Electronics Measurement & Instrumentation
4EC3-06
Unit -2
Electronic Instruments

4EC3-06: Electronics Measurement & Instrumentation

Credit: 3 **Max. Marks: 150(IA:30, ETE:120)**

3L+0T+0P **End Term Exam: 3 Hours**

ELECTRONIC INSTRUMENTS - Electronic Voltmeter, Electronic Multimeters, Digital Voltmeter, and Component Measuring Instruments: Q meter, Vector Impedance meter, RF Power & Voltage Measurements, Introduction to shielding & grounding.

Electronic Voltmeter;

Electrical instruments

1 absolute insto give o/p in form of const. No perivious calibration or comparision is necessary.

eg. tagent galvanometer → in laboratoris only

2 secondary inst.

↓ o/p determined from deflection of inst only when they have pre calibrated by comparision from absolute insto

Galv. + R ⇒ Am.

⇒ $\boxed{\text{volt}}$

abs. ins + comparision + calibration

Basic principle;

1. Magnetic effect – for A & V
2. Electrodynamic " – for A & V
3. Electromagnetic " – wattmeter → power
4. Thermal – A & V.
5. Chemical – dc A hr. meter
6. Electrostatic – V only

Secondary insto → electronic voltmeter

household meter

1. Indicating insto

Ordinary A, V & Watt meter

2. recording insto

give a continuous record carry inked pen

3. Integrating inst.

measure & register the total quantity of electricity

Amp-hr. & Watt-hr meter

Essential of Indicating Instrument–

(i) Deflecting Torque :– utilize one or more factor from above
(ii) Controlling Torque – spring, gravity
(iii) Damping Torque ; to decr inertia

1. Moving iron type
2. Moving coil type
3. permanent magnet type
4. electrodynamic

Electronic voltmeter; The voltmeter which uses the amplifier ~~for~~ to increases their sensitivity.

→ It gives accurate reading because of high i/p Resistance

↳ detects signals of very weak strength

Digital voltmeter

~~AA~~ Analog voltmeter

AC ↓ Tr FET OP-Amp → electronic CKt

→ moving coil voltmeter is not able to detect low voltage

→ vaccum tube — measure current → Ammeters

→ transistor or FETs — measure voltage only

↳ voltmeters

Moving coil voltmeter; → The magnitude of measured voltage is directly proportional to the deflection of the pointer

→ The pointer is fixed on calibrated scale

→ The point at which the pointer deflects indicates the magnitude of i/p voltage

μV

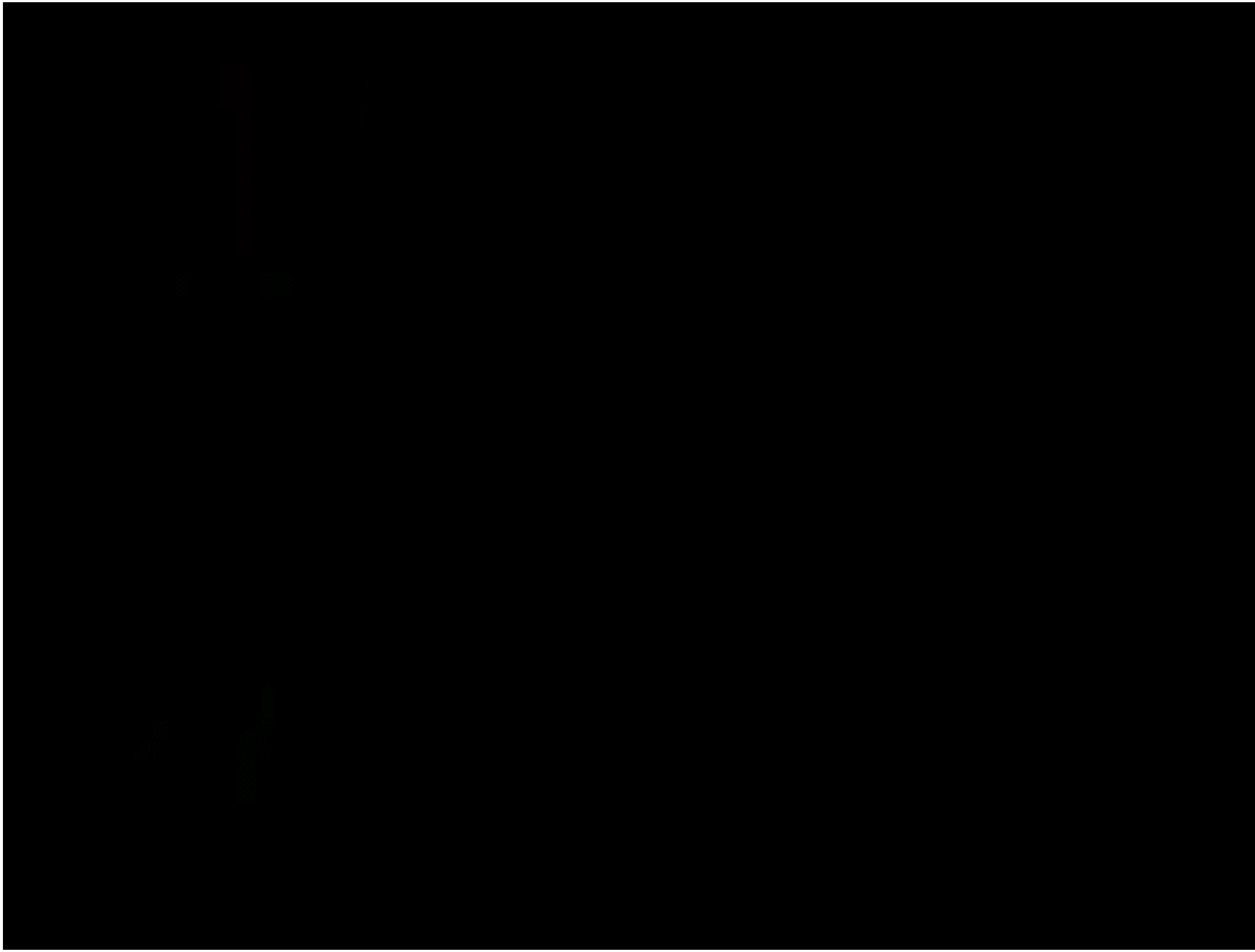
10^{-6} V

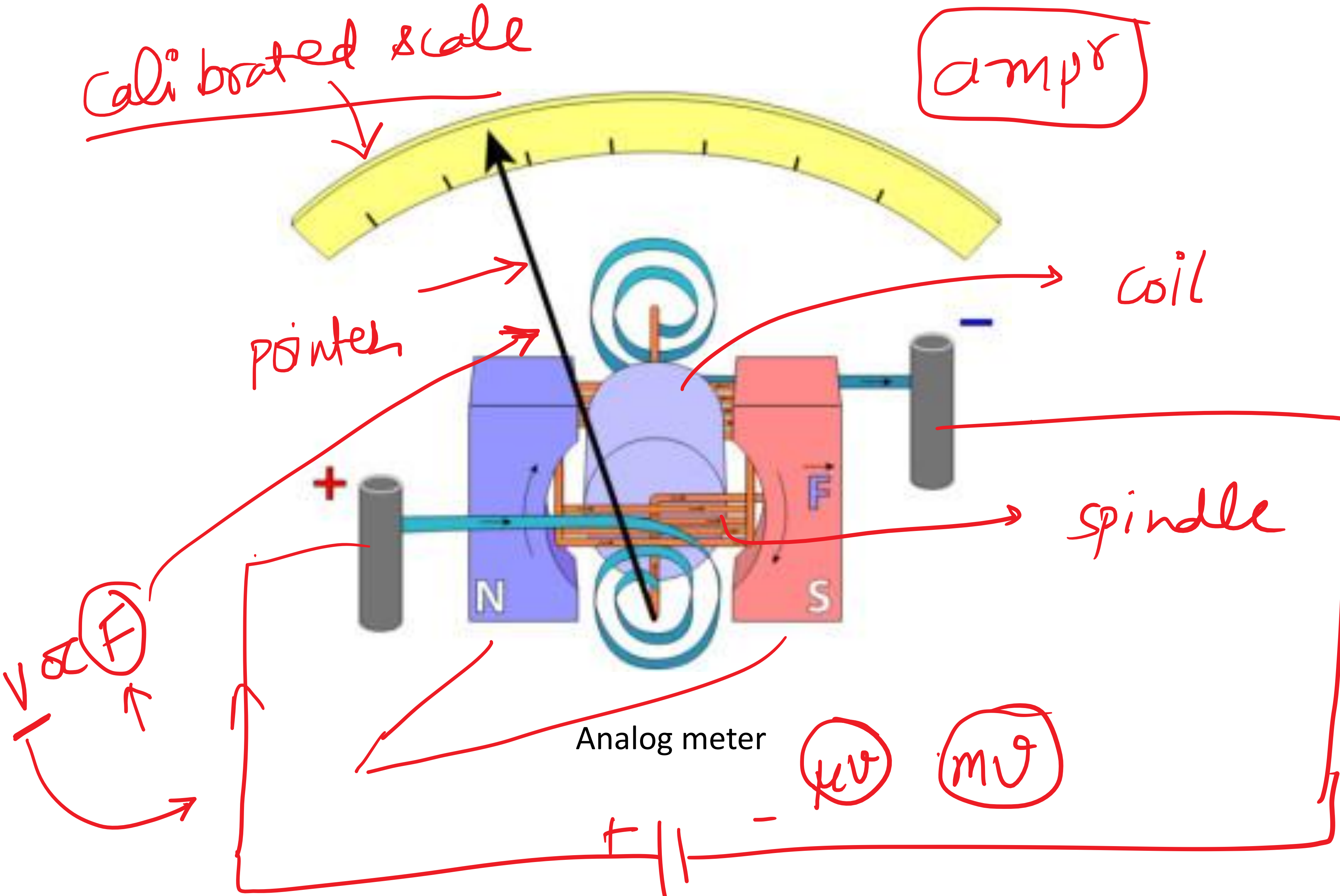
amp^r → M

problem with moving coil voltmeter,

→ large ~~problem~~ is drawn from measured ckt because of which the error occurs in their reading.

→ Power





Analog meter

Electronic voltmeter

Power supply ← auxillary ampr ckt

Input → EV → measurement Result.

→ In EV, the pointer is deflected by taking supply from auxiliary amplifier circuit.

→ The extra power is not passing through the deflector, hence meter gives accurate reading.

AC — def. of pointer (AC, DC)

def. of pointer

DC — gives digital O/p reading → seven segment display / LCD

Advantages of Electronic voltmeter;

(1) Detection of low-level signals – 50mA / 50μv

(2) low power consumption

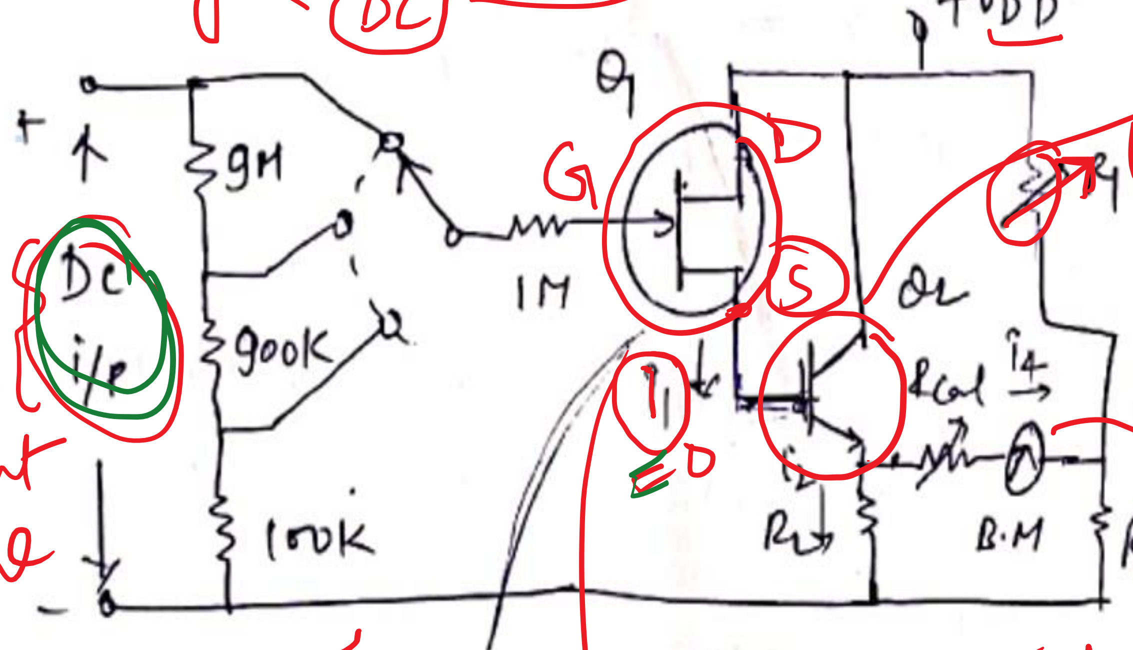
(3) High freqn range

Tr, FET, Diodes

Basic electronic voltmeter ('Transistor voltmeter) {DC}

↳ Analog < AC / DC

input which we want measure — DC i/p



BJT

zero adjustment

Balanced ckt

meter

PMMC

voltage divider

↓

Range selector

voltage

0-2V

2-10V

10-100V

FET (source follower)

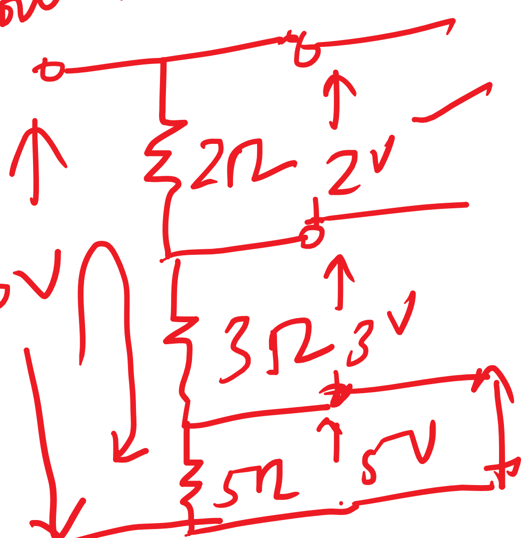
Highest i/p Imp

⇓

⇒ High sensitivity

$\frac{10V}{10} = 1A$

10V

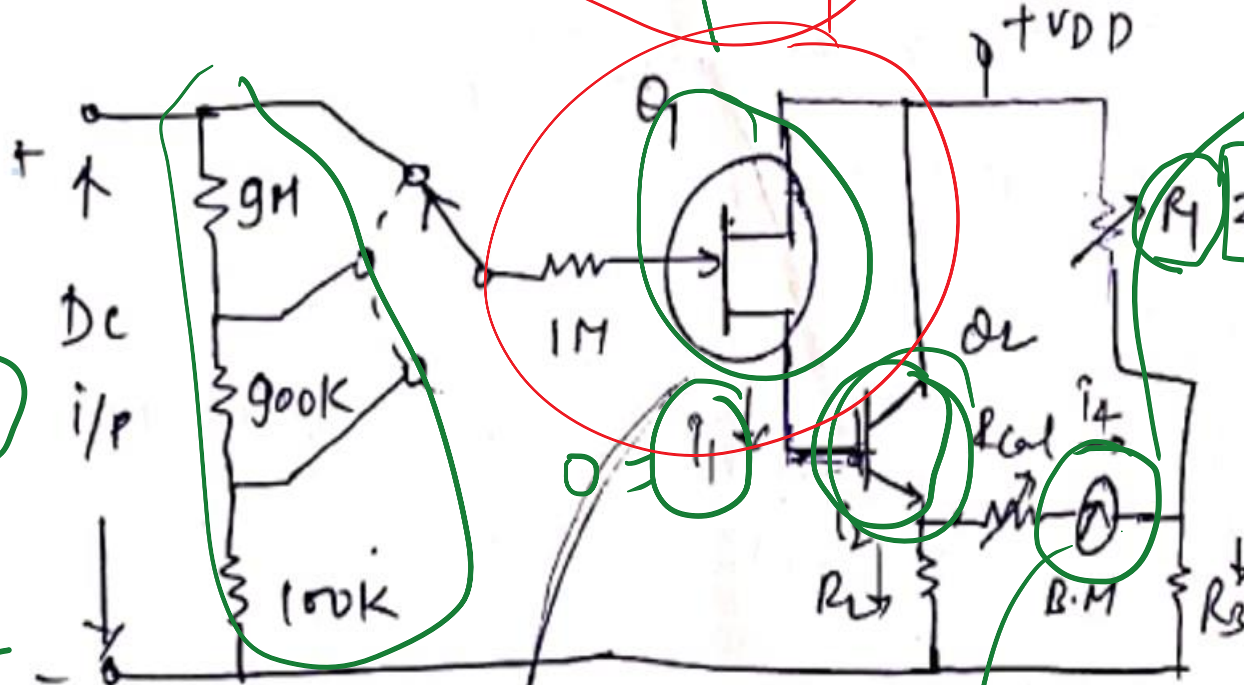


Input →

High I/P Imp

Meter

Moving coil



$= 0$

v_i

$0 = i_1$

$i_2 = i_3$

$\boxed{i_4 = 0}$

Balancing condition

Reading = zero

$i_2 \neq i_3$

$\boxed{i_4 \propto v_i}$

↳ voltage Reading

→ Q_2 with Resistor form balanced bridge

→ Bridge balance obtaine by R_f

→ zero i/p → meter show zero

→ bias on Q_2 is such $i_2 = i_3$ when i/p = zero

→ in this condition $i_4 = 0$

→ when i/p is applied bias on Q_2 inc^r

→ V_x inc^r

→ i_4 flows through meter

→ deflection of meter $\propto$ i/p voltage

FET

Advantage ;

