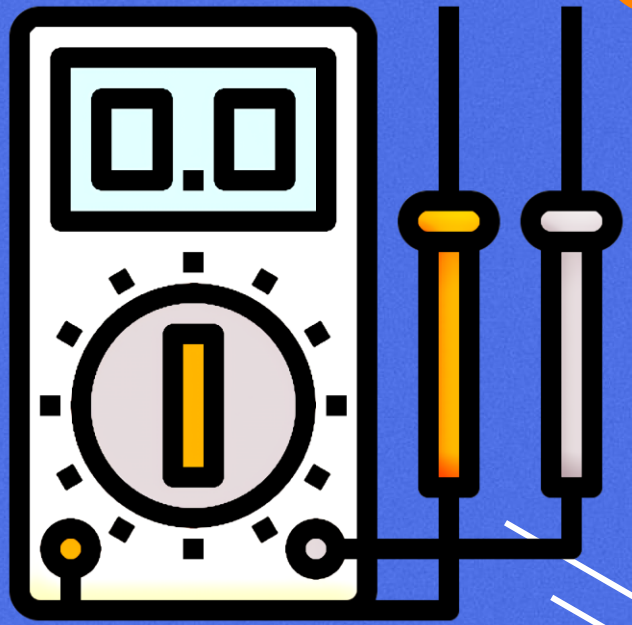
Electronics and Electrical Communications Engineering Dep.

2nd Year / 2nd Term

Electronic Measurements (2)

Lecture (1)

By Dr. Hager Fouda



Lecture Content

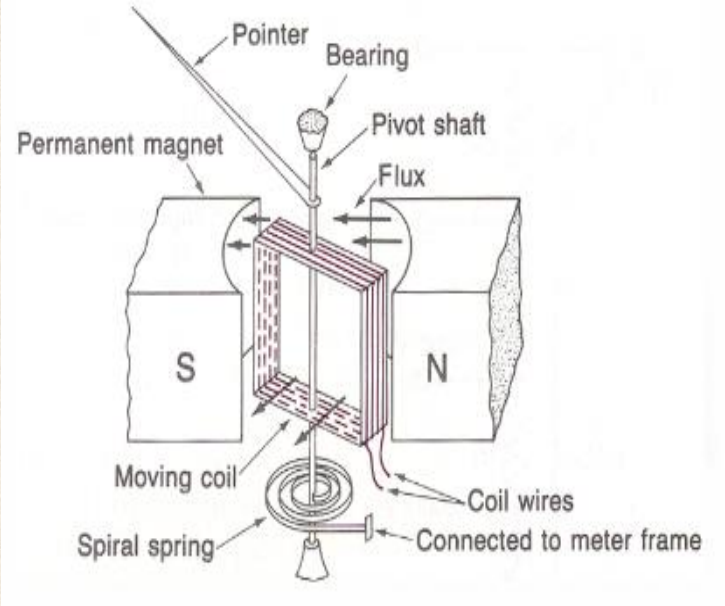
- Electrical analog Voltmeter
- Electronic analog Voltmeter
- AC/DC Amplifiers
- Transistor Voltmeter (TVM)
- Attenuator circuit
- Balanced Bridge TVM
- DC Differential Voltmeter
- Chopper type DC Amplifier Voltmeter (Microvoltmeter)

Electrical analog Voltmeter

Electrical Voltmeter

Permanent Magnet Moving Coli (PMMC) Voltmeter

- It is an electromechanical measuring instrument.
- It works by deflecting a pointer in response to an electric current flowing through a coil in a constant magnetic field.
- It can be considered as a kind of actuator.



Advantages of PMMC Instruments

- Very accurate and reliable
- Low power consumption, varies from 25 μW to 200 μW

Electrical analog Voltmeter

Disadvantages of PMMC Instruments

- They are only used for measuring the Direct Current (DC). If we were to use Alternating Current (AC), the direction of current will be reversed during the negative half cycle, and hence the direction of torque will also be reversed. This results in an average value of zero torque, hence no net movement against the scale.
- Insufficient sensitivity to detect low level signal.
- They have low input impedance (high loading effect) (coil resistance: 10 Ω-1 kΩ)
- The moving system is very delicate and can easily be damaged by rough handling.
- The coil cannot withstand prolonged overloading.
- It is costlier.
- The ageing of the instrument (permanent magnet and control spring) may introduce some errors.

Electronic analog Voltmeter

Electronic voltmeters

- It use rectifiers, diodes, amplifiers, and other electronic circuits to produce a current proportional to the quantity to be measured.
- In olden days, vacuum tubes were in use, (consist of two plates, namely, Cathode and Anode where the cathode is exited and emits electrons resulting in current passage) and the voltmeters were called vacuum tube voltmeters (VTVM). They have large size and need warm up time.
- Today, transistors and semiconductors are used in electronic voltmeters (small size, portable, no warm up time)

Electronic analog Voltmeter

Advantage of Electronic Voltmeters

- Low level signal detection (due to using amplifier)
- Low power consumption
- High input Impedance (from 10-100 MΩ)
- Less loading effect
- Higher sensitivity
- High frequency range from DC to hundreds of MHz (measurements can be made independent of frequency)
- Improved dynamic range (it can measure very low as well as very high input signals)
- High accuracy
- Compactness and portability (due to the small size of electronic components)

