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# Internal Assessment Test 1 – Sept. 2018

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|---|---|---|---|---|---|---|---|---|---|
| Sub: | Electronic Instrumentation | | | | | Sub Code: | 17EC32 | Branch: | ECE/TCE |
| Date: | 10/ 09 / 2018 | Duration: | 90 minutes | Max Marks: | 50 | Sem & Sec | 3rd Sem A | | OBE |

1. a) Define the following terms as applied to an instrument: i) Accuracy ii) Random error iii) Absolute error iv) Gross error v) Systematic error.

Accuracy
The degree of exactness closeness of a measurement compared to the expected (desired)value.

4Resolution
The smallest change in a measured variable to which an instrument will respond.

Precision
A measure of the consistency or repeatability of measurements, i.e.successive reading do not differ. Precision is the consistency of the instrument out put for a given value of input.

b) Write a note on statistical analysis of error.

2. Design an Ayrton shunt to provide an ammeter with a current range of 1mA, 10mA, 50mA and 100mA. Given a D’Arsonval movement with an internal resistance of 100Ω and full scale current of 100µA. List its advantages over a simple multi-range ammeter.

$I_{m=}$100µA $R_m$ =100 Ω

***0-1mA Range:***

I=1mA

$I_{sh}$ =I-$I_m$ =900µA

$R_1+R_2+R_3+R_4 = I_mR_m/I_{sh}$

$R_1+R_2+R_3+R_4$ = 11.111 Ω ………………. (1)

***0-10mA Range:***

I=10mA

$I_{sh}$ =I-$I_m$ =49900µA

$R_2+R_3+R_4 = I_m(R_m+R_1)/I_{sh}$ .................. (2)

***0-50mA Range:***

I=50mA

$I_{sh}$ =I-$I_m$ =9900µA

$R_3+R_4 = I_m(R_m+R_1+ R_2)/I_{sh}$ .................. (3)

***0-100mA Range:***

$I=100mA$

$I_{sh} = I-I_m = 99900\mu A$

$R_4 = I_m(R_m+R_1+ R_2+ R_3)/I_{sh}$ .................. (4)

Solving equations (1),(2),(3) and (4)

$R_1 = 9.99\ \Omega$

$R_2 = 0.8898\ \Omega$

$R_3 = 0.111\ \Omega$

$R_4 = 0.111\ \Omega$

3. With a neat block diagram and waveforms explain the working of Dual Slope Integrating type digital voltmeter. Derive the expression for measured value.

Dual Slope Integrating Type DVM – In ramp techniques, superimposed noise can cause large errors. In the dual ramp technique, noise is averaged out by the positive and negative ramps using the process of integration.
Principle of Dual Slope Type DVM
As illustrated in Fig. 3.1, the input voltage 'ei' is integrated, with the slope of the integrator output proportional to the test input voltage.

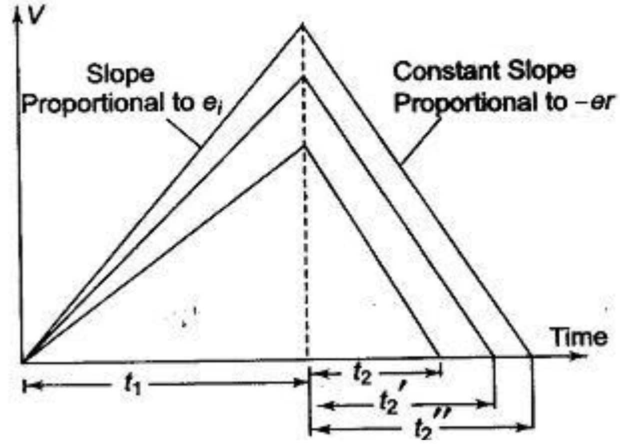

Fig 3.1 Principle of operation

After a fixed time, equal to t1, the input voltage is disconnected and the integrator input is connected to a negative voltage -er The integrator output will have a negative slope which is constant and proportional to the magnitude of the input voltage. The block diagram is given in Fig. 3.2. At the start a pulse resets the counter and the F/F output to logic level '0'. Si is closed and Sr is open. The capacitor begins to charge. As soon as the integrator output exceeds zero, the comparator output voltage changes state, which opens the gate so that the oscillator clock pulses are fed to the counter. (When the ramp voltage starts, the comparator goes to state 1, the gate opens and clock pulse drives the counter.)

