# Electronic Measurements and Instruments (4331102) - Winter 2022 Solution

Milav Dabgar

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## Question 1(a) [3 marks]

**Draw and explain working of Basic Q-Meter.**

**Solution**

**Q-meter** is an instrument used to measure the quality factor (Q) of an inductor or capacitor.
**Block Diagram**:

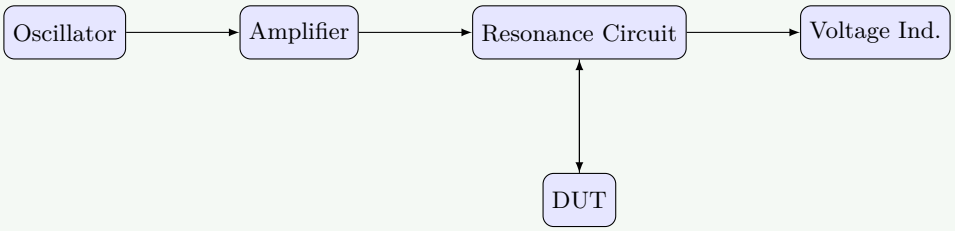


**Figure 1.** Basic Q-Meter Block Diagram

**Functions**:
- **Oscillator**: Generates variable frequency signal.
- **Amplifier**: Amplifies the signal to required level.
- **Resonance Circuit**: Contains the component under test and tuning elements.
- **Voltage Indicator**: Measures the voltage across the component (V) relative to input (E).

**Mnemonic**

"OARV - Oscillate, Amplify, Resonate, View"

## Question 1(b) [4 marks]

**Explain Spectrum Analyzer in brief.**

**Solution**

A **Spectrum Analyzer** measures the magnitude of an input signal versus frequency within the full frequency range of the instrument.
**Block Diagram**:

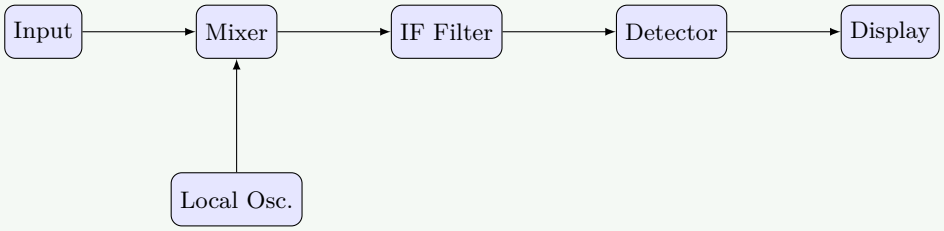


**Figure 2.** Spectrum Analyzer Block Diagram

**Key Aspects**:
- **Input Signal Processing**: Signals enter through attenuator and filters.
- **Frequency Domain Conversion**: Converts time domain to frequency domain.
- **Display System**: Shows amplitude vs. frequency plot.
- **Applications**: Signal analysis, distortion measurement, EMI testing.

**Mnemonic**

"SAME-FD: Signal Analysis Measures Everything in Frequency Domain"

## Question 1(c) [7 marks]

**Explain Wheatstone bridge with circuit diagram. List its advantages and disadvantages.**

**Solution**

**Wheatstone bridge** is a circuit used to measure unknown resistance with high accuracy.
**Circuit Diagram**:

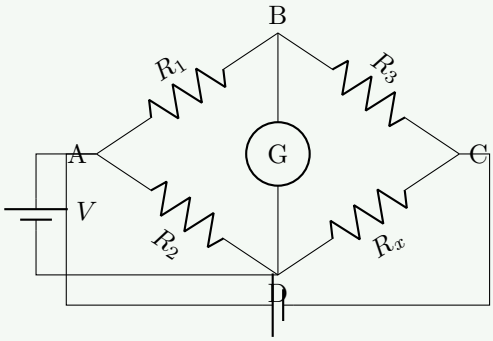


**Figure 3.** Wheatstone Bridge

Where:
- $R_1, R_2, R_3$ are known resistances.
- $R_x$ is unknown resistance.
- $G$ is galvanometer.

