Electronic Measurements & Instruments (4331102) - Winter 2023 Solution

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Question 1(a) [3 marks]

Give Definition of Accuracy, Reproducibility and Repeatability.

Solution

Table 1. Definitions

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

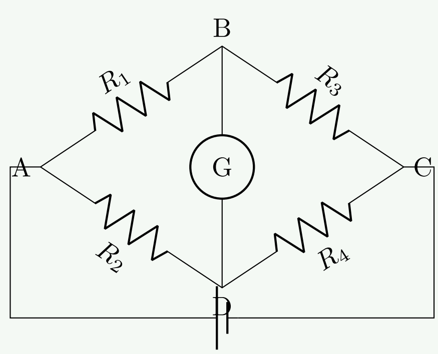


Figure 1. Wheatstone Bridge

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:

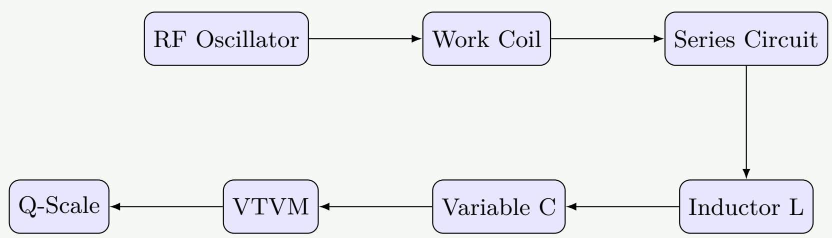


Figure 2. Practical Q Meter

Table 3. Components

Component	Function
RF Oscillator	Provides variable frequency signals
Work Coil	Inductively couples signal to test circuit
Resonant Circuit	Test inductor L in series with variable capacitor C
VTVM	Measures voltage across capacitor
Q-Scale	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:

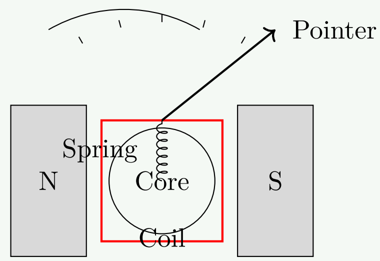


Figure 3. PMMC Construction

Table 4. Construction Details

Component	Description
Permanent Magnet	Creates strong magnetic field
Moving Coil	Lightweight coil wound on aluminum frame, placed in magnetic field
Springs	Provide controlling torque and electrical connections
Pointer	Attached to coil, moves over calibrated scale
Core	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

Gross Errors
Systematic Errors
Random Errors
Environmental Errors
Loading Errors

Explanation:

1. **Systematic Errors**: Consistent and predictable deviations from actual value. Caused by instrument calibration, design, or method.
2. **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:

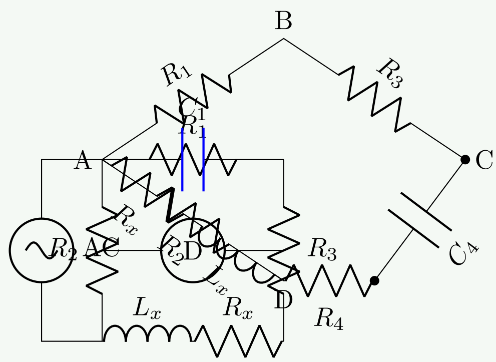


Figure 4. Maxwell's Inductance-Capacitance Bridge

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

"MBLR - Maxwell Bridge Links Resistance"

Question 2(c) [7 marks]

Draw and explain construction of moving iron type instruments.

Solution

Construction Diagram:

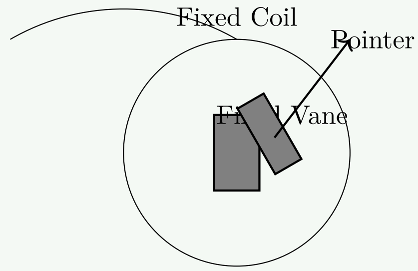


Figure 5. Moving Iron (Repulsion Type)

Table 7. Construction Details

Component	Description
Coil	Fixed coil that carries measuring current
Iron Vanes	Two soft iron pieces (one fixed, one movable)
Pointer	Attached to movable vane
Control Spring	Provides restraining torque
Damping	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:

