B.E.

Sixth Semester Examination, Dec.-2009

Telemetry Data Processing & Recording (IC-304-E)

Note : Answer any *five* questions. All questions carry equal marks.

Q. 1. Discuss the various types of instrumentation system. Explain the block diagram and applications of typical instrumentation system.

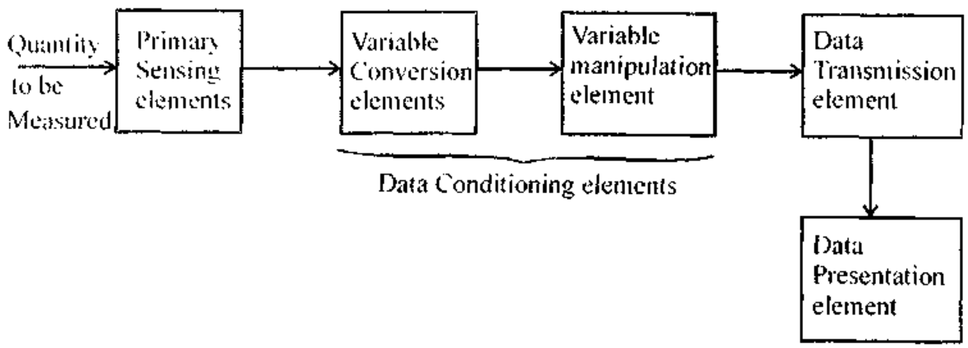
Ans. Types of Instrumentation System : An instrument is a device for determining the value or magnitude of a quantity or variable. There are three category of Instrument System.

(i) Mechanical Instruments : The first instruments were mechanical in nature and the principles on which they worked are even used today. These instruments are very reliable for static and stable conditions.

(ii) Electrical Instruments : These instruments are more rapid in indicating the output of detectors than mechanical instruments. Unfortunately electrical instruments has to depend on mechanical instruments as indicating device since mechanical instruments have some intension, they have limited time and hence frequency response.

(iii) Electronic Instruments : The requirements to step up response time and also the direction of dynamic changes in certain parameters, requires the monitoring time of the order of ms and quite often µs, have led to the development of electronic instruments and their associated circuitary. These instruments use either vacuum tube or semiconductor device, latter being used more in practice.

Block Diagram of Instrumentation System :



It is desirable to describe the operation of a measuring instrument or a system in generalized way without involving details of the physical aspects of a specific instrument or a system. The whole operation can be described in terms of three functional elements. Each functional element is made up of a distinct component or groups of components which perform required and definite steps in measurement.

(i) Primary Sensing Element : The quantity under measurement make its first contact with primary sensing element of a measurement system. Immediately after this a transducer converts measurement into an analogous electrical signal. This is true in most of the cases but in many cases the measured is directly converted into an electrical quantity by a transducer.

(ii) Variable Conversion Element : The output of the primary sensing element may be any kind of electrical signal. It may be a voltage, a frequency or some other electrical parameter. Often this output does not suit to the system. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form while retaining the original signal.

(iii) Data Presentation Element : *The information about the quantity under measurement has to be* conveyed to the personnel handling the instrument or the system for monitoring control, or analysis purposes. The information conveyed must be in a form intelligible to the personnel. This function is done by data presentation element. In case data is to be monitored, visual display devices are needed.

Applications of Instrumentation System :

(i) Experimental Engineering Analysis : Theoretical and experimental methods are variable for solving engineering problems. Many problem require the use of both the methods and the amount of each method employed depends up the nature of the problem. For fact theory and experimentation should always be considered as complementary of each other.

(ii) Automatic Control of Processes and Operations : Another important application is in the field of automatic control often referred as automation which solely depends on measurements. Automatic control requires the measured difference between the actual and the desired performance.

(iii) Monitory of Processes and Operations : Weather bureau uses wet and dry bulb thermometers, barometers and anemometers to perform monitoring for only because they simply give the condition of the atmosphere and there readings do not serve any control functions. Similarly, in a thermal power plant, steam pressure, temperature and flow rates alongwith various combustion measurement are continuously measured.

Q. 2. Explain the working of current and position telemetry system with detail.

Ans. Working of Current and Position Telemetry System with Details : The current telemetry system can develop higher signal power making it more immune to interferences arising mainly due to thermal and induced emf. effects.

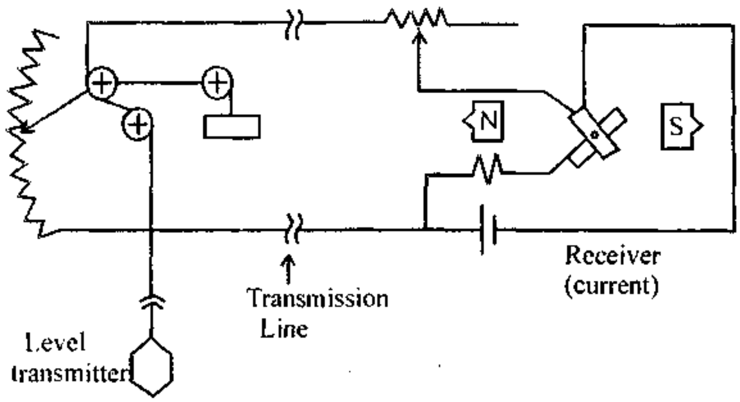


Fig. The current telemetry scheme derived

The receiver is a cross-coil current meter. It must be mentioned that the current must have a non-zero minimum value or a line-zero for open circuit protection in the system. As would be noticed, the source on the receiver side is used to supply the transmitter system as well. Current transmitters used for quite a long time for process or any other variables, use force-balance principle also called feedback system.

Synchro transmitter-receiver system is a wired telemetry system and is in use since long. It is basically a position telemetry system used commonly in control and communication systems. The rotor with its axis oriented in a specific direction receives the ac supply to set up alternating flux which links the star-connected stator windings S_{1t}, S_{2t} and S_{3t} and each has an induced emf proportional to the rotor voltage V_{rt} and the angle between the rotor axis and the corresponding rotor axis. If the rotor axis makes an angle α and the stator winding 3.