**Working Principle**:
- Bridge is balanced when potential at B equals potential at D and no current flows through G.
- **Balance Condition**: $\frac{R_1}{R_2} = \frac{R_3}{R_x}$
- **Unknown Resistance**: $R_x = R_3(\frac{R_2}{R_1})$

**Table 1.** Advantages and Disadvantages

| Advantages | Disadvantages |
|---|---|
| High accuracy | Limited range |
| Good sensitivity | Temperature effects |
| Null type measurement | Requires balance adjustment |
| No need for calibrated meter | Not suitable for very low/high resistances |

**Mnemonic**

"BARN - Balance Achieved when Ratios are Null"

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

**Define Instrument and explain its characteristics.**

**Solution**

An **instrument** is a device used for measuring, displaying or recording physical quantities.
**Instrument Block Diagram**:

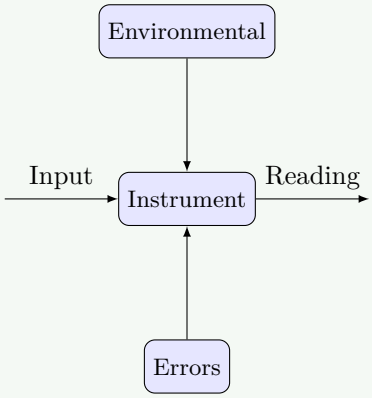


**Figure 4.** General Instrument System

**Table 2.** Instrument Characteristics

| Characteristic | Description |
|---|---|
| **Accuracy** | Closeness of measurement to true value |
| **Precision** | Repeatability of measurements |
| **Resolution** | Smallest change that can be detected |
| **Sensitivity** | Ratio of output signal to input signal change |
| **Linearity** | Proportional relationship between input and output |
| **Range** | Minimum to maximum measurable values |
| **Response time** | Time required to show true reading |

**Types**:
- **Static Characteristics**: Properties that don't vary with time.
- **Dynamic Characteristics**: Properties that vary with time.

**Mnemonic**

"APRS-LRR: Accuracy and Precision, Resolution and Sensitivity, Linearity, Range, Response time"

# Question 2(a) [3 marks]

**Draw the construction diagram of Energy meter.**

## Solution

**Energy meter** measures electrical energy consumption in kilowatt-hours (kWh).
**Diagram**:

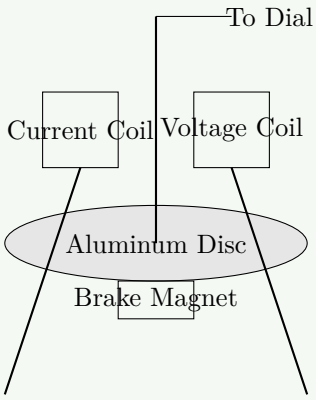


**Figure 5.** Induction Type Energy Meter

**Components**:
- **Rotating Aluminum Disc**: Moves proportional to power.
- **Current Coil**: Creates flux proportional to current.
- **Voltage Coil**: Creates flux proportional to voltage.
- **Permanent Magnet**: Provides braking torque.

## Mnemonic

"DVCP: Disc Velocity measures Consumed Power"

# Question 2(b) [4 marks]

**Explain working of PMMC in short.**

## Solution

**PMMC (Permanent Magnet Moving Coil)** is a basic mechanism used in various DC meters.
**Construction Diagram**:

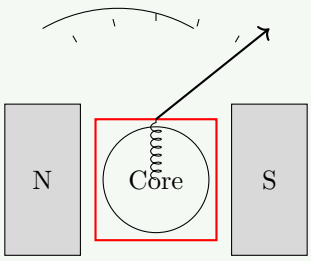


**Figure 6.** PMMC Construction

**Table 3.** Key Components

| Component | Function |
|---|---|
| Permanent Magnet | Creates strong magnetic field |
| Moving Coil | Carries current to be measured |
| Spring | Provides controlling torque |
| Pointer | Indicates reading on scale |

**Working**: When current flows through the coil placed in a magnetic field, a force is exerted on it, producing a deflecting torque $T_d \propto I$.