(i) High i/p impedance to isolate meter from measurment ckt

(ii) Amount of power drawn is very low

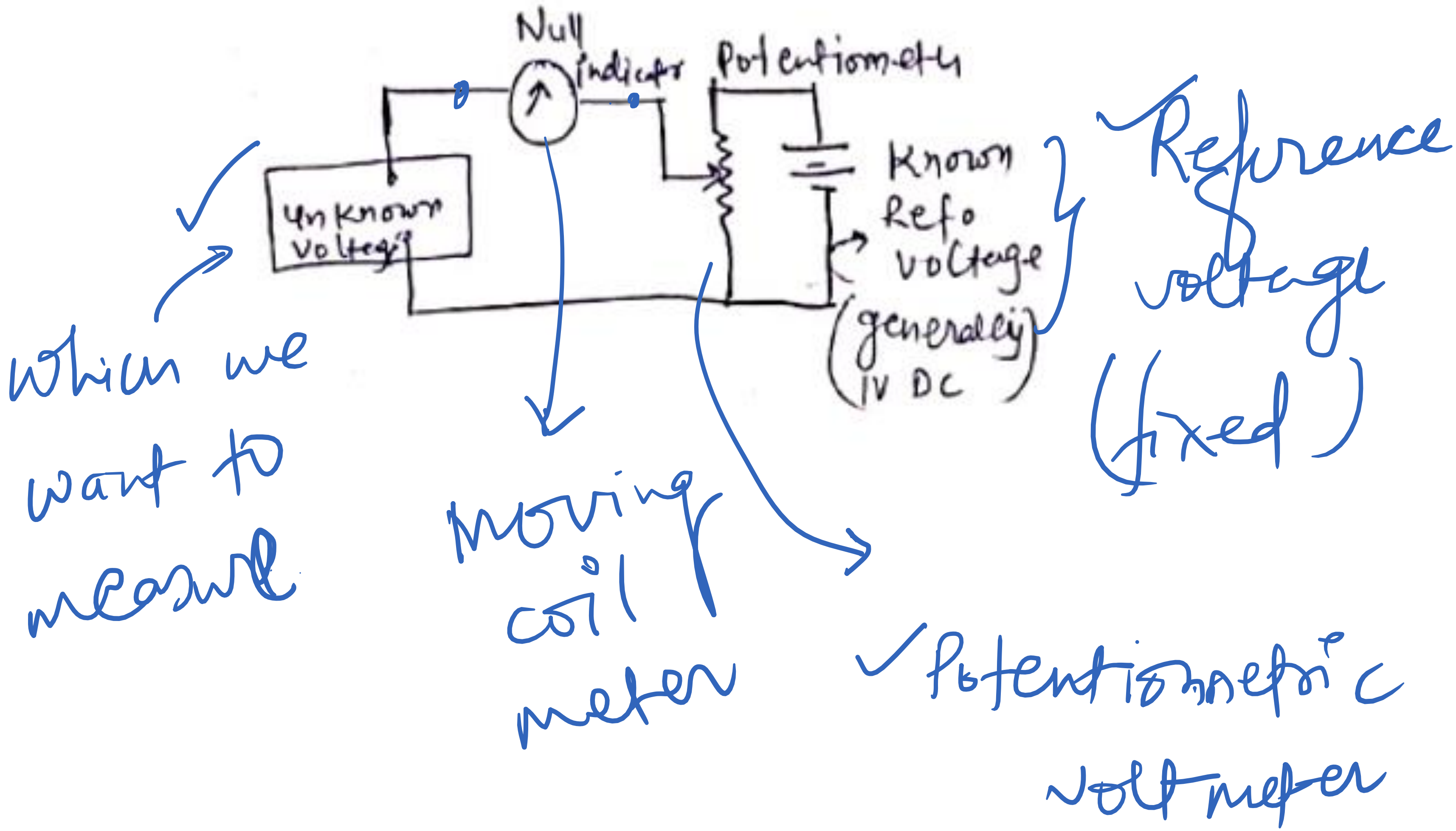
(iii) Sensitivity very high 10 time the PMMC meter

(iv) Can work in mV range

(v) overload can not damage the meter [Ampr saturates & limit current through meter]

② Differential voltmeter: (Analog/DC)

→ It indicates difference B/w Known & unknown voltages.
most common method of measuring unknown voltage.



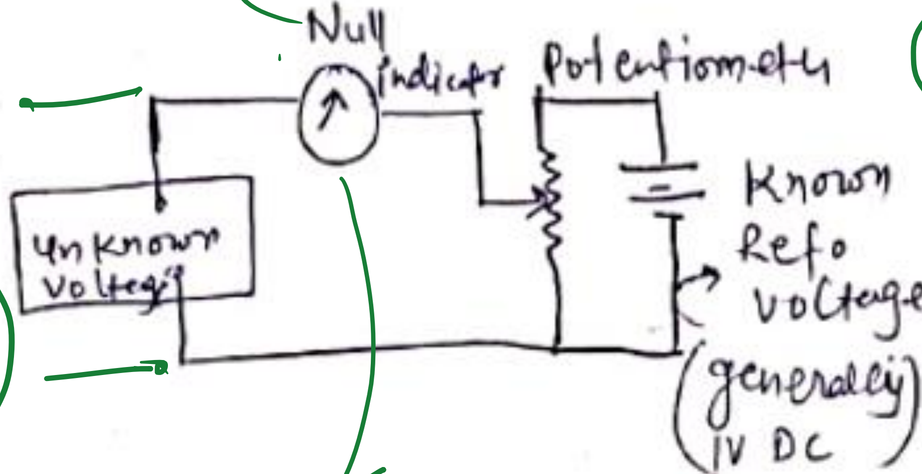
Zero Reading

X

5V

$V_i \neq 0$

Ref = unknown



Ref ↑ ↓

→ Null Meter

→ Principle similar to potentiometer hence also known as potentiometric voltmeter

→ Pot is varied till voltage across it becomes equal to unknown voltage

→ equality is indicated by null detector

- when two voltages are same, two ends of null meter are at same pot. hence $i=0$
- $i=0$ indicates ∞ impedance to unknown voltage
- under null condition, voltage across divider is fraction of the known voltage & it can be measured which is ~~not~~ nothing but unknown voltage

Advantage – very high accuracy

– high input impedance

disadvantage :– Need of high ref. supply for high voltage measurement

– loading effect.

AC

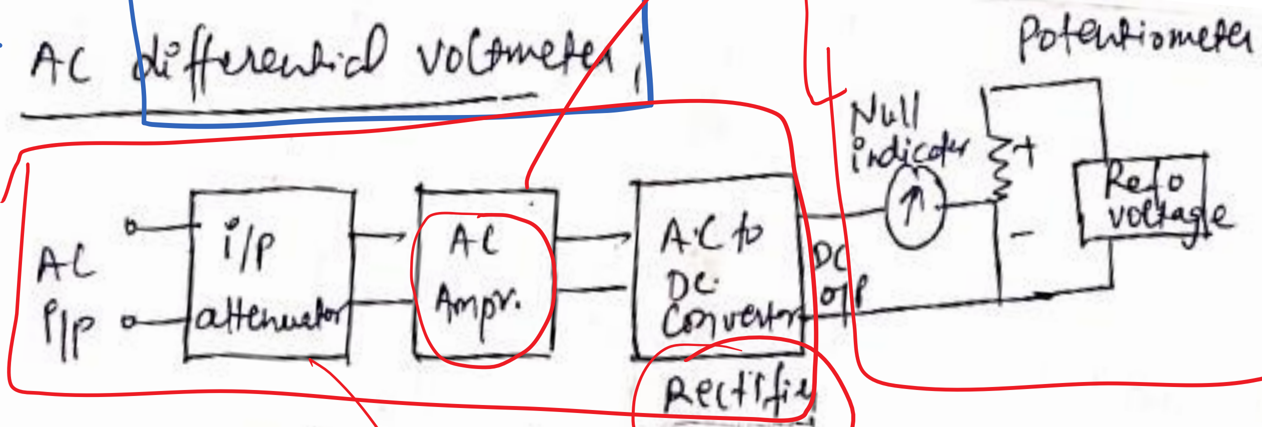
Rest

sensitivity

pure AC Amp ↑↑

AC differential voltmeter;

dc diff voltmeter



→ AC is applied at the i/p

→ AC applied to att. consisting no. of resistors used in voltage divider

→ att. o/p → to ampr

→ Ampr o/p → converted to DC using precision rectifier ckt.

i/p attenuator

AC + D~~C~~

AC → DC

↓↓ dc

AC

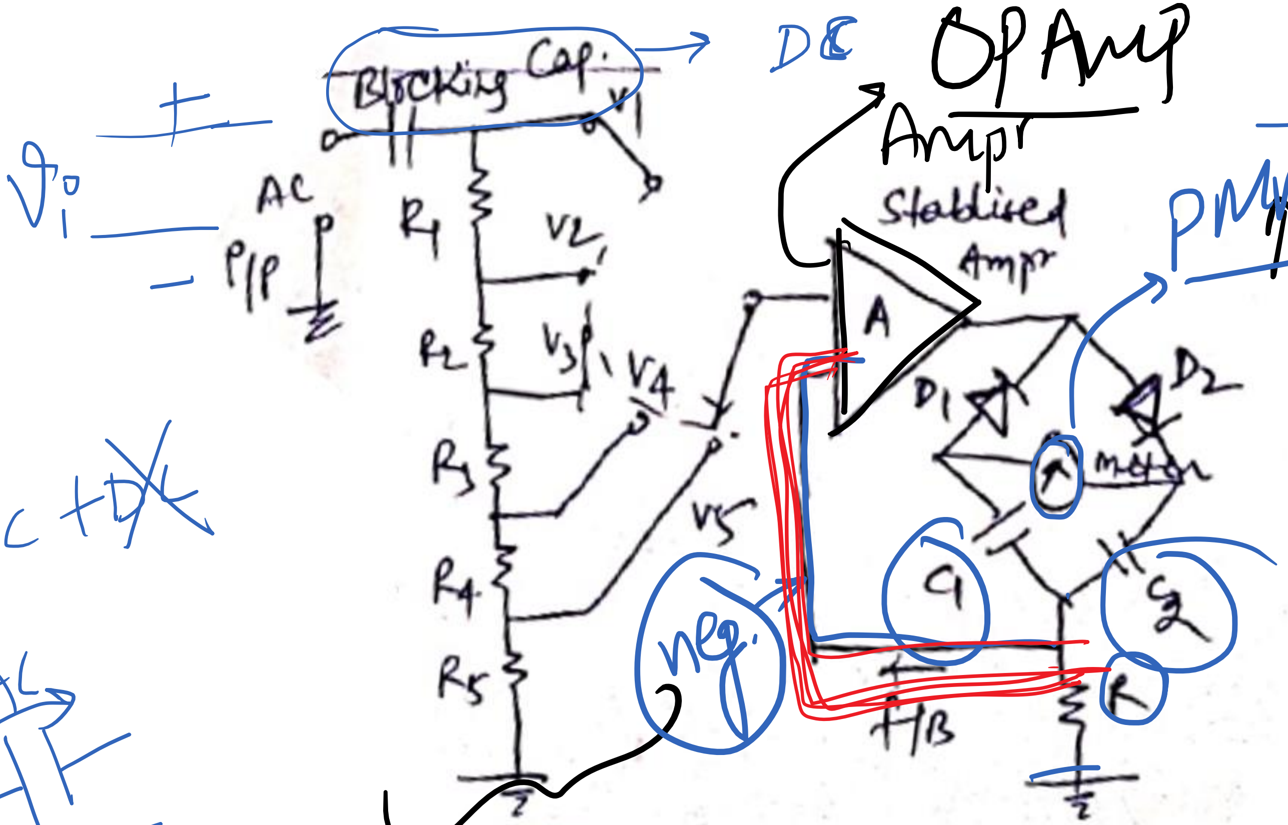
Average responding voltmeter:

AC / Analog voltmeter

OpAmp

$DC \Rightarrow f = 0$

$AC : f$



$$X_C = \frac{1}{2\pi f C}$$

$$X_C = \frac{1}{\omega C}$$

AC + ~~DC~~

AC

DC ×

DC

$X_C = \infty$

Range selector

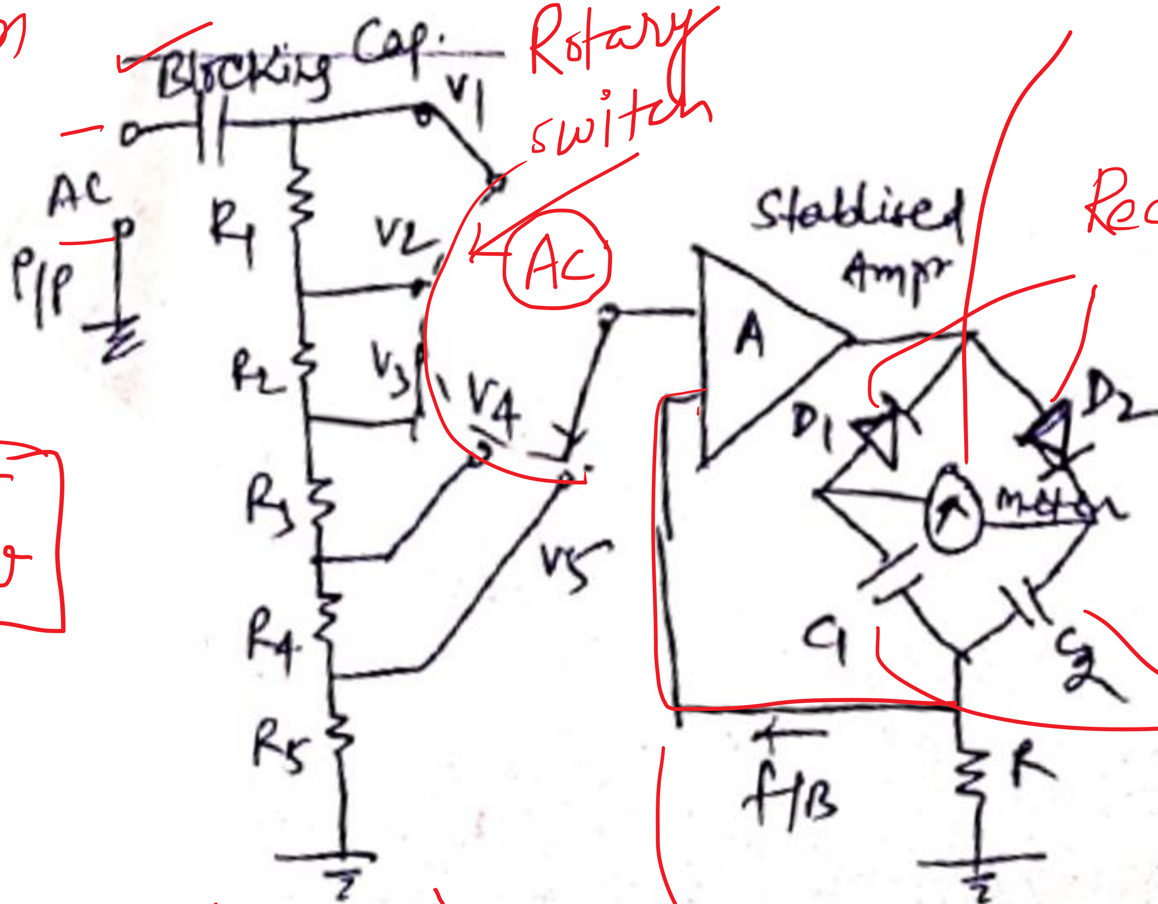
$$X_L = \omega L = 2\pi f L$$

AC

~~AC+DC~~ DC

PMMC

unknown voltage AC input signal



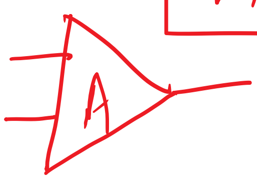
Rectifying diode

↳ AC → DC

Pulsating

filtering cap.