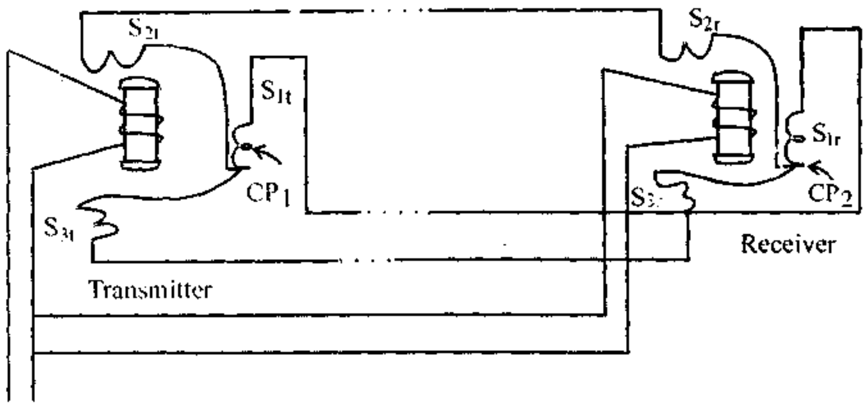


Fig. Synchro-position telemetry scheme

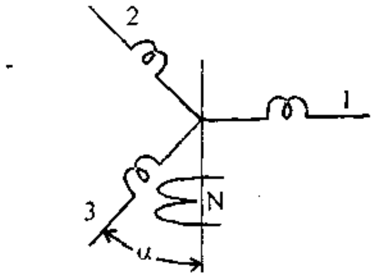


Fig. The rotor axis with an angle

$$E_{3ts} = kV_{rt} \sin \omega t \cos \alpha$$

$$E_{2ts} = kV_{rt} \sin \omega t \cos (\alpha + 120°)$$

$$E_{1ts} = kV_{rt} \sin \omega t \cos (\alpha + 240°)$$

With the line voltages

$$E_{12ts} = \sqrt{3}\, kV_{rt} \sin \omega t \sin \alpha$$

$$E_{23ts} = \sqrt{3}\, kV_{rt} \sin \omega t \sin (\alpha + 240°)$$

$$E_{31ts} = \sqrt{3}\, kV_{rt} \sin \omega t \sin (\alpha + 120°)$$

Where ω is the angular supply frequency and k is the transformer constant.

Q. 3. (a) Explain the operation of TDM in telemetry system.

Ans. The Operation of TDM in Telemetry System : For time division multiplexing (TDM) each signal can get the entire bandwidth and the signals time-share the channel such that each signal is transmitted for a brief period of time over a time frame. If there are n signals, the time frame is divided into n slots and jth signal gets its chance to be transmitted only at (n + j)th slot in time. For a five-signal system the time frame is explained.

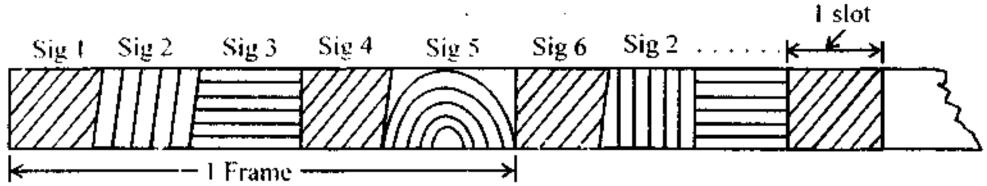


Fig. The Five Signal Time Frame Explained

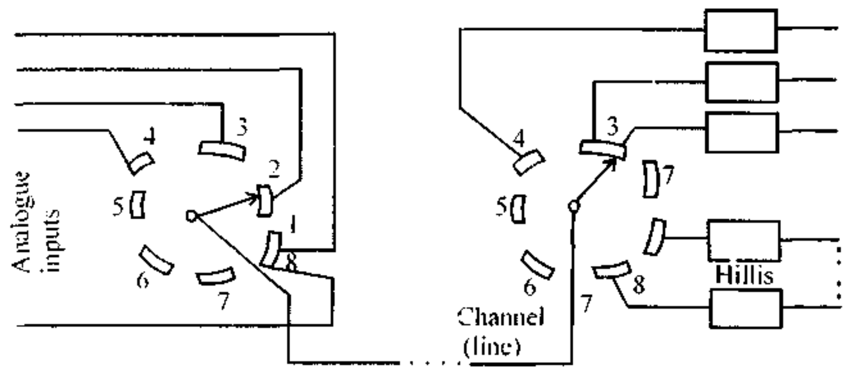


Fig. The Basic Scheme of a TDM Telemetry System

Where time slots are considered equal. They may, however, be different so that slot durations are different in magnitude. The basic scheme of a TDM telemetry system where eight inputs are shown to be put into channel sequentially by what is known as a rotary switch multiplexe. It is something like the commutator of a dc machine. For retrieval on the receiving side, similarly, an identical rotary switch has to be sequentially and synchronously operated for the outputs corresponding to the individual inputs. A sort of decommutator demultiplexer has to be there. The two sides are linked by a wired or an rf channel.

Q. 3. (b) Derive the expression for frequency modulated waveform and also draw its spectra.

Ans. Expression for frequency modulated waveform general equation

$$x = A \sin(\omega t + \phi) \quad \text{...(i)}$$

Frequency modulation is a system in which the amplitude of the modulated carrier is kept constant, while its frequency is varied by the modulating signal. The instantaneous frequency f of the frequency-modulated wave is given by

$$f = f_c(1 + kV_m \cos \omega_m t) \quad \text{...(ii)}$$

Where, f_c = unmodulated carrier frequency

k = proportionality constant

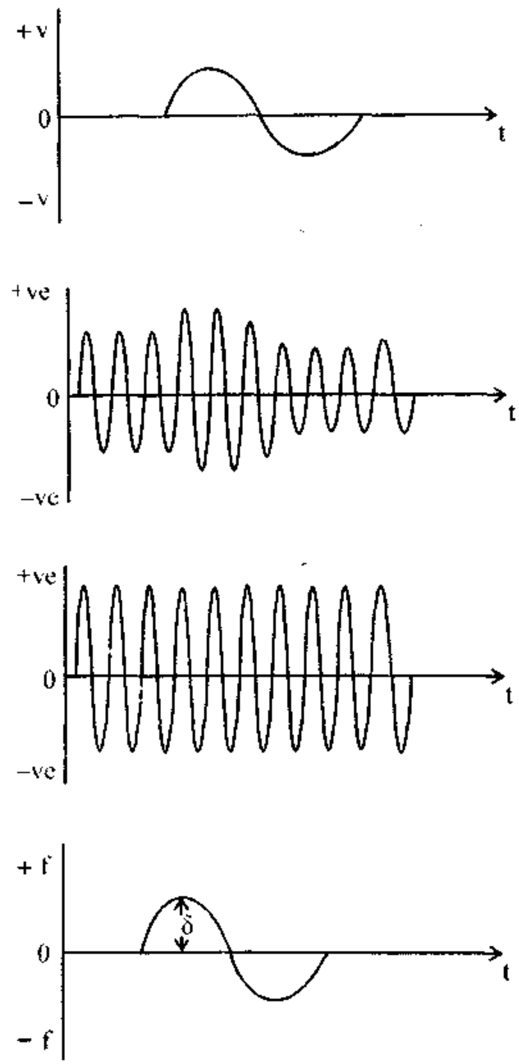
$V_m \cos \omega_m t$ = instantaneous modulating voltage