**Mnemonic**

"CODA: Current through cOil causes Deflection by Attraction"

## Question 2(c) [7 marks]

**1- A moving coil ammeter reading up to 1 ampere has a resistance of 0.02 ohm. How this instrument could be adopted to read current up to 100 amperes? 2- A moving coil voltmeter reading up to 20 mV has a resistance of 2 ohms. How this instrument can be adopted to read voltage up to 300 volts?**

**Solution**

**Part 1: Ammeter Range Extension**
To extend ammeter range, a **Shunt Resistance** ($R_sh$) is connected in parallel.
**Diagram**:

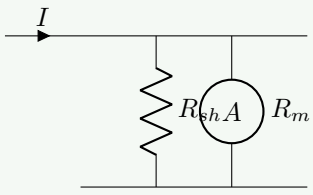


**Figure 7.** Ammeter with Shunt

Given: $I_m = 1A$, $R_m = 0.02\Omega$, $I = 100A$. Formula: $R_{sh} = \frac{R_m \cdot I_m}{I - I_m}$ Calculation:

$$R_{sh} = \frac{0.02 \times 1}{100 - 1} = \frac{0.02}{99} \approx 0.000202\Omega$$

**Part 2: Voltmeter Range Extension**
To extend voltmeter range, a **Series Multiplier Resistance** ($R_s$) is connected in series.
**Diagram**:

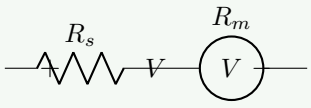


**Figure 8.** Voltmeter with Multiplier

Given: $V_m = 20mV = 0.02V$, $R_m = 2\Omega$, $V = 300V$. Formula: $R_s = R_m(\frac{V}{V_m} - 1)$ Calculation:

$$R_s = 2 \times (\frac{300}{0.02} - 1) = 2 \times (15000 - 1) = 2 \times 14999 = 29,998\Omega$$

**Mnemonic**

"SHIP: Shunt Has Inverse Proportion for current; Series for voltage"

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

**Explain working of electronic multimeter.**

**Solution**

**Electronic Multimeter** measures voltage, current, and resistance using active electronic components.
**Block Diagram**:


**Figure 9.** Electronic Multimeter Block Diagram

**Working**:
- **Range Selection**: Attenuator/Amplifier network selects range.
- **Signal Conditioning**: Converts AC to DC, Current to Voltage, Resistance to Voltage.
- **ADC**: Analog to Digital Converter digitizes the signal.
- **Display**: LCD/LED shows the numeric value.

**Mnemonic**

"RSAD: Range Select, Amplify, Digitize"

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

**Explain working of Moving Iron type instruments.**

**Solution**

**Moving Iron instruments** utilize the magnetic force between a fixed coil and a moving iron piece.
**Working Principle**:
- Current flows through a fixed coil, creating a magnetic field.
- Iron piece placed in the field gets magnetized.
- **Attraction Type**: Iron bar attracted into the coil.
- **Repulsion Type**: Two iron vanes magnetized with same polarity repel each other.

**Diagram (Repulsion Type)**:

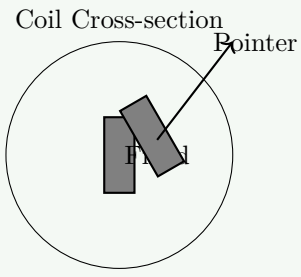


**Figure 10.** Moving Iron Mechanism

**Features**: Non-linear scale, Used for AC & DC, Robust.

**Mnemonic**

"CADS: Current Activates, Deflection Shows"

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

**Draw the block diagram of Ramp type DVM. Illustrate process of obtaining Multirange DC voltmeter with circuit diagram.**