μV
mV



op-amp

↳ √ + → osc

→ ⊖

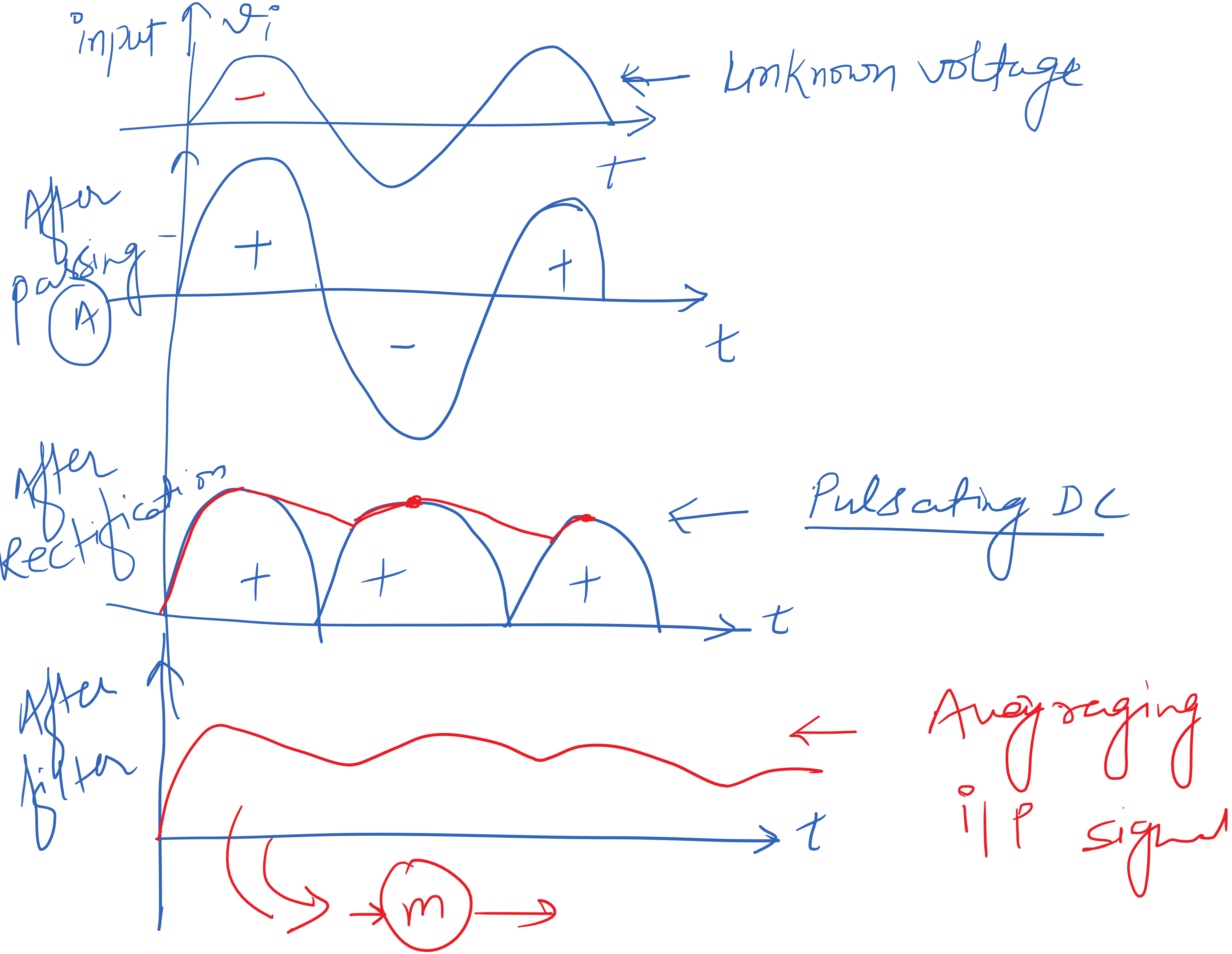
↳ Ampr → stability

voltage divider

Range selector

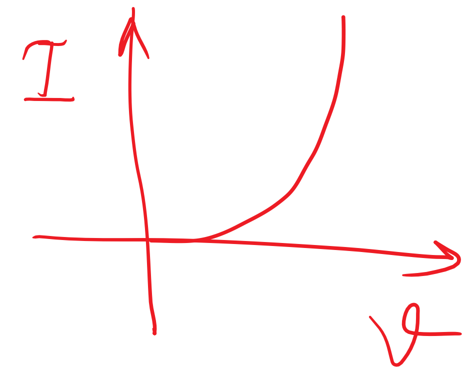
① High I/P Impo

② Ampr (input is low)



input
v_i
Unknown voltage
t
After passing
A
t
After rectification
Pulsating DC
t
After filter
Averaging
i/p signal
t
m

→ AC i/p amplified by A upon required level
→ This voltage then rectified using D_1 & D_2
→ rectified voltage fed to dc milliampammeter
→ Current obtain from rectifier is averged by using a filter to produce steady deflection of meter pointer.



→ blocking cap. used to blocks any dc compo in the i/p
→ negative f/B is used to ensure stability for measurment
→ Effect of diode nonlinearity is minimised by including meter in f/B p
→ C_1 & C_2 = storing cap. / filter cap. acts as coupling capacitor in f/B pa
→ rectified current is averaged using filter, the meter responds to avg. reading of i/p

Advantage – diode non linearity minimised
– variation in meter impedance are compensated by negative feed back
– high freq range
– high i/p impedance

O p-amp

Disadvantage : distorted, nonuniform, nonsinusoid produce e in readi
: accuracy of meter depend on phase also.

FET voltmeter;

1. Difference Amplifier Type FET voltmeter
2. Source follower type FET voltmeter

To incr i/p impedance

MOSFET

Transistor

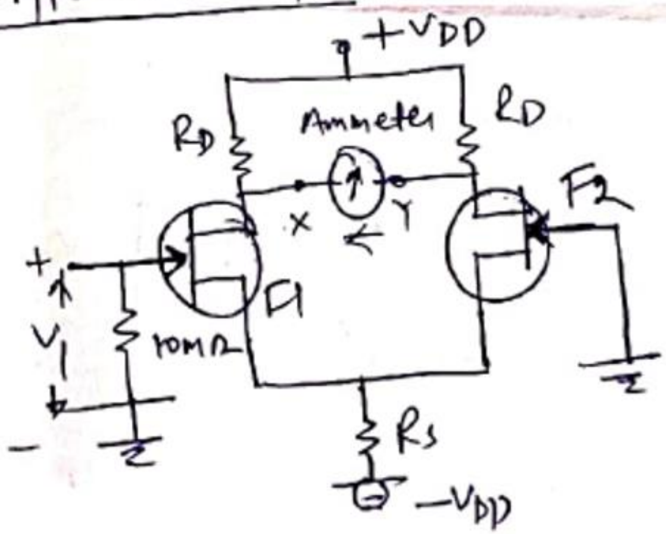
FET → Field effect Transistor

High sensitivity

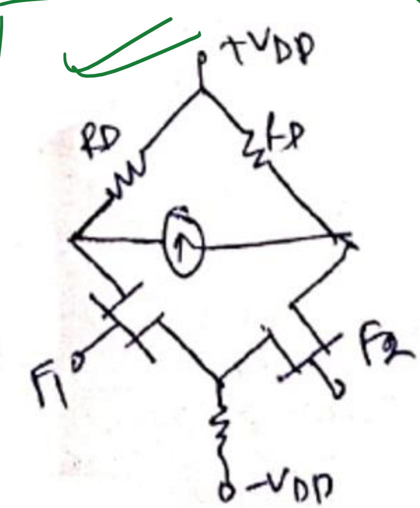
Analog / AC

Difference Amplifier Type FET voltmeter;

(differential ampr)



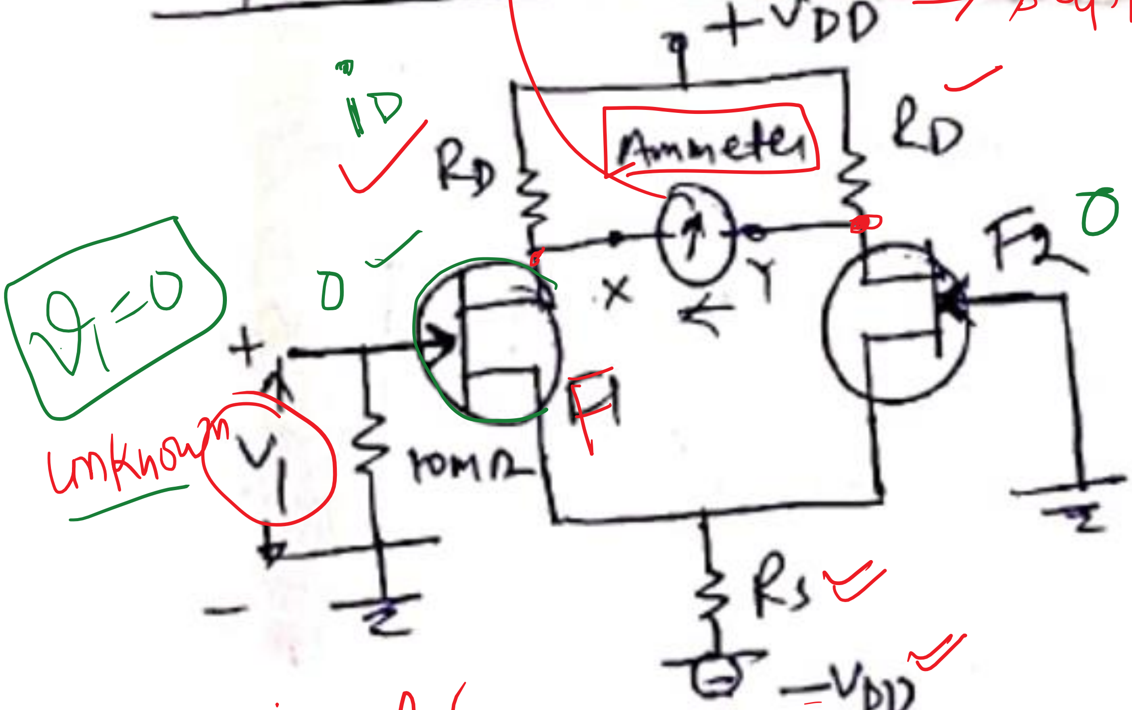
Bridge Type FET voltmeter



PMMC = zero

Difference Amplifier Type FET voltmeter ;

(differential ampr)



F_1, F_2 are two identical FET

⇓

Same char

BJT → E, B, C

Differential form

unknown voltage ∝ current in the meter

BJT Vs. FET

→ F_1 & F_2 two FETs have matching char
reqr for thermal stability.

→ An incr in source current in one FET is offset by corresponding decr in the source current of other FET.

- R_D – upper arm of balanced bridge
- F_1 F_2 – lower arm

– Bridge is balance for two identical FET zero i/p produce zero current through indicating ammeter

– when neg. dc applied to gate of F_1 current will flow through ammeter

→ magnitude of this current is proportion to input voltage.

Thermal stability of FET > BJT

Thermal runaway

paralex error

Digital voltmeter:

ADC → 0,1 → binary, octal Hex BCD

↳ converts the analog signals into digital & display the voltages to be measured as discrete numericals instead of pointer deflection. → 0, 9

PMMC

Advantages — (i) less human reading errors
(ii) wide range (1v to 1000v)
(iii) highly accurate (±0.005% of reading)

least

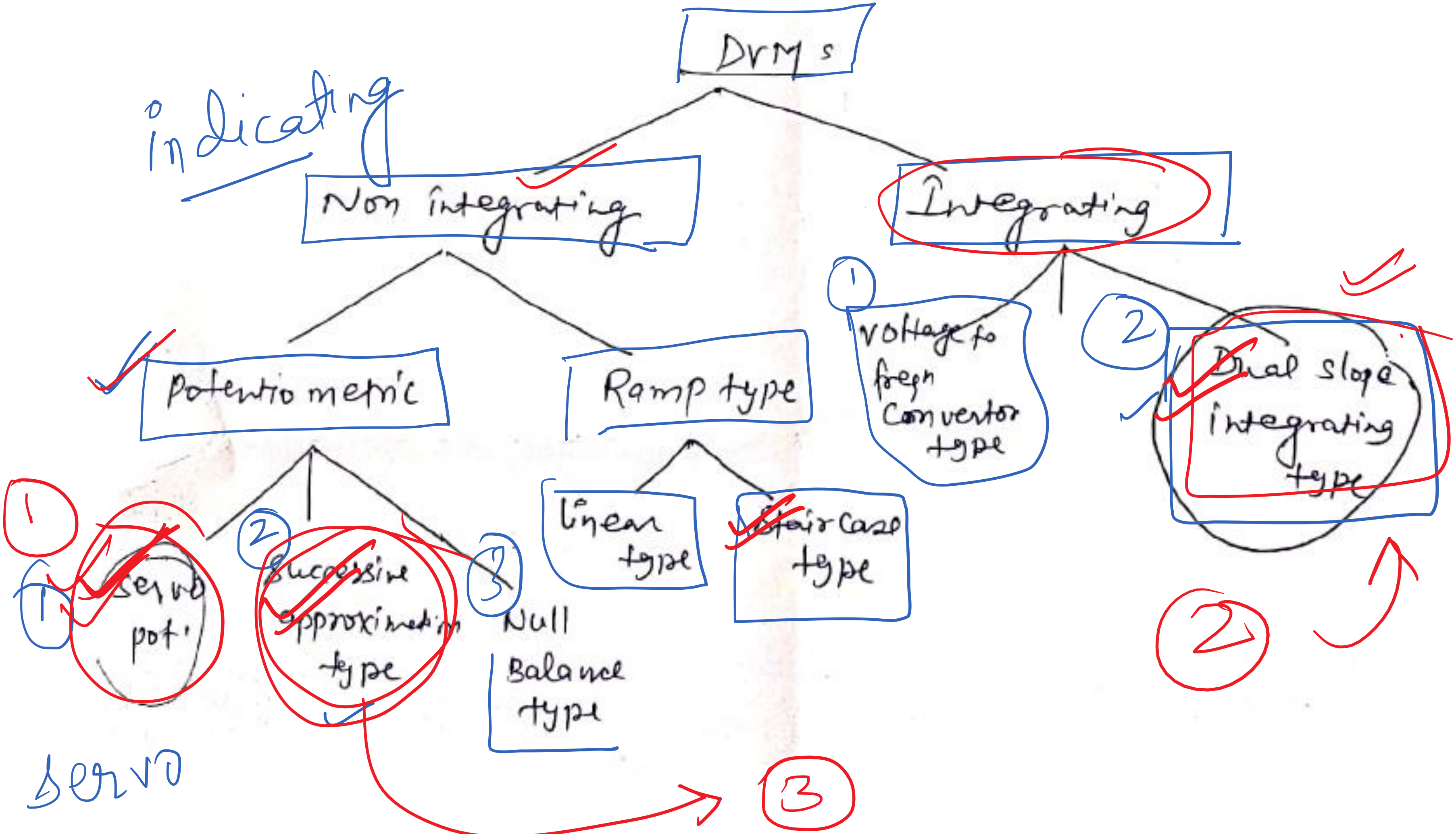
→ (iv) better resolution (1μv) $\boxed{10^{-6}V}$ → pointer
(v) High i/p impedance (≃10 MΩ) → incr sensitivity
(vi) High reading speed.

seven seg. LED

(vii) Can be programmed & computerised control.
(viii) with development of IC chips, Cost of DVM's is low
(ix) portable (small size)
(x) Internal calibration not dependent on measuring ckt.
(xi) BCD o/p can be printed or used for DSP
(xii) Addition ckt can be installed to measure, pressure current, impedance, cap. etc

