

# Electronic Measurements & Instruments (4331102) - Winter 2023 Solution

Milav Dabgar

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## Question 1(a) [3 marks]

Give Definition of Accuracy, Reproducibility and Repeatability.

### Solution

**Table 1.** Definitions

Term	Definition
<b>Accuracy</b>	Closeness of measured value to the true or actual value of the quantity being measured
<b>Reproducibility</b>	Ability of an instrument to give identical measurements for the same input when measured under different conditions (different operators, locations, times)
<b>Repeatability</b>	Ability of an instrument to give identical measurements for the same input when measured repeatedly under the same conditions

### Mnemonic

“ARR - Accurate Results Repeatedly”

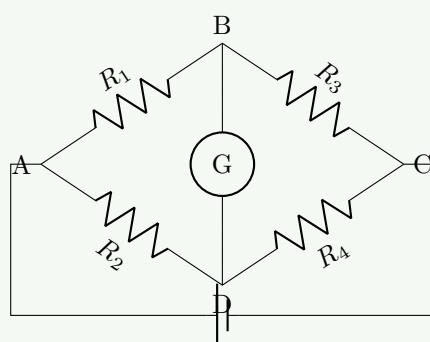
## Question 1(b) [4 marks]

Draw and Explain Wheatstone bridge.

### Solution

**Wheatstone Bridge** is used for precise measurement of unknown resistance.

Circuit Diagram:



**Figure 1.** Wheatstone Bridge

**Table 2.** Key Features

Feature	Description
Configuration	Four resistors connected in diamond pattern
Balance Condition	$R_1/R_2 = R_3/R_4$ (when output voltage is zero)
Application	Precise measurement of unknown resistance
Operation	Unknown resistor placed in one arm, remaining resistors adjusted until bridge is balanced

**Mnemonic**

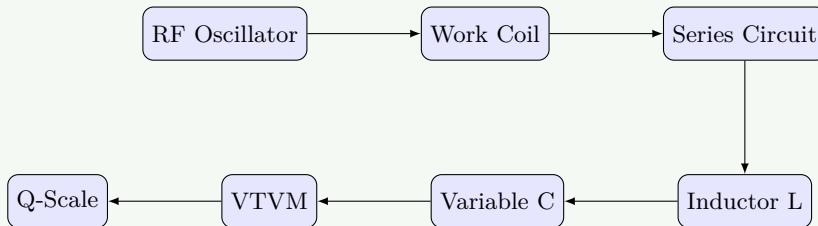
“WBMP - When Balanced, Measure Precisely”

**Question 1(c) [7 marks]**

Explain Principle of Q meter. Also draw and explain Practical Q Meter.

**Solution**

**Principle of Q Meter:** The Q-meter operates on the principle of **series resonance**, where Q factor is measured as the ratio of voltage across the capacitor to the applied voltage at resonance.

**Block Diagram:**

**Figure 2.** Practical Q Meter

**Table 3.** Components

Component	Function
<b>RF Oscillator</b>	Provides variable frequency signals
<b>Work Coil</b>	Inductively couples signal to test circuit
<b>Resonant Circuit</b>	Test inductor L in series with variable capacitor C
<b>VTVM</b>	Measures voltage across capacitor
<b>Q-Scale</b>	Calibrated to read Q value directly

- Resonant Formula:**  $f = \frac{1}{2\pi\sqrt{LC}}$
- Q Calculation:**  $Q = \frac{V_c}{V_s}$  (voltage across capacitor / source voltage)

**Mnemonic**

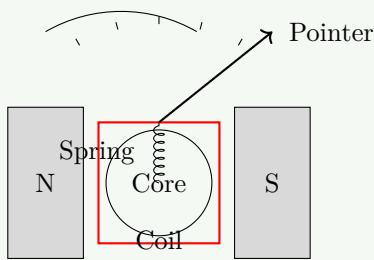
“RIVQ - Resonance Indicates Valuable Quality”

**Question 1(c) OR [7 marks]**

Draw and explain construction of Moving coil type instruments.