**Solution**

**Ramp Type DVM** converts voltage to time ($V \propto t$).
**Block Diagram**:

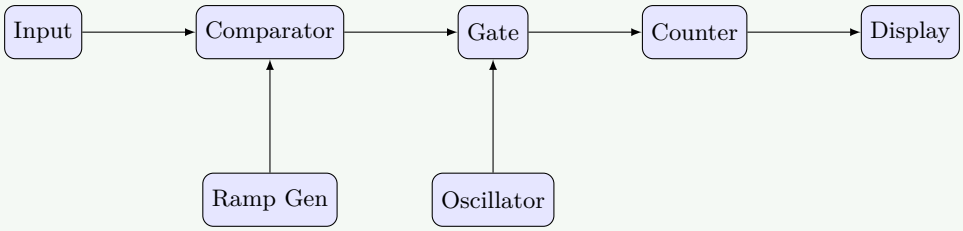


**Figure 11.** Ramp Type DVM

**Multirange DC Voltmeter Circuit**: To measure different voltage ranges, a voltage divider network is used.

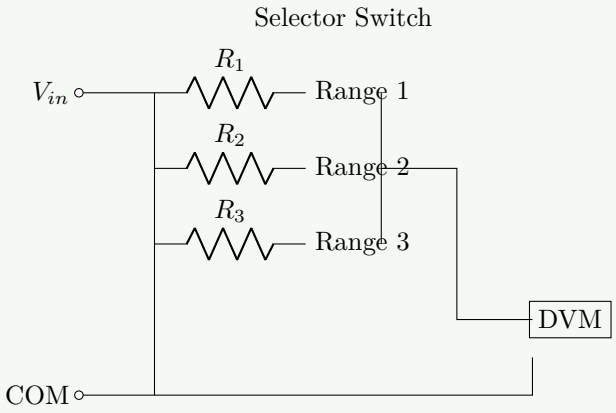


**Figure 12.** Multirange Attenuator

**Mnemonic**

"CRCD: Compare Ramp, Count Duration"

## Question 3(a) [3 marks]

**Describe features of Digital storage oscilloscope (DSO).**

**Solution**

**Features of DSO**:

- **Digital Storage**: Stores waveforms in memory for infinite time.
- **Pre-trigger Viewing**: Can see events before the trigger point.
- **Automatic Measurements**: Calculates Vpp, Vrms, Freq automatically.

- **PC Connectivity**: USB/LAN mainly for data logging.
- **Advanced Triggering**: Pulse width, video, pattern triggering.

**Mnemonic**

"SACRED: Storage, Analysis, Connectivity, Resolution, Extended functions, Digital processing"

## Question 3(b) [4 marks]

**Explain frequency measurement method using Lissajous pattern.**

**Solution**

**Lissajous Patterns** are formed when two sine waves are applied to X and Y plates of a CRO.
**Method**:

1. Connect Unknown Frequency ($f_y$) to Y-input.
2. Connect Standard Variable Frequency ($f_x$) to X-input.
3. Adjust $f_x$ until a stable closed loop pattern appears.

**Formula**:

$$\frac{f_y}{f_x} = \frac{\text{Number of horizontal tangencies } (N_x)}{\text{Number of vertical tangencies } (N_y)}$$

**Patterns**:

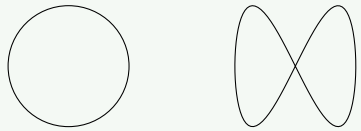


**Figure 13.** Lissajous Patterns

**Mnemonic**

"XTYN: X-Tangents to Y-tangents gives the Number ratio"

