# Ohmmeters:

The ohmmeter is a convenient direct reading device for measurement of resistance. An ohmmeter is useful for determining the approximate resistance of circuit components such as heater elements or machine field coils, measuring & sorting of resistance used in electronic circuits, checking of semiconductor diodes & for checking continuity of circuits.

Series type ohmmeter
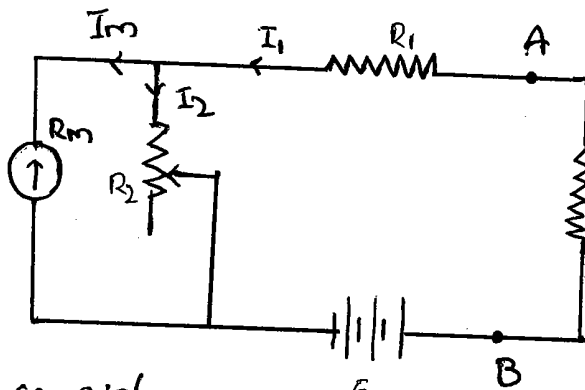
R_1 = current limiting R
R_2 = zero adjustment R
R_m = internal R of d Arsonval movement.

It consists of basic d Arsonval movement connected in parallel with a shunting resistance R_2. This parallel circuit is in series with resistance R_1 & a battery of emf E. This series circuit is connected to the terminals A & B of the unknown resistance R_x.

when the unknown resistance $R_x = 0$ i.e terminals A & B are shorted maximum current flows through the meter. under this condition resistor R_2 is adjusted until the basic meter indicates full scale current I_{fs}.

This full scale current position of the pointer is marked as 0Ω on the scale i.e since $R_x = 0$. So at the full scale end of the pointer i.e right side as '0Ω' is indicated.

Similarly when R_x is removed from the circuit $R_x = \infty$ when terminals A & B are open, the current in the meter drops to zero & the movement indicates zero current which can be indicated as ∞
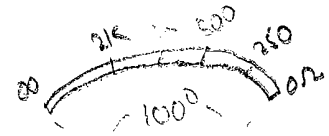
Thus the meter will read infinite resistance at the zero current position & zero resistance at full scale current position.

When the unknown resistance is inserted at terminals A, B the current through the meter is reduced & hence the pointer drops lower on the scale. Intermediate scale readings may be placed on the scale by different known values of resistance R_x to the instruments.

A convenient quantity to use in the design of Series ohmeter is the value of R_x which causes the half scale deflection of the meter. At this position, the resistance across the terminal A & B is defined as the half scale position resistance $[R_h]$

When R_h is connected across terminals A & B the meter current reduces to one half of the full scale value or with $R_x = R_h$, $I_m = 0.5 I_{fs}$

Thus R_h is equal to the internal resistance of ohmmeter looking into terminals A & B. Values of R_1 & R_2 can be determined from the value of R_x which gives half scale deflection.

$$R_h = R_1 + R_2 // R_m$$

$$= R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

The battery current at half scale deflection $I_h = E/2R_h$.

In order to produce full scale deflection the battery current must be doubled.

$$I_1 = 2I_h = E/R_h$$

Current through the shunt $I_2 = I_1 - I_{fs}$

The voltage drop across R_2 is equal to the voltage drop across meter.

$$I_2 R_2 = I_{fs} R_m \quad \text{or} \quad R_2 = (I_{fs}/I_2) R_m$$

Sub $I_2 = I_1 - I_{fs}$ we get $R_2 = \dfrac{I_{fs} R_m}{I_1 - I_{fs}} = \dfrac{I_{fs} R_m R_h}{E - I_{fs} R_h} \quad \because (I_1 = E/R_h)$

From $R_h = R_1 + \dfrac{R_2 R_m}{R_2 + R_m} \Rightarrow R_1 = R_h - \dfrac{R_2 R_m}{R_2 + R_m}$

$$R_1 = R_h - \frac{\dfrac{I_{fs} R_m R_h}{E - I_{fs} R_h} \times R_m}{\dfrac{I_{fs} R_m R_h}{E - I_{fs} R_h} + R_m}$$

$$R_1 = R_h \left[1 - \frac{I_{fs} R_m}{E} \right]$$

If R_h & R_m are known R_1 & R_2 can be determined.

$$R_h = \frac{R_2 E}{I_{fs}(R_m + R_2)} \quad R_h \text{ in } R_2 \qquad R_h = \frac{E R_1}{E - I_{fs} R_m} \quad R_h \text{ in } R_1$$

The series type ohmeter is most popular & is used extensively in portable instruments. But it possess certain difficulties. The internal battery voltage decreases gradually with time & age due to which full scale current drops & the meter does not read '0'. When terminals A & B are shorted.