Electronic analog Voltmeter

Sr. No.	Electronic meters	Conventional analog meters
1.	The electronic components such as rectifiers, transistors, diodes etc. are used.	The electronic components are not used.
2.	Amplifiers are present.	Amplifiers are absent.
3.	Low level signal detection is possible	Low level signal detection is not possible.
4.	Power consumption is low.	Power consumption is high.
5.	Power required for the deflection is provided from the external circuit using amplifiers.	Power required for the deflection is provided from the signal to be measured.
6.	Loading effects are less.	Very severe loading effects.
7.	Sensitivity is high.	Sensitivity is less.
8.	Input impedance in very high.	Input impedance is low.
9.	The frequency range is high.	The frequency range is limited.
10.	The range of measurement is more.	The range of measurement is less.
11.	The accuracy is very high.	The accuracy is comparatively less.
12.	The meters are compact and portable.	The meters are not compact and portable.
13.	The meters are not rugged.	The meters are rugged.

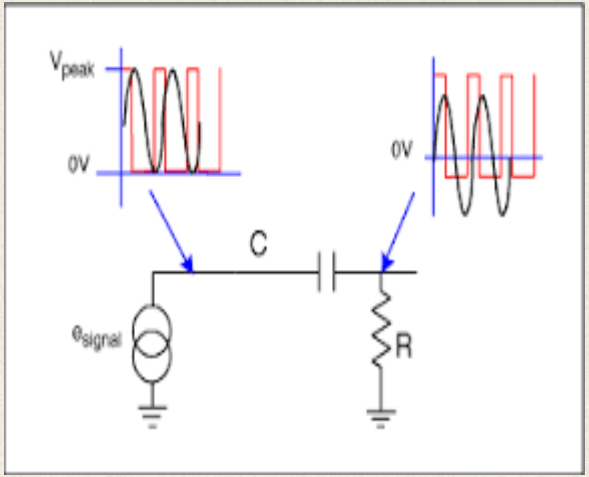
Electronic analog Voltmeter

DC Electronic Analog Voltmeter

- Transistor Voltmeter (TVM)
- Balanced Bridge TVM
- Differential Voltmeter
- Chopper Type DC Amplifier Voltmeter

Meaning of AC and DC in AC/DC Amplifiers

- Terms AC and DC in amplifiers don't exactly refer to current.
- These terms refer to the coupling method between different stages of amplification.
- AC in AC amplifiers tells us that different stages of amplification are coupled with a capacitor or a transformer.
- These capacitors/transformers are, therefore, known as coupling capacitors/transformers. AC coupling consists of using a capacitor to filter out the DC signal component from a signal with both AC and DC components.

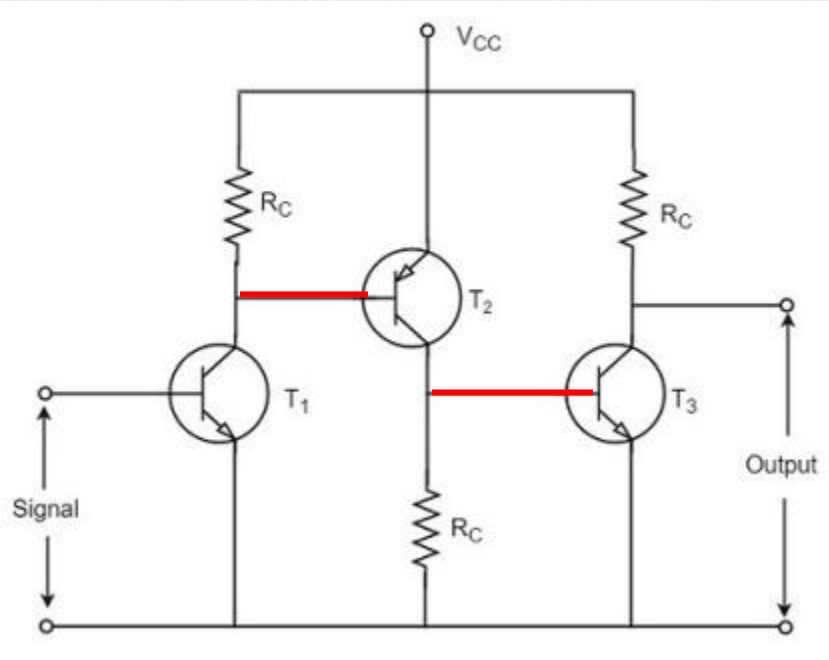


- The capacitor must be in series with the signal.
- AC coupling is useful because the DC component of a signal acts as a voltage offset, and removing it from the signal can increase the resolution of signal measurements.
- It helps remove the DC component from the signal, which centers the AC signal at 0 volts.

Meaning of AC and DC in AC/DC Amplifiers

Direct Coupled Amplifier

- It is especially used to amplify lower frequencies, such as amplifying photo-electric current or thermo-couple current or so.
- As no coupling devices are used, the coupling of the amplifier stages is done directly and hence called as Direct coupled amplifier.
- The frequency response of the direct coupled amplifier is similar to low pass filter and hence it is also known as ”Low-Pass Amplifier”.



Meaning of AC and DC in AC/DC Amplifiers

Advantages:

- The circuit arrangement is simple because of the minimum use of resistors.
- The circuit is of low cost because of the absence of expensive coupling devices.