## Question 3(c) [7 marks]

**Explain CRO with help of Block diagram.**

**Solution**

**Cathode Ray Oscilloscope (CRO)** displays signal voltage vs time.
**Block Diagram**:

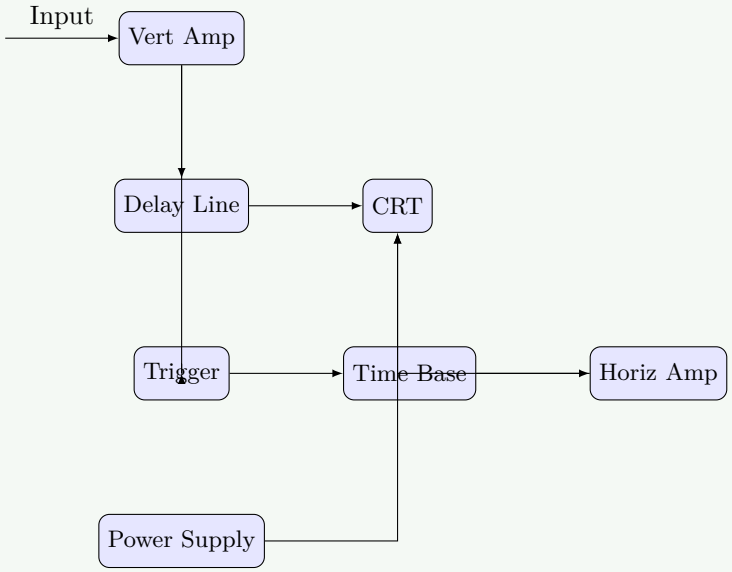


**Figure 14.** CRO Block Diagram

**Key Blocks**:

- **Vertical Amplifier**: Strengthens input signal.
- **Delay Line**: Delays vertical signal so horizontal sweep can start.
- **Time Base**: Generates sawtooth wave for horizontal deflection.
- **Trigger**: Synchronizes sweep with signal.
- **CRT**: Displays the electron beam trace.

**Mnemonic**

"VCTHP: Vertical input, Conditioned signal, Triggered sweep, Horizontal deflection, Phosphor display"

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

**Explain different types of CRO probes.**

**Solution**

**CRO Probes** connect the test circuit to the oscilloscope.

**Table 4.** Types of Probes

| Type | Characteristics |
|---|---|
| **Passive Probe** | Rugged, simple, 1:1 or 10:1 attenuation. High input impedance. |
| **Active Probe** | Built-in FET amplifier. Low capacitance, high bandwidth. Requires power. |
| **Current Probe** | Measures current via magnetic field (clip-on). No circuit breaking. |
| **Differential Probe** | Measures voltage difference between two points, rejecting common mode noise. |

**Mnemonic**

"PACD: Passive, Active, Current, Differential"

# Question 3(b) OR [4 marks]

**Draw internal structure of CRT. Explain in brief.**

**Solution**

**CRT (Cathode Ray Tube)** is a vacuum tube that produces visual display.
**Structure Diagram**:

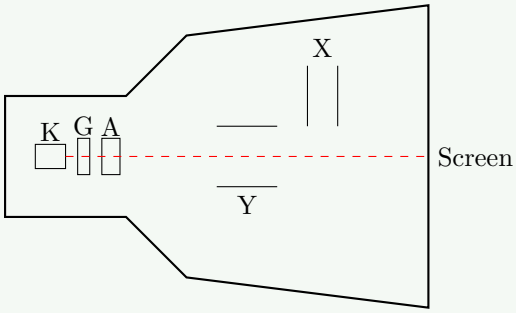


**Figure 15.** CRT Construction

**Parts**:
- **Electron Gun**: K, G, A produce focused beam.
- **Deflection Plates**: Y-plates (Vertical) and X-plates (Horizontal) move the beam.
- **Screen**: Coated with phosphor, glows when hit by electrons.

