Electronic Measurements and Instruments (4331102) - Summer 2025 Solution

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Question 1(a) [3 marks]

Define Accuracy, Precision, and Sensitivity.

Solution

- **Accuracy**: The closeness of a measured value to the actual or true value of a quantity.
- **Precision**: The ability of an instrument to reproduce the same output reading when the same input is applied repeatedly under the same conditions.
- **Sensitivity**: The ratio of change in output of an instrument to the change in input, indicating how much output changes for a small change in input.

Table 1. Differences between Accuracy and Precision

Parameter	Accuracy	Precision
Definition	Closeness to true value	Repeatability of measurement
Focus on	Correctness	Consistency
Representation	Bulls-eye center hits	Clustered hits

Mnemonic

"APS - Accuracy Pinpoints truth, Precision Shows repeatability, Sensitivity Signals small changes"

Question 1(b) [4 marks]

Describe the working and limitations of the Wheatstone bridge with circuit diagram.

Solution

Working: The Wheatstone bridge measures unknown resistance by balancing two legs of a bridge circuit.
Circuit Diagram:

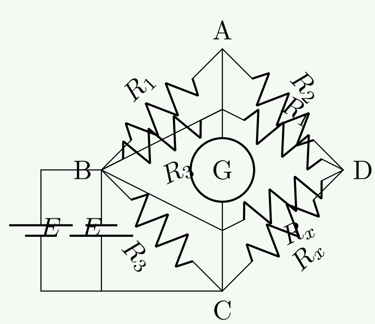

Figure 1. Wheatstone Bridge

When bridge is balanced: $\frac{R_1}{R_2} = \frac{R_3}{R_x}$, so $R_x = R_3 \times (\frac{R_2}{R_1})$
Limitations:

- **Limited range**: Not suitable for very low or very high resistances
- **Temperature effects**: Resistance changes with temperature
- **Battery errors**: Output voltage must remain stable
- **Galvanometer sensitivity**: Limited by detector sensitivity

Mnemonic

"BALR - Balance is key, Adjust until null, Low/high resistances problematic, Range is limited"

Question 1(c) [7 marks]

Explain various transducers used for temperature measurement. Explain the construction and working of the following in detail: (i) Thermocouple (ii) Thermistor.

Solution

Temperature Transducers Types:

Table 2. Temperature Transducers Comparison

Type	Working Principle	Range	Advantages	Disadvantages
Thermocouple	Seebeck effect	$-270°C$ to $2300°C$	Wide range, robust	Nonlinear, reference needed
Thermistor	Resistance change	$-50°C$ to $300°C$	High sensitivity	Nonlinear, limited range
RTD	Resistance change	$-200°C$ to $850°C$	High accuracy, linear	Expensive, self-heating
IC Sensors	Semiconductor	$-55°C$ to $150°C$	Linear output, easy interface	Limited range

(i) Thermocouple: **Construction**: Two dissimilar metal wires (like copper-constantan or iron-constantan) joined at one end to form measuring junction and other ends connected to measuring instrument.
Diagram:

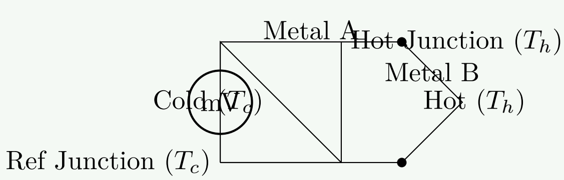

Figure 2. Thermocouple

Working: When junctions are at different temperatures, a small voltage proportional to temperature difference is generated (**Seebeck effect**).
Key Points:

- **Seebeck effect**: Temperature difference creates voltage
- **Cold junction compensation**: Required for accuracy
- **Types**: J, K, T, E based on metal combinations

(ii) Thermistor: **Construction**: A semiconductor material (metal oxides like manganese, nickel, cobalt) shaped into a bead, disk, or rod with two lead wires.
Diagram:

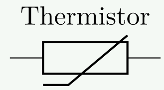

Figure 3. Thermistor Symbol

Working: Resistance decreases as temperature increases (NTC type) or increases with temperature (PTC type).
Key Points:
- **NTC (Negative Temperature Coefficient)**: Most common type
- **High sensitivity**: Large resistance change for small temperature change
- **Nonlinear response**: Requires linearization circuits
- **Self-heating**: Current passing through it causes heating

Mnemonic

"TRIP - Thermocouples React to junction differences, Thermistors Intensely change resistance, Point sensors at what you measure"

Question 1(c) OR [7 marks]

Explain the working principles of the following sensors: Temperature sensor, Gas sensor, Humidity sensor and Proximity sensor.