Shunt type ohmmeter:
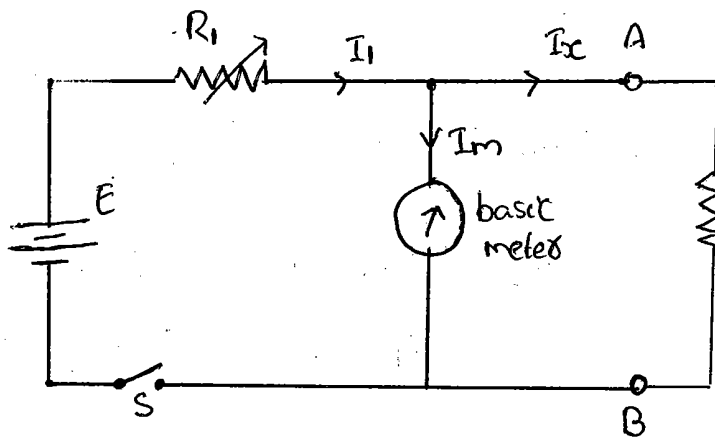
It consists of a battery in series with an adjustable resistor R_1 & a basic d Arsonval movement. The unknown resistance is connected across terminals A & B parallel with the meter. In this circuit it is

necessary to have an off-on switch to disconnect the battery from the circuit when the instrument is not in use.

when the unknown resistor $R_x = 0$ ie A & B are shorted the meter current is zero. If the unknown resistance $R_x = \infty$ i.e A & B are open, the current finds path only through the meter & selecting a proper value for resistance R_1, the pointer may be made to read full scale.

this ohmeter therefore has zero mark on the left hand side of the scale (no current) & infinite mark on the right hand side of the scale i.e full scale deflection current.

The analysis of the shunt type ohmeter is similar to that of a series type ohmmeter.