**Mnemonic**

"GAFDS: Gun Aims, Focusing Directs, Screen shows"

# Question 3(c) OR [7 marks]

**Draw and explain block diagram of DSO in detail.**

**Solution**

**Digital Storage Oscilloscope (DSO)** digitizes and stores waveforms.
**Block Diagram**:

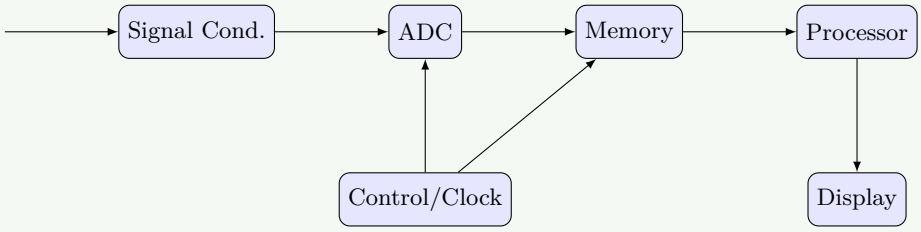


**Figure 16.** DSO Block Diagram

**Working**:
1. Input signal is conditioned (amplified/attenuated).
2. **ADC** samples the signal and converts to binary data.
3. Data is stored in **Digital Memory**.
4. **Microprocessor** reads memory and reconstructs waveform for display.

**Mnemonic**

"SAMPLE-D: Signal Acquisition, Memory Processing, Locking trigger, Display"

## Question 4(a) [3 marks]

**Give the comparison of NTC and PTC thermistor.**

**Solution**

**Table 5.** NTC vs PTC Thermistor

| Parameter | NTC (Negative Temp Coeff) | PTC (Positive Temp Coeff) |
|---|---|---|
| Resistance Change | Decreases as Temp Increases | Increases as Temp Increases |
| Material | Semiconductor oxides (Mn, Ni) | Barium Titanate |
| Linearity | Non-linear (Exponential) | Non-linear (Sharp rise) |
| Application | Temp measurement, Compensation | Overcurrent protection, Heating |

**Mnemonic**

"IN-DP: Increase Negative, Decrease Positive"

## Question 4(b) [4 marks]

**Explain working principle and construction of Thermocouple.**

**Solution**

**Thermocouple** measures temperature based on Seebeck Effect.
**Construction**: Two dissimilar metal wires joined at one end (Hot Junction). The other ends (Cold Junction) go to the meter.
**Diagram**:

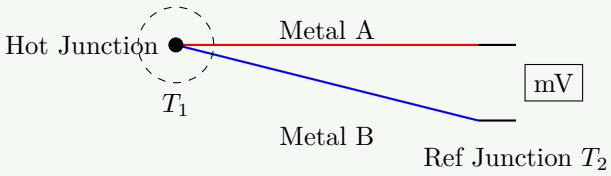


**Figure 17.** Thermocouple

**Principle**: When two different metals are joined and junctions are at different temperatures ($T_1 \neq T_2$), an electromotive force (EMF) is generated. $E = k(T_1 - T_2)$.

**Mnemonic**

"STEM: Seebeck-effect Transforms temperature to EMF in Metals"

## Question 4(c) [7 marks]

**Explain Working of strain Gauge and Load cell. Give advantages and disadvantages of RTD.**

**Solution**

**Strain Gauge**: Measures mechanical strain.
- **Variable Resistance Transducer**.
- Construction: Fine wire grid on paper/backing.
- Working: Tension → Length ↑, Area ↓ → Resistance ↑.
- Gauge Factor $G.F. = \frac{\Delta R/R}{\Delta L/L}$.

**Load Cell**: Force transducer.
- Uses strain gauges bonded to a metal element (column/beam).
- Force causes deformation, detected by strain gauges in Wheatstone bridge.

**RTD (Resistance Temperature Detector)**:
- **Advantages**: High accuracy, stable, linear.
- **Disadvantages**: Self-heating, slower response than thermocouple, external power needed.

**Mnemonic**

"SPANNER: Strain Proportionally Alters Nominal Nominal Electrical Resistance"

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

### Explain Humidity Sensor Hygrometer.

**Solution**

**Humidity Sensor (Hygrometer)** measures relative humidity (RH).
**Types**:
- **Resistive**: Hygroscopic material absorbs moisture → Resistance decreases.
- **Capacitive**: Moisture absorption changes dielectric constant → Capacitance changes.