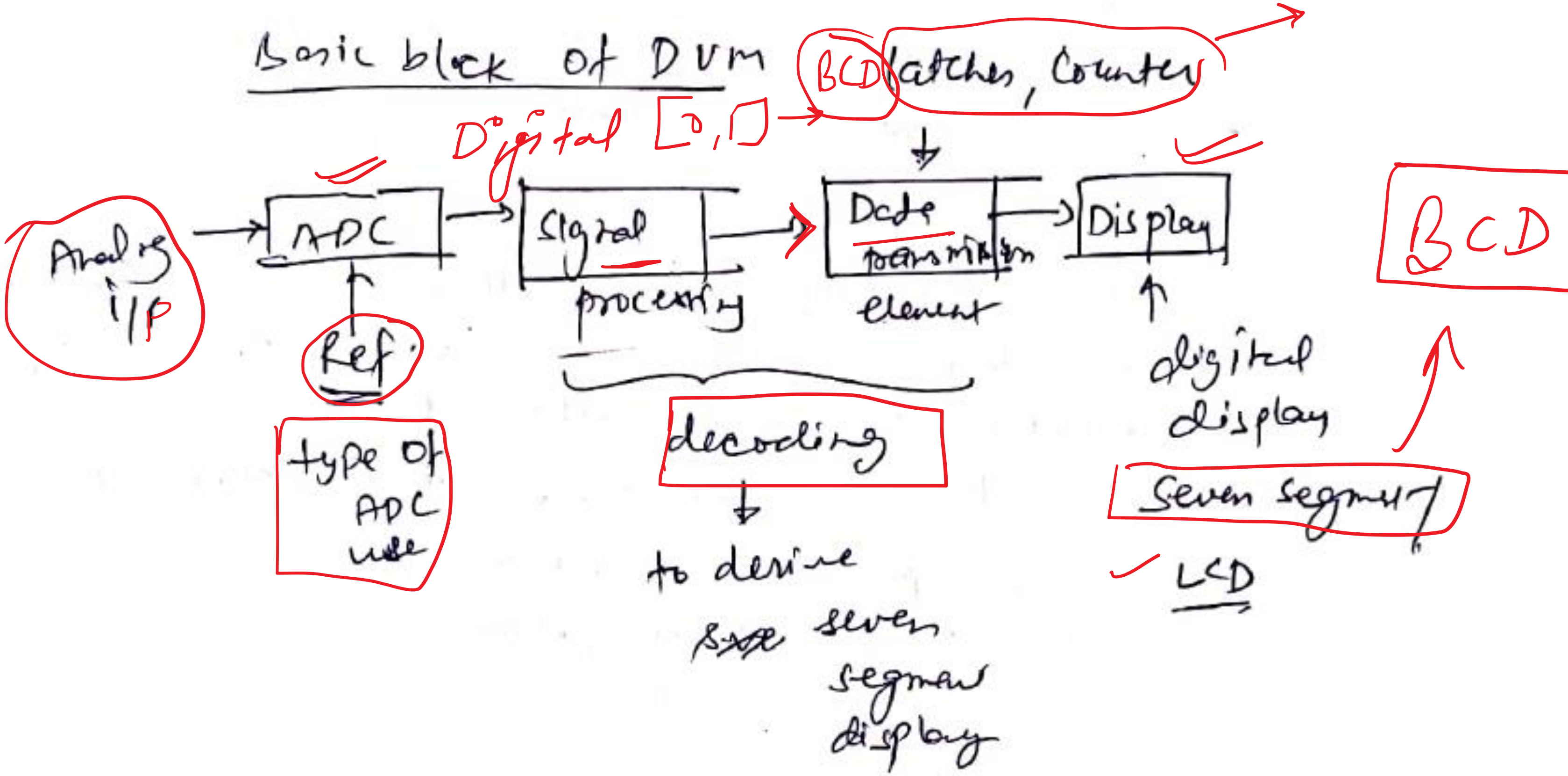
0 0

9 9

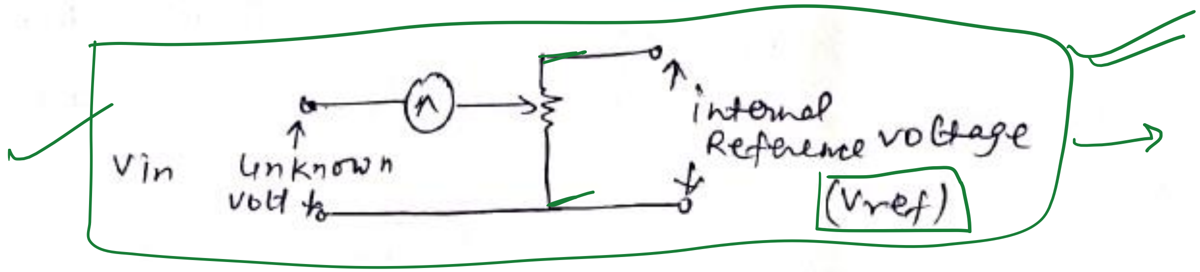

DVMs
indicating
Non integrating
Integrating
Potentiometric
Ramp type
voltage to freqn Convertor type
Dual slope integrating type
1
2
Servo pot.
Successive approximation type
Null Balance type
Linear type
~~Staircase~~ type
3

Servo
DVM

General Block diagram of DVM :-



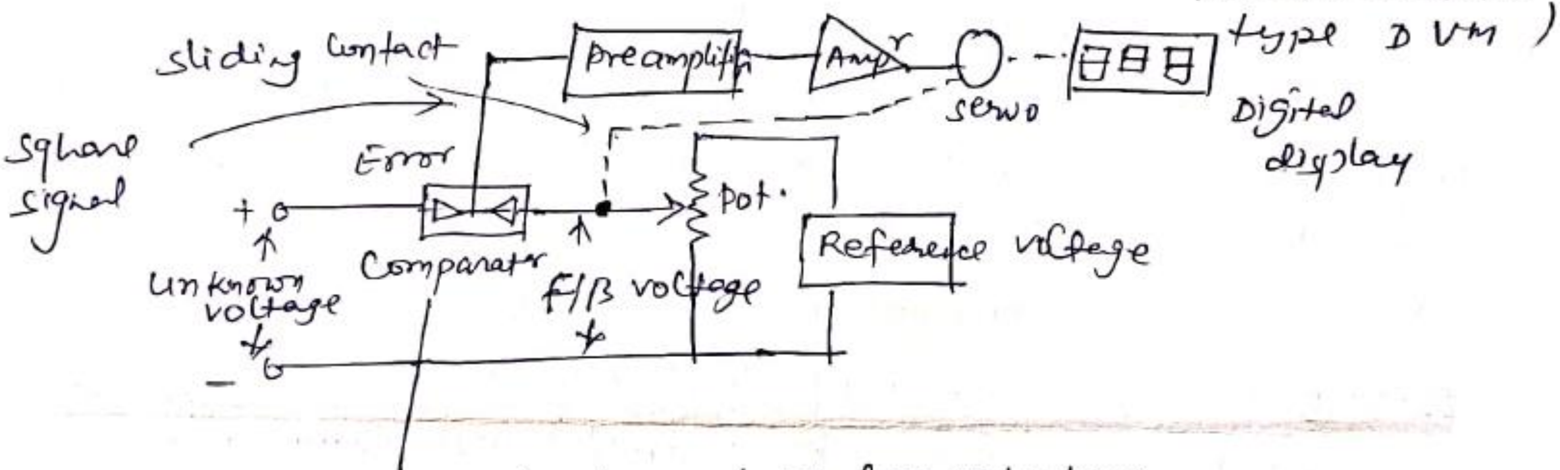
Servo potentiometric Type DVM;



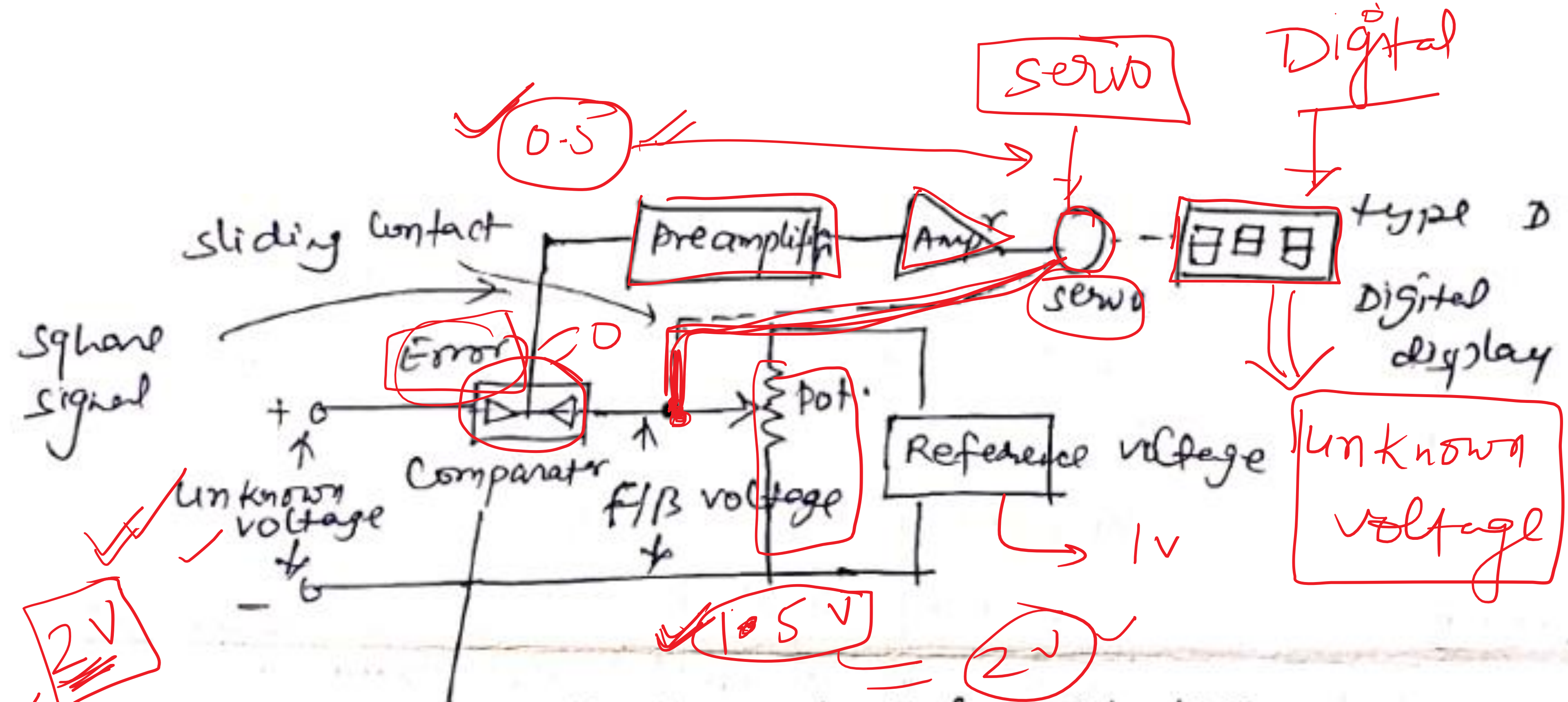
Analog Voltmet

→ voltage comparision tech' is used to measure i/p voltage

In DVM; null balancing is obtained automatically using servomotor. this is called as (self balancing potentiometric type DVM)



Mechanical Chopper type Comparator.



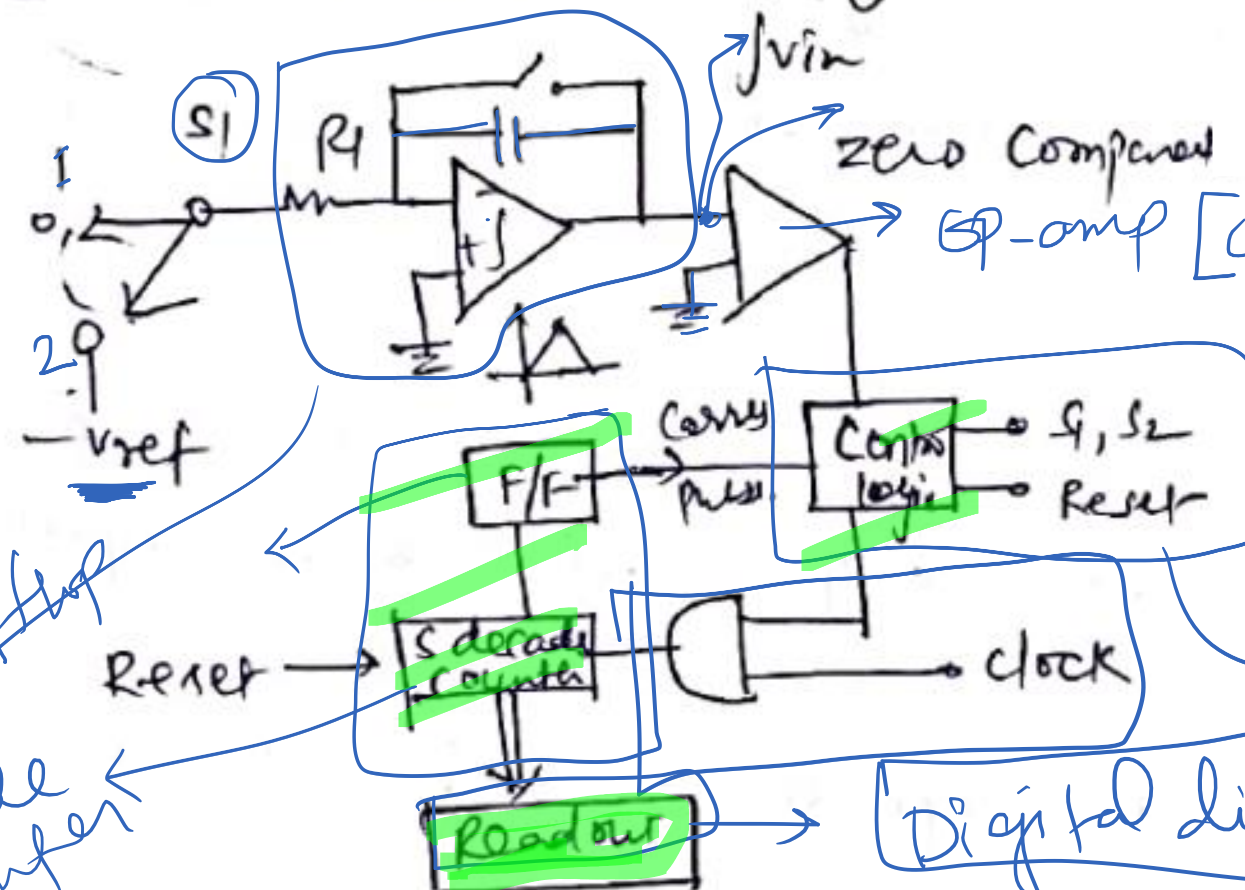
Mechanical chopper type Comparator.

dual slope integrating DVM ①

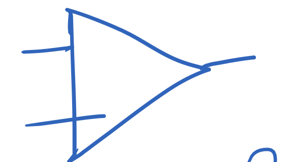
$\boxed{5 \text{ blocks}}$

Int, comp, clock pulse gen. decimal counter, control logic

v_{in}



op-amp [comparator]



op.amp

flipflop

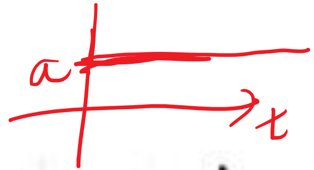
decade counter

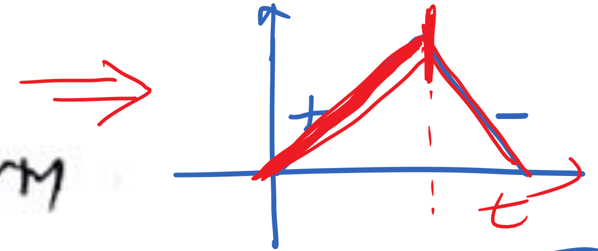
control logic

Digital display

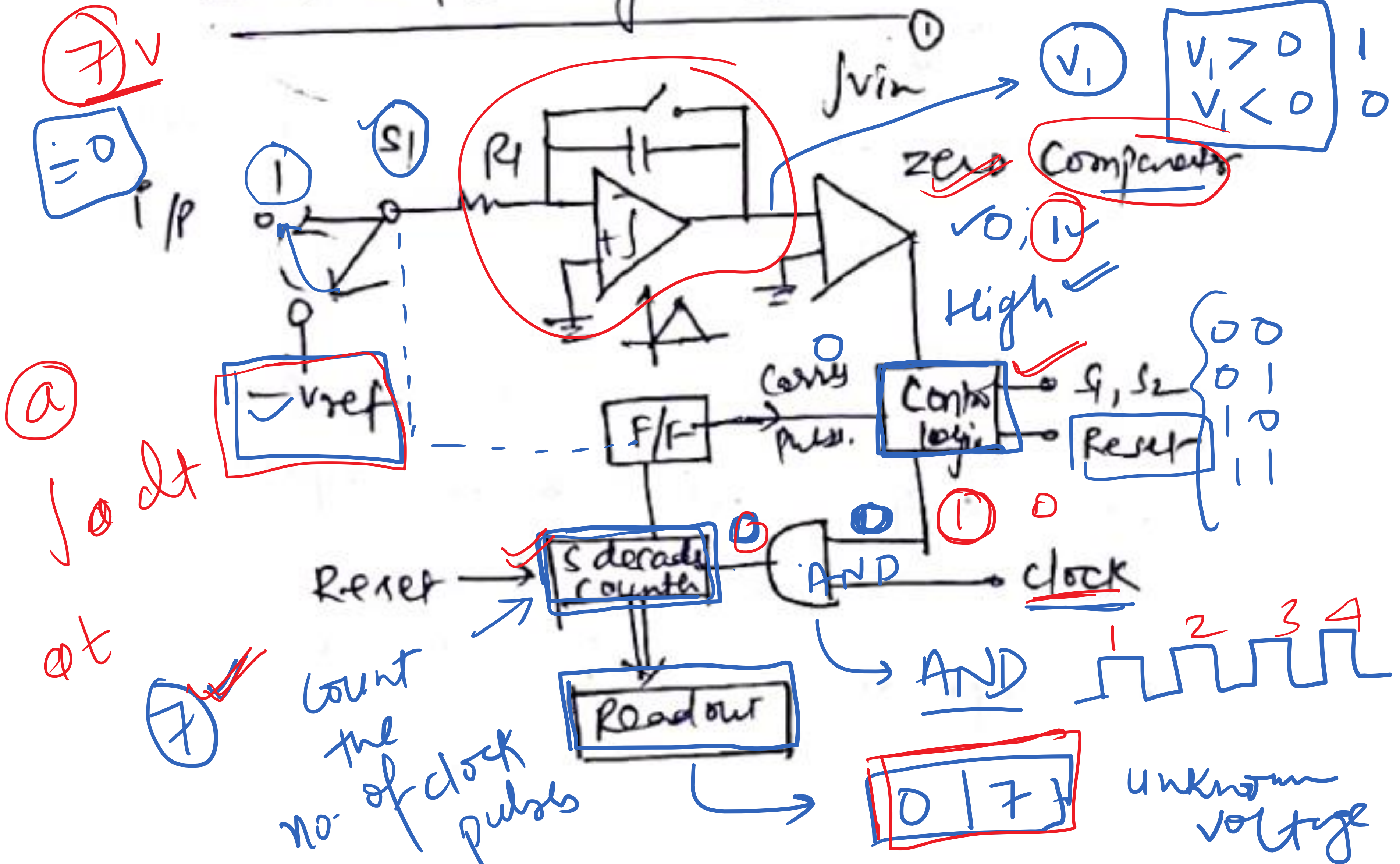
integrating $v_o = \int v_{in}$

$\int c\,dt = ct$





dual slope integrating DVM



Step ① Counter reset to zero
O/P of F/F = zero
given to control logic
control logic ~~sends~~ sends command
to put S_1 at ①

integration starts
till t1

→ zero comparator o/p changes
→ signal to control logic which
opens the gate &
counting of clock pulse
starts