The maximum deviation for this particular signal will occur when the cosine term has its maximum value, that is, ± 1, under these conditions, the instantaneous frequency will be

$$f = f_c(1 \pm k V_m) \quad \text{...(iii)}$$

So, that the maximum deviation δ will be given by

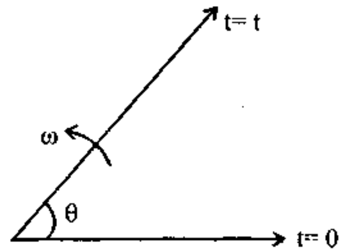
$$\delta = kV_m f_c \qquad \text{...(iv)}$$



The instantaneous amplitude of the FM signal will be given by a formula of the form

$$v = A \sin\left[F(\omega_c, \omega_m)\right] = A \sin\theta \qquad \text{...(v)}$$

θ is the angle traced out by the vector A in time t. If A were rotating with a constant angular velocity, say ρ, this angle θ would be given by Pt.



$$\theta = \int \omega \, dt = \int \omega_c (1 + kV_m \cos \omega_m t) \, dt$$

$$= \omega_c \int (1 + kV_m \cos \omega_m t) \, dt$$

$$= \omega_c \left(t + \frac{kV_m \sin \omega_m t}{\omega_m} \right)$$

$$= \omega_c t + \frac{kV_m \omega_c \sin \omega_m t}{\omega_m}$$

$$= \omega_c t + \frac{kV_m f_c \sin \omega_m t}{f_m}$$

$$= \omega_c t + \frac{\delta}{f_m} \sin \omega_m t \qquad \text{...(vi)}$$

The deviation utilized, in turn, the fact that ω_c is constant, the formula

$$\int \cos nx \, dx = \frac{\sin nx}{n}$$

$$v = A \sin \left(\omega_c t + \frac{\delta}{f_m} \sin \omega_m t \right) \qquad \text{...(vii)}$$

The modulation index for FM, m_f, is defined as

$$m_f = \frac{\text{(Max.) frequency deviation}}{\text{Modulating frequency}} = \frac{\delta}{f_m} \qquad \text{...(viii)}$$

Substituting equation (viii) into (vii)

$$v = A \sin (\omega_c t + m_f \sin \omega_m t) \qquad \text{...(ix)}$$

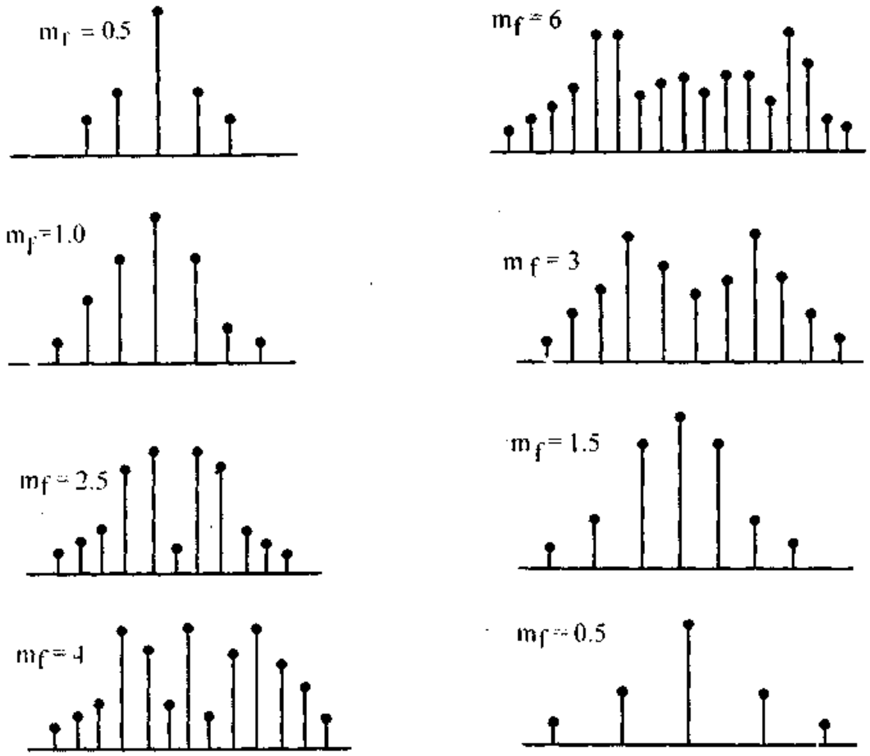
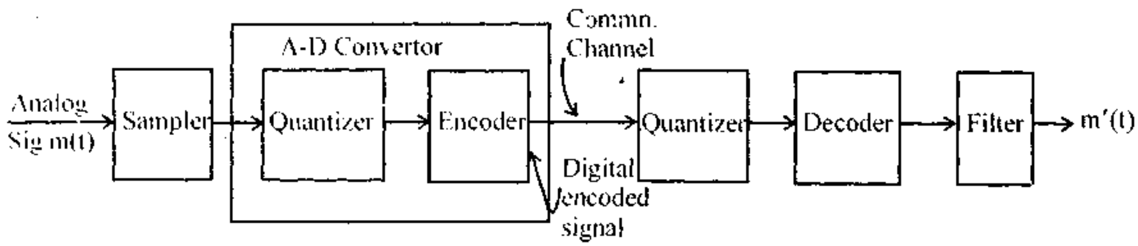


Fig. (a) Constnat f_m increasing δ   *Fig. (b) Constant δ, increasing f_m*

Q. 4. (a) Explain the operation of PCM system with block diagram.

Ans. PCM System : The analog signal m(t) is sampled, and these samples are subjected to the operation of quantization. The quantized samples are applied to an encoder. The encoder responds to each such sample by the generation of a unique and identified binary pulse pattern. At the receiver, however, identify the level from the pulse pattern.