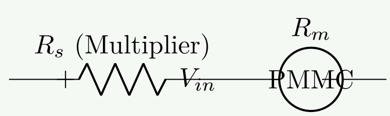


Figure 6. Basic DC Voltmeter

Table 8. Components

PMMC Movement	Basic current-sensitive movement
Multiplier Resistor	High-value series resistor to limit current
Scale	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:

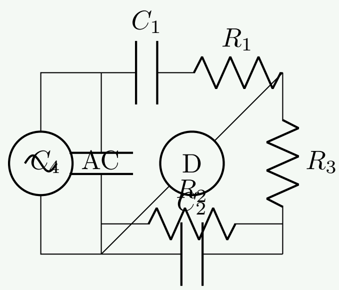


Figure 7. Schering Bridge

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
Functions	Measures Voltage, Current, Resistance (AC/DC)
Sensitivity	High (typically 10MΩ input impedance)
Ranges	Switchable ranges for wide measurement capability
Accuracy	Better than VOM (Volt-Ohm-Milliammeter)
Display	Analog (PMCC) 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
Passive Probe (1X)	Direct connection probe with no attenuation
Passive Probe (10X)	Attenuates signal by factor of 10, reduces circuit loading
Active Probe	Contains active components (FETs) for high impedance, low capacitance
Current Probe	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:

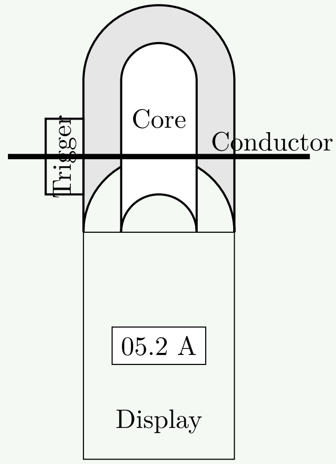


Figure 9. Clamp Meter Construction

Table 12. Components

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

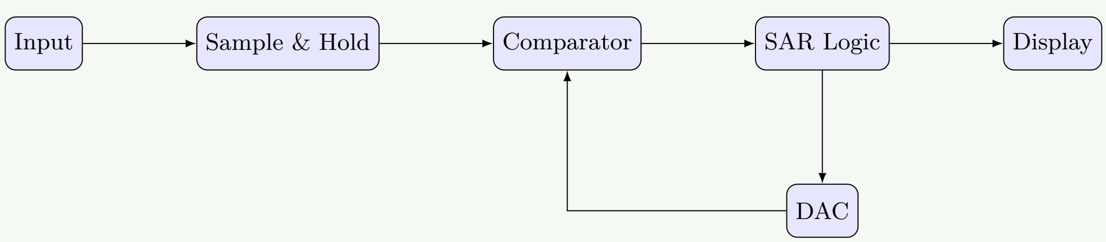


Figure 10. Successive Approximation DVM

Table 13. Functional Blocks

Block	Function
Sample & Hold	Captures and holds input voltage stable during conversion
Comparator	Compares input voltage with DAC output
SAR Logic	Sets bits from MSB to LSB. If $V_{DAC} > V_{in}$, resets bit; else keeps it
DAC	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:

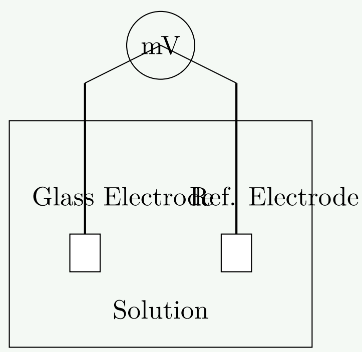


Figure 11. pH Measurement System

- **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:

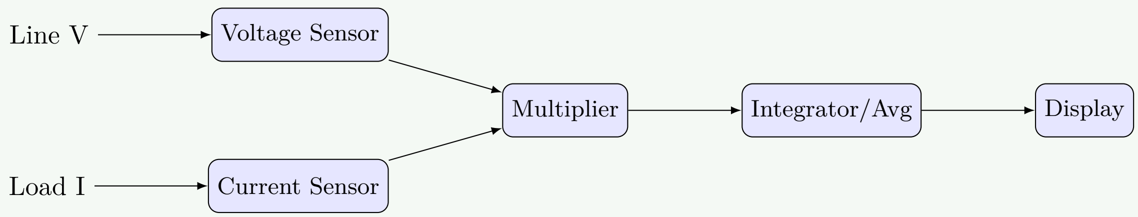


Figure 12. Electronic Wattmeter

- **Multiplier**: Produces instantaneous power signal $p(t) = v(t) \times i(t)$.
- **Integrator/Averager**: Averagers 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:

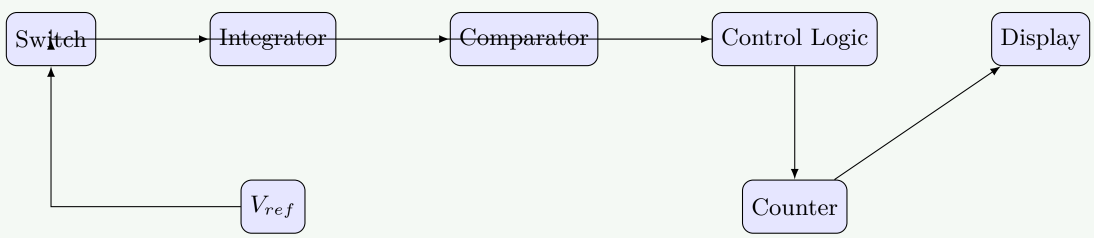


Figure 13. Dual Slope DVM

Table 14. Phases

Phase 1 (Signal Integration)	Integrate V_{in} for fixed time T_1. Capacitor charges.
Phase 2 (Reference Integration)	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:

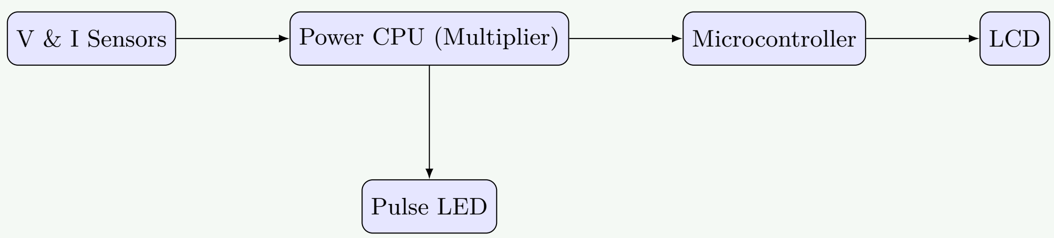


Figure 14. Energy Meter System

- **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:

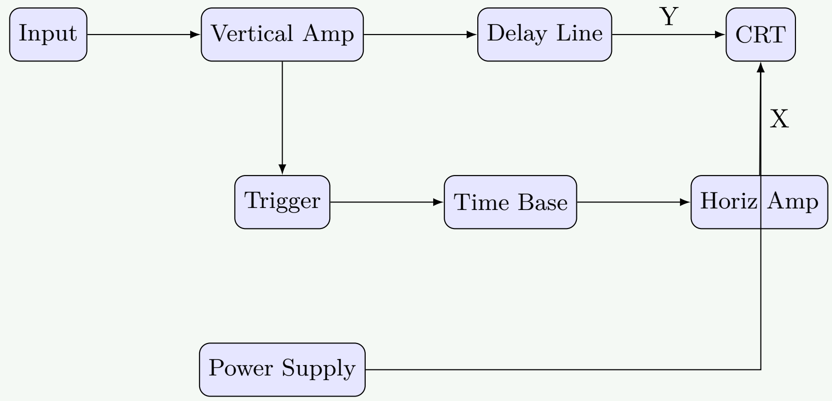


Figure 15. CRO Block Diagram

Table 16. Block Functions

Block	**Function**
Vertical Amplifier	Amplifies weak input signals for Y-deflection
Delay Line	Delays signal to Y-plates to allow sweep to start
Trigger Circuit	Synchronizes sweep with input signal for stable display
Time Base	Generates sawtooth wave for X-deflection (sweep)
Horizontal Amplifier	Amplifies sawtooth wave for X-plates
CRT	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:

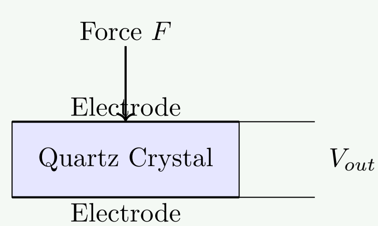


Figure 16. Piezoelectric Crystal

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

Mnemonic

"PFVD - Pressure Forms Voltage via Displacement"

Question 4(b) OR [4 marks]

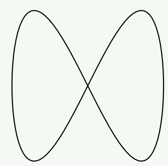
Draw and explain Measurement of Frequency by using CRO.