from fig $R_x = \infty$, the full scale meter current is

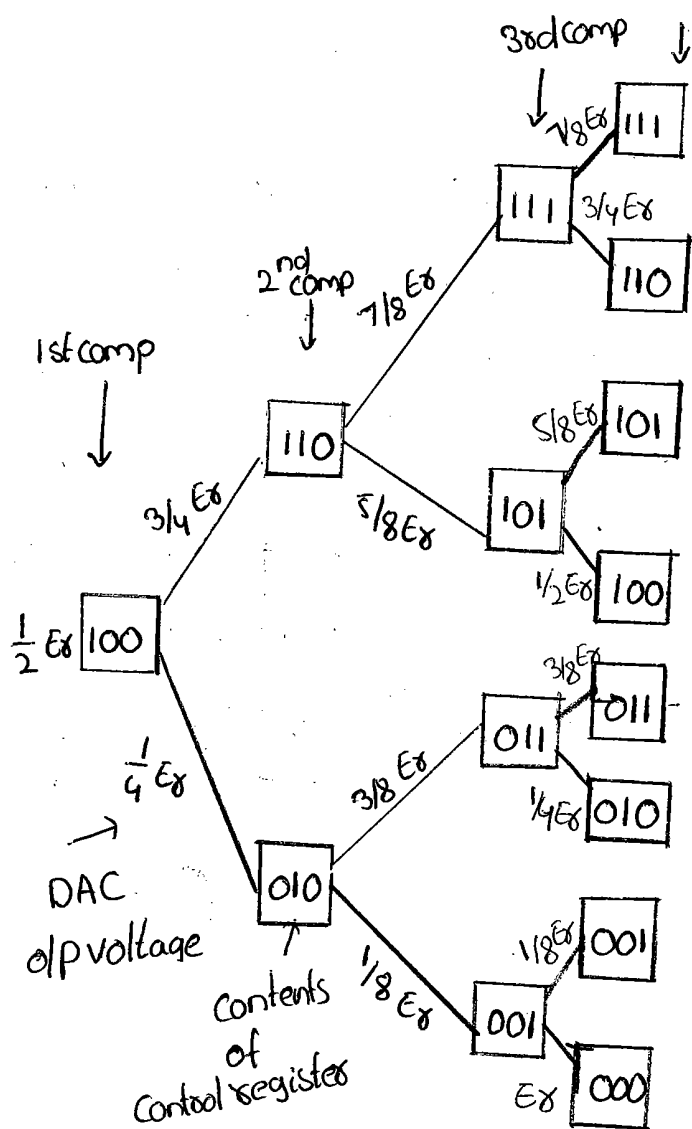$$I_{fs} = \frac{E}{R_1 + R_m}$$

$$I_{fs} R_1 + I_{fs} R_m = E$$

$$R_1 = \frac{E}{I_{fs}} - R_m$$

with any resistance R_x to be measured, the meter current

$$I_m = \left[\dfrac{i}{R_1 + \dfrac{R_m R_x}{R_m + R_x}} \right] \left(\dfrac{R_x}{R_m + R_x} \right)$$

$$I_m = \dfrac{E R_x}{R_1 R_m + R_x (R_1 + R_m)}$$

Successive approximation method

The potentiometric AID converter is probably the most widely used in general practice on account of high resolution & high speed.

Successive approximation type DVM works on the principle of successive approximation. This DVM compares the analog input to a Decade Assembly counter (DAC) reference voltage which is repeatedly

divided in half. The process is shown in fig; where a four digit binary number 1000, representing the full reference voltage E_r is divided in half (binary number 100) to corresponding voltage $\frac{1}{2} E_r$. A comparison of this reference voltage $\frac{1}{2} E_r$ & the analog voltage is made. If the result of this comparison shows that this first approximation is too small (ie $\frac{1}{2} E_r < i/p$) then the next comparison is made against $\frac{3}{4} E_r$ (binary 110). If the comparison showed that the first approximation was too large ($\frac{1}{2} E_r > i/p$) then the next comparison will be made against $\frac{1}{4} E_r$ (binary 010). After four successive approximations the digital number is resolved.
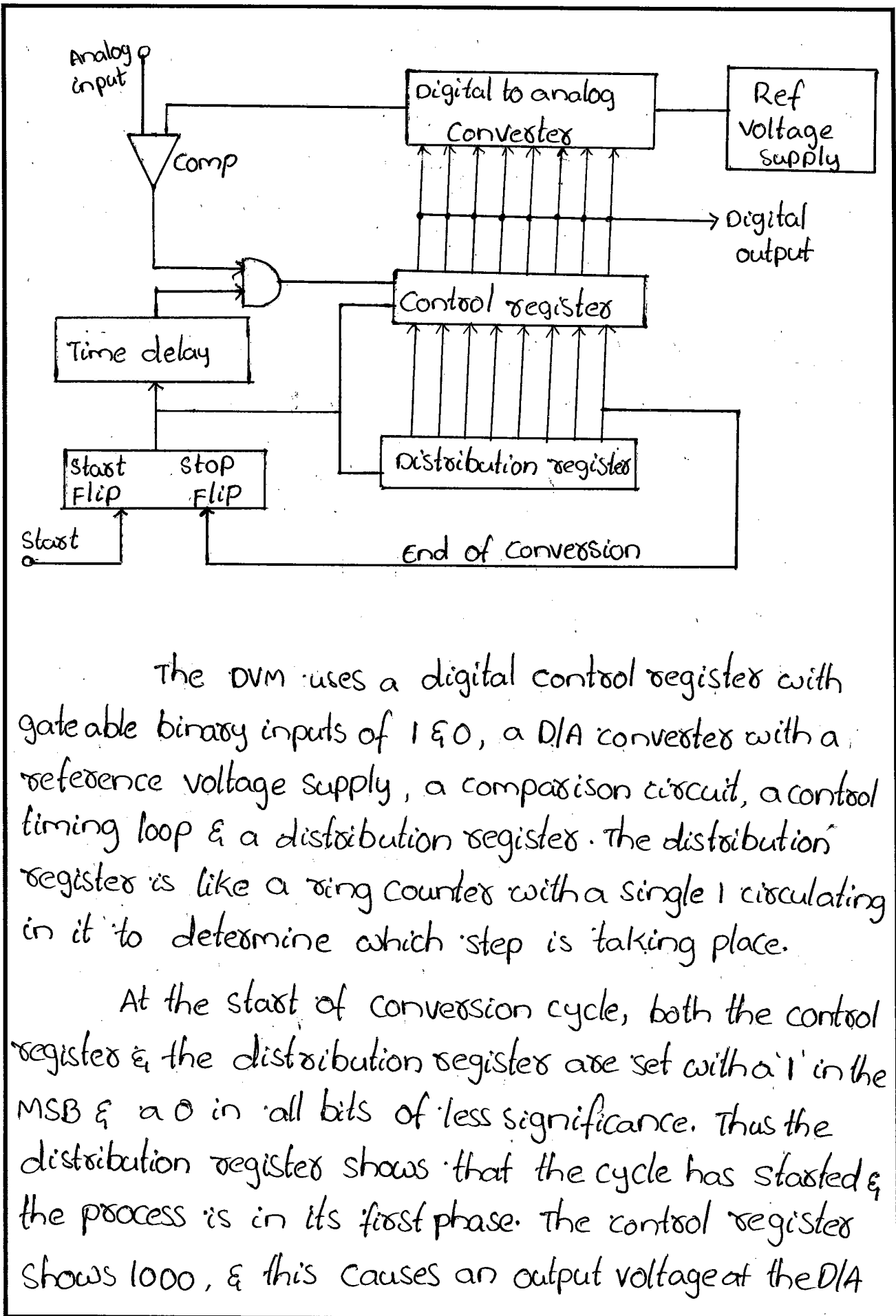
The DVM uses a digital control register with gate able binary inputs of 1 & 0, a D/A converter with a reference voltage supply, a comparison circuit, a control timing loop & a distribution register. The distribution register is like a ring counter with a single 1 circulating in it to determine which step is taking place.