### Solution

**Construction Diagram:**



**Figure 3.** PMMC Construction

**Table 4.** Construction Details

Component	Description
<b>Permanent Magnet</b>	Creates strong magnetic field
<b>Moving Coil</b>	Lightweight coil wound on aluminum frame, placed in magnetic field
<b>Springs</b>	Provide controlling torque and electrical connections
<b>Pointer</b>	Attached to coil, moves over calibrated scale
<b>Core</b>	Soft iron cylindrical core to concentrate magnetic flux

- Operating Principle:** Deflecting torque  $T_d = BILN$  (B-field strength, I-current, l-length, N-turns)
- Controlling Torque:** Provided by springs proportional to deflection angle ( $T_c \propto \theta$ )

### Mnemonic

“MAPS-C: Magnet Acts, Pointer Shows Current”

## Question 2(a) [3 marks]

List out different Types of errors. Explain any Two.

### Solution

**Table 5.** Types of Errors

<b>Gross Errors</b>
<b>Systematic Errors</b>
<b>Random Errors</b>
<b>Environmental Errors</b>
<b>Loading Errors</b>

### Explanation:

- Systematic Errors:** Consistent and predictable deviations from actual value. Caused by instrument calibration, design, or method.
- Random Errors:** Unpredictable variations in measurements. Caused by noise, environmental fluctuations, or observer limitations.

### Mnemonic

“GSREL - Good Systems Reduce Error Levels”

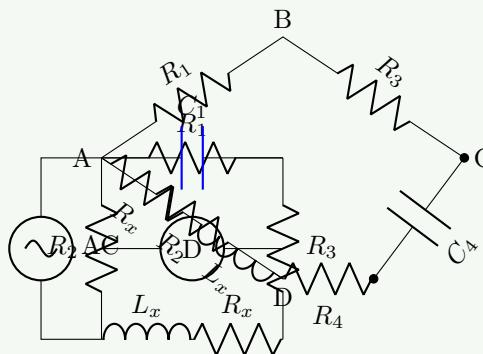
## Question 2(b) [4 marks]

Draw and Explain Maxwell's bridge.

### Solution

Maxwell's Bridge measures inductance by comparing it with a standard capacitor.

Circuit Diagram:



**Figure 4.** Maxwell's Inductance-Capacitance Bridge

**Note:** The standard Maxwell bridge puts capacitor in parallel with resistance opposite to the inductor.

**Table 6.** Components

Component	Function
$R_1, R_2, R_3, R_4$	Precision resistors
$L_x$	Unknown inductor with resistance $R_x$
$C_1$	Standard capacitor
Detector	Headphones or null indicator

- Balance Equation:**  $L_x = R_2 R_3 C_1$
- Resistance Equation:**  $R_x = \frac{R_2 R_3}{R_1}$
- Application:** Medium Q coils ( $1 < Q < 10$ ).

### Mnemonic

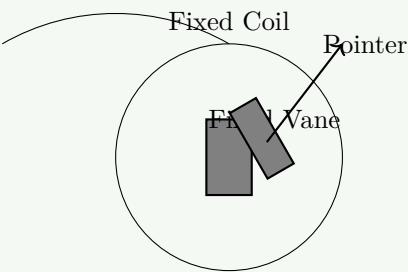
"MLBR - Maxwell Bridge Links Resistance"

## Question 2(c) [7 marks]

Draw and explain construction of moving iron type instruments.

### Solution

Construction Diagram:

**Figure 5.** Moving Iron (Repulsion Type)**Table 7.** Construction Details

Component	Description
<b>Coil</b>	Fixed coil that carries measuring current
<b>Iron Vanes</b>	Two soft iron pieces (one fixed, one movable)
<b>Pointer</b>	Attached to movable vane
<b>Control Spring</b>	Provides restraining torque
<b>Damping</b>	Air friction damping using light aluminum piston

- Working Principle:** When current flows through coil, both iron pieces get magnetized with same polarity, causing repulsion.
- Advantages:** Robust, cheap, measures AC and DC.
- Disadvantages:** Non-linear scale, higher power consumption.

### Mnemonic

“IRAM - Iron Repulsion Activates Movement”

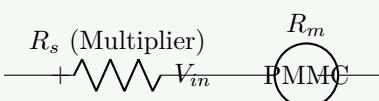
## Question 2(a) OR [3 marks]

Explain basic DC voltmeter.