When the counter reaches maximum count, i.e. the counter is made to run for a time ‘t1‘ in this case 9999, on the next clock pulse all digits go to 0000 and the counter activates the F/F to logic level ‘1’. This activates the switch drive, ei is disconnected and –er is connected to the integrator. The integrator output will have a negative slope which is constant, i.e. integrator output now decreases linearly to 0 volts. Comparator output state changes again and locks the gate. The discharge time t2 is now proportional to the input voltage. The counter indicates the count during time t2. When the negative slope of the integrator reaches zero, the comparator switches to state 0 and the gate closes, i.e. the capacitor C is now discharged with a constant slope. As soon as the comparator input (zero detector) finds that e0, is zero, the counter is stopped.

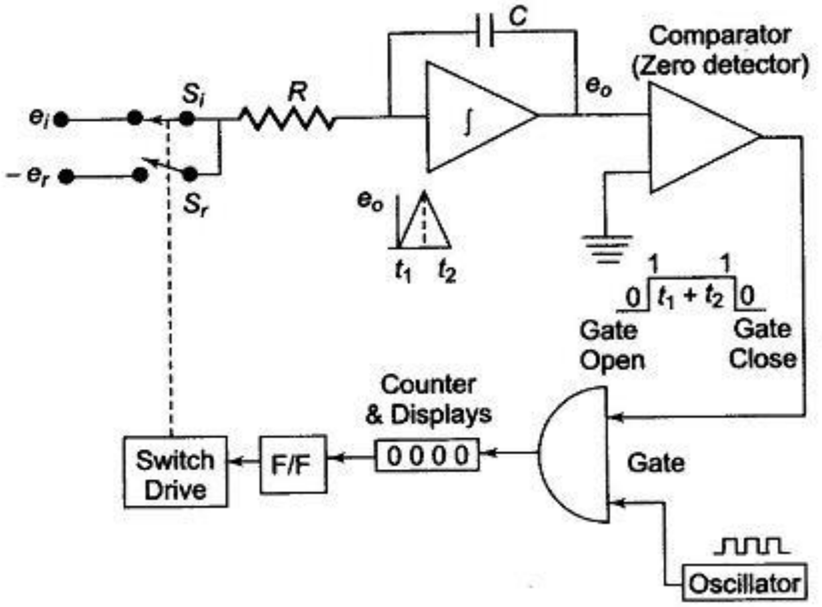

Fig 3.2 Block Diagram

The pulses counted by the counter thus have a direct relation with the input voltage.

During charging

$$e_o = -\frac{1}{RC}\int_0^{t_1} e_i\,dt = -\frac{e_i\,t_1}{RC}$$

During discharging

$$e_o = \frac{1}{RC}\int_0^{t_2} -e_r\,dt = -\frac{e_r\,t_2}{RC}$$

From the above equations we have

$$e_o - e_o = \frac{-e_r t_2}{RC} - \left(\frac{-e_i t_1}{RC}\right)$$

$$0 = \frac{-e_r t_2}{RC} - \left(\frac{-e_i t_1}{RC}\right)$$

$$\frac{e_r t_2}{RC} = \frac{e_i t_1}{RC}$$

$$e_i = e_r \frac{t_2}{t_1}$$

If the oscillator period equals T and the digital counter indicates n1 and n2 counts respectively,

$$e_i = \frac{n_2 T}{n_1 T} e_r \quad \text{i.e.} \quad e_i = \frac{n_2}{n_1} e_r$$

Now, n1 and er are constants.

$$\text{Let } K_1 = \frac{e_r}{n_1}. \text{ Then } e_i = K_1 n_2$$

From these it is evident that the accuracy of the measured voltage is inde-pendent of the integrator time constant. The times t1 and t2 are measured by the count of the clock given by the numbers n1 and n2 respectively. The clock oscil-lator period equals T and if n1 and $e_r$ are constants, the accuracy of the method is also independent of the oscillator frequency.

The dual slope technique has excellent noise rejection because noise and superimposed ac are averaged out in the process of integration. The speed and accuracy are readily varied according to specific requirements; also an accuracy of ± 0.05% in 100ms is available.

4. Explain the working of RF ammeter and true RMS voltmeter.
   True RMS voltmeter:

Complex waveform are most accurately measured with an rms voltmeter. This instrument produces a meter indication by sensing waveform heating power, which is proportional to the square of the rms value of the voltage. This heating power can be measured by amplifying and feeding it to a thermocouple, whose output voltages is then proportional to the $E_{rms}$. However, thermocouples are non-linear devices. This difficulty can be overcome in some instruments by placing two thermocouples in the same thermal environment.

Figure 4a shows a block diagram of a true rms responding voltmeter.