The combination of the quantizer and encoder in is called A to D converter, usually abbreviated A/D converter. The signal transmitted over the communications channel in a PCM system is referred to as a digitally encoded signal. A quantized PAM signal has been transmitted, the receiver quantizer would have to decide which of the levels 0 to 7 was transmitted, while with a binary PCM signal the quantizer only distinguish between two possible levels. The relative reliability of the Y or N decision in PCM over the multivalued decision required for quantized PAM constitutes an important advantage for PCM.

The decoder also called a D to A converter mutilevel sample pulses. The quantized PAM signal is now reconstituted. It is then filtered to reject any frequency components lying outside of the baseband. The final otuput signal m'(t) is identical with the input m(t) except for quantization noise and the occasionai error in Y-N decision making at the receiver due to the presence of channel noise.

Q. 4. (b) Explain the various types of channels in telemetry system.

Ans. 24 incoming PCM channels were synchronized with each other and running at the same bit rate. This condition would hold if the voice channels had reached the originating earth station in analog form and had been digitized by modulators running on a common clock. But if the channels came into the station in digital form, their synchronization would not be guaranteed. They may be resynchronized for TDM transmission by a technique called pulse stuffing. In pulse stuffing the incoming words for each channel flow into an elastic buffer. There is one such buffer per channel, and each buffer can hold several words. The multiplexer will go to the buffer and find less than a full word remaining. When that happens it inserts a dummy word called a stuff word into the frame in place of the word it would have taken from the buffer. At the same time it places a message on the signalling channel that states that a stuff word has been inserted. When the demultiplexer at the other end of the link receives the message it ignores the stuff word. When it is time for the next frame to be sent the buffer will have more than a full word waiting for transmission.

Pulse stuffing is normal on satellite links that transmit digital signals between different terrestrial TDM systems, because the TDM systems will not be synchronized. The satellite link is run at a bit rate slightly higher than either of the terrestrial TDM systems that it joins. Stuffing bits and words are added to the satellite data stream as needed to fill empty bit and word spaces.

Q. 5. (a) An audio frequency signal $10 \sin 2\pi \times 500t$ is used to amplitude modulate a carrier of $50 \sin 2\pi \times 10^5 t$. Calculate the following :

- **(i) Modulation index**
- **(ii) Sideband frequencies**
- **(iii) Amplitude of each side band frequencies**
- **(iv) Bandwidth required**
- **(v) Total power delivered to the load of 600 Ω**
- **(vi) Transmission efficiency**

Ans.

$$v_m = 10 \sin 2\pi \times 500t$$

$$v_c = 50 \sin 2\pi \times 10^5 t$$

(i) Modulation index

$$m = \frac{v_m}{v_c}$$

$$= \frac{10}{50}$$

$$m = 0.2$$

(ii) Sideband frequency

$$f_{SB} = f_c \pm nf_m$$

& in the first pair n = 1

$$f_c = 2\pi \times 10^5$$

$$f_m = 2\pi \times 500$$

$$f_{SB} = 2\pi\,(10^5 \pm 1 \times 500)$$

$$= 2\pi\,(10^5 \pm 500)$$

$$= 631140,\ 624860 \text{ Hz}$$

(iii)

$$A = v_c + v_m$$

$$= 50 + 10 \sin 2\pi \times 500t$$

(iv)

$$\text{Bandwidth} = \frac{f_m}{2}$$

$$= \frac{2\pi \times 500}{2}$$

$$= 500 \times \pi$$

$$= 1.57 \text{ kHz}$$

(v)

$$P_t = P_c\left(1 + \frac{m_2^2}{2}\right)$$

$$= \frac{(500)^2}{600}\left[1 + \frac{(0.2)^2}{2}\right]$$

$$= \frac{500 \times 500}{600}\left[1 + \frac{0.04}{2}\right]$$

$$= \frac{1250}{3}(1.02) = 425 \text{ W}$$

(vi)

$$\eta = \frac{(0.2)^2}{2 + (0.2)^2} \times 100 = 1.96\%$$

Q. 5. (b) Explain the diode matrix circuit for conversion of BCD system to decimal readout.

Ans. One number system may be converted into another number of system with the help of diode matrix circuit.