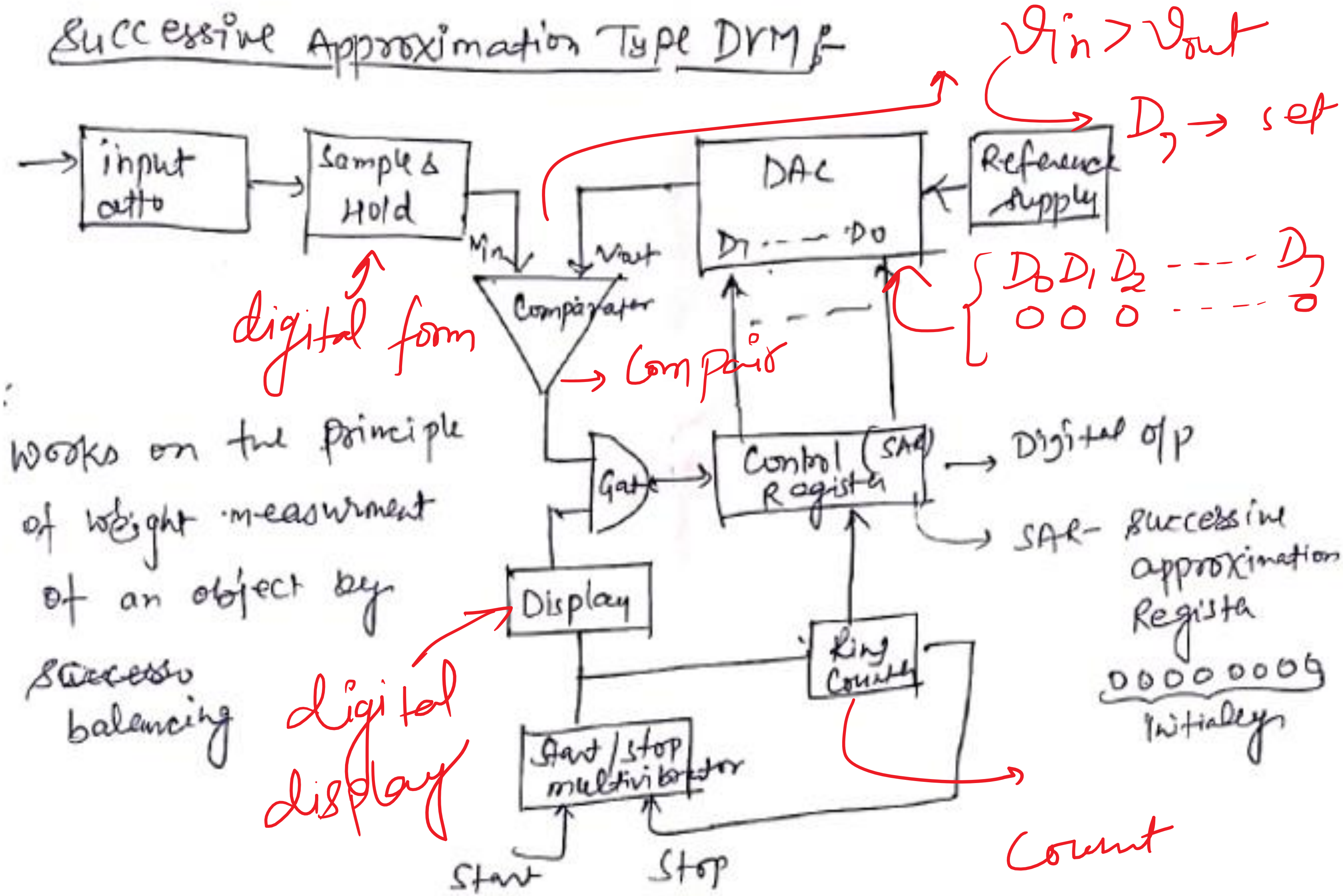
—

case ① S_1 — $-\frac{V_{in}\, t_1}{R_1 C} = V_{o1}$

S_{ref} — $\hookrightarrow -\frac{V_{ref}\, t_2}{R_1 C} = V_{o2}$

Counter counts pulse & when reaches 9999 it generates
a carry ~~flag~~ pulse and all digits go to zero.
F/F o/p → activated to logic level 1 —
This activates the control logic. This sends
a signal which change S_1 position ② → $-V_{ref}$ connect to int. → Reverse
Cap discharge.

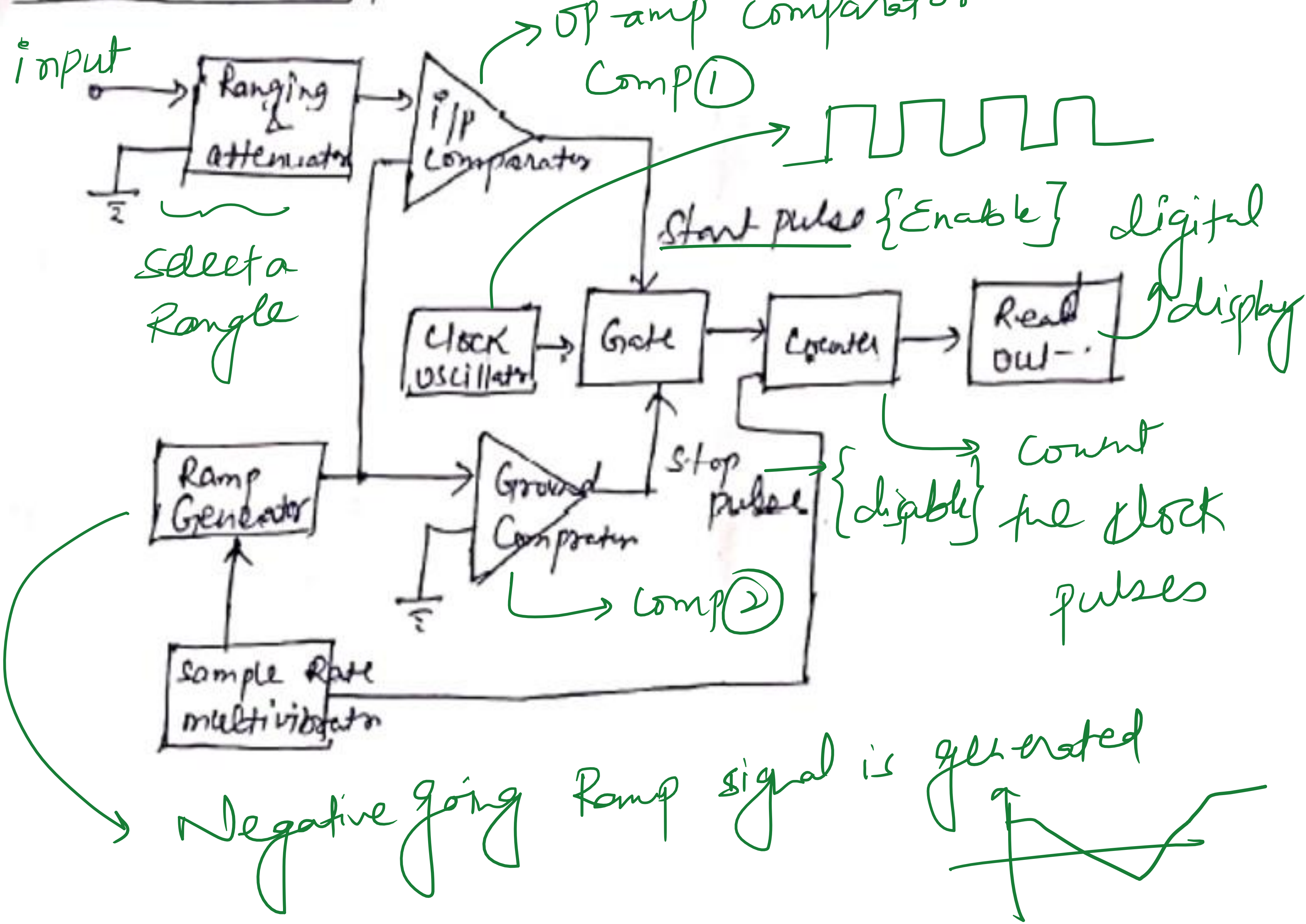
Successive Approximation Type DVM :-



works on the principle of weight measurment of an object by successive balancing

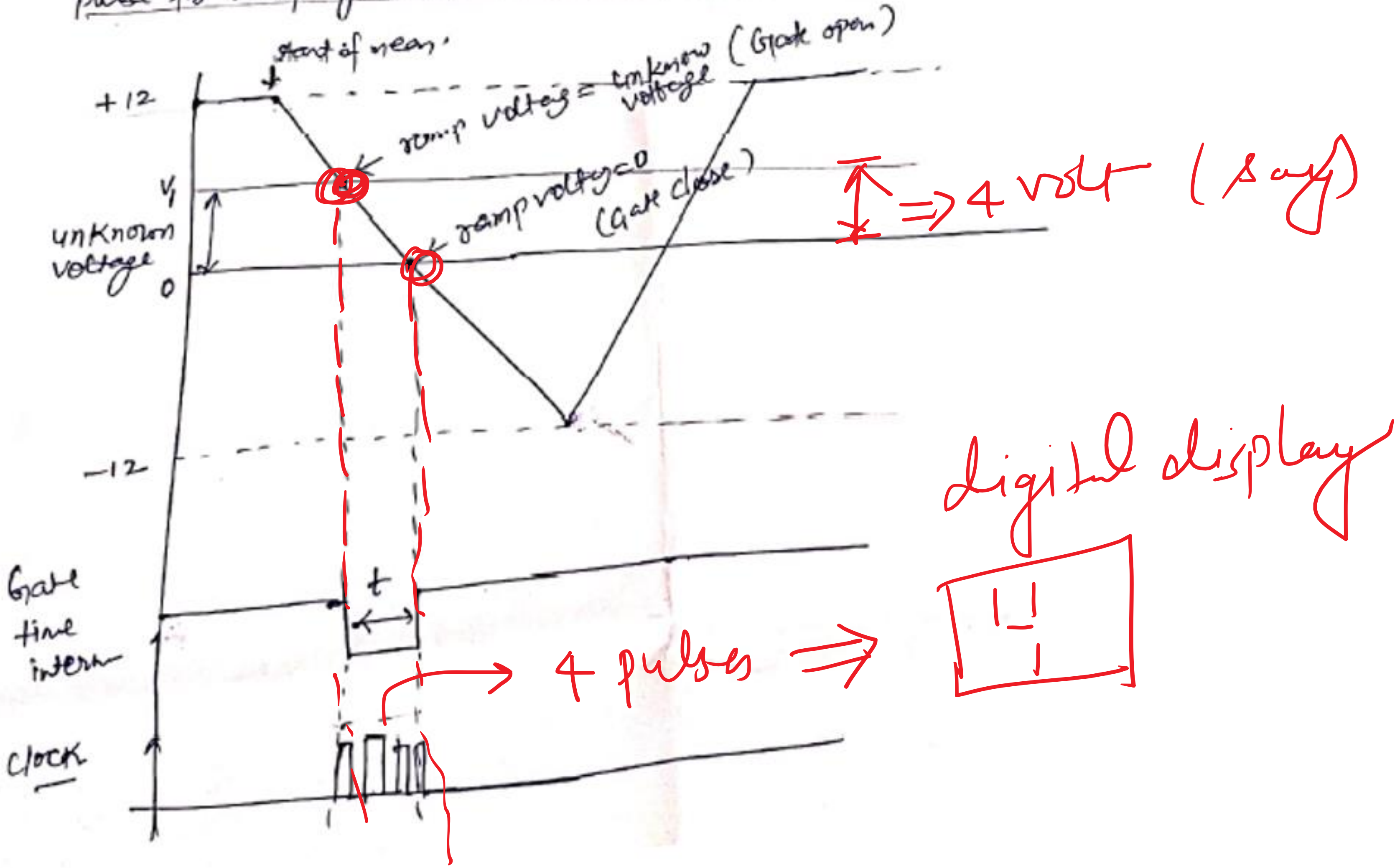
V_{in}	Operation	V_{out}								Compare	Comparator output	Action
		D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0			
00110011	D_7 Set	1	0	0	0	0	0	0	0	$V_{in} < V_{out}$	–Ve	D_7 Rese
00110011	D_6 Set	0	1	0	0	0	0	0	0	$V_{in} < V_{out}$	–Ve	D_6 Rese
00110011	D_5 Set	0	0	1	0	0	0	0	0	$V_{in} > V_{out}$	+Ve	D_5 Set
00110011	D_4 Set	0	0	1	1	0	0	0	0	$V_{in} > V_{out}$	+Ve	D_4 Set
00110011	D_3 Set	0	0	1	1	1	0	0	0	$V_{in} < V_{out}$	–Ve	D_3 Rese
00110011	D_2 Set	0	0	1	1	0	1	0	0	$V_{in} < V_{out}$	–Ve	D_2 Rese
00110011	D_1 Set	0	0	1	1	0	0	1	0	$V_{in} > V_{out}$	+Ve	D_1 Set
00110011	D_0 Set	0	0	1	1	0	0	1	0	$V_{in} > V_{out}$	+Ve	D_0 Set

Ramp Type DVM:



→ Based on voltage to time conversion technique.

→ The sample rate multivibrator determines the rate at which the measurements cycles are initiated it also provides initiating pulse for ramp generator to start its next ramp voltage.



Digital multi meter:

→ capable of measuring a.c voltages, dc voltages, ac and dc currents and resistances over several ranges.