**Block Diagram**:

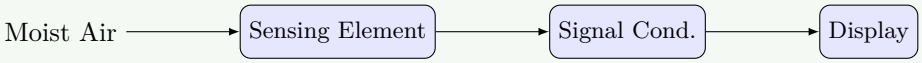


**Figure 18.** Humidity Sensor

**Mnemonic**

"CRT-H: Capacitance/Resistance/Thermal changes with Humidity"

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

### Draw and explain Piezoelectric transducer.

**Solution**

**Piezoelectric Transducer** converts pressure/acceleration to voltage.
**Diagram**:

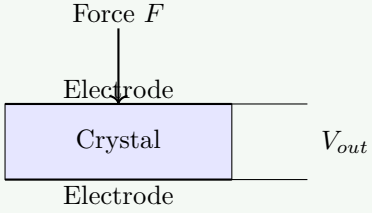

**Figure 19.** Piezoelectric Crystal

**Working**:
- Based on **Piezoelectric Effect**.
- When pressure is applied to crystal (Quartz, Rochelle Salt, PZT), charges accumulate on faces.
- $V = Q/C = d \cdot F/C$.
- **Active Transducer** (Self-generating).

**Mnemonic**

"PEMS: Pressure Ensures Measurable Signal"

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

**Give the classification of transducers in detail.**

**Solution**

**Transducer Classification**:
1. **Based on Transduction Principle**:
   - Resistive (Potentiometer, Strain Gauge)
   - Capacitive (Var distance, dielectric)
   - Inductive (LVDT)
   - Piezoelectric
   - Photovoltaic/Photoconductive
2. **Active vs Passive**:
   - **Active**: Generates own voltage (Thermocouple, Piezo).
   - **Passive**: Needs external power (RTD, Strain Gauge, LVDT).
3. **Primary vs Secondary**:
   - **Primary**: Detects physical phenomenon (Bourdon Tube).
   - **Secondary**: Converts primary output to electrical (LVDT on Bourdon).
4. **Analog vs Digital**:
   - Analog: Continuous output.
   - Digital: Pulse/Binary output (Encoders).

**Mnemonic**

"APAD RICE: Active/Passive, Analog/Digital with Resistive, Inductive, Capacitive, Electromagnetic"

## Question 5(a) [3 marks]

**Write short note on various Capacitive transducer.**

**Solution**

**Capacitive Transducers** work on $C = \frac{\epsilon A}{d}$.
**Types**:
1. **Variable Separation** ($d$): Moving plate changes distance. Used for displacement, pressure.
2. **Variable Area** ($A$): Moving plate overlaps fixed plate distinctively. Used for large displacement.
3. **Variable Dielectric** ($\epsilon$): Dielectric material moves between plates. Used for liquid level.

**Mnemonic**

"PALD: Parameter Alters the Leading Dielectric"

# Question 5(b) [4 marks]

**Explain LVDT Transducer.**

**Solution**

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

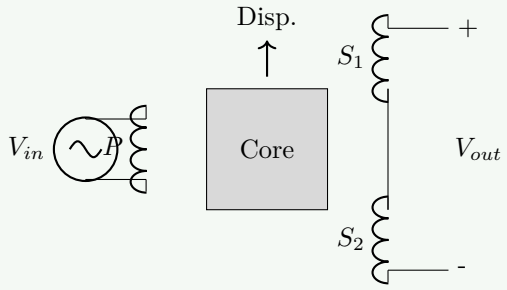


**Figure 20.** LVDT Construction

**Working**:
- Primary powered by AC.
- Voltage induced in secondaries depends on core position.
- Secondaries connected in **Series Opposition**: $V_{out} = V_{s1} - V_{s2}$.
- At center (Null): $V_{out} = 0$.