Solution

Comparison of Sensors:

Table 3. Sensor Comparison

Sensor Type	Working Principle	Output	Applications
Temperature	Resistance/voltage change	Analog/Digital	HVAC, Medical devices
Gas	Chemical reaction	Resistance change	Safety systems, Air quality
Humidity	Capacitance/resistance change	Analog	Weather stations, HVAC
Proximity	Electromagnetic field disruption	Digital	Automation, Security

1. Temperature Sensor (LM35):
- **Principle**: Semiconductor junction voltage varies with temperature
- **Working**: Integrated circuit provides output voltage proportional to temperature ($10mV/°C$)
- **Features**: Linear output, no external calibration needed

2. Gas Sensor (MQ-2):
- **Principle**: Chemical reaction between gas and sensing material
- **Working**: Gas molecules interact with metal oxide semiconductor, changing its resistance
- **Detection**: When gas concentration exceeds threshold, output voltage changes

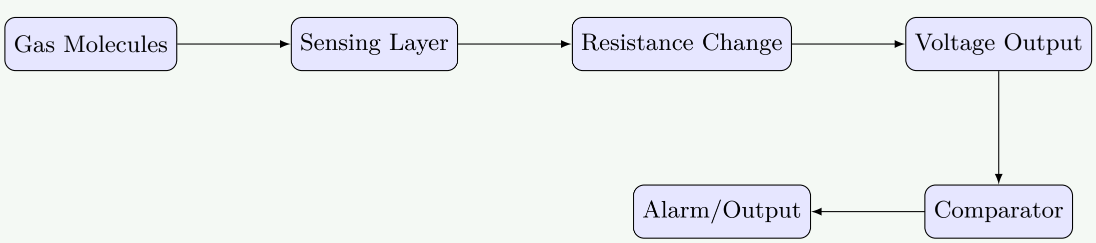

Figure 4. Gas Sensor Working

3. Humidity Sensor (Hygrometer):
- **Principle**: Capacitance or resistance varies with moisture absorption
- **Working**: Dielectric material absorbs moisture, changing electrical properties

- **Types**: Capacitive (more accurate) and resistive (simpler)

4. Proximity Sensor:

- **Principle**: Detects objects without physical contact
- **Working**: Emits electromagnetic field/beam; detects changes when object enters field
- **Types**: Inductive (metals), capacitive (any material), ultrasonic (distance)

Mnemonic

"TGHP - Temperature Generates voltage, Gas Hits semiconductors, Humidity Holds moisture, Proximity Perceives objects"

Question 2(a) [3 marks]

List types of DVM and mention one advantage of each.

Solution

Types of Digital Voltmeters (DVM):

Table 4. DVM Types

DVM Type	Working Principle	Advantage
Ramp Type	Compares input with reference ramp	Simple design, low cost
Integrating Type	Measures average over time	Good noise rejection
Successive Approximation	Binary search algorithm	Fast conversion speed
Dual Slope	Integration with fixed time	Excellent noise rejection

Key Points:

- **Ramp type**: Simple but affected by noise
- **Integrating type**: Reduces effect of periodic noise
- **Successive approximation**: Quick readings, good for changing signals
- **Dual slope**: Best accuracy, immune to most noise

Mnemonic

"RISD - Ramp Is Simple Design, Integrating Ignores noise, Successive Secures speed, Dual Deals with interference"

Question 2(b) [4 marks]

Draw and explain Maxwells's bridge.

Solution

Maxwell's Bridge is used to measure unknown inductance by comparing it with a standard capacitance.
Circuit Diagram:

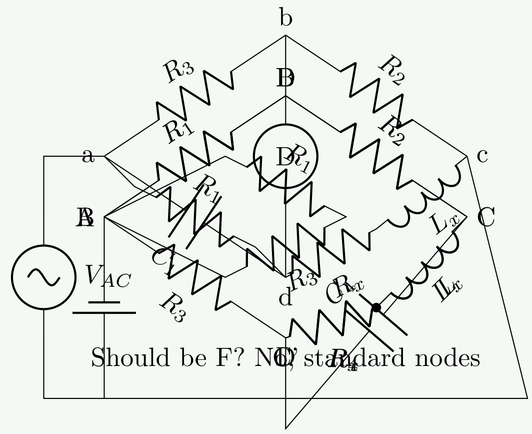

Figure 5. Maxwell's Inductance-Capacitance Bridge

Balance Equations:

- Unknown inductance $L_x = R_2R_3C_1$
- Resistance $R_x = \frac{R_2R_3}{R_1}$

Working:

- Bridge contains four arms.
- When bridge is balanced, no current