At the start of conversion cycle, both the control register & the distribution register are set with a 1 in the MSB & a 0 in all bits of less significance. Thus the distribution register shows that the cycle has started & the process is in its first phase. The control register shows 1000, & this causes an output voltage at the D/A

Converter Section of one half of reference supply. At the same time, a pulse enters the time delay circuitry. By the time that the D/A converter & the comparator have settled, this delayed pulse is gated with the comparator output.

When the next MSB is set in control register by the action of the timing circuit, the MSB remains in the 1 state or it is reset to 0 depending upon the comparator output. The single '1' in the distribution register is shifted to the next position & keeps track of the comparison mode.

The procedure repeats itself & until the final approximation has been corrected & the distribution register indicates the end of the conversion.

For a successive approximation converter, the digital output corresponds to some value that the analog input had during the conversion. Thus the aperture time is equal to the conversion time. The aperture time can be reduced by using 'Sample Hold circuit'.

prob: Find the successive approximation A/D output for a 4 bit converter to a 3.217 V input if the reference is 5V.

i) Set $d_3 = 1$ $\therefore$ output $= 5/2^1 = 2.5V$

Now $3.217 > 2.5$ & $\therefore$ Set $d_3 = 1$

ii) Set $d_2 = 1$ $\therefore$ output $= 2.5 + 5/2^2 = 3.75$

Now $3.217 < 3.75$ $\therefore$ Set $d_2 = 0$

iii) Set $d_1 = 1$ $\therefore$ output $= 2.5 + 5/2^3 = 3.125$
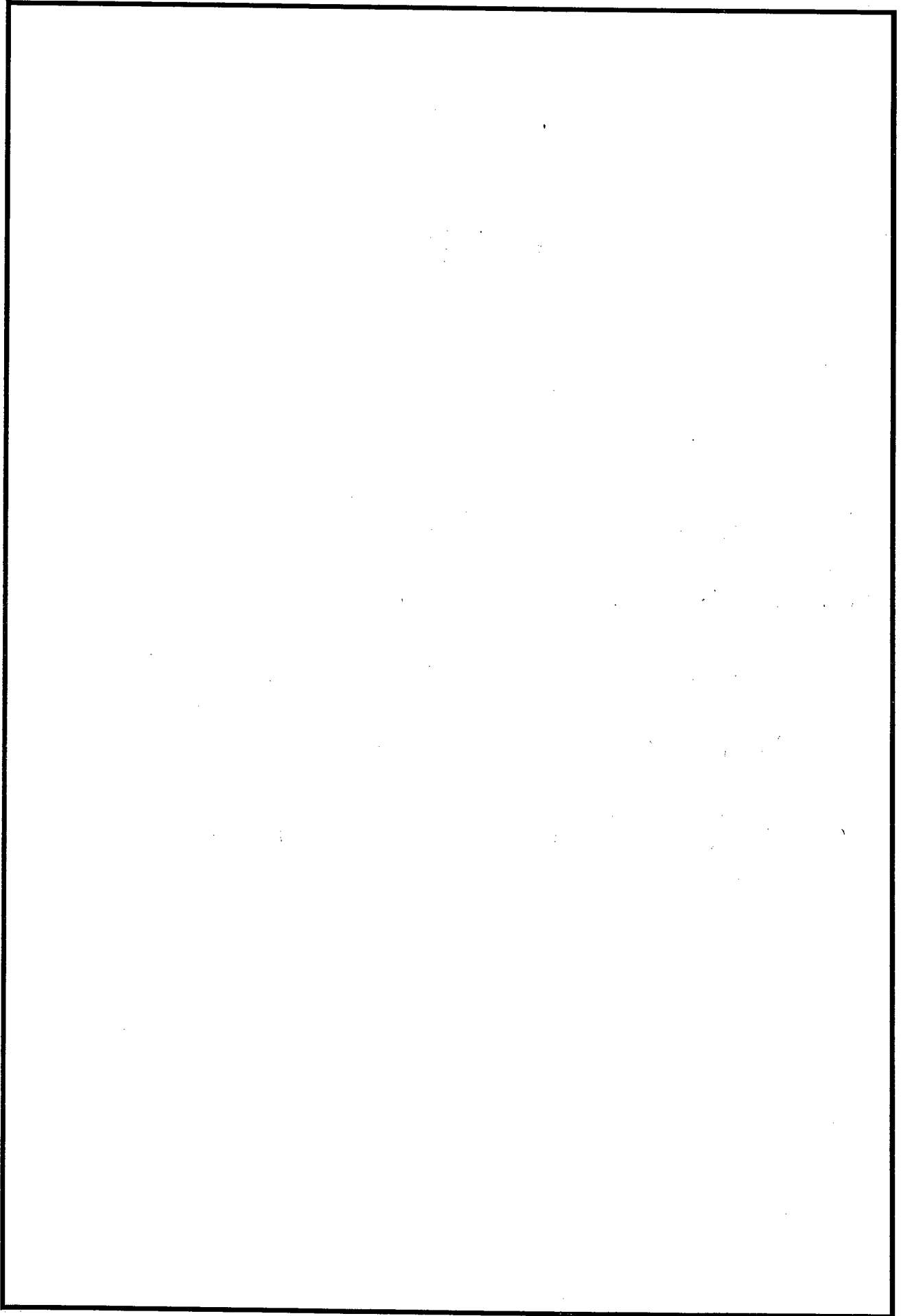
Now $3.217 > 3.125$ $\therefore$ Set $d_1 = 1$

iv) Set $d_0 = 1$ $\therefore$ output $= 3.125 + 5/2^4 = 3.4375$

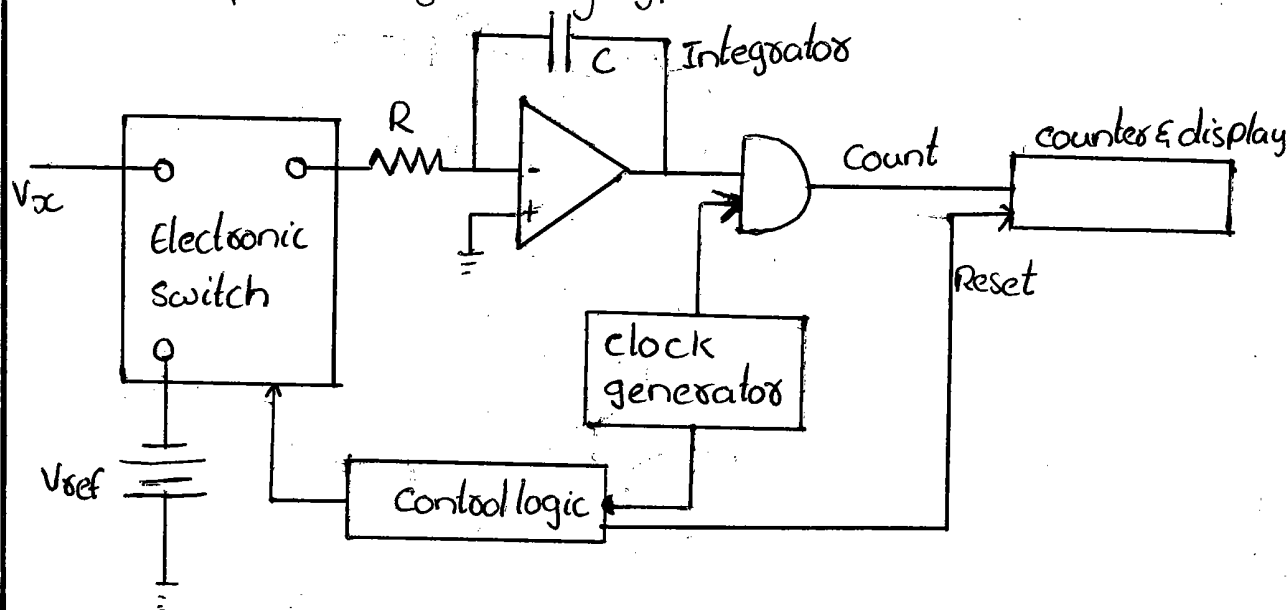Now $3.217 < 3.4375$ $\therefore$ Set $d_0 = 0$