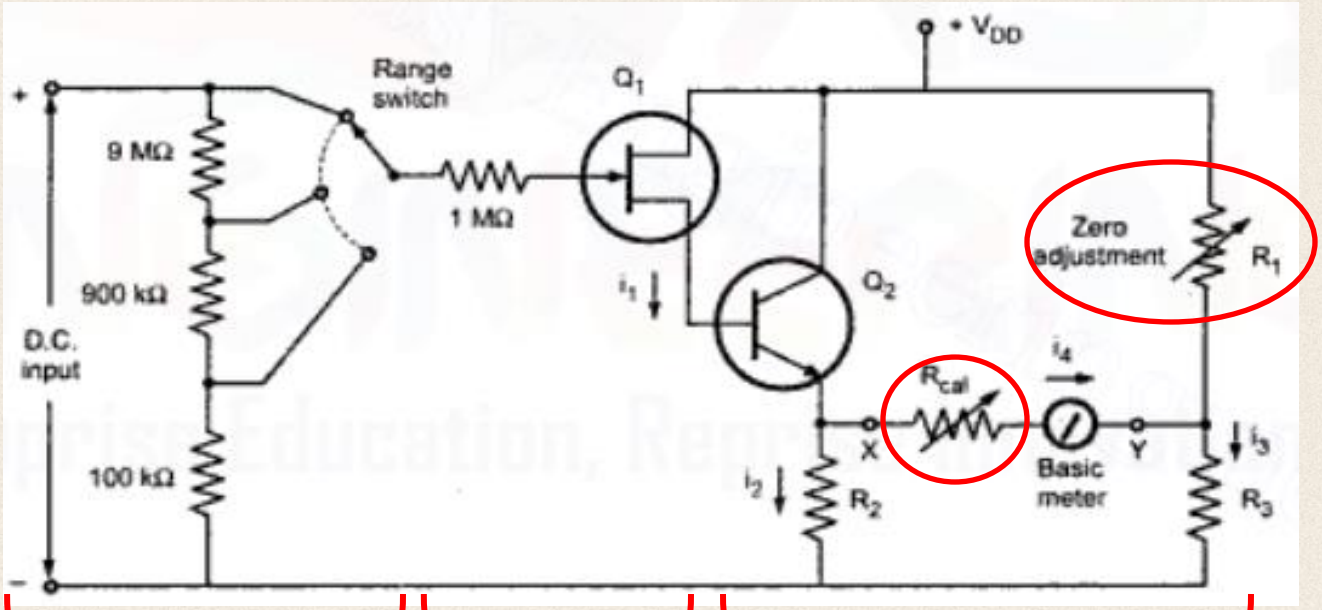
Disadvantages:

- It cannot be used for amplifying high frequencies.
- The operating point is shifted due to temperature variations.

Applications:

- Low-frequency amplification
- Low current amplification

Transistor Voltmeter



Attenuator

FET

Bridge

Transistor Voltmeter

- To measure the low voltage signals, an amplifier is used in electronic voltmeters.
- A DC amplifier with one or more stages is used in DC electronic voltmeter before the basic PMMC meter.
- FET Q1 acts as a source follower, which provides high input impedance ($> 10M\Omega$). Due to this, the meter circuit can be effectively isolated from the circuit under measurement.
- The bipolar junction transistor (BJT) Q2 along with the resistors forms a balanced bridge circuit.
- The bridge balance is obtained by zero adjustment resistor such that for zero input. The pointer shows zero.
- The bias in Q2 is such that $i_2 = i_3$ when the input is zero.
- Under such condition, $V_x = V_y$ and $i_4 = 0$.
- When the input voltage is applied, the bias on Q2 increases. This causes V_x to increase hence proportional current i_4 flows through the meter. Thus the deflection of the meter is proportional to the input voltage.

Transistor Voltmeter

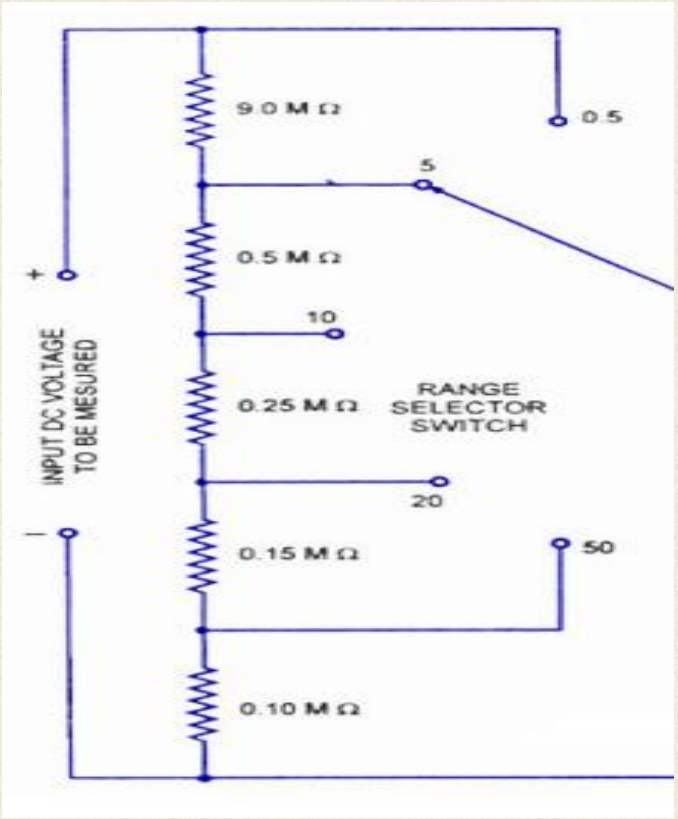
- The value of the input which causes maximum meter deflection is the basic range of the meter.
- High ranges can be obtained by using an input attenuator which can be in the form of resistance voltage divider.
- The full scale voltage appears across the divider hence the voltage at each tap is increasing lower fraction of the full input voltage.