### Solution

**DC Voltmeter** consists of a PMMC meter in series with a high resistance.

**Circuit:**

**Figure 6.** Basic DC Voltmeter**Table 8.** Components

<b>PMMC Movement</b>	Basic current-sensitive movement
<b>Multiplier Resistor</b>	High-value series resistor to limit current
<b>Scale</b>	Calibrated to read voltage directly

- Principle:** Current is proportional to voltage ( $I = V/(R_s + R_m)$ ).
- Calculation:**  $R_s = \frac{V}{I_m} - R_m$ .

**Mnemonic**

“SVM - Series Voltage Measurement”

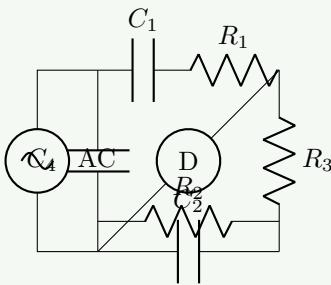
**Question 2(b) OR [4 marks]**

Draw and Explain Schering bridge.

**Solution**

**Schering Bridge** is used for measuring capacitance and dielectric loss.

**Circuit Diagram:**



**Figure 7.** Schering Bridge

**Table 9.** Components

Component	Function
$C_1$	Unknown capacitor (modelled with series loss $R_1$ )
$C_2, R_2$	Parallel RC arm
$R_3$	Non-inductive resistor
$C_4$	Standard loss-free capacitor

- **Balance Equations:**  $C_1 = C_4 \frac{R_2}{R_3}$
- **Dissipation Factor:**  $D = \omega C_1 R_1 = \omega C_2 R_2$
- **Application:** High voltage capacitor testing.

**Mnemonic**

“SCDR - Schering Capacitance Determines Resistance”

**Question 2(c) OR [7 marks]**

Write shortnote on Electronic Multimeter.

**Solution**

**Electronic Multimeter** uses electronic circuits (amplifiers) to drive the meter, offering high input impedance.

**Block Diagram:**



**Figure 8.** Electronic Multimeter Block Diagram

**Table 10.** Features and Description

Feature	Description
<b>Functions</b>	Measures Voltage, Current, Resistance (AC/DC)
<b>Sensitivity</b>	High (typically $10M\Omega$ input impedance)
<b>Ranges</b>	Switchable ranges for wide measurement capability
<b>Accuracy</b>	Better than VOM (Volt-Ohm-Milliammeter)
<b>Display</b>	Analog (PMMC) or Digital (LCD/LED)

- **Advantages:** Minimal loading effect, reliable, compact.

**Mnemonic**

“VCAR-D: Voltage, Current And Resistance - Displayed”

**Question 3(a) [3 marks]**

Explain Various probes for CRO.

**Solution****Table 11.** Types of Probes

Type	Description
<b>Passive Probe (1X)</b>	Direct connection probe with no attenuation
<b>Passive Probe (10X)</b>	Attenuates signal by factor of 10, reduces circuit loading
<b>Active Probe</b>	Contains active components (FETs) for high impedance, low capacitance
<b>Current Probe</b>	Measures current by sensing magnetic field (clip-on)

- **Selection Criteria:** Bandwidth, loading effect, measurement range.
- **Compensation:** 10X probes require adjustment to match oscilloscope input capacitance.

**Mnemonic**

“PAC-S: Probes Allow Circuit Sensing”

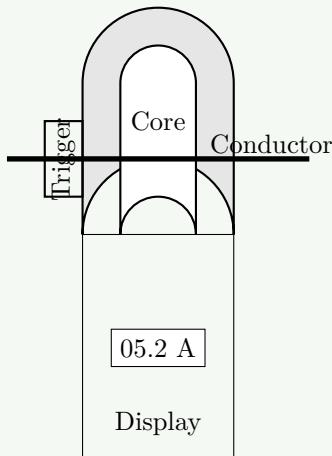
**Question 3(b) [4 marks]**

Draw and explain construction of Clamp on Meter.