Thus output of A/D converter is : 1010

1,3,8,13,14,19,22,26,28,35,39,9

8,19,35

Dual slope Integrating type

In this technique, an integrator is used to integrate an accurate reference voltage for a fixed period of time. The Same integrator is then used to integrate with the reverse slope, the input voltage. The time required to return to the starting voltage is measured.

The input voltage to be measured V_x is applied to the integrator by means of an electronic switch, the integration is done for a fixed amount of time, as determined by the Counter. As soon as integration starts, the counter is also initiated by the control logic. when the counter reading reaches a predetermined value integration is stopped. The output of the integrator will have opposite polarity to that of the input voltage V_x. The counter is reset Reference voltage V_{ref} which of opposite polarity to the input voltage is now connected to the integrator. The

Integrator output voltage will now go in opposite direction. At the same time counter is also initiated. Integration is done till the output voltage of the integrator becomes 0 V

The counts accumulated during this period are a measure of the input voltage. The counts are accumulated & the digital display or read out is given.

In this method, the accuracy of conversion will not depend on the precision of the resistor & capacitor of the ramp generator current or the op amp

output of integrator $|V_0| = \dfrac{1}{RC} V_i \, T_{integrate}$

where $T_{integrate}$ is the period of integration when V_i is connected to the integrator. This time period depends on the counter, to count a predefine count, at the rate rate determined by the clock.

This $|V_0|$ is also the same when integration is being done for the second time with V_{ref} connected to the integrator

$\therefore \quad |V_0| = \dfrac{1}{RC} V_{ref} \, T_{discharge}$

For a 5 decade counter

$$T_{integrate} = \dfrac{10^5}{f_c}$$

$T_{discharge} = $ Accumulated counts in the counter$/f_c$

where f_c = clock frequency

$$\frac{V_i}{RC} \; T \text{integrate} = \frac{V_{ref}}{RC} \; T\text{discharge}$$

$$V_i \left(\frac{10^5}{f_c}\right) = V_{ref} \; T\text{discharge}$$

$$T\text{discharge} = \left[\frac{V_i}{V_{ref}}\right] \left[\frac{10^5}{f_c}\right]$$

$$\text{Accumulated counts}/f_c = \left[\frac{V_i}{V_{ref}}\right]\left[\frac{10^5}{f_c}\right]$$

$$\therefore \; \text{Accumulated counts} = \left[\frac{V_i}{V_{ref}}\right] 10^5$$

Therefore V_{ref} & the decade counter prefixed count (10^5) are constants & the counter reading is proportional to the input voltage V_i. The digital readout is independent of R & C of the integrator & f_c. Therefore the precision of R & C will not affect the measurement.

→ one should known I_{fsd}

Ex: A 50μA is required for full scale deflection. This full scale value will produce a voltmeter with a sensitivity of 20,000Ω per V. The sensitivity is based on the fact that the full scale current of 50μA results whenever 20,000Ω of resistance is present meter circuit for each voltage applied.