Advantages of TVM

- High input impedance
- Low power consumption
- High sensitivity
- Wide voltage range
- The overload cannot damage the meter because amplifier saturates and limits the current through the meter

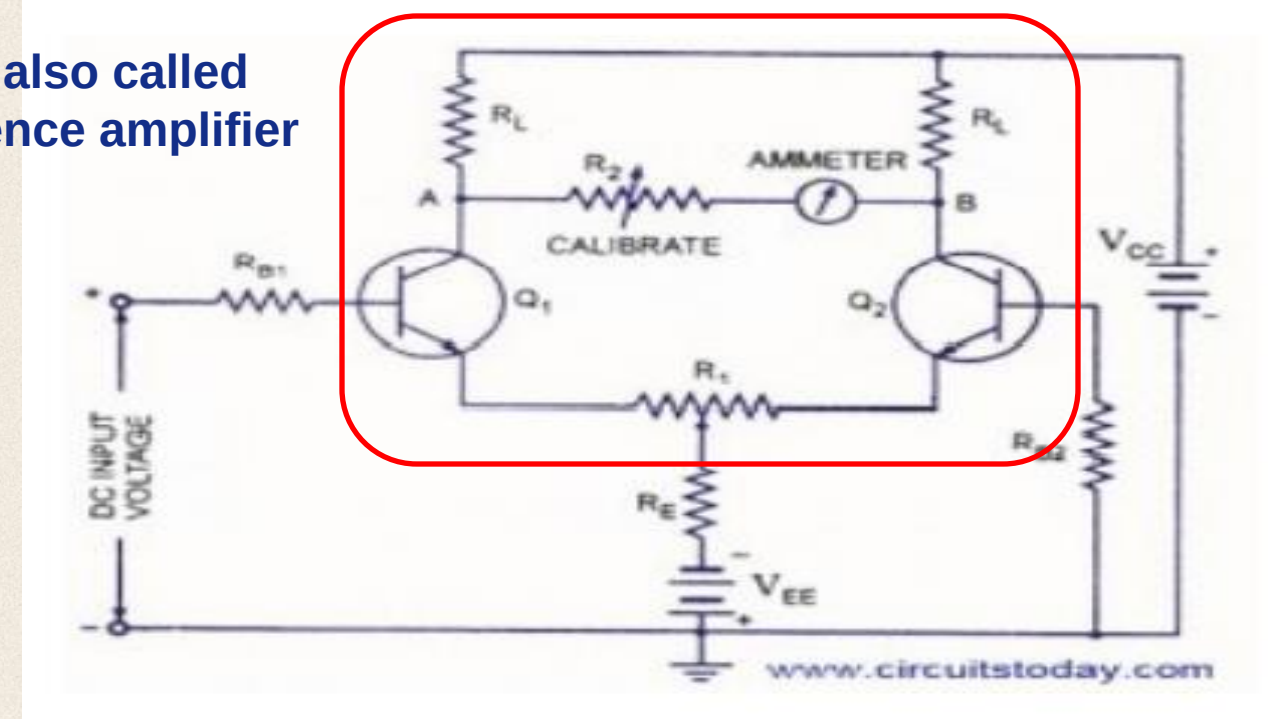
Attenuator Circuit

- An attenuator is used in input stage to select voltage range.
- The input attenuator accurately divides the voltage to be measured before it is applied to the input transistor to keep the input voltage of amplifier within certain level.
- Calculation shows that the amplifier input voltage is always 0.5 volt when the maximum input is applied on any range.
- Ex: 50 × 0.1/10 = 0.5 volt and 20 × 0.25/10 = 0.5 volt.
- The measurement point always sees a constant input resistance ($10M\Omega$).



Balanced Bridge TVM

It is also called difference amplifier



Balanced Bridge TVM

- In balanced bridge TVM **two identical** transistors Q1 and Q2 are used.
- When the positive input dc voltage is applied to the base of transistor Q1, emitter current of this transistor **increases** which causes the **increase** in voltage drop across resistor RL and therefore**, reduces** the potential VA of the collector of transistor Q1.
- $IE1 \uparrow\rightarrow Ic1 \uparrow\rightarrow VRL \uparrow\rightarrow VA \downarrow= (Vcc - VRL)$.
- With the **increase** in emitter current, voltage drop across resistance RE **increases** and so the emitter current of transistor Q2 is **reduced.**
- This **increases** the potential of the collector of transistor Q2.
- $IE1 \uparrow\rightarrow VRE \uparrow\rightarrow VE \downarrow= (VEE - VRE) \rightarrow IE2 \downarrow\rightarrow Ic2 \downarrow\rightarrow VRL \downarrow\rightarrow VB \uparrow= (Vcc - VRL)$
- A current **proportional to** the applied input voltage starts flowing in the ammeter connected between collectors of transistors Q1 and Q2.