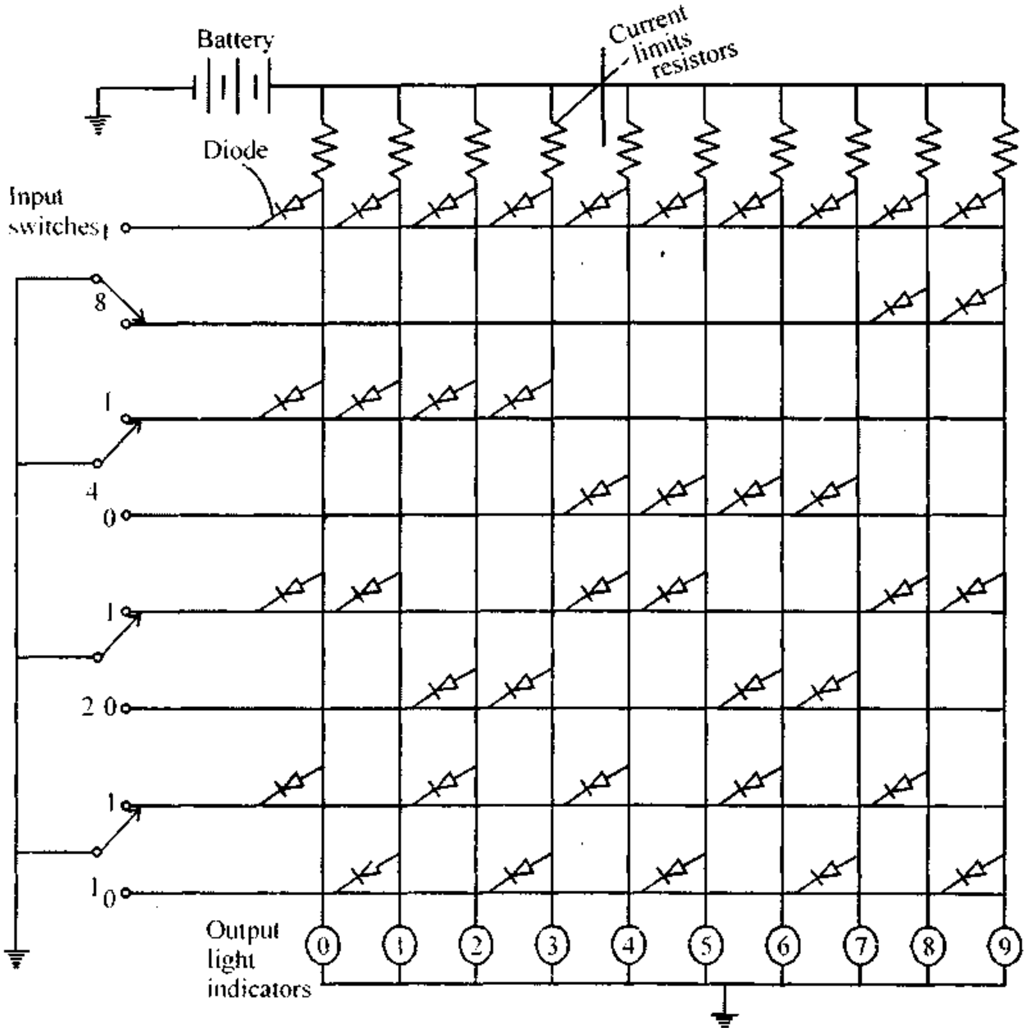


Fig. Diode matrix ckt for conversion of BCD to decimal read out

For example, BCD number system can be converted into a decimal read out by using the diode matrix circuit of fig. switches 1, 2, 4, 8 provide input to the matrix and the decimal indicators 0 to 9 are the outputs of the matrix. In order to energize in output decimal indicator, the connection from the battery to the indicator must not be connected to ground through a diode as under these conditions the diode will short the indicator.

Fig. shows how may number output 7 is indicated. For no. 7 to be indicated corresponding to a BCD input, switch 8 should be at 0 position. Switch 4 should be at 1 position switch 2 should be at 1 position and switch 1 should be at its 7 position.

Under these conditions :

Switch 8 shorts indicators 8 and 9

Switch 4 shorts indicators 0, 1, 2, 3, 8 and 9

Switch 8 shorts indicators 0, 2, 4, 6 and 8

Switch 2 shorts indicators 0, 1, 4, 5, 8, 9

Q. 6. Design a BCD to seven segment converter. Implement it using NOR gates.

Ans.

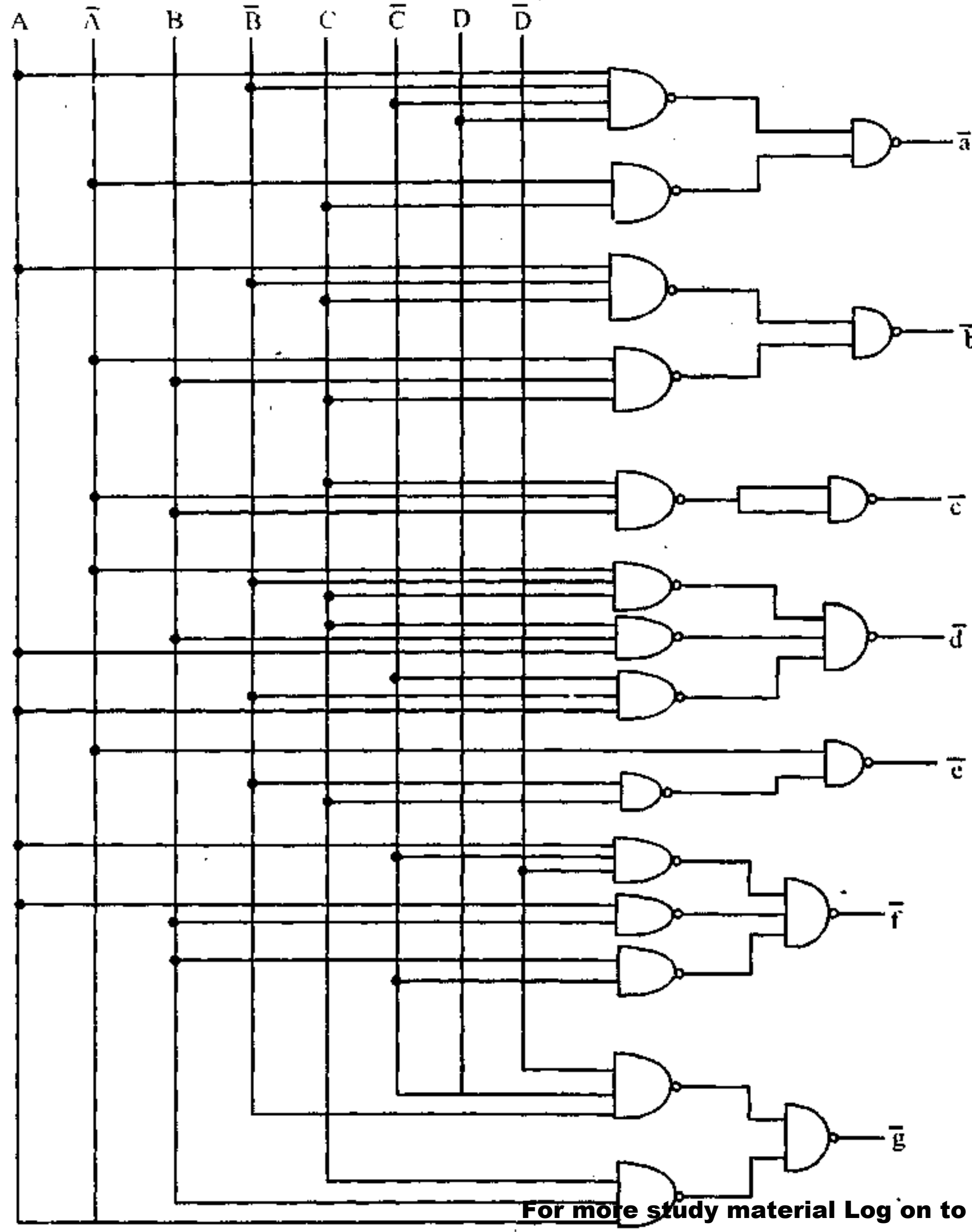


Fig. BCD to 7 Segment Converter

A BCD to seven segment converter required to convert a four bit BCD input to control the outputs for driving a 7 segment numeric characters such as those which use LED's and LCD's.

The conversion of BCD code to 7 segment code is given

Decimal No.	BCD No.				7 Segment Output						
	D	C	B	A	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	0	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	0	1	0	0	1	1

The output code is logic 1 type. However, inverted type may also be used where it is logic 0.

Q. 7. (a) Explain the theory and working of LCDs. Also discuss their advantages.

Ans. Liquid Crystal Diode (LCD) : These are used in similar applications where LED's are used. These applications are display of numeric and alphanumeric characters in dot matrix and segment displays.