**Solution**

**Clamp Meter** (Tong Tester) measures AC current without breaking the circuit.

**Construction Diagram:**

**Figure 9.** Clamp Meter Construction**Table 12.** Components

Component	Function
<b>Split Core CT</b>	Ferrite core that clamps around conductor (Primary winding is the conductor itself)
<b>Coil Winding</b>	Secondary winding on core that generates induced current
<b>Signal Circuitry</b>	Converts current to measurable signal
<b>Display Unit</b>	Digital/analog display calibrated in amps
<b>Trigger</b>	Opens/closes core jaws

- **Principle:** Current Transformer (CT).  $I_s = I_p \times \frac{N_p}{N_s}$ .
- **Application:** Measuring high current in live wires safely.

### Mnemonic

“CAMP - Current Analyzed by Magnetic Principle”

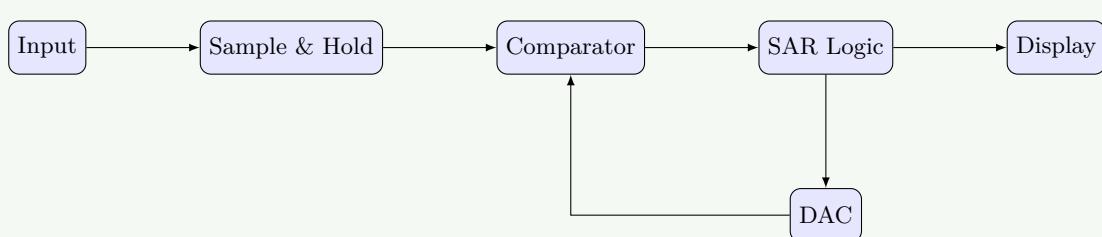
## Question 3(c) [7 marks]

Write shortnote on successive approximation type DVM.

### Solution

**SAR DVM** uses a binary search algorithm to digitize analog voltage.

**Block Diagram:**

**Figure 10.** Successive Approximation DVM**Table 13.** Functional Blocks

Block	Function
<b>Sample &amp; Hold</b>	Captures and holds input voltage stable during conversion
<b>Comparator</b>	Compares input voltage with DAC output
<b>SAR Logic</b>	Sets bits from MSB to LSB. If $V_{DAC} > V_{in}$ , resets bit; else keeps it
<b>DAC</b>	Converts digital code back to analog for comparison

- **Conversion Time:** Fixed ( $n$  clock cycles for  $n$ -bit).  $T = n \times T_{clk}$ .
- **Advantages:** Moderate speed (faster than dual slope), constant conversion time.

### Mnemonic

“SACD - Sample, Approximate, Compare, Display”

## Question 3(a) OR [3 marks]

Explain PH Sensor.

### Solution

**pH Sensor** measures the acidity or alkalinity of a solution.

Diagram:

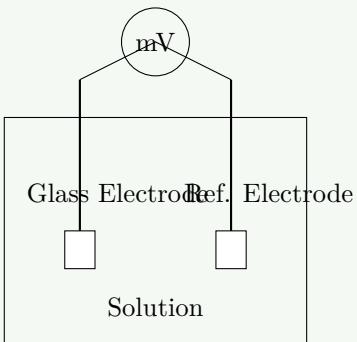


Figure 11. pH Measurement System

- **Glass Electrode:** Sensitive to  $H^+$  ion concentration.
- **Reference Electrode:** Provides stable potential (Ag/AgCl).
- **Nernst Equation:**  $E = E_0 - \frac{kT}{nF} \ln[H^+]$ .
- **Output:** Approx 59mV change per pH unit at 25°C.

### Mnemonic

“PHRV - PH Related to Voltage”

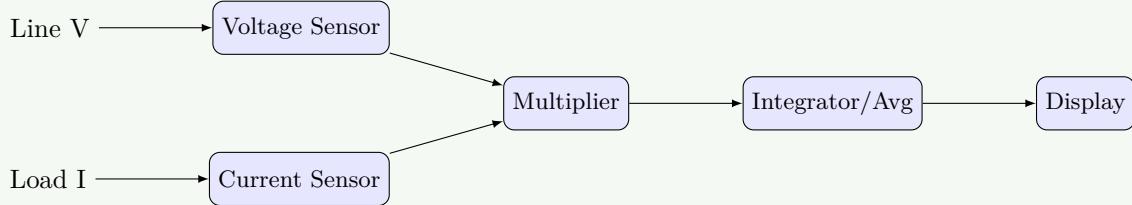
## Question 3(b) OR [4 marks]

Draw and explain construction of Electronic Watt Meter.