Balanced Bridge TVM

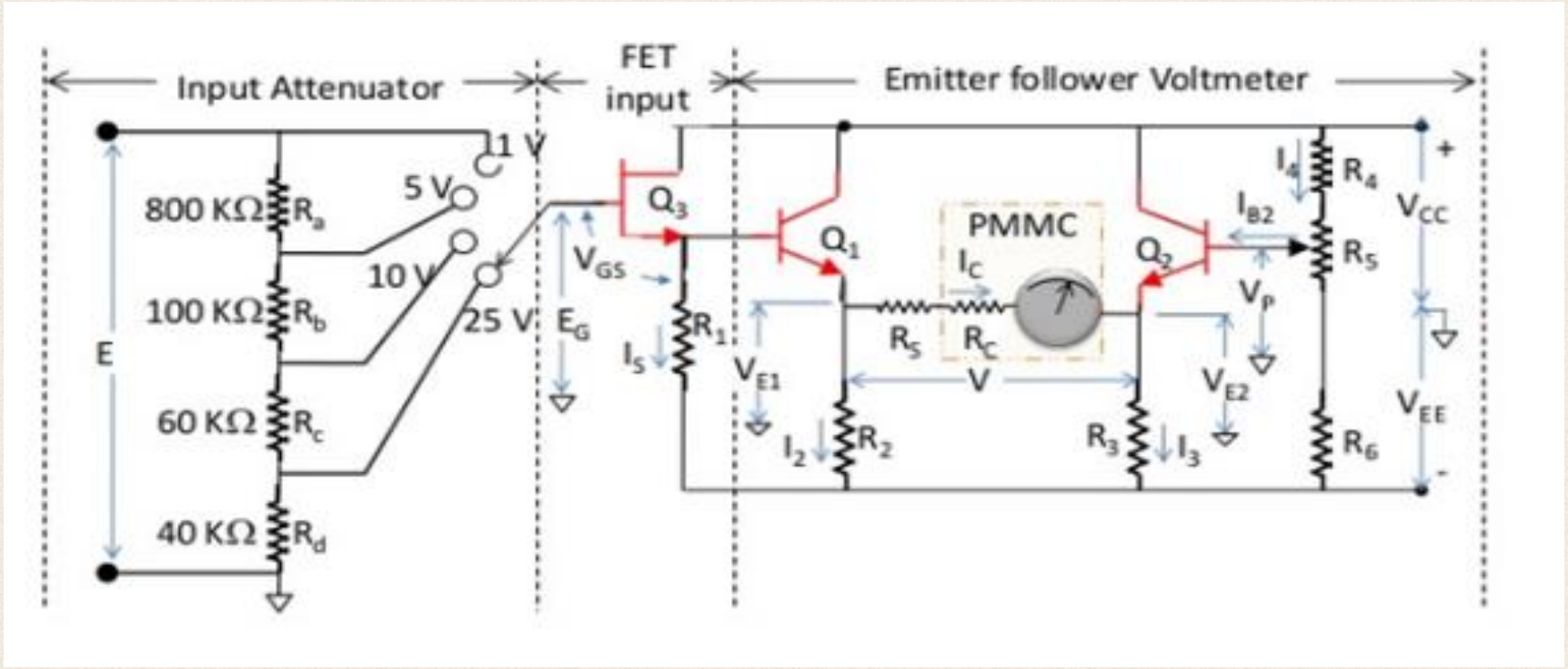
- Resistor R1 is used to achieve **zero position** in ammeter under the absence of dc input voltage.
- Resistor R2 is used for **calibration purpose**.

Advantages

- If both transistors Q1 and Q2 are similar then with the change in ambient temperature, β values of both the transistors **will change equally** so, there will be no effect on collector current in changed ambient temperature condition.
- Also with the change in ambient temperature, saturation current of both the transistors will **change equally** and therefore the meter reading will remain unaffected.

Balanced Bridge TVM

FET input balanced bridge TVM



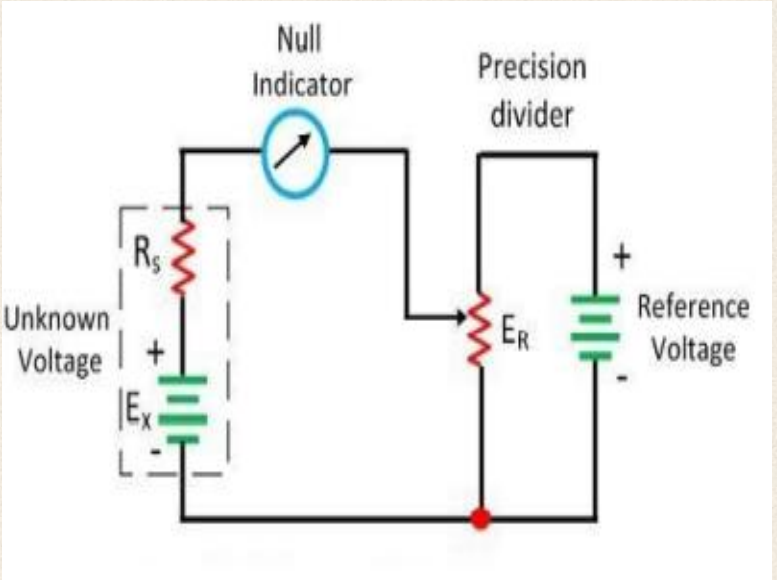
Balanced Bridge TVM

- The attenuator allows various voltage ranges to be measured **(the smallest resistance corresponds to the highest voltage).**