Voltage AC / DC

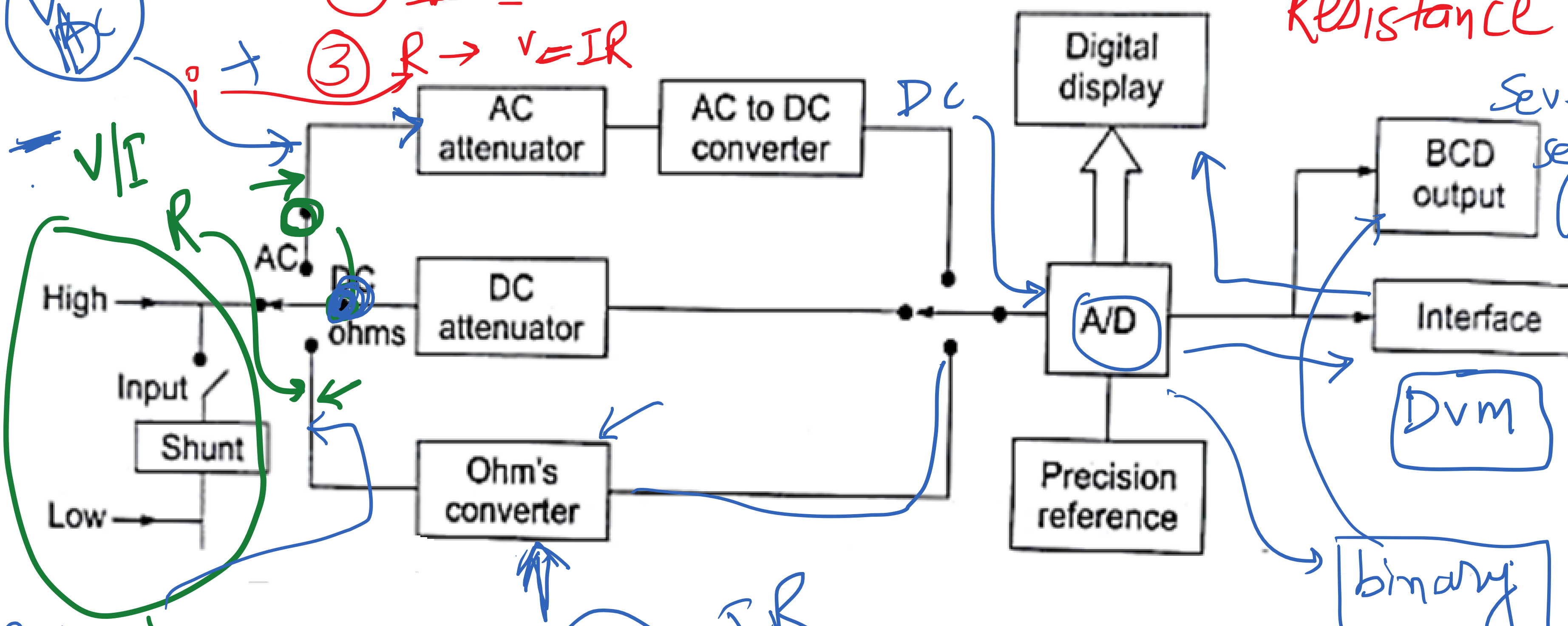
Current AC / DC

Resistance

① AC → DC → Digital → $\boxed{\text{Digital}}$

② V → I →

③ R → V = IR



V/I

R

DC

Seven seg.

DVM

binary

V = IR

DC

R

Protection

CRT

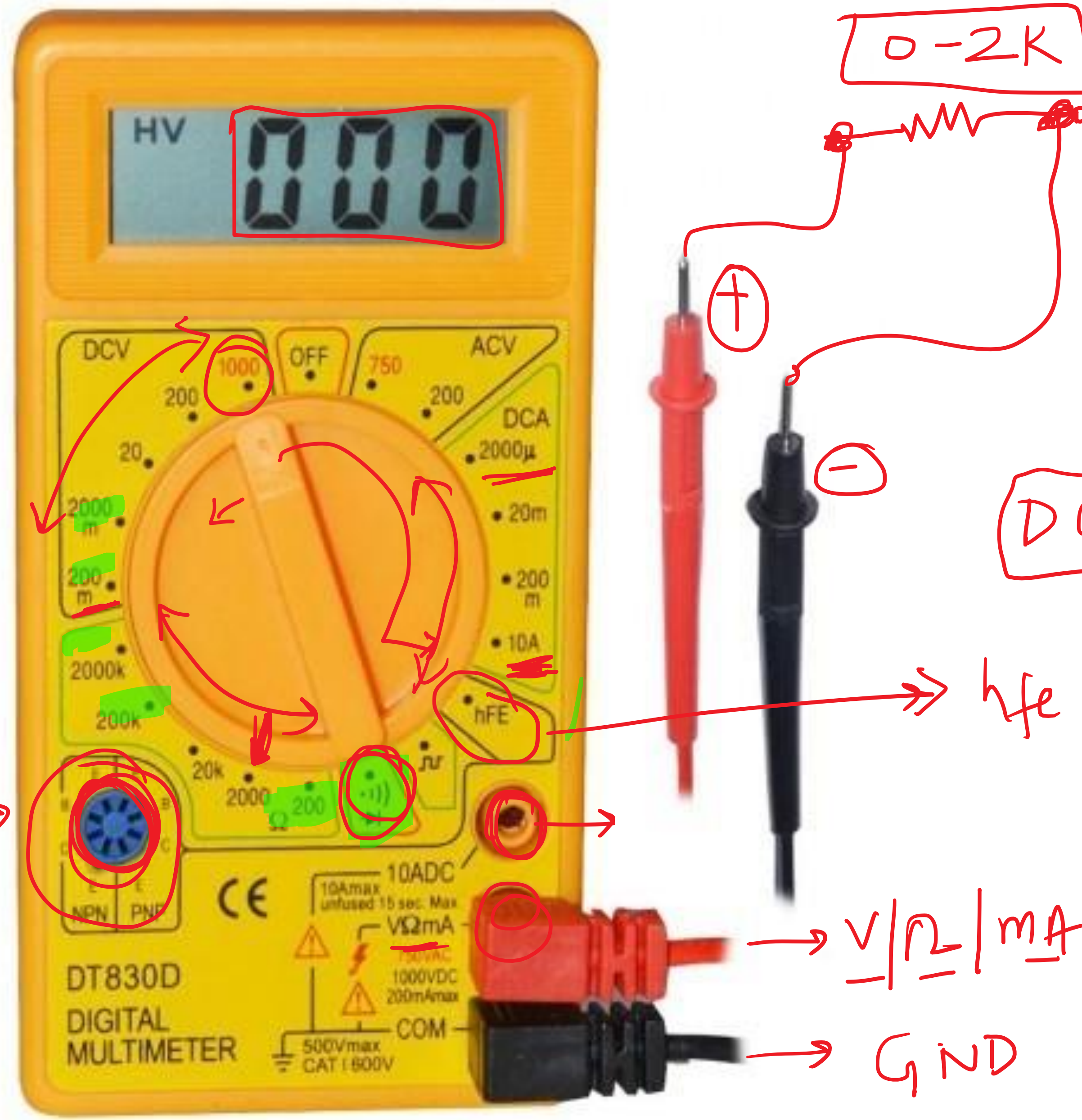
~~DW~~

DCV

BC107

NPN|PNP

Tr



DCA

hfe going

Tr

V|Ω|mA +

GND −

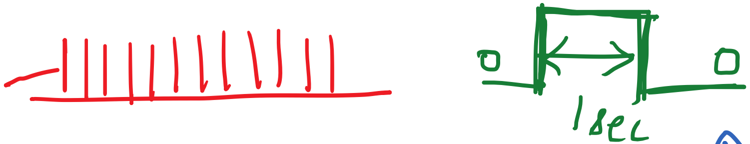
→ Current is converted to voltage by passing through low shunt resistance

→ A.C quantities are converted to d.c. by using rectifiers

→ All quantities are digitised using A/D convertors & displayed ~~on~~ in digital form on the display

→ Advantages

↳ { low price, small size, immune from electric noise
{ can be used with external equipment



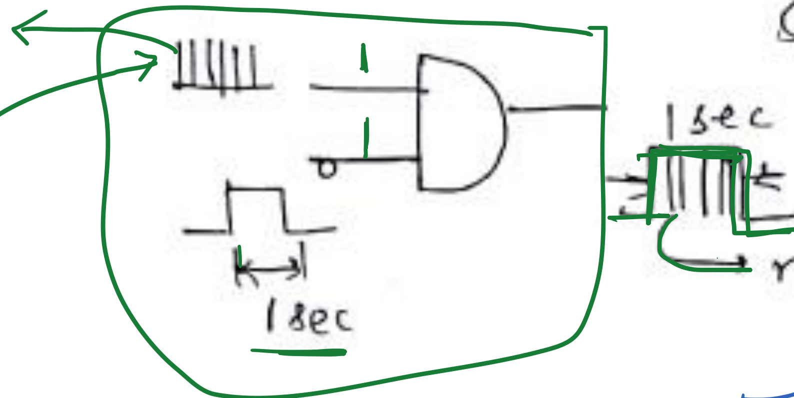
Used to measure freqn

Digital Freqn meter :

$f = \frac{N}{t}$

1 sec

Signal → trigger pulses



no. of pulses counted = freqn.

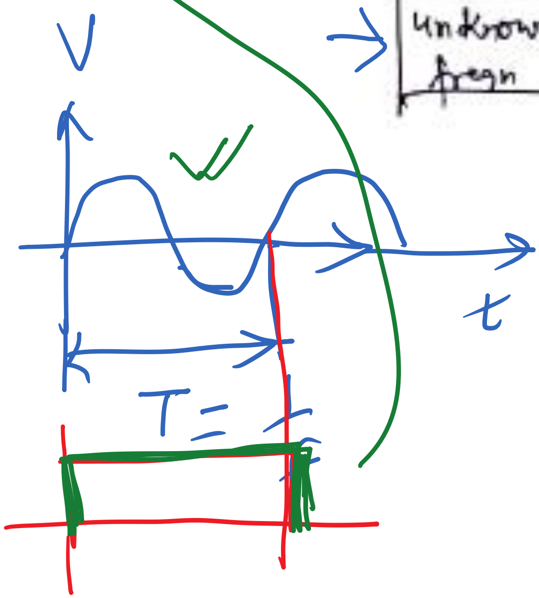
Tr $\boxed{555}$

NAND

→ Unknown freqn → Ampr → Schmitt trigger → Start/stop gate → Digital read out

Ampn

Enable/disable



Analog signal → Square signal
(sinusoidal)

Imp.

Q - meter:

↳ Device used for testing radio freq coils (RFC), inductor and capacitors.

$$Q = \frac{\omega_0 L}{R}$$

Q - storage factor

ω_0 = resonant angular freq^n

L = inductance

R = effective resistance of coil

↳ never determined directly (depends on freq^n)

Q meter is an instrument which is designed to measure the value of Q; directly & very useful in measuring characteristics of coils and capacitors.

$$Q = \frac{\omega_0 L}{R}$$

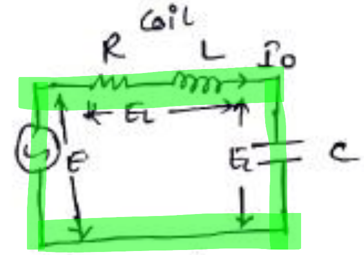
→ angular Reso freq^n

→ Inductance

→ Resistance

Working principle:

↳ series resonant ckt



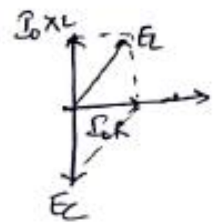
at resonant freq^n f_0

$$X_C = X_L$$

$$X_C = \frac{1}{\omega_0 C} = \frac{1}{2\pi f_0 C}$$

$$X_L = \omega_0 L = 2\pi f_0 L$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



current $I_0 = \frac{E}{R}$

voltage across cap. $E_C = I_0 X_C = I_0 X_L = I_0 \omega_0 L$

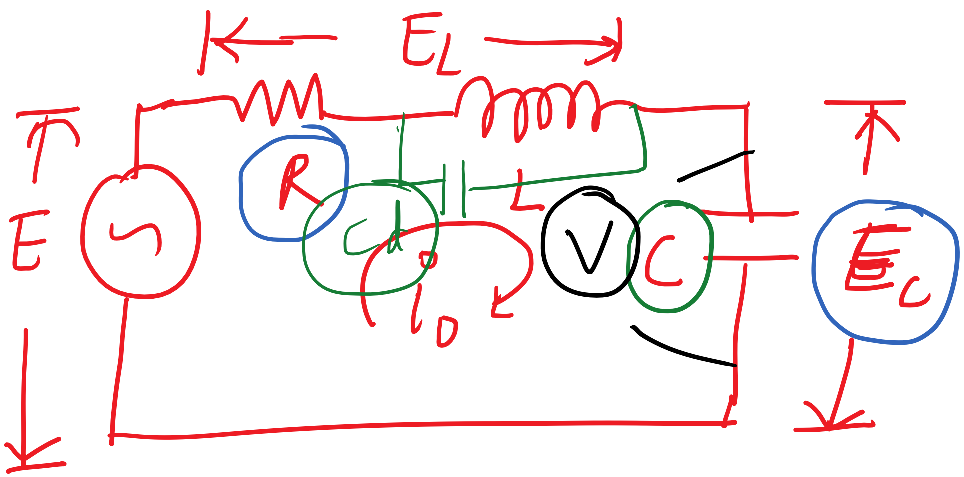
input voltage $E = I_0 R$ $\therefore$ $\frac{E_C}{E} = \frac{I_0 \omega_0 L}{I_0 R} = \frac{\omega_0 L}{R} = Q$.

$$\boxed{E_C = QE}$$

input is magnified Q times.

Working Principal of Q-meter :

Series Resonant ckt :



$$i_0 = \frac{E}{R}$$

$$Q = \frac{E_C}{E}$$

$$\boxed{E_C = Q E}$$

at Resonance

$$X_C = X_L$$

$$Z = \sqrt{R^2 + \cancel{(X_L - X_C)^2}}$$

$$Z = R$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \qquad \omega_0 = \frac{1}{\sqrt{LC}}$$

$$X_C = \frac{1}{\omega_0 C} \qquad X_L = \omega_0 L$$

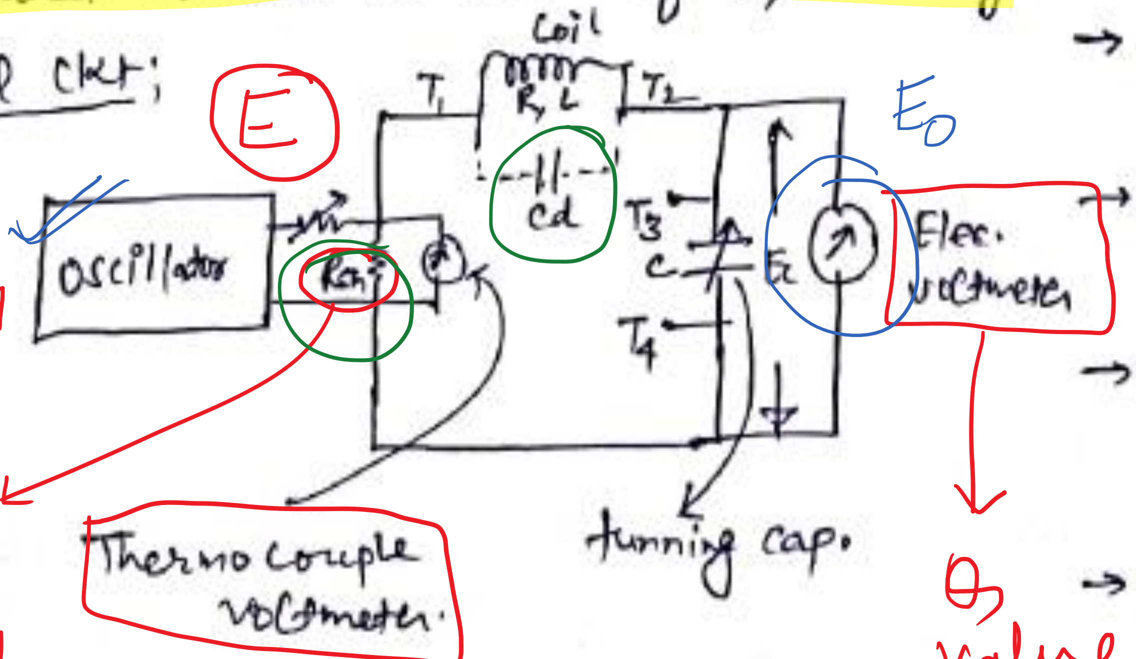
$$E_C = i_0 X_C = i_0 X_L$$

$$E_C = i_0 \omega_0 L$$

$$E_C = E \left(\frac{\omega_0 L}{R}\right) \rightarrow Q$$

If i/p voltage is kept const, the voltage appearing across the capacitor is Q times E and a voltmeter connected across the cap. can be calibrated to read the value of Q directly.

Practical ckt;



→ self contained variable freq oscillator

→ deliver current to low value Rsh $I_{s\,0.02\Omega}$

→ Through Rsh – small value of E injected into ckt.

→ E is measured by a thermocouple voltmeter

Rsh ↳ low value (0.018 Ω)

Q value

$$\boxed{Q_{th} = \frac{\omega_0 L}{R}}$$

Q_{mes}

Applications:

① **Measurement of Q:** Oscillator set at desired freq. & then tuning cap. is adjusted for maxm value of E_0. Under this condition $Q = E_0/E$; if the voltage kept const., the voltmeter connected across the cap. may be calibrated to read Q directly.