$$\text{sensitivity} = 1/I_{fsd} = 1/50\mu A = 20k\Omega/V$$

Hence a 0-1mA would have sensitivity of $1V/1mA = 1k\Omega/V$ or 1000Ω

→ calculate the sensitivity of a 200μA meter movement which is used as dc voltmeter → $1/I_{fsd} = \dfrac{1}{200\mu A} = 5k\Omega/V$
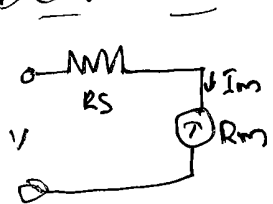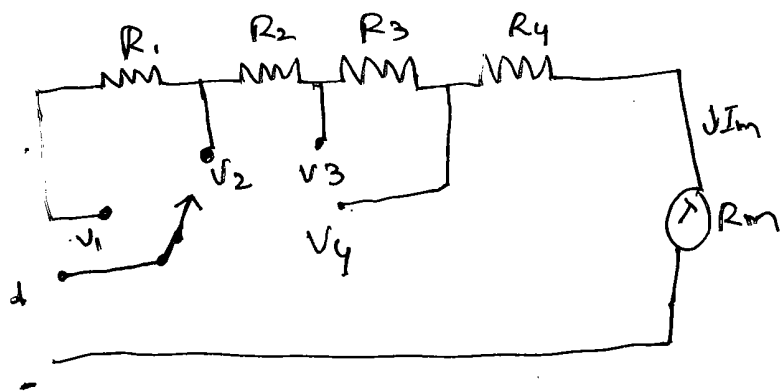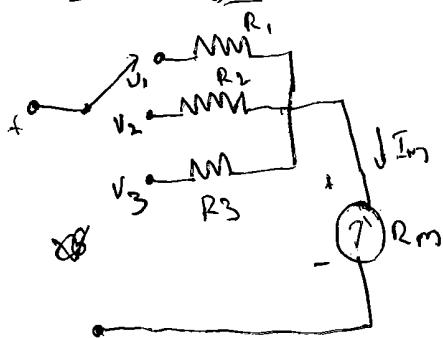
DC voltmeter:

$$V = I_m(R_s + R_m) \Rightarrow V = IR$$

$$R_s = \dfrac{V - I_m R_m}{I_m} = \dfrac{V}{I_m} - R_m$$

→ A basic D'Arsonval movement with a full scale deflection of 50μA & internal resistance of 500Ω is used as a voltmeter. Determine the value of multiplier resistance needed to measure a voltage range of 0-10V

$$R_s = \dfrac{V}{I_m} - R_m = \dfrac{10}{50\mu A} - 500 = 200k - 500 = 199.5 k\Omega$$

Multirange

The first resistor or low range multiplier, R_4, is the only special resistor which has to be

→ Convert a basic D'Arsonval movement with an internal resistance of 50Ω & full scale deflection current of 2mA into a multirange dc voltmeter with voltage ranges of 0-10V, 0-50V, 0-100V, 0-250

→ For 10V range (V_4 position of switch), the total resistance is

$$R_t = \frac{V}{I_{fsd}} = \frac{10}{2mA} = 5K\Omega \quad \therefore R_4 = R_t - R_m = 5k - 50 = 4950\,\Omega$$

→ For 50V range (V_3), the total resistance is

$$R_t = \frac{V}{I_{fsd}} = \frac{50}{2mA} = 25K\Omega \quad \therefore R_3 = R_t - (R_4 + R_m) = 25k - (4950 + 50) = 20K\Omega$$

→ For 100V range (V_2); the total
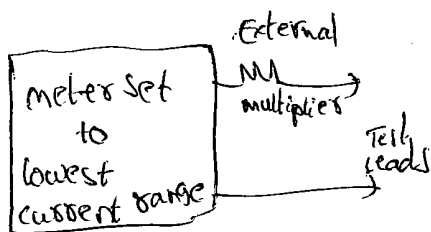
$$R_t = \frac{100}{2mA} = 50K\Omega; \therefore R_2 = R_t - (R_3 + R_4 + R_m) = 25K\Omega$$

→ For 250

$$R_t = \frac{250}{2mA} = 125K\Omega; \therefore R_1 = R_t - (R_2 + R_3 + R_4 + R_m) = 75K\Omega$$

Extending voltmeter Range

| meter set to lowest current range | External → multiplier → Test leads |

sensitivity: It is the ratio of the total circuit resistance R_t to the voltage range. It is essentially the reciprocal of I_{fsd}

$$S = 1/I_{fsd}$$

→ The advantage of sensity → It can be used to calculate the value of multiplier resistors in a dc voltmeter.

$$R_t = R_s + R_m$$

$$\therefore R_s = R_t - R_m \;\& \; R_t = S \times V \quad \Rightarrow \quad S = \frac{R_t}{V}$$

$$R_s = (S \times V) - R_m$$

48

.... the value of the multiplied resistance on the dc voltmeter, that uses a 200μA meter movement with an internal resistance of 100Ω