- At full scale 1v: the FET input = 1v × (1MΩ/1MΩ).
- At full scale 5v: the FET input = 5v × (200kΩ/1MΩ).
- At full scale 10v: the FET input = 10v × (100kΩ/1MΩ).
- At full scale 25v: the FET input = 25v × (40kΩ/1MΩ).

DC Differential Voltmeter

- It Is the voltmeter which measures the difference between the known and the unknown voltage source.
- It works on the principle of comparison between the reference and the unknown voltage sources.
- The accuracy of the differential voltmeter is very high.
- The principle of operation of the differential voltmeter is similar to that of the potentiometer, and hence it is called potentiometer voltmeter.



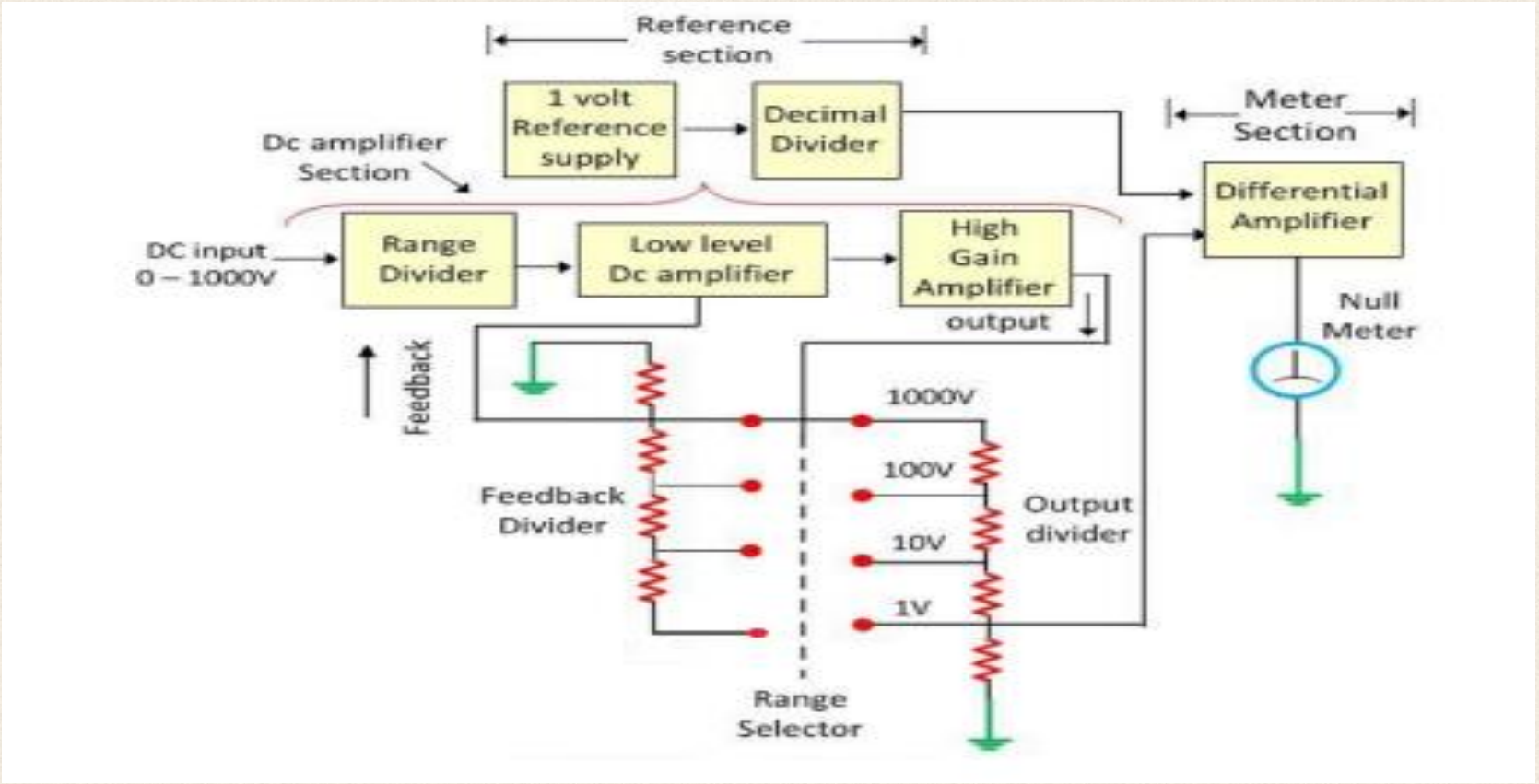
- The null meter is placed between the unknown voltage source and the precision divider.
- The output of the precision divider is connected to the known voltage source.

