration transducers.

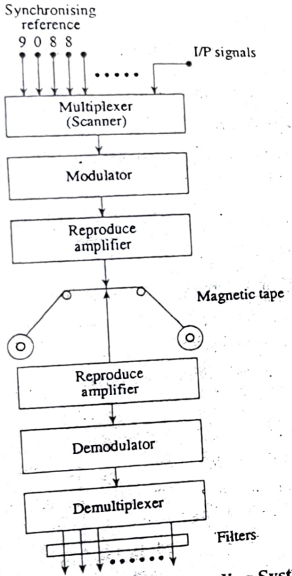
Disadvantages of FM Recording

1. It is extremely sensitive to speed fluctuations as it introduces unwanted modulation of the carrier (i.e. noise) reducing the system's dynamic range.
2. The circuitry of FM becomes complicated.
3. It needs high tape speed.
4. It needs better quality of tape transport.
5. It is comparatively costlier than direct recording system.

10.6 PULSE DURATION MODULATION RECORDING

It is often desired for simultaneous recording of numerous slowly changing variable by using time division multiplexing (TDM). The PDM

recording needs the input signal at the instant of sampling to be converted to a pulse. The duration of which becomes proportional to the signal amplitude at that instant. As an example, for recording a sine wave it is sampled and recorded at uniformly spaced discrete intervals instead of continuously recording the instantaneous values.



Diag. 110.5. PDM Recording System

The original sine wave can be constructed on playback by passing the discrete reading via an suitable filter. The schematic of PDM recording system with TDM for a sine-wave signal is illustrated in diag. 110.5.

The system makes 900 samples via 90 scanner (multiplexer) positions. The number of channels per track are 86 provided that the input frequencies are less than 1.5 HZ. The rest of four scanner positions are used for zero and maximum voltage levels and for synchronizing purpose.

Advantages PDM Recording

1. It has ability to simultaneously recording information from a large number of channels.
2. It has high accuracy due to the fact that it can be self calibrated.
3. It has high signal to noise (S/N) ratio.

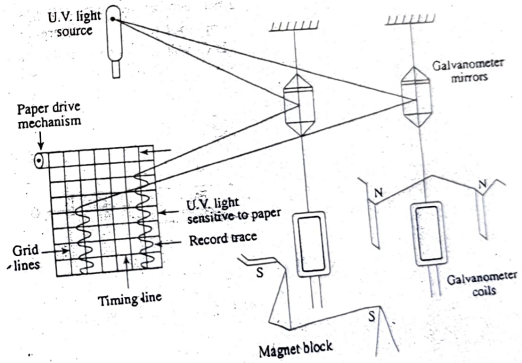
Disadvantages of PDM Recording

1. It has a limited frequency response.
2. It has highly complex electronic circuitry and hence the system reliability becomes low.
3. It is used only for special applications such as flight recorders, where a large number of slowly changing variables are involved

10.7 OSCILLOSCOPE RECORDER

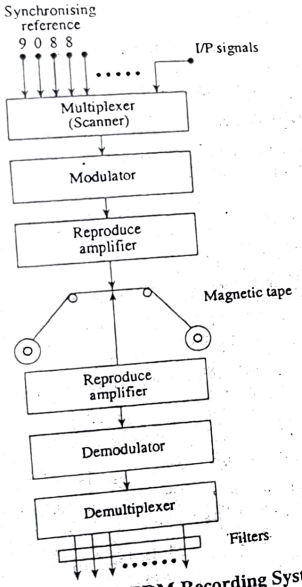
Ultraviolet Recorders

These are basically electromechanical Oscillographic recorders and are modified version of Duddel's oscillographs.



Diag. 110.6. Ultraviolet Recorder.

recording needs the input signal at the instant of sampling to be converted to a pulse. The duration of which becomes proportional to the signal amplitude at that instant. As an example, for recording a sine wave it is sampled and recorded at uniformly spaced discrete intervals instead of continuously recording the instantaneous values.



Diag. 110.5. PDM Recording System

The original sine wave can be constructed on playback by passing the discrete reading via an suitable filter. The schematic of PDM recording system with TDM for a sine-wave signal is illustrated in diag. 110.5.

The system makes 900 samples via 90 scanner (multiplexer) positions. The number of channels per track are 86 provided that the input frequencies are less than 1.5 HZ. The rest of four scanner positions are used for zero and maximum voltage levels and for synchronizing purpose.

Advantages PDM Recording

1. It has ability to simultaneously recording information from a large number of channels.
2. It has high accuracy due to the fact that it can be self calibrated.
3. It has high signal to noise (S/N) ratio.

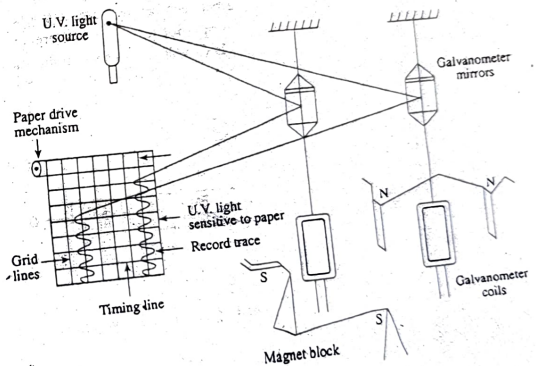
Disadvantages of PDM Recording

1. It has a limited frequency response.
2. It has highly complex electronic circuitry and hence the system reliability becomes low.
3. It is used only for special applications such as flight recorders, where a large number of slowly changing variables are involved

10.7 OSCILLOSCOPE RECORDER

Ultraviolet Recorders

These are basically electromechanical Oscillographic recorders and are modified version of Duddel's oscillographs.