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.

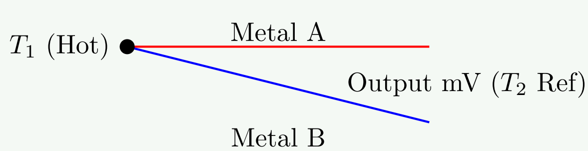


Figure 18. Thermocouple

- **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:

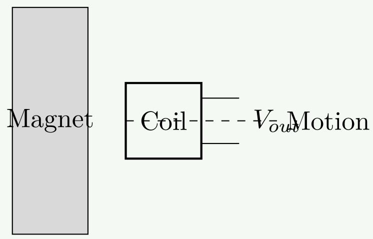


Figure 19. Velocity Transducer

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

Mnemonic

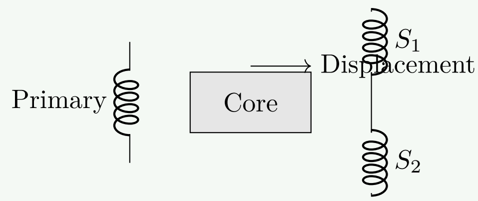
"APRCI - Active Passive Resistive Capacitive Inductive"

Question 5(c) [7 marks]

Write shortnote on LVDT.

Solution

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



Schematic:

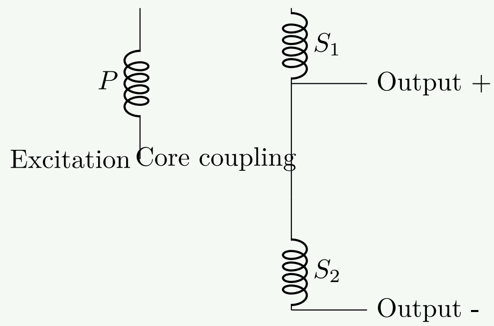


Figure 20. LVDT Schematic

- **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:

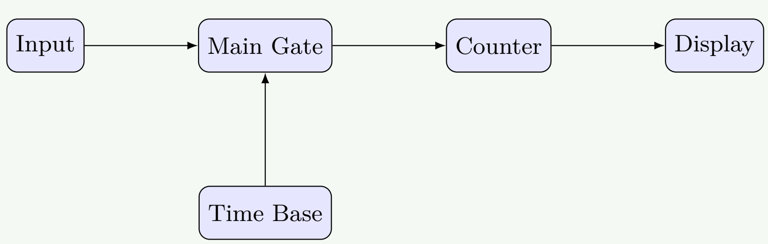


Figure 21. Frequency Counter

- **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** (ϵ): Dielectric moves between plates.

Diagram:

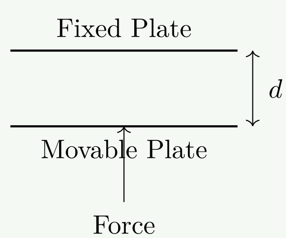


Figure 22. Variable Gap Capacitive Transducer

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:

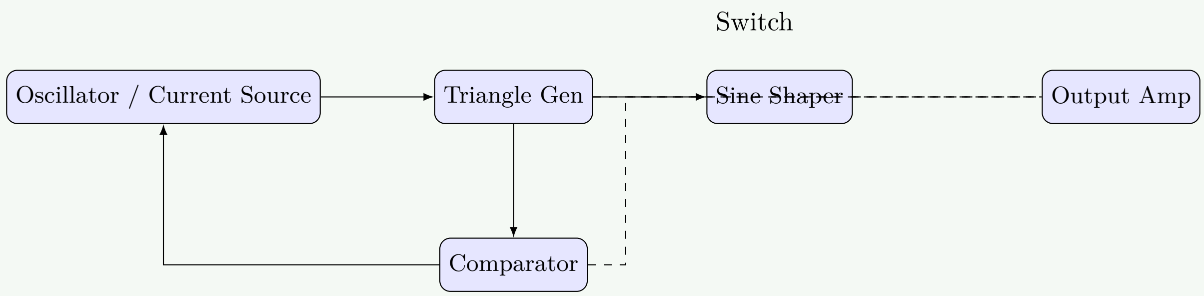


Figure 23. Function Generator

Table 18. Working

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

Mnemonic

"FWMASO - Frequency Waveform Mode Amplitude Sweep Output"