The measured value is Q of whole ckt. not of the coil & also errors caused on account of shunt resistance & also due to distributed cap. of ckt.

$$\boxed{Q_{mes} = \frac{\omega_0 L}{R + R_{sh}}} \qquad \boxed{Q_{true} = \frac{\omega_0 L}{R}} \quad R\uparrow$$

R_{sh} = I/P reso

$$\boxed{Q_{true} = Q_{mes}\left(1 + \frac{R_{sh}}{R}\right)}$$

at low Q – neglected.

at high Q → can't neglected. ↳ R↑↑

Correction for distributed capo ↳ self cap.

$$\boxed{Q_{true} = Q_{meas}\left(1 + \frac{C_d}{C}\right)}$$

R_{sh} = Series Res.

C_d = Self Cap.

$$Q_{true} = \frac{\omega_0 L}{R}$$

(2) Measurement of Inductance:

$$\boxed{L = \frac{1}{4\pi^2 f_0^2 C}}$$

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$$

(3) Measurement of Effective Resistance:

$$\boxed{R = \frac{\omega_0 L}{Q_{true}}}$$

(4) Measurement of self cap:

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_d)}}$$

C_1 = self cap.

$$\boxed{C_d = \frac{C_1 - n^2 C_2}{3}}$$

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2+C_d)}}$$

C_2 = self cap. at double fe.

$$\boxed{f_2 = 2f_1} \Rightarrow \boxed{C_d = \frac{C_1 - 4C_2}{3}}$$

$$\boxed{f_2 = n f_1}$$

(5) Measurement of B.W:

$$\boxed{Q = \frac{\omega_0}{B.W}} \Rightarrow \boxed{B.W = \frac{\omega_0}{Q} = \frac{2\pi f_0}{Q}}$$

$L = ?$ $R = ?$

Example 2.10: ***When connected to a Q-meter an inductor is made to resonate at 400 kHz. The Q-factor of circuit is found to be 100 and the capacitance of Q-meter capacitor is set to 400pF. Determine***

(a) the inductance ***(b) the resistance of inductance.***

Solution: Given $f_C = 400$ kHz

$f_0 = \underline{400\text{ kHz}}$

$Q = \underline{100}$

$C = \underline{400\text{ PF}}$

(a) At resonance

$$\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$$

$$2\pi f_r = \frac{1}{\sqrt{C}}$$

$$\Rightarrow \quad \boxed{L = \frac{1}{(2\pi f_r)^2 C}}$$

$$= \frac{1}{(2\pi \times 400\times 10^3)^2(400\times 10^{-12})}$$

$$= 396\ \mu\text{H}$$ **Ans.**

$P = 10^{-12}$

(b) Q-factor at resonance $= \dfrac{2\pi f_r L}{R}$

$$Q = \frac{\omega_0 L}{R} = \frac{2\pi f_0 L}{R}$$

$$\boxed{R = \frac{2\pi f_r L}{Q}}$$

$$= \frac{2\pi(400\times 10^3)(0.396\times 10^{-3})}{100}$$

$$= 9.95\Omega$$ **Ans.**

Example 2.13: The self capacitance of a coil is measured by a Q meter. The circuit is set into resonance at 2 MHz and the tuning capacitor is at value of 460pF. The frequency is now adjusted to 4 MHz and resonance conditions are obtained the tuning capacitor at 100 pF. Calculate the value of self capacitance of the coil.

$$C_d = \frac{C_1 - n^2 C_2}{n^2 - 1}$$

$$9$$

$$\boxed{C_d = \frac{C_1 - 4C_2}{3}} = \frac{460 - 4 \times 100}{3} = 20 \text{ pF}$$

$f_1 = 2 \text{ MHz}$

$f_2 = 6 \text{ MHz}$

$C_1 = 460 \times 10^{-12} F$

$C_2 = 100 \times 10^{-12} F$

$\boxed{n = f_2 / f_1}$

$\boxed{n = \frac{5}{2}}$

Example 2.17: *To check the distributed capacitance of a coil it is resonated at 10 MHz with 120 pF and then is resonated at 15 MHz with 40 pF. What is the inductance of the coil and what is its equivalent distributed capacitance?* [Raj.Univ. 2003]

Given – $f_1 = 10 \text{ mHz}$ $\quad f_2 = 15 \text{ mHz}$

$C_1 = 120 \text{ PF}$ $\quad C_2 = 40 \text{ PF}$

$$n = f_2/f_1 = \frac{15}{10} = 1.5$$

$$C_d = \frac{C_1 - n^2 C_2}{n^2 - 1} = \frac{120\times10^{-12} - (1.5)^2 40\times10^{-12}}{(1.5)^2 - 1}$$

$= \_\_\_\_\_$

Example 2.17: *To check the distributed capacitance of a coil it is resonated at 10 MHz with 120 pF and then is resonated at 15 MHz with 40 pF. What is the inductance of the coil and what is its equivalent distributed capacitance?* **[Raj.Univ. 2003]**

$f_1 = 10$

$f_2 = 15$

Solution:

$$\boxed{L = \frac{1}{(2\pi f)^2 C}} = \frac{1}{(2\pi \times 10 \times 10^6)^2 \times 120 \times 10^{-12}} = 2\times 10^{-6}\,H$$

10×10^6

If C_d is the distributed capacitance,

$$f_1 = \frac{1}{2\pi\sqrt{L(C_1+C_d)}}$$

$f_2 = 2 f_1$

and

$$f_2 = \frac{1}{2\pi\sqrt{L(C_2+C_d)}};\ f_2 = 1.5 f_1$$

$\boxed{n = f_2/f_1}$

$\frac{15}{10} = 1.5$

$$\therefore \quad \frac{1}{2\pi\sqrt{L(C_2+C_d)}} = \frac{1.5}{2\pi\sqrt{L(C_2+C_d)}}$$

$$C_d = \frac{C_1 - n^2 C_2}{n^2 - 1}$$

$$\therefore \quad \frac{1}{C_2+C_d} = \frac{2.25}{C_1+C_d} \Rightarrow 1.25C_d = C_1 - 2.25C_2$$

or in general, $\boxed{C_d = \frac{C_1 - n^2C_2}{n^2-1}}$ where n - integral ratio of frequencies.

$$\boxed{C_d = \frac{C_1 - 4C_2}{3}}$$

Substituting the values of C_1 and C_2 then

$$\boxed{C_d = \frac{120 - 2.25\times 40}{1.25}} = \frac{30}{1.25} = 24\,pF$$

Example 2.16: *A coil with a resistance of 3Ω is connected to the terminals of a Q meter. Resonance occurs at an oscillator frequency of 5 MHz with a capacitance of 100 pF. Calculate the percentage of error introduced by the insertion resistane $R_{sh} = 0.1\Omega$*

[Raj.Univ. 2003]

$R = 3\Omega$

$f_0 = 5\times10^6 Hz$

$C = 100\times10^{-12} F$

$R_{sh} = 0.1\Omega$

$L = \dfrac{1}{(2\pi f_0)^2 C}$

$Q_{true} = \dfrac{\omega_0 L}{R} = \dfrac{2\pi f_0 L}{R}$

$= \_\_\_\_\_\_$

$Q_{mes} = \dfrac{\omega_0 L}{R+R_{sh}} = \_\_\_\_\_\_$

$\% \, err = \dfrac{Q_{true} - Q_{mes}}{Q_{true}} \times 100$

Example 2.16: *A coil with a resistance of 3Ω is connected to the terminals of a Q meter. Resonance occurs at an oscillator frequency of 5 MHz with a capacitance of 100 pF. Calculate the percentage of error introduced by the insertion resistane R_{sh} = 0.1Ω*

[Raj.Univ. 2003]

Solution:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

or

$$L = \frac{1}{(2\pi f)^2 C}$$

$$L = \frac{1}{(2\pi \times 5 \times 10^6)^2 \times 100 \times 10^{-12}} = 10.13\mu H$$

Qtrue =

$$Q_{actual} = \frac{\omega L}{R} = \frac{2\pi \times 5 \times 10^6 \times 10.13 \times 10^{-6}}{3} = 106.08$$

With insertion resistance $R_{sh} = 0.1\ \Omega$

$$Q_{observed} = \frac{\omega L}{R + R_{sh}} = \frac{2\pi \times 5 \times 10^6 \times 10.13 \times 10^{-6}}{3.1} = 102.66$$

$$\%\ \text{error} = \frac{106.08 - 102.66}{106.08} \times 100 = 3.2$$

$$\frac{Q_{act}}{Q_{obs}} = \frac{R + R_{sh}}{R} = 1 + \frac{R_{sh}}{R}; \quad Q_{act} = Q_{obs}\left(1 + \frac{R_{sh}}{R}\right)$$

To make observed value as near as Q_{actual}, R_{shunt} should be as small as possible.

1

Grounding: Ground is the reference point in an electrical circuit from which other voltages are measured.

or

2 → A common return path for electrical current.

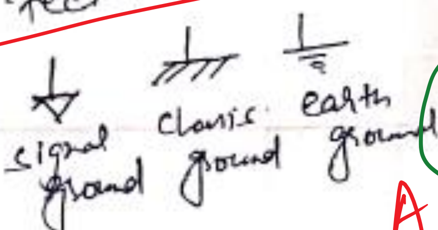
or

3 A direct physical connection to the earth.

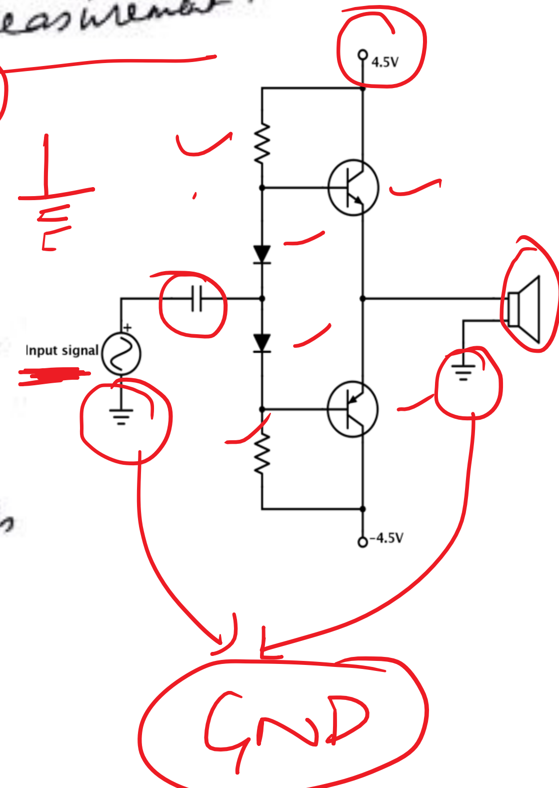
★ earth is electrically neutral → considered at zero potential
↳ ref. point for voltage measurement.

A V_A B V_B $V_B - V_A$

* A true earth ground physically consists of a conductive pipe or rod driven in to a min. depth of 3 feet.



V_A V_B A B $V = V_B - V_A$



Purpose of grounding:

(i) over voltage protection; lightning, line surges

(ii) voltage stabilization

(iii) over current protection.

Shielding: It can be defined as the placing of sensitive electronic parts & component in a metal casing to prevent electric & magnetic fields entering in that case.

use to block electrostatic & magnetic interference

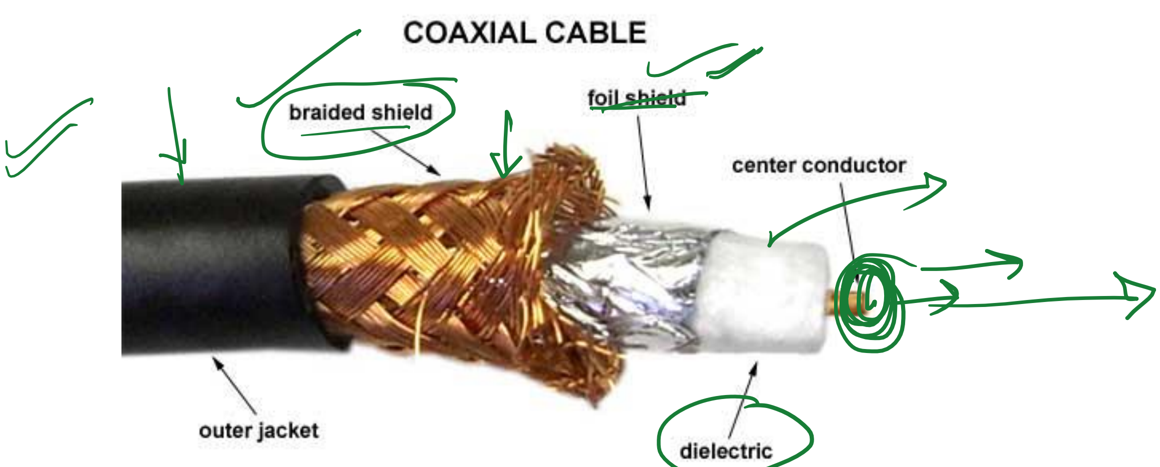
eg. -
↳ co-axial cable

~~characteristics~~ characteristics of good shielding :-

→ it must confine undesired signal generated within case

→ The shielding material must have low surface impedance good electrical continuity

→ It must prevent equipment from receiving undesired signal



Vector impedance meter

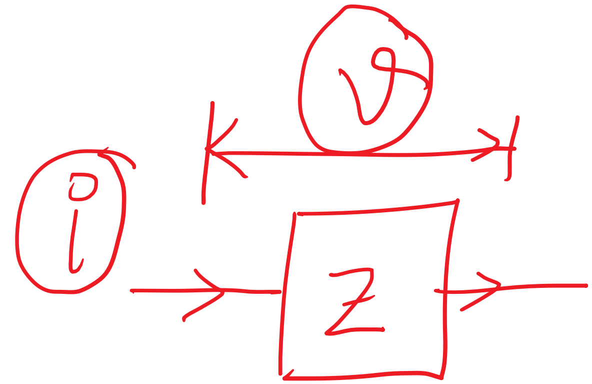
- The vector impedance meter is used to measure impedance of unknown component over a wide frequency range & simultaneously it determines the phase angle.
- The quality of component whether is inductive or capacitive or resistive can be determined by determining phase difference between the voltage across the component & current through component.
- The component whose impedance magnitude and phase angle to be measured is simply connected across the input terminals of the instrument.
- The desired frequency is selected by tuning the front panel control.
- There are two indicators to indicate the magnitude and the phase angle.

Because two quantities (magnitude and phase angle) have to be measured, the two principles are used.

Vector Impedance Meter

$Z = \frac{v}{i}$

Z — R, L, C $\}$ $\underline{R + jX}$



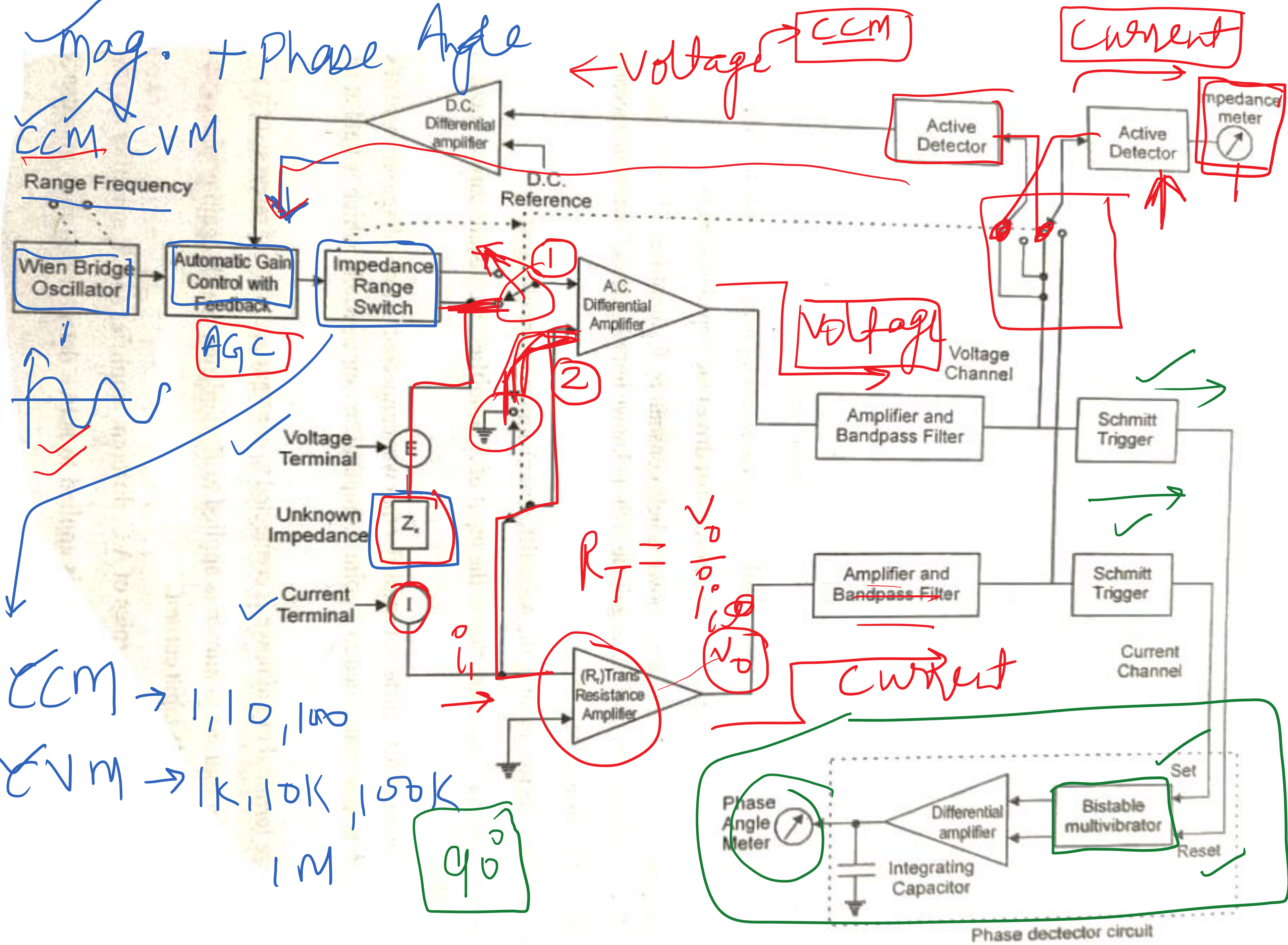
Z — mag., Phase Angle

V —
I — phase diff^{r}.