It is of two types :

1. Dynamic scattering type
2. Field effect type.

The construction of dynamic scattering LCD is shown in fig. The liquid crystal material may be one of several organic compounds which exhibit optical properties of a crystal though they remain in liquid form. It is layered between glass sheets with transparent electrodes deposited on the inside faces.

When a potential is applied across the cell, charge carriers flowing through the liquid disrupt the molecular alignment and produce turbulence. When the liquid is not activated, it is not transparent.

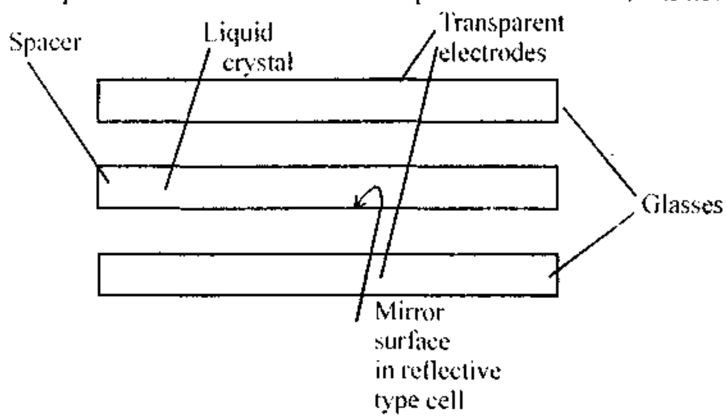


Fig. Liquid Crystal Diode Cell

When the liquid is activated the molecular turbulence causes light to be scattered in all directions and cell appears to be bright.

The phenomenon is called dynamic scattering. Liquid crystal cells are of two types :

1. Transmittive type   2. Reflective type

In the transmittive type cell, both glass sheets are transparent, so that light from a rear source is scattered in the forward direction when the cell is activated. The reflective type cell has a reflective d-a surface on one side of glass sheets. The incident light on the front surface of the cell is dynamically scattered by an activated cell. Both type of cell appears quite bright then activated even under ambient light conditions.

Advantages :

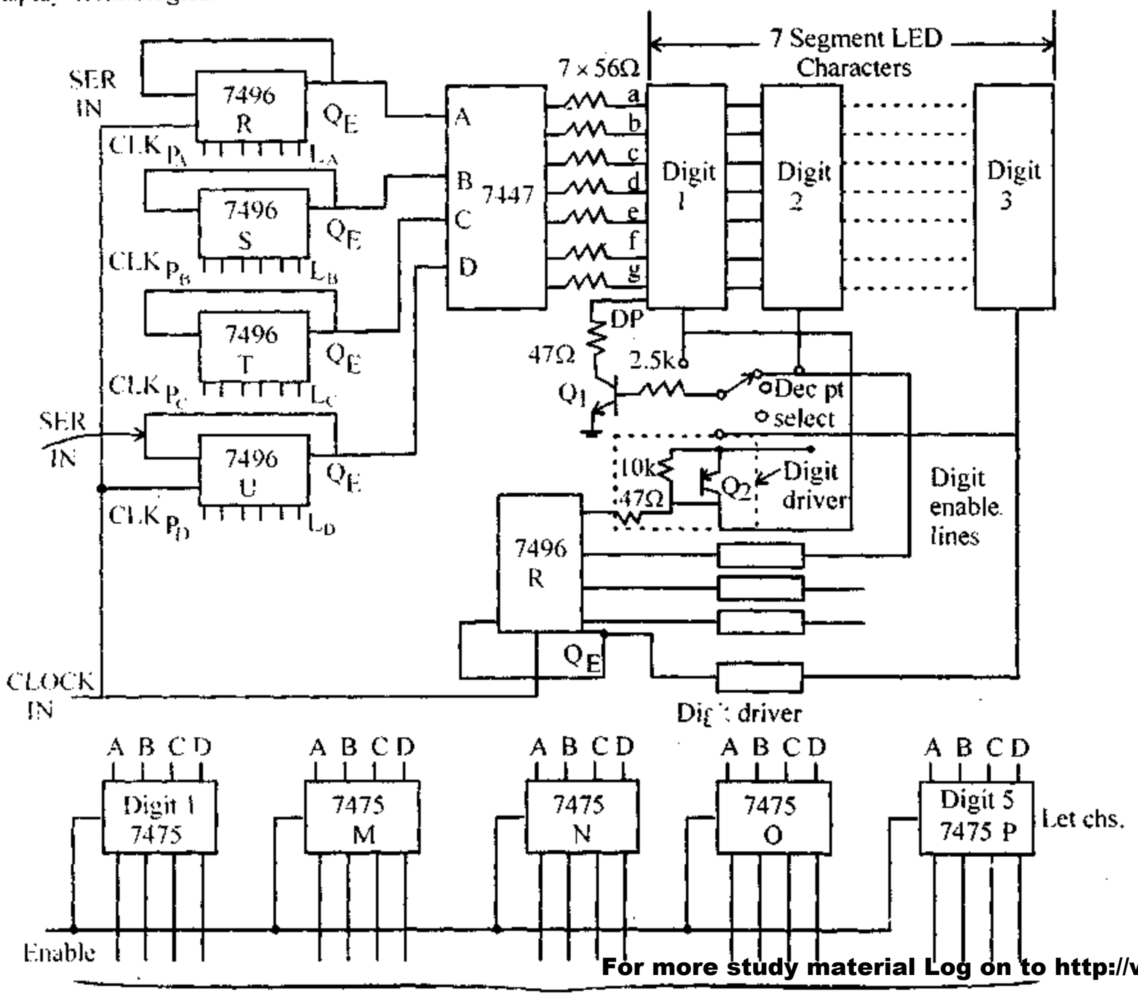
1. It has low power consumption. It require about 140 μw.
2. It has low cost.

Disadvantages :

1. It is slow devices. The turn on time and turn off time are large typically order of few millisecond.
2. Where used on d.c. their life span is quite small.
3. They occupy large area.

Q. 7. (b) Explain the functioning of 5 × 7 LED matrix display.

Ans. Functioning of 5 × 7 LED Matrix Display : The display of numeric data can be done using difficult display technologies.



While the display of numerals 0-9 is directly possible using gas-filled plasma displays such as Nixie tubes, segmented and dot-matrix approached are common with LED and liquid crystal displays. A 5-digit display system using 7-segment LED characters at the output of a frequency counter is considered here as a typical example. In this, it is required to display the state of the counting decades at the appropriate time. Usually, the output of these decades is transferred to storage latches at the end of every sample of measurement. These latches serve as input stage for the display system and the data stored here is available for providing a flicker free display of the measurement.