### Solution

**Electronic Wattmeter** measures power ( $P = VI \cos \phi$ ).

Block Diagram:

**Figure 12.** Electronic Wattmeter

- **Multiplier:** Produces instantaneous power signal  $p(t) = v(t) \times i(t)$ .
- **Integrator/Averager:** Averages the instantaneous power to get true power  $P_{avg}$ .
- **Display:** Shows value in Watts.

**Mnemonic**

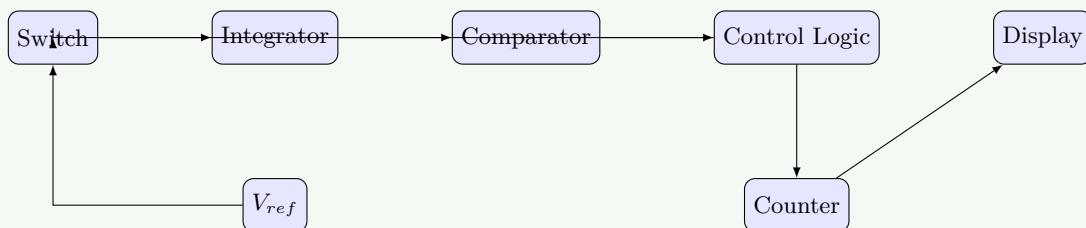
"VIMP - Voltage & Intensity Make Power"

**Question 3(c) OR [7 marks]**

Write shortnote on Integrating type DVM.

**Solution**

**Integrating DVM** measures true average value of input voltage over a fixed period. Example: Dual-Slope Integrating DVM.

**Block Diagram:****Figure 13.** Dual Slope DVM**Table 14.** Phases

<b>Phase 1 (Signal Integration)</b>	Integrate $V_{in}$ for fixed time $T_1$ . Capacitor charges.
<b>Phase 2 (Reference Integration)</b>	Integrate fixed $-V_{ref}$ . Capacitor discharges to zero. Measure time $T_2$ .

- **Principle:**  $V_{in} = V_{ref} \times \frac{T_2}{T_1}$ .
- **Features:** Excellent noise rejection (averages out noise), high accuracy, slower speed.

**Mnemonic**

"TINA - Time Integration Nullifies Average"

**Question 4(a) [3 marks]**

Write advantages and applications of Digital storage oscilloscope.

**Solution****Table 15.** Advantages and Applications

Advantages	Applications
Pre-trigger Viewing	Capturing transient events
Infinite Storage	Analyzing intermittent faults
Waveform Processing (FFT, Math)	Complex signal analysis
Hard Copy/PC Interface	Data logging and documentation

**Mnemonic**

“SPADE - Storage, Processing, Analysis, Display, Events”

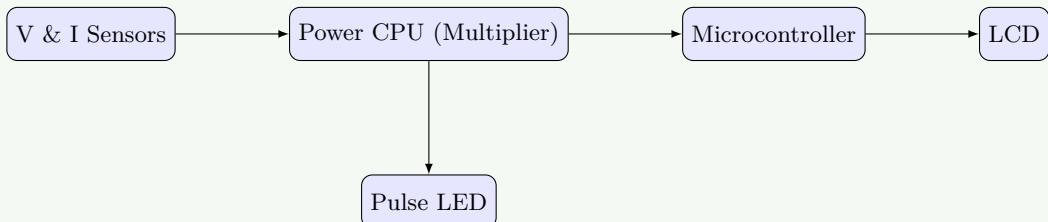
**Question 4(b) [4 marks]**

Write shortnote on Electronic Energy Meter.