$R_s = S \times Range$ - Internal resistance $\therefore S = 1/I_{fsd} = 1/200\mu A = 5k\Omega/V$
the value of multiplier R_s is ca

$$R_s = 5k \times 50 - 100 = 250k - 100 = 249.9k\Omega$$

→ calculate the value of the multiplier resistance for the multiple ranged dc voltmeter circuit

the sensitivity $= \dfrac{1}{50\mu A} = 20k\Omega/V$

The value of multiplier resistance for 5V

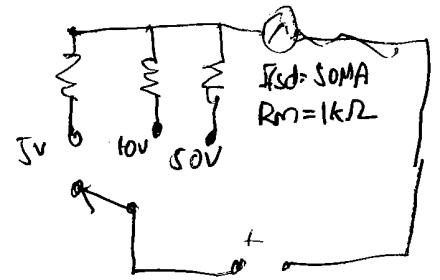$$R_{s_1} = S \times V - R_m = 20k \times 5 - 1k = 99k\Omega$$

For 10V

$$R_{s_2} = S \times V - R_m = 20k \times 10 - 1k = 199k\Omega$$

For 50V

$$R_{s_3} = S \times V - R_m = 20k \times 50 - 1k = 999k\Omega$$

Loading effect

Fig 4.6 show a simple series circuit of R_1 & R_2 connected to a 100V dc source. If the voltage across R_2 is to be measured by voltmeter having accurate value of voltage across R_2. Both meters are used on 50V range

a) a sensitivity of 1000Ω/V
b) a sensitivity of 20,000Ω/V
find which voltmeter will read the

S/: the voltage across R_2 without connecting voltmeter is $\dfrac{10k}{10k+10k} \times 100V = 50V$ → true voltage
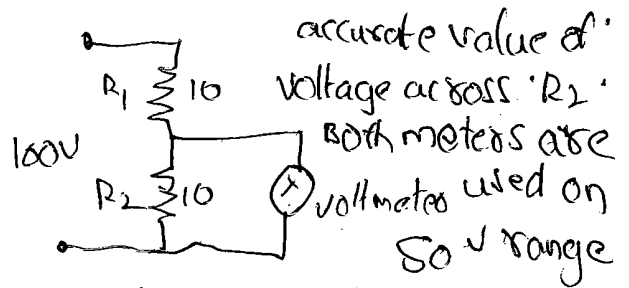
case1: using voltmeter of 1000Ω/V

It has resistance of ~~R=S~~ $1000 \times 50 = 50k\Omega$ on its 50V range connecting meter across R_2 causes an equivalent parallel resistance given by $R_{eq} = \dfrac{10k \times 50k}{10k + 50k} = 8.33k\Omega$

$$V_1 = \frac{R_{eq}}{R_1 + R_{eq}} \times V = \frac{8.33K}{10K + 8.33K} \times 100V = 45.43V$$

Hence this voltmeter indicates 45.43V

case: voltmeter having sensitivity of 20,000 Ω/V. Therefore it has

resistance of $20,000 \times 50 = 1000K = 1MΩ$

This voltmeter when connected across R_2 produces an equivalent

parallel resistance $R_{eq} = \frac{10K \times 1MΩ}{10K + 1MΩ} = 9.9KΩ$

Now the voltage across the total combination is given by

$$V_2 = \frac{9.9K}{9.9K + 10K} \times 100V = 49.74V$$

Hence this voltmeter will read 49.7

this example shows that a high sensitivity voltmeter should be

used to get accurate readings

∴ Error = $\dfrac{\text{actual voltage} - \text{voltage reading observed}}{\text{actual voltage}}$

∴ Two different voltmeters are used to measure the voltage across
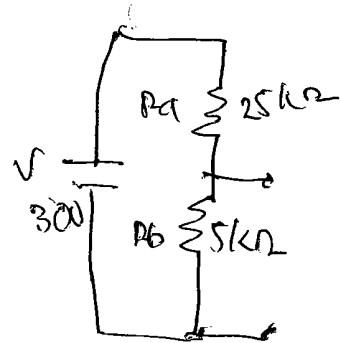
Rb

The meters are

1. S=1KΩ/V, Rm = 0.2K range 10V

2. S=20KΩ/V, Rm = 1.5K range 10V

calculate i) voltage across Rb without any meter

ii) voltage across Rb when meter 1 is used

iii) ,,   ,,   2

iv) error in the voltmeter

∴ i) $V_{Rb} = \dfrac{5K}{5K + 25K} \times 30 = 5V$

, $R_{eq} = \dfrac{Rb + Rm_1}{Rb + Rm_1} = 3.33KΩ$