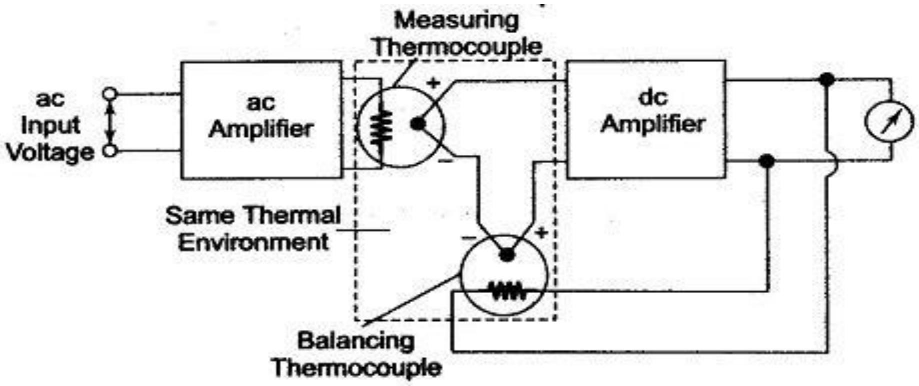

*Fig 4a True RMS voltmeter*

The effect of non-linear behavior of the thermocouple in the input circuit (measuring thermocouple) is cancelled by similar non-linear effects of the thermocouple in the feedback circuit (balancing thermocouple). The two couples form part of a bridge in the input circuit of a dc amplifier. The unknown ac voltage is amplified and applied to the heating element of the measuring thermocouple. The application of heat produces an output voltage that upsets the balance of the bridge.

The dc amplifier amplifies the unbalanced voltage; this voltage is fed back to the heating element of the balancing thermocouple, which heats the thermocouple, so that the bridge is balanced again, i.e. the outputs of both the thermocouples are the same. At this instant, the ac current in the input thermo-couple is equal to the dc current in the heating element of the feedback thermo-couple. This dc current is therefore directly proportional to the effective or rms value of the input voltage, and is indicated by the meter in the output circuit of the dc amplifier. If the peak amplitude of the ac signal does not exceed the dynamic range of the ac amplifier, the true rms value of the ac signal can be measured independently.

5. Explain loading effect with respect to voltage measurement.
   When a voltmeter is connected across two points in a circuit, and the resistance of the voltmeter is comparable with the circuit impedance, the parameters of the circuit gets affected. The voltmeter will be drawing significant amount of current thus introducing error into measurement. This is called loading.

(b) Find the voltage reading and % error in each case if the voltmeter is used on (i) 10V range and (ii) 20V range. The instrument has a 10KΩ/V sensitivity and is connected across $R2$ of Fig.5

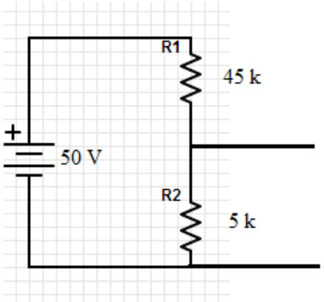

Fig. 5

Meter resistance=$R_m$, Effective resistance across the measurement points= $R_{AB}$

***Expected voltage= (50*5k)/50k = 5V***

(i) 10V range:

***$R_m$= 10k*10=100k***

***$R_{AB}$= 5kII100k = 4.72k***

***Measured Voltage = (50V*4.762k)/49.762k = 4.785V***

***%Error = (5V-4.785V)/5V = 4.3%***

(iI) 20V range:

***$R_m$= 10k*20=200k***

***$R_{AB}$= 5kII200k = 4.878k***

***Measured Voltage = (50V*4.878k)/49.878k = 4.8899V***

***%Error = (5V-4.8899V)/5V = 2.2%***

6. Explain the working of Successive approximation type DVM with the neat block diagram. Depict the conversion step in table format for an 8bit converter with reference voltage of 5V and the test voltage applied is 3V.