**Solution**

**Electronic Energy Meter** measures energy consumption in kWh using digital circuits.

**Block Diagram:**

**Figure 14.** Energy Meter System

- **Sensors:** Resistive divider for Voltage, Shunt/CT for Current.
- **Metering IC:** Multiplies V and I to get power, converts to frequency (pulses).
- **Microcontroller:** Accumulates pulses to calculate Energy ( $\int Pdt$ ).
- **Display:** Shows total kWh.

**Mnemonic**

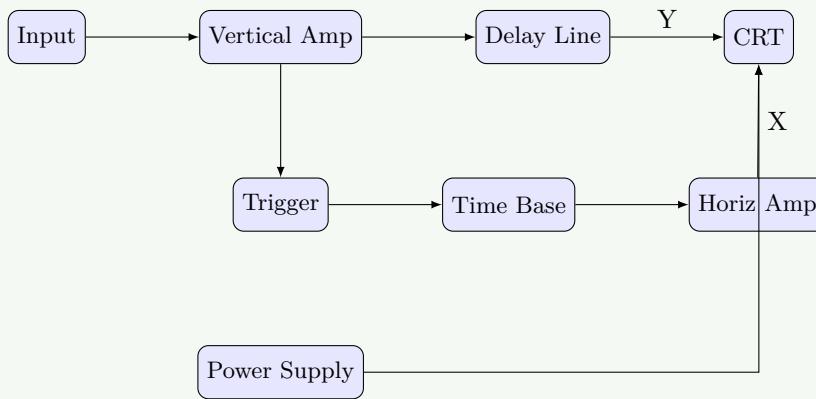
“VICES - Voltage & Current Energy Summation”

**Question 4(c) [7 marks]**

Draw and explain Block diagram of Analog C.R.O. and working of each block in brief.

**Solution**

**Block Diagram:**

**Figure 15.** CRO Block Diagram**Table 16.** Block Functions

Block	Function
<b>Vertical Amplifier</b>	Amplifies weak input signals for Y-deflection
<b>Delay Line</b>	Delays signal to Y-plates to allow sweep to start
<b>Trigger Circuit</b>	Synchronizes sweep with input signal for stable display
<b>Time Base</b>	Generates sawtooth wave for X-deflection (sweep)
<b>Horizontal Amplifier</b>	Amplifies sawtooth wave for X-plates
<b>CRT</b>	Displays waveform (Electron gun, Deflection system, Screen)

**Mnemonic**

“VTHCP - Vertical, Time, Horizontal, CRT, Power”

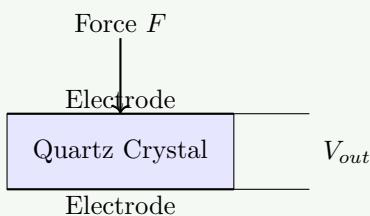
**Question 4(a) OR [3 marks]**

Draw and explain PIEZO-ELECTRIC transducer.

**Solution**

**Piezoelectric Transducer** is an active transducer converting pressure to voltage.

Diagram:

**Figure 16.** Piezoelectric Crystal

- **Principle:** Piezoelectric Effect. Stress → Charge.
- **Materials:** Quartz, Rochelle Salt, PZT.
- **Output:**  $V = g \cdot t \cdot P$  ( $P = \text{Pressure}$ ,  $t = \text{thickness}$ ,  $g = \text{voltage sensitivity}$ ).
- **Application:** Dynamic pressure, Accelerometers.

**Mnemonic**

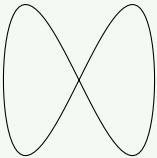
“PFVD - Pressure Forms Voltage via Displacement”

**Question 4(b) OR [4 marks]**

Draw and explain Measurement of Frequency by using CRO.

**Solution****Method 1: Time Base (Direct)**

- Measure Time Period  $T$  of one cycle on screen.
- Calculate  $f = 1/T$ .