DC Differential Voltmeter

- The precision divider is adjusted until the meter shows the zero deflection.
- During the null deflection, neither the known nor the unknown source applies current to the meter (as the magnitude of both sources becomes equal).
- At low voltage, the reference DC voltage usually a 1 V dc battery or Zener diode.
- To measure the high voltage, a high voltage known reference supply is required.

- To avoid this, voltage dividers (attenuators) are connected across the unknown input voltage source.
- Thus, instead of comparing the entire high known voltage, the fraction of the unknown voltage is used for comparison.
- Such an attenuation has a loading effect.

DC Differential Voltmeter

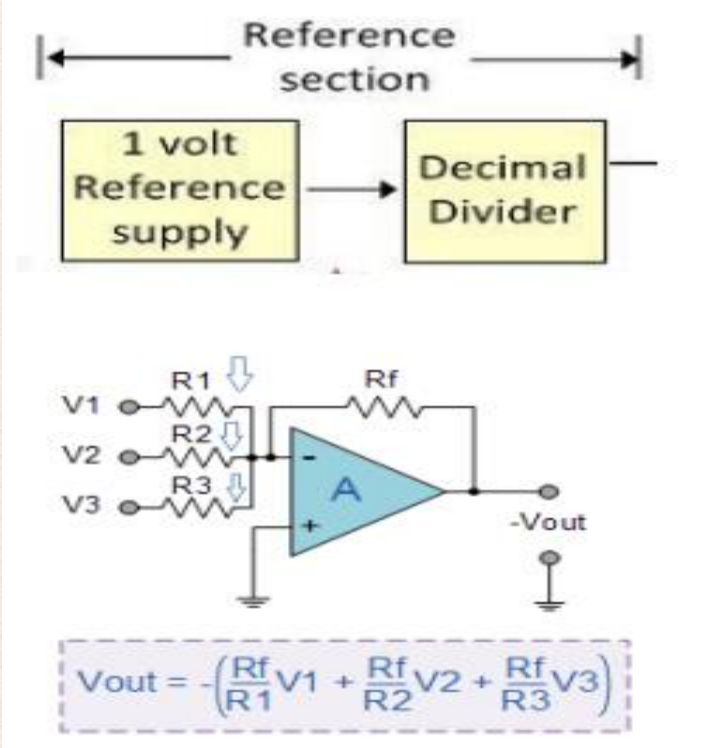


DC Differential Voltmeter

Reference Section

- A decimal divider in the reference section is used to divide the reference voltage into precise and smaller increments, which allows for accurate voltage measurements across a wide range with finer resolution.

- It enables the voltmeter to measure small differences in voltage by subdividing the reference voltage into smaller, manageable increments, like tenths or hundredths.

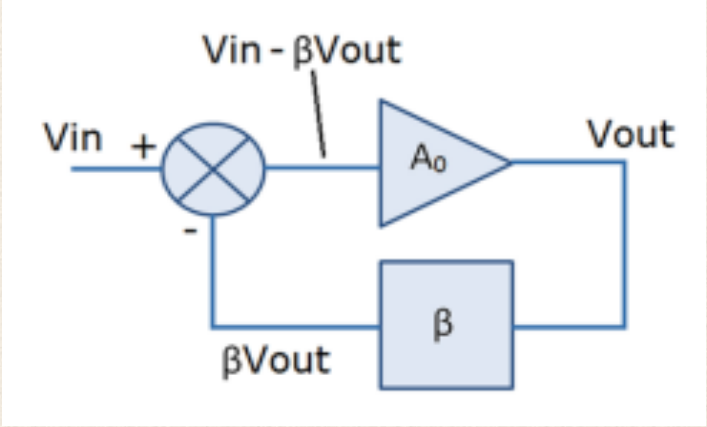


- ❑ 1 V range (0.9999) (step=0.1 mV)
- ❑ 10 V range (9.999) (step=1 mV)
- ❑ 100 V range (99.99) (step= 10 mV)
- ❑ 1000 V range (999.9) (step= 100 mV)

DC Differential Voltmeter

DC amplifier Section

- Closed loop gain: $G = \frac{A_0}{1+\beta A_0}$
- where A_0 is the open loop gain without feedback, β is the feedback ratio.
- For high gain amplifier $A_0 \gg$ (usually > 100) the gain depends only on β such that, G ≈ 1/β .