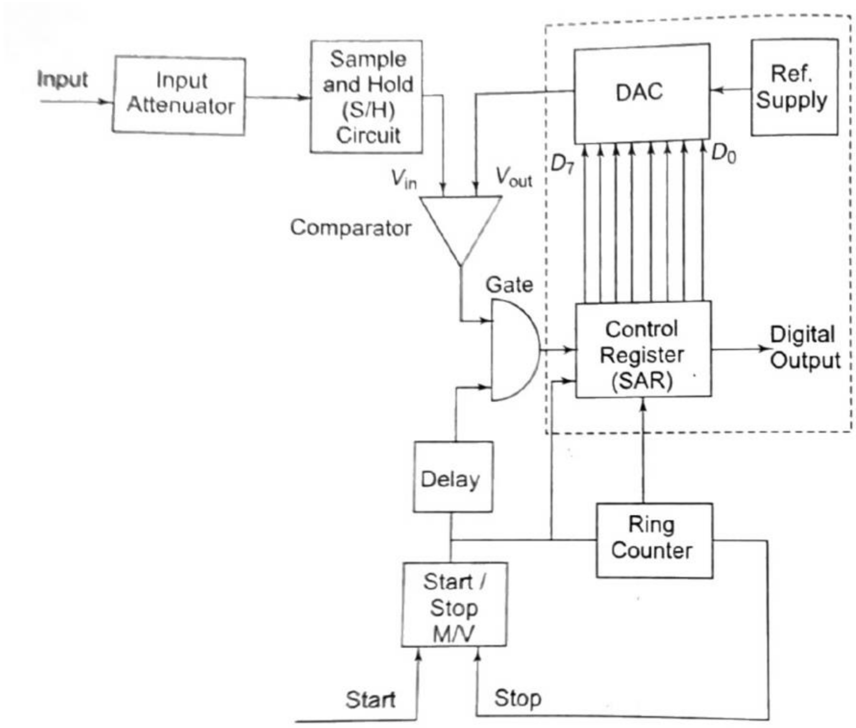

Fig 6. Block Diagram of Successive Approximation Type DVM

The successive approximation DVM works on the principle of comparison. The unknown signal is compared with half the reference value and depending on whether the input signal is higher or lower additional comparison voltage is added or removed. Then the process continues for a predefined number of comparisons.

Its basic block diagram is shown in Fig. 6. When the start pulse signal activates the control circuit, the successive approximation register (SAR) is cleared. The SAR register is an 8 bit one. The output of the SAR is 00000000. Vout of the D/A converter is 0. Now, if Vin > Vout the comparator output is positive. During the first clock pulse, the control circuit sets the D7 to 1, and Vout jumps to the half reference voltage. The SAR output is 10000000. If Vout is greater than Vin the comparator output is negative and the control circuit resets D7. However, if Vin is greater than Vout the comparator output is positive and the control circuits keep D7 set. Similarly the rest of the bits beginning from D7 to D0 are set and tested. Therefore, the measurement is completed in 8 clock pulses.

At the beginning of the measurement cycle, a start pulse is applied to the start-stop multivibrator. This sets a 1 in the MSB of the control register and a 0 in all bits (assuming an 8-bit control) its reading would be 10000000. This initial setting of the register causes the output of the D/A converter to be half the reference voltage, i.e. 1/2 V. This converter output is compared to the unknown input by the comparator. If the input voltage is greater than the converter reference voltage, the comparator output produces an output that causes the control register to retain the 1 setting in its MSB and the converter continues to supply its reference output voltage of 1/2 Vref.

The ring counter then advances one count, shifting a 1 in the second MSB of the control register and its reading becomes 11000000. This causes the D/A converter to increase its reference output by 1 increment to 1/4 Vref, i.e. 1/2 Vref + 1/4 Vref, and again it is compared with the unknown input. If in this case the total reference voltage exceeds the unknown voltage, the comparator produces an output that causes the control register to reset its second MSB to 0. The converter output then returns to its previous value of 1/2 Vref and awaits another input from the SAR. When the ring counter advances by 1, the third MSB is set to 1 and the converter output rises by the next increment of 1/2 Vref + 1/8 Vref. The measurement cycle thus proceeds through a series of successive approximations. Finally, when the ring counter reaches its final count, the measurement cycle stops and the digital output of the control register represents the final approximation of the unknown input voltage.

Table 6 depicts the steps involved in the voltage measurement if Successive approximation type DVM is used.

$V_{in}$ =3V, $V_{ref}$= 5V

| Sl no | $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | $D_0$ | $V'_{ref}$ | Condition | Decision | $V_{out}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.5V | $V_{in} > V'_{ref}$ | $D_7$ set | 2.5V |
| 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3.75V | $V_{in} < V'_{ref}$ | $D_6$ reset | 2.5V |
| 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3.125V | $V_{in} < V'_{ref}$ | $D_5$ reset | 2.5V |
| 4 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2.8125V | $V_{in} > V'_{ref}$ | $D_4$ set | 2.8125V |
| 5 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2.96875V | $V_{in} > V'_{ref}$ | $D_3$ set | 2.96875V |
| 6 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 3.046875V | $V_{in} < V'_{ref}$ | $D_2$ reset | 2.96875V |
| 7 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 3.0078125V | $V_{in} < V'_{ref}$ | $D_1$ reset | 2.96875V |
| 8 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 2.98828V | $V_{in} > V'_{ref}$ | $D_0$ set | 2.98828V |

Table 6. Steps

**Final SAR data = 10011001**

**The voltage displayed by the meter =** 2.98828V

% error= 0.39%