**Method 2: Lissajous Figures (XY Mode)**

Pattern for  $f_y : f_x = 2 : 1$

**Figure 17.** Lissajous Pattern Example

- Apply unknown  $f_y$  to Y and standard  $f_x$  to X.
- $\frac{f_y}{f_x} = \frac{\text{Number of horizontal tangents}}{\text{Number of vertical tangents}}$

**Mnemonic**

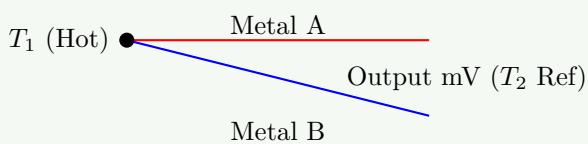
“LTX - Lissajous or Time for X-axis”

**Question 4(c) OR [7 marks]**

Draw and explain Thermistor and Thermocouple.

**Solution**

1. **Thermistor:** Variable resistor sensitive to temperature.
  - **Types:** NTC (Negative Temp Coeff) - R decreases as T increases (most common). PTC - R increases.
  - **Characteristic:** Highly sensitive, non-linear.
2. **Thermocouple:** Active transducer based on Seebeck Effect.



**Figure 18.** Thermocouple

- **Principle:** Junction of dissimilar metals at different temperatures generates EMF.
- **Types:** J (Iron-Constantan), K (Chromel-Alumel).
- **Range:** Wide temperature range, robust.

**Mnemonic**

“TRT/TVJ - Temperature Resistance/Voltage Junction”

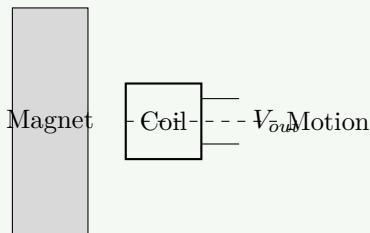
**Question 5(a) [3 marks]**

Draw and Explain Velocity transducer.

**Solution**

**Electromagnetic Velocity Transducer** (Moving coil type).

Diagram:



**Figure 19.** Velocity Transducer

- Principle:** Faraday's Law ( $e = N \frac{d\phi}{dt}$ ). Since  $\frac{d\phi}{dt} \propto$  velocity.
- Output:** Voltage is directly proportional to linear velocity of coil relative to magnet.
- Application:** Vibration monitoring.

**Mnemonic**

“VMMF - Velocity Makes Magnetic Flux”

**Question 5(b) [4 marks]**

Give Classification of transducers and explain it.

**Solution**

**Table 17.** Classification

Basis	Types
<b>Power Source</b>	<b>Active:</b> Self-generating (Thermocouple, Piezo). <b>Passive:</b> External power required (RTD, LVDT).
<b>Transduction</b>	Resistive, Inductive, Capacitive, etc.
<b>Function</b>	<b>Primary:</b> Detects phenomenon (Bourdon tube). <b>Secondary:</b> Converts to electrical (LVDT).
<b>Output</b>	Analog vs Digital.

**Mnemonic**

“APRCI - Active Passive Resistive Capacitive Inductive”

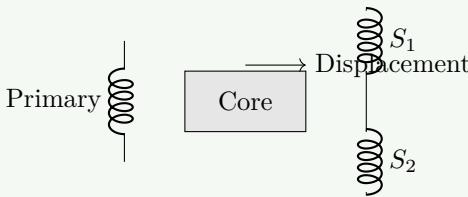
## Question 5(c) [7 marks]

Write shortnote on LVDT.

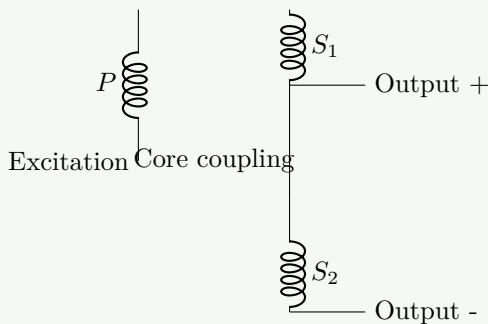
### Solution

LVDT (Linear Variable Differential Transformer) is an inductive transducer for displacement.

Diagram:



Schematic:



**Figure 20.** LVDT Schematic

- **Construction:** One primary winding, two secondary windings connected in **series opposition**. Movable soft iron core.
- **Working:**
  - Null Position: Voltages in  $S_1$  and  $S_2$  equal and cancel out ( $V_{out} = 0$ ).
  - Displacement: Core movement changes flux coupling, creating differential output ( $V_{out} = V_{s1} - V_{s2}$ ).
- **Advantages:** Linearity, infinite resolution, rugged.