Diag. 110.6. Ultraviolet Recorder.

The basic configuration of U.V. recorder is illustrated in diag.110.6 wherein the recorder consists of a number of galvanometer (moving coil) components mounted in a single magnet block. This is unlike the Duddel's multi channels oscillograph where a separate magnet assembly is used for each galvanometer element and hence there becomes great reduction in size and cost. The galvanometer uses a source of ultraviolet light in place of white light. A paper sensitive to ultraviolet light is used for producing a trace for recording purpose. The ultraviolet light is projected on paper with the help of mirrors attached to the moving coils.

Operation Principle

When current is passed via moving (galvanometer) coil. It deflects under the influence of the magnetic field of the permanent magnet. The ultraviolet light falling on the mirrors is deflected and is projected onto the U.V. light sensitive paper via a lens and mirror system. The paper is driven past the moving light spot and thus a trace of variation of current with respect to time is produced. Some system may facilitate with provision of controlling the paper speed with the help of an externally applied voltage. The U.V. sensitive paper get processed via photo developed, permanized or photocopied.

In addition to traces of input current, the recorder includes additional traces such as:

1) Grid Lines: These lines are along the length of the paper and one can obtain by shining the U.V. light on the paper via a comb.

2) Timing Lines: These lines are along the width of the paper and one can obtain from a vapour tube actuated from a external source or an internal source of known frequency.

3) Trace Identification: The U.V. recorders are multichannel recorders and most of the recorders have 25 channels. Since each channel may yields a 100mm wide peak to peak trace on a 30cm wide paper, there becomes considerable overlapping of traces produced by different channels. Thus it becomes essential to provide an identification mark for each trace, to avoid confusion. A simplified identification process is to interrupt each trace momentarily in turn and to coincide this interruption with a numeral marked on the side of record by passing U.V. light via cutouts of the numeral.

Applications

The U.V. recorder used for both D.C. and A.C. signals having a fundamental frequency up to 400 to 500 Hz. The frequency range depends on the recorder being used and paper driving speeds some typical application of U.V. recording are in recording.

1) Output of Transducer.
2) Control System Performance.
3) Regulation transients of generator.

These recorder are also useful in recording the magnitude of low frequency signals that cannot be measured with analog type instruments.

SUMMARY

This chapter is mainly devoted to various types of output devices that are most commonly used in instrumentation system. The significance of output devices and its important role in instrumentation system are discussed with following ideas.

- Introduction to output devices with display and record function.
- Recorder as a output device is discussed with its significance and importance:
  - Graphic Recorder.
  - Magnetic Tape Recorder.
  - Oscilloscope Recorder.
- A basic features of strip-chart recorder and mechanism of recording are discussed with following ideas:
  - Paper Drive System.
  - Marking Mechanism.
  - Tracing System.
- A basic features of $X - Y$ recorder and mechanism of recording are discussed with its typical uses for various recording purpose.
- Magnetic tape recorder as output device is discussed with its significance and importance.
  - Tape Transport Mechanism.

- Advantages of Magnetic Tape Recorder, Direct Recording.
- Frequency Modulation Recording.
- Pulse Duration Modulation Recording.

- Oscilloscope Recorder as output device discussed with following ideas:
  - Ultraviolet Recorder.
  - Operation Principle.
  - Applications.

REFERENCES

1. Umesh Sinha, "Electrical, Electronics measurement and instrumentations." Satya Prakashan, New Delhi, 1978 to 1997.
2. A.K. Sawhney, "Electtrical and Electronic Measurement and instrumenatation" Dhanpat Rai and Sons, 1996.
3. G.B.Gupta, "Electronics and electrical measurement and instrumentation", S. K. Kataria and Sons, January 2007–2008.
4. Dr. S.N. Talbar and A.R. Upadhyay, "Electronics measurement and instrumentation", Dhanpat Rai Publication, 2004.
5. C.S. Rangan, G.R. Sharma, VSV Mani, "Instrumentation devices and system", Mc Graw Hill New Delhi, 1983–1997.

PROBLEMS

1. Define output device. Discuss output devices with terms mentioned below.
   a) Single number output devices.
   b) Time domain output devices.
   c) Machine interpretable output.
2. Draw strip chart recorder and for strip-chart recorder discuss the terms mentioned below.
   a) Basic features of strip chair recorder.

   b) Paper drive system.
   c) Marking mechanism.
   d) Tracing system.
3. Draw X-Y recorder and for X-Y recorder discuss the terms mentioned below.
   a) Basic features and importance of X-Y recorder.
   b) Typical uses of X-Y recorder.
4. For magnetic Tape recorder. Discuss the terms mentioned below.
   a) Tape transport mechanism.
   b) Recording head.
   c) Advantages of magnetic tape recorder.
5. For direct recording discus the terms mentioned below.
   a) Basic features of direct recording.
   b) Advantages of direct recording.
   c) Disadvantage of direct recording.
6. Draw block diagram of frequency modulation recording system and for FMR discuss the terms mentioned below.
   a) FM recording system with two important factors. Modulation index (m) and deviation ratio δ.
   b) Advantages of FMR.
   c) Disadvantage of FMR.
7. Draw pulse duration modulation recording system and for PDM recording system, discuss the terms mentioned below.
   a) Basic operation of PDM recording system.
   b) Advantages of PDM recording.
   c) Disadvantages of PDM recording.
8. Draw ultra-violet recording system and discus the terms mentioned below for UV recording system.
   a) Operation principle of UV recorder.
   b) Applications of UV recorder.