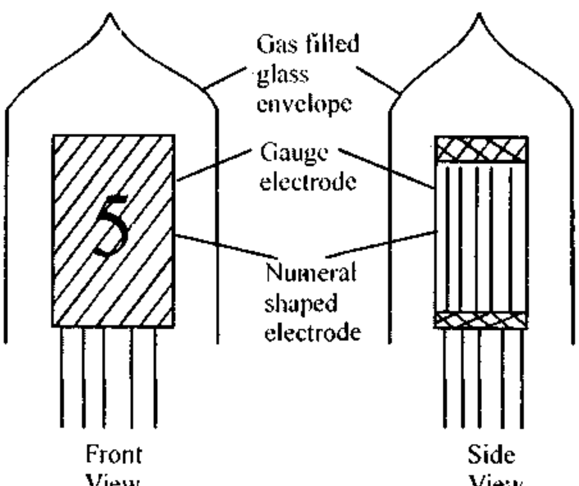
In addition to reducing the number of code converters and drivers, the stroking technique provides a considerable saving in DC power to achieve the same display intensity. For C_{ra} $A_{sl-x}P_x$ LED characters providing red colour output, a peak segment current of 40 mA is adequate in the strobed mode for the 5-character array to provide similar illumination as obtained by a segment current of 10 mA in the static display mode. This value of current is within the limits of sinking current of code converter in TTL IC form, i.e., type 7447.

Q. 8. Discuss the following :

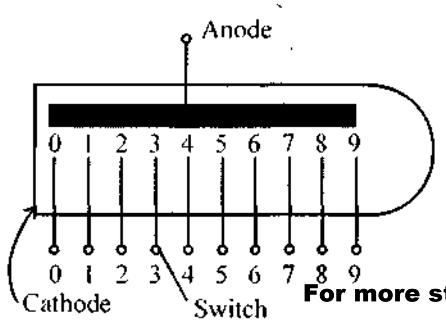
(i) Nixie tube **(ii) Decade counter**

(iii) Quantization and aperture time.

Ans. (i) Nixie Tube :



Nixie Tube



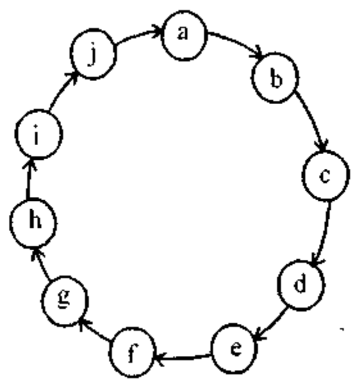
The penic construction of a digital indicator tub is shown. It is a cold cathode glow discharge tube which is popularly known as Nixie which is trade mark of M/s Burrnyh's Corporation USA. IT works on principle that when a gas breaks down, a glow discharge is produced. A gauge electrode with positive voltage supply functions as an anode and there are 10 separate wire cathode, each in the shape of a numeral from 0 to 9. The electrode are enclosed in a glass filled envelope with connecting pins at the bottom. Neon gas is usually employed and it given an orange red glow when activated. However other colours are available when different gases are used.

There are one anode and 10 cathodes. After a negative voltage is applied to the selected cathode, a simple gas discharge diode is formed which lights the selected digit. A transistor gate is usually employed at each cathode so that the desired numerals can be switched on. The circuity driving the nixie tubes is simpler than that for 7 segment displays. However, high voltages are required to produce glow discharge. The current required is of order of 1-5 mA. It is bulker in size than the seven segment display.

(ii) Decade Counter : For designing decade counter, the number of flip flops required is four. So it has 10 states

a, b, c, d, e, f, g, h, i, j.

Step 1 : State Diagram :



Step 2 : State Table :

Present State	Next Sate
a	b
b	c
c	d
d	e
e	f
f	g
g	h
h	i
i	j
j	a

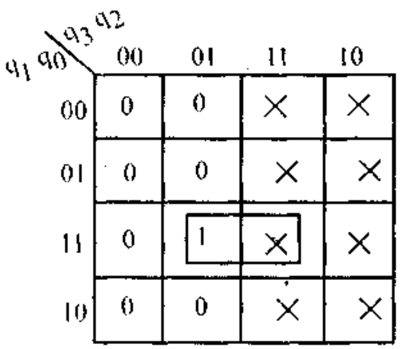
Step 3 : State Assignment :

a = 0000 b = 0001 c = 0010 d = 0011 e = 0100
f = 0101 g = 0110 h = 0111 i = 1000 j = 1001

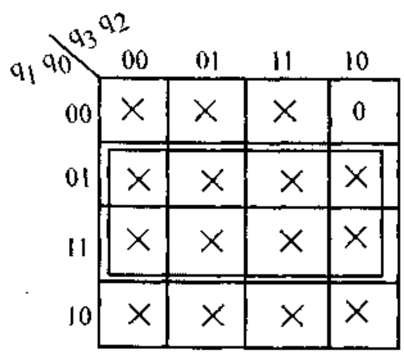
Step 4 : Excitation Table :

P.S				N.S				Excitation Inputs							
q_3	q_2	q_1	q_0	Q_3	Q_2	Q_1	Q_0	J_3	K_3	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	0	0	0	1	0	×	0	×	0	×	1	×
0	0	0	1	0	0	1	0	0	×	0	×	1	×	×	1
0	0	1	0	0	0	1	1	0	×	0	×	×	0	1	×
0	0	1	1	0	1	0	0	0	×	1	×	×	1	×	1
0	1	0	0	0	1	0	1	0	×	×	0	×	0	1	×
0	1	0	1	0	1	1	0	0	×	×	0	1	×	×	1
0	1	1	0	0	1	1	1	0	×	×	0	×	0	1	×
0	1	1	1	1	0	0	0	1	×	×	1	×	1	×	1
1	0	0	0	1	0	0	1	×	0	0	×	0	×	1	×
1	0	0	1	0	0	0	0	×	1	0	×	0	×	×	1
1	0	1	0	×	×	×	×	×	×	×	×	×	×	×	×
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
1	1	1	1	×	×	×	×	×	×	×	×	×	×	×	×

Step 5 : Excitation Maps :



$J_3 = q_2 q_1 q_0$



$K_3 = q_0$

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0	×	×	0
01	0	×	×	0
11	1	×	×	×
10	0	×	×	×