### Mnemonic

“CPSO: Core Position Shifts Output”

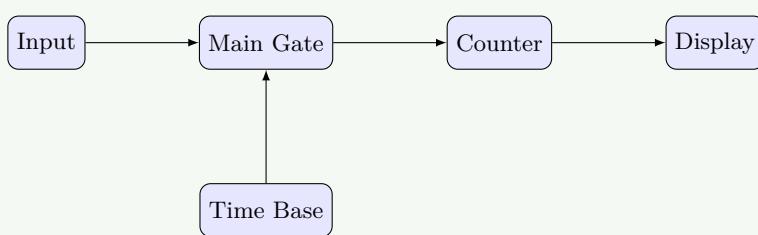
## Question 5(a) OR [3 marks]

Draw and Explain block diagram of simple frequency Counter.

### Solution

Digital Frequency Counter counts pulses over a fixed time measuring frequency ( $f = N/t$ ).

Block Diagram:



**Figure 21.** Frequency Counter

- **Time Base:** Generates precise "Gate" signal (e.g., 1 sec).
- **Main Gate:** Allows input pulses to pass only for gate duration.
- **Counter:** Counts pulses. Reading represents frequency.

**Mnemonic**

"IGTCD - Input Gated Time Counts Display"

**Question 5(b) OR [4 marks]**

Draw and Explain Capacitive Transducer.

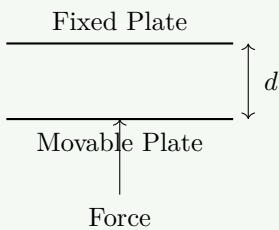
**Solution**

Capacitive Transducer works on  $C = \frac{\epsilon A}{d}$ .

**Principles:**

1. **Variable Separation ( $d$ ):** Moving plate changes distance. Used for pressure/displacement.
2. **Variable Area ( $A$ ):** Overlapping area changes.
3. **Variable Dielectric ( $\epsilon$ ):** Dielectric moves between plates.

**Diagram:**

**Figure 22.** Variable Gap Capacitive Transducer**Mnemonic**

"CGAD - Capacitance Gap Area Dielectric"

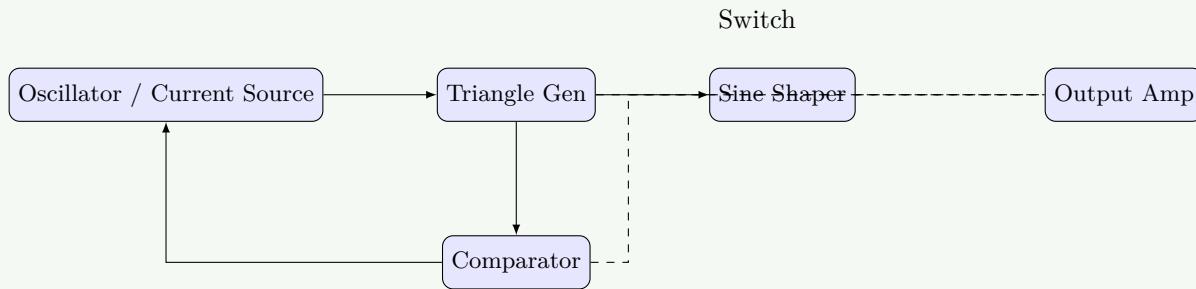
**Question 5(c) OR [7 marks]**

Draw and Explain block diagram of Function generator.

**Solution**

**Function Generator** produces Sine, Square, and Triangular waves over wide frequency range.

**Block Diagram:**

**Figure 23.** Function Generator**Table 18.** Working

<b>Frequency Control</b>	Varies current to integrating capacitor
<b>Triangle</b>	Basic waveform generated by constant current charging/discharging
<b>Comparator</b>	Switches current direction, generates Square wave
<b>Sine Shaper</b>	Networks convert triangle to sine
<b>Output Amplifier</b>	Sets amplitude and impedance

**Mnemonic**

“FWMASO - Frequency Waveform Mode Amplitude Sweep Output”