**Mnemonic**

"MDVN: Movement Determines Voltage from Null"

# Question 5(c) [7 marks]

**Draw and explain Harmonics Distortion Analyzer.**

**Solution**

**Harmonic Distortion Analyzer** measures Total Harmonic Distortion (THD).
**Block Diagram**:

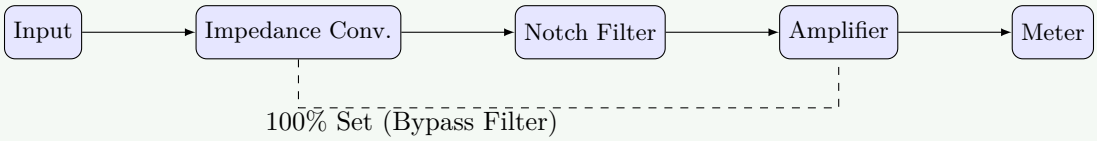


**Figure 21.** Fundamental Suppression Analyzer

**Working**:
1. **Set Level**: Filter bypassed. Meter reads total signal (Fundamental + Harmonics). Adjust gain to mark 100%.
2. **Measure**: Filter inserted. Fundamental frequency removed. Meter measures remaining harmonics.
3. $THD = \frac{\sqrt{\sum V_n^2}}{V_1}$.

**Mnemonic**

"FAIR-D: Filter And Isolate Residuals for Distortion"

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

**Explain the working principle of Proximity sensors.**

**Solution**

**Proximity Sensors** detect presence of objects without contact.
**Types**:
- **Inductive**: Detects metal objects via eddy currents.
- **Capacitive**: Detects any object by dielectric change.
- **Optical**: Detects via light beam interruption/reflection.

**Working**: An electromagnetic or electrostatic field is emitted. Object entering the field changes field properties (damping oscillation or changing capacitance), triggering switching circuit.

**Mnemonic**

"CUPS: Capacitive, Ultrasonic, Photoelectric, Sense"

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

**Explain absolute and incremental type of Optical encoder.**

**Solution**

**Optical Encoder** measures angular position/speed.
**Absolute Encoder**:
- Disc has multiple tracks with unique binary code for each angle.
- Outputs absolute position immediately.
- Doesn't lose position on power loss.

**Incremental Encoder**:
- Disc has slots on periphery.
- Outputs pulses as it rotates.
- Measures speed and relative change.
- Loses position on power loss.

**Diagram**:

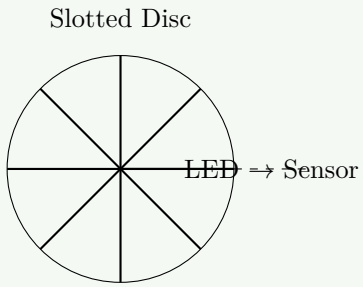


**Figure 22.** Basic Encoder Principle

**Mnemonic**

"APIR-CD: Absolute Provides Immediate Reading, Counter Determines incremental"

# Question 5(c) OR [7 marks]

**Write short note on Digital IC Tester.**

## Solution

**Digital IC Tester** checks functionality of logic gates, Flip-flops, etc.
**Block Diagram**:

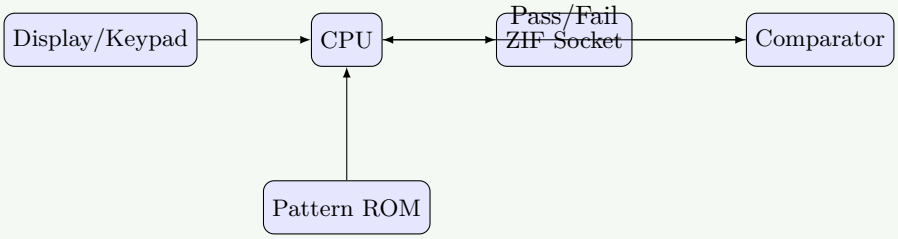


**Figure 23.** IC Tester

**Operation**:
1. User enters IC number (e.g., 7400).
2. CPU fetches truth table from ROM.
3. CPU applies inputs to IC Pins via ZIF socket.
4. Comparator compares actual outputs with expected outputs.
5. If all match → PASS. Else → FAIL.

## Mnemonic

"GATES: Generate And Test Every Signal"