$J_2 = q_1 q_0$

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	×	0	×	×
01	×	0	×	×
11	×	1	×	×
10	×	0	×	×

$K_2 = q_1 q_0$

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0	0	×	0
01	1	1	×	0
11	×	×	×	×
10	×	×	×	×

$J_1 = \bar{q}_3 q_0$

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	×	×	×	×
01	×	×	×	×
11	1	1	×	×
10	0	0	×	×

$K_1 = q_0$

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	1	1	×	0
01	×	×	×	×
11	×	×	×	×
10	1	1	×	×

$J_0 = 1$

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	×	×	×	×
01	1	1	×	1
11	1	1	×	×
10	×	×	×	×

$K_0 =$

Step 6 : Diagram

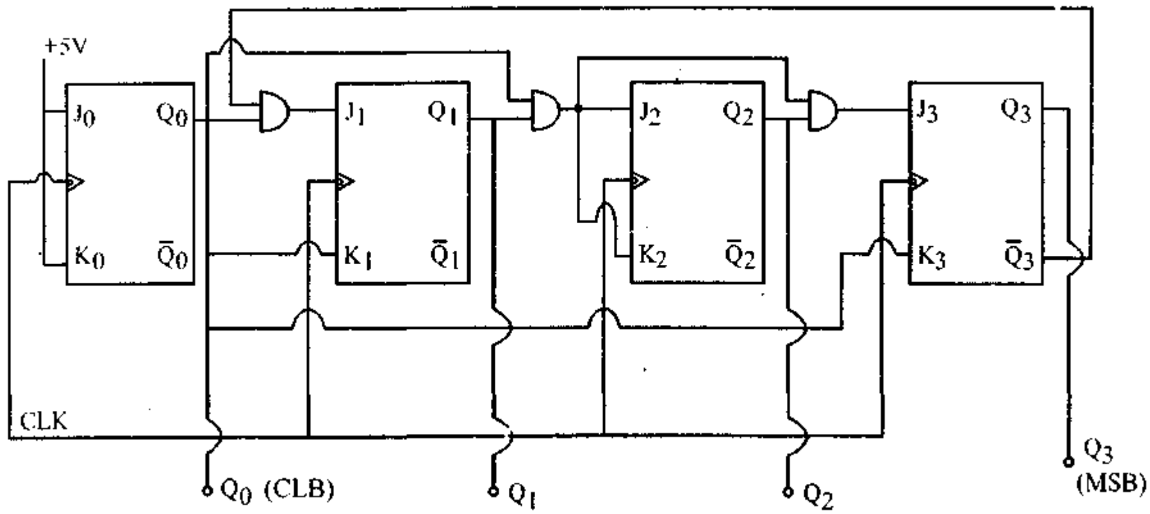


Fig. Circuit Diagram for MOD-10 (Decade) Counter

(iii) Quantization and Aperture Time : In order to convert an analog quantity to a digital number involves "quantization". The characteristics of quantizer are shown in fig.

This is used for conversion of analog voltage of 0-7 V. Now in binary code, decimal number 7 = binary 111. Therefore the digital number has 3 bits.

The analog input is shown in fig. on the horizontal axis and the discrete output voltage level on the vertical axis.

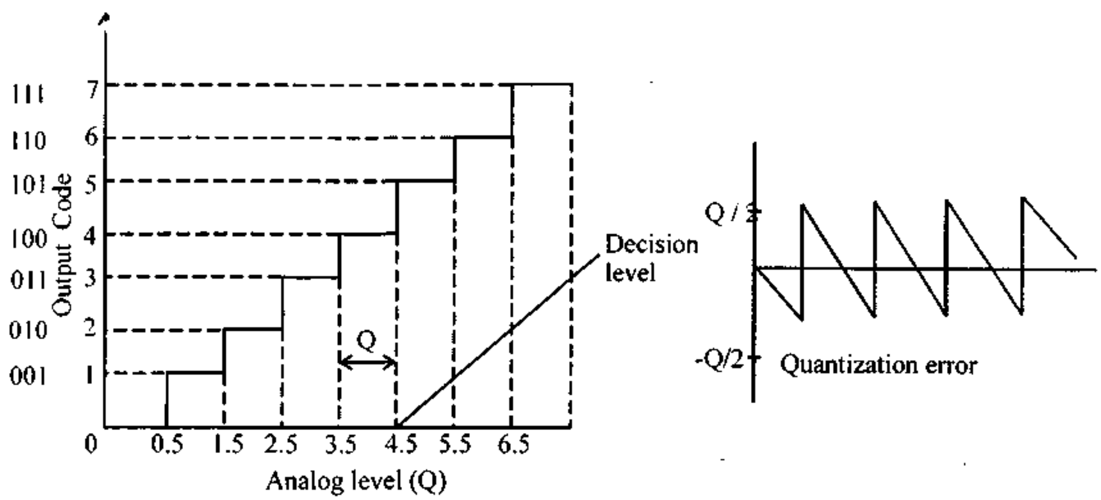


Fig. Characteristics of a quantizer

The decision level of A/D converters are at 0.5, 1.5, 2.5, 3.5 etc. Thus, the design levels are spaced IV apart. Analog values between tw, decision levels is Q, the quantization size. An n bit A/d converter has 2^n discrete levels with resolution = $\frac{1}{2^n}$ or 1 part in 2^n. Therefore for n bit converter :

$$\text{Discrete level} = 2^n$$

$$\text{Resolution} = \frac{1}{2^n}$$

$$\text{Decision level} = 2^n - 1$$

if the input to the quantizer is word through its full range and subtracted from the discrete output levels, the error signal shown in fig. This is called quantization error. The output of a quantizer can be considered as a noise signal with an rms value of -

$$E_q = -\frac{Q}{2\sqrt{3}}$$

Q = Quantization Error.

Aperture Time : In order to perform the operation of quantizing and coding of a signal, A/D convertor requires an aperture time. A sample and hold system is used in order to avoid the use of very fast and expensive A/D converters. The use of a sample and hold circuit is useful because it provides a very small time for taking a very rapid sample of the signal and then holding its value till it is converted. For a sinusoidal signal to be converted into a digital form, the maximum rate of change occurs at the instant where the voltage goes through zero. The amplitude change of voltage at this instant is :

$$\Delta E = \left[\frac{d}{dt}(E_m \sin \omega t)\right]_{t=0} \times t_a$$

$$= E_m \omega t_a$$

∴ Aperture time

$$\boxed{t_a = \frac{\Delta E}{\omega E_m} = \frac{\Delta E}{2\pi f E_m}}$$