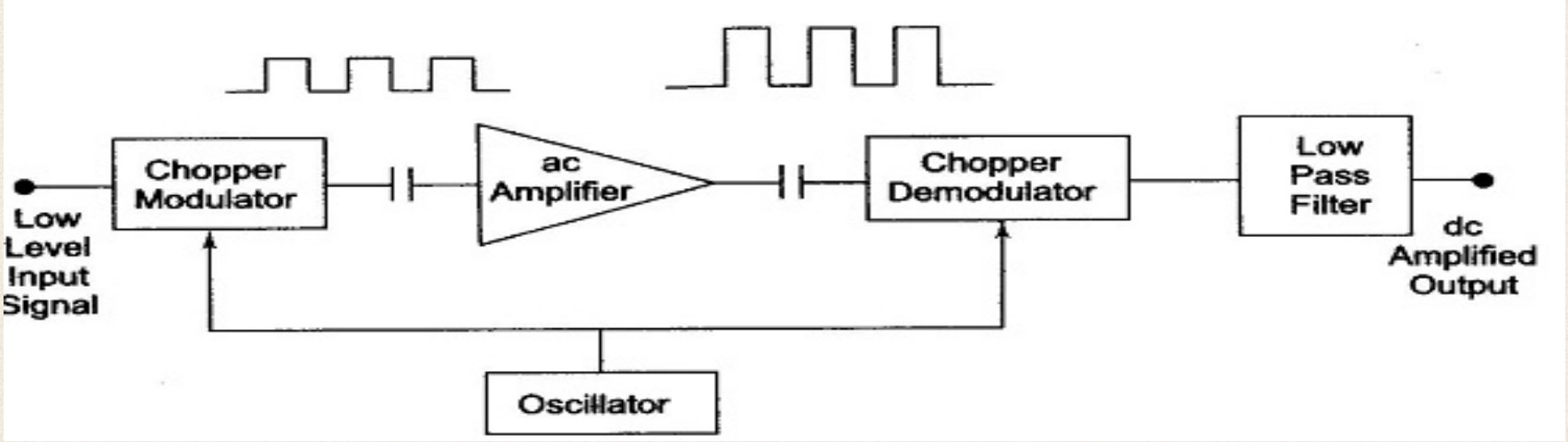


DC Differential Voltmeter

- The unknown dc voltage is applied to the input of the amplifier section and a part of the output voltage is fed back to the input stage with the help of one divider network, which controls the closed loop gain of the amplifier.
- The other section of the voltage divider network applies a fraction of the output voltage to the differential input of the meter amplifier.
- The meter circuit measures the difference between the feedback voltage and the reference voltage, indicating a null deflection when the two voltages are equal .
- The range selector (on the front panel) controls both the feedback voltage and the voltage that is applied in opposition to the reference divider output, such that 1 V capacity of the reference supply is never exceeded .

Chopper Type DC Amplifier Voltmeter (Microvoltmeter)

- The balanced bridge voltmeter has limitations caused by drift problems in dc amplifier.
- Any fluctuations of voltage supply or variation in the Q characteristics due to ageing or rise in temperature causes a change in the zero setting or balance.
- This drift problem limits the minimum voltage that can be measured. To measure small voltages, a chopper type dc amplifier is used.

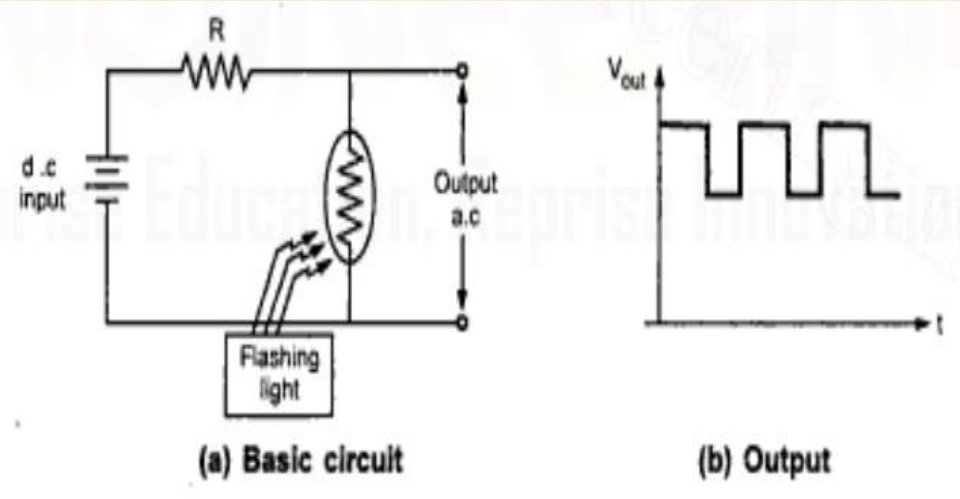


Chopper Type DC Amplifier Voltmeter (Microvoltmeter)

- A chopper amplifier is normally used for the first stage of amplification in very sensitive instruments of a few μV range.
- In such an amplifier the dc voltage is chopped to a low frequency of 100 – 300 Hz.
- It is passed through a blocking capacitor, amplified and then passed through another blocking capacitor, in order to remove the dc drift or offset of the amplified signal.
- The chopper may be mechanical or electronic.
- Photo diodes are used as non-mechanical choppers for modulation (conversion of dc to ac) and demodulation (conversion of ac to dc).
- Photo conductors have a low resistance, ranging from a few hundreds to a few thousand ohms, when they are illuminated by a neon or incandescent lamp.
- The photo conductor resistance increases sharply, usually to several Mega ohms when not illuminated.

Chopper Type DC Amplifier Voltmeter (Microvoltmeter)

- A flashing light source, whose intensity varies from maximum to minimum almost instantaneously, causes the photo diode resistance to change from Rmin to Rmax quickly.
- Therefore the output voltage is an ac, because the photo diode has a high output when its resistance is high and a low output when its resistance is low



Lecture References

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2. Kishore, K. Lal. Electronic Measurements and Instrumentation. Pearson Education India, 2009.
3. Dr. Nansy El-Shaer. Electronics and Electrical Communications Engineering Faculty of Engineering Tanta University. Electronic Analog Voltmeters lectures.

Thank you!

Any question?

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