mag. — Constant current mode, Constant voltage Mode

Vector impedance meter

-


Mag. + Phase Angle
CCM CVM
← Voltage → CCM
Current
Range Frequency
Wien Bridge Oscillator
Automatic Gain Control with Feedback
AGC
Impedance Range Switch
D.C. Differential amplifier
D.C. Reference
Active Detector
Active Detector
Impedance meter
1
2
A.C. Differential Amplifier
Voltage
Voltage Channel
Voltage Terminal
E
Unknown Impedance
Z_x
Current Terminal
I
Amplifier and Bandpass Filter
Schmitt Trigger
Amplifier and Bandpass Filter
Schmitt Trigger
$R_T = \frac{V_0}{i_0}$
i_1
V_0
(R_t)Trans Resistance Amplifier
Current
Current Channel
Set
Reset
Phase Angle Meter
Differential amplifier
Bistable multivibrator
Integrating Capacitor
Phase dectector circuit
CCM → 1, 10, 100
CVM → 1K, 10K, 100K, 1M
90°

- Magnitude is determined by measuring the current through the unknown component when a known voltage is applied across it or by measuring the voltage across the component when a known current is passed through it.
- The block diagram of vector impedance meter is shown in the figure 2.26.
- In this a wein bridge oscillator is used as signal source, which can produce different frequency signals.
- The signal is fed to AGC amplifier (automatic gain control), which allows accurate gain adjustment by means of feedback voltage.
- The gain is adjusted by impedance range switch.
- The impedance range switch is a precise attenuator network which controls the output voltage of oscillator.

The impedance range switch operates in two modes.

1. Constant current mode (three lower ranges X1, X10 and X100).
2. Constant voltage mode (four higher ranges X 1K, X 10K, X 100K and X 1M)

(a) Constant Current Mode

- In this mode the unknown component is connected to the input of A.C. differential amplifier.
- The current supplied to the unknown component is decided by setting of range switch.
- This supplied current is held constant by the action of trans-resistance of R_T amplifier.
- R_T amplifier converts the current through the unknown impedance into a voltage output.
- The output voltage is proportional to the supplied input current.
- The output of R_T amplifier is fed to the amplifier and Band pass filter.
- Band pass filter consists of low and high band filters, which restricts the amplifier bandwidth
- This output of band pass filter is fed to active detector and D.C. differential amplifier.
- The D.C. differential amplifier compares the input with a D.C. reference voltage.
- The output of D.C. differential amplifier is fed to AGC amplifier to regulate the gain of AGC amplifier and hence the voltage applied to the range switch.
- The output of A.C. differential amplifier is applied to an amplifier and band pass filter.
- The output of filter is connected to detector that drives the impedance meter.
- Since the current through the unknown is held constant by R_T amplifier. The impedance meter deflects in the proportion of the magnitude of the unknown impedance and it calibrated accordingly.

(b) Constant Voltage Mode

- In this mode the two input to the A.C. differential amplifier are changed.
- The terminal that was connected to the input of R_T amplifier in constant current mode is now grounded.
- The other input of A.C. different amplifier that was connected to the voltage terminal of known impedance is now connected to a point in impedance range switch, which is held at constant potential.
- The voltage terminal of unknown is connected to constant potential of range switch.
- The current through the unknown is applied to R_T amplifier, which again produces an output voltage proportional to input current.
- In constant voltage mode, the roles of A.C. different amplifier and R_T amplifier are reversed.
- The voltage output of R_T amplifier is applied to active detector and then impedance meter through amplifier and band pass filter.
- The output voltage of A.C. differented amplifier controls the gain of AGC amplifier in the same manner that the R_T amplifier did in the constant current mode.

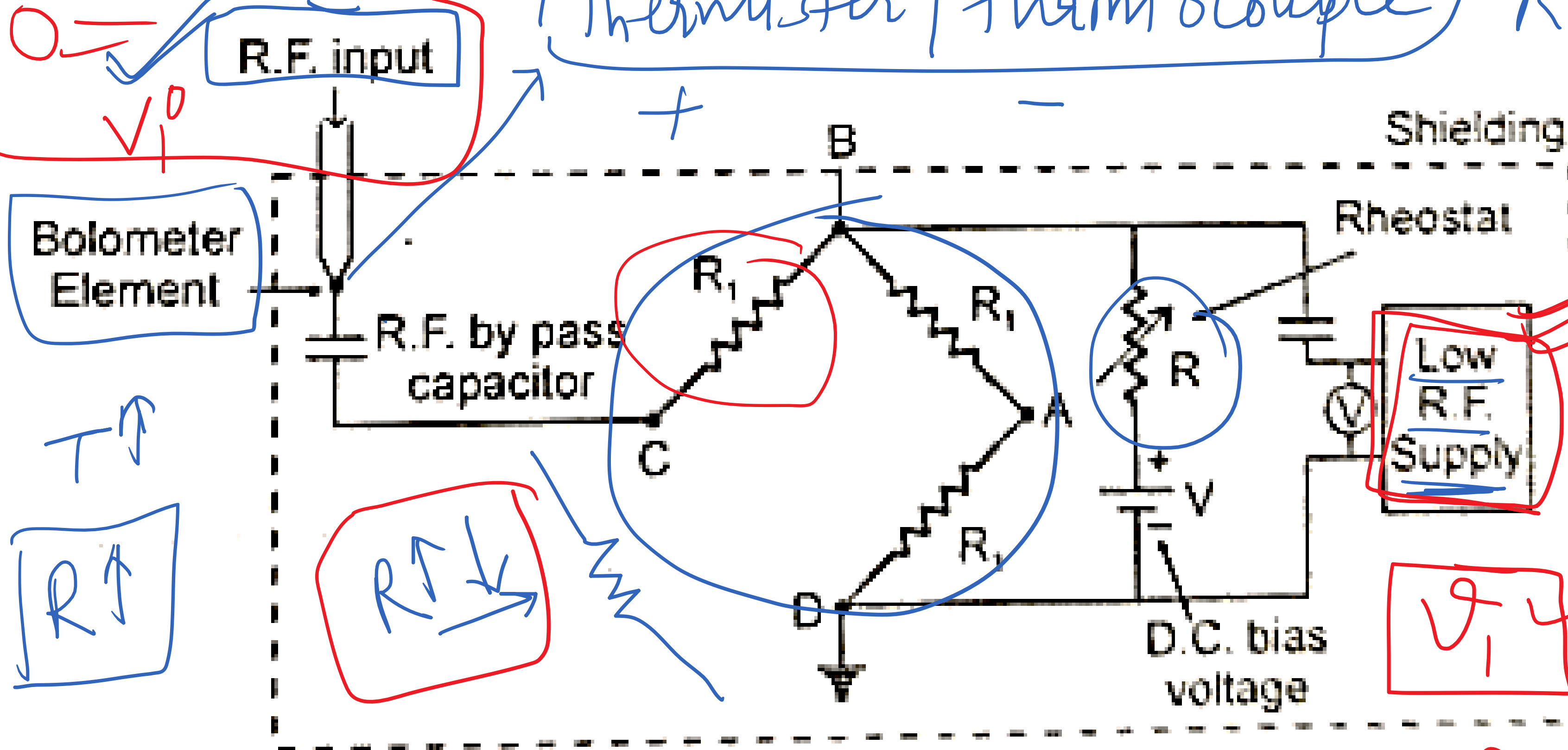
Radio freqn → High freqn

2.8.2 R.F. Power Measurements

- There are various methods of R.F. power measurement. One of the most popular method is bolometer method.
- In this method, the unknow power is absorbed in a specially constructed bolometer element of resistive element.
- The resultant temperature rise is then detected by measuring the change in bolometer resistance by means of an auxillary bridge circuit.
- The bolometer element may consist of normal resistive element with a positive temperature coefficient or thermisters which has negative temperature coefficient made up of metallic oxide materials.
- Here the radio frequency power enters from a coaxial line.
- The bypass capacitor provides a return path for the R.F. current and an insulated connection to the bolometer.

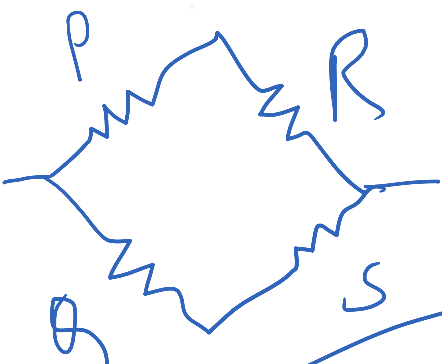
Power = $I \cdot V$

Thermister | thermocouple RTD



T↑

R↑



- The resistance change in the bolometer is measured with the bridge ABCD.
- The arm CD is supplied by the resistance of bolometer element.

$$P/Q = R/S$$

The bridge simultaneously excited by direct current from voltage V and by a low R.F.

The D.C. current is adjusted by rheostat R until bridge is balanced.

At balance condition measure the voltage V_1 of low R.F. supply

Now turn off the R.F. power, the bridge again unbabalcned.

The balance is again restored by increasing the power from low R.F. supply.

Now measure the voltae V_2 of low RF power is

The radio frequency power is

$$\boxed{= \frac{V_2^2 - V_1^2}{4R_1}}$$

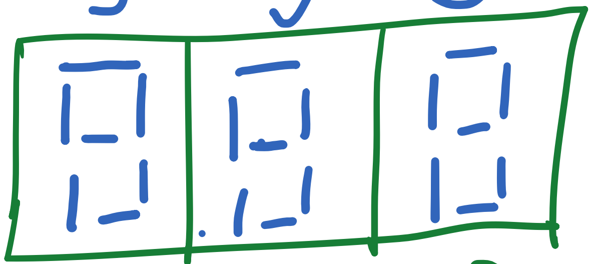
- The lead from bolometer to the bridge is shielded to avoid stray fields from radio and ... frequency into the system.

Range & $\underbrace{\text{Resolution}}_{\text{least count}}$ of digital volt-meter

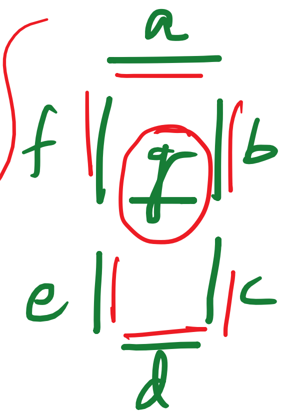
↳ Seven Segment LED

3 digit display

9 9 9



1 2 3



0 - 9 $= 0.001$

$\frac{1}{1000}$

1 → b, c

① Reset count - 000

② Min. count - 001 ✓

③ Max. count - 999

Total count = 1000

~~Resoul~~

Resolution

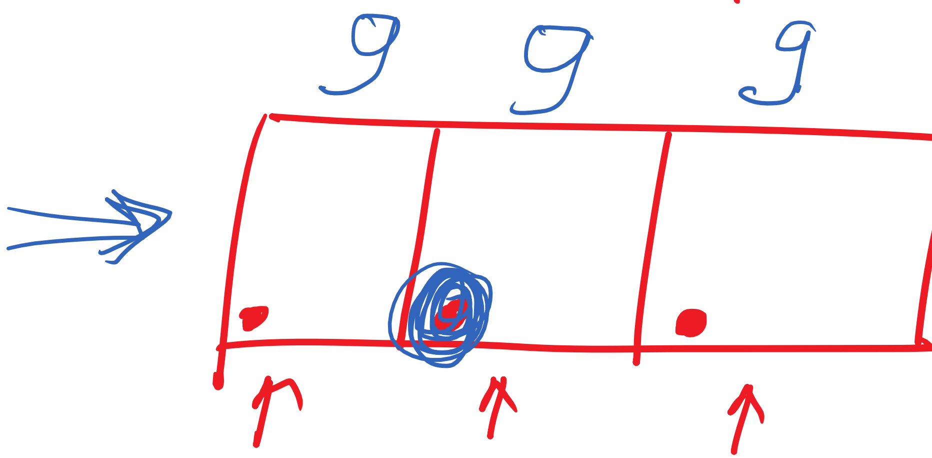
$= \frac{1}{10^N}$

$N = 3$

N = No. of full digit

$$\text{Resolution} = \frac{\text{Range}}{10^N}$$

N = No. of full digit



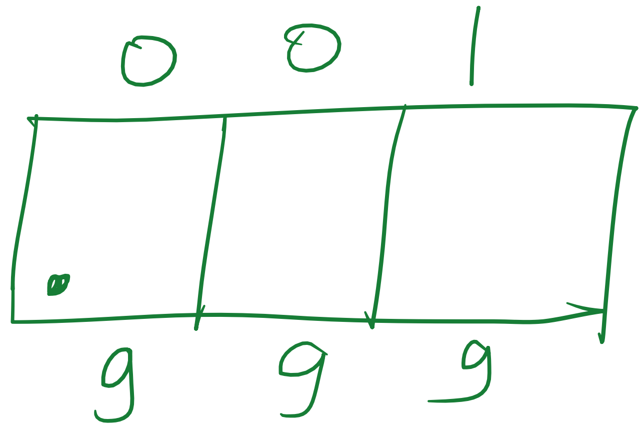
$$R = \frac{10}{10^3} = 0.01$$

10 mV

Reset count 000

min count $0.01 = 10\,mV \Rightarrow$ least count

max count $= 9.99 = 10\,V$] Range

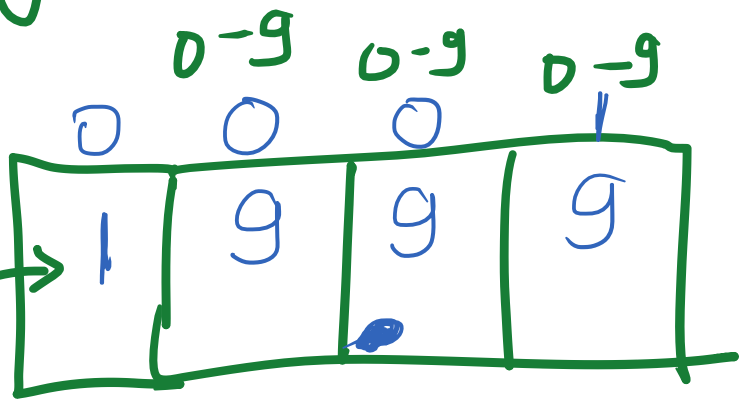


min·count 0·001 = 1mV

max count ·999 = 1V

Rangle Extention

3 ① 1 digital display
② 0-1



0|1

3 full digit

Half digit

3 ④ ⑤

0, 1, 2, 3, 4

min count
= 0.01

max count 19.99

⇒ 20V

Example 2.14: A $4\frac{1}{2}$ digit voltmeter is used for voltage measurements. Find :

(i) Its resolution

(ii) How 12.98 V will be displayed on a 10 V range?

(iii) How 0.6973 will be displayed on 1V and 10V ranges? [R.T.U. 2008]

Solution: (i) Resolution $= \frac{1}{10^n} = \frac{1}{10^4} = 0.0001$

where the number of full digits is $n = 4$

(ii) there are 5 digiti places in $4\frac{1}{2}$ digit, therefore 12.98 should be displayed as 12.980.

Resolution on 1V range is $1V \times 0.0001 = 0.0001$ any reading upto the 4th decimal can be displayed. Hence 0.6973 will be displayed as 0.6973.

(iii) Resolution on 10V range $= 10V \times 0.0001 = 0.001V$ hence the third decimal up to 3rd decimal places can be displayed. Therefore on a 10V range, the reading will be 0.697 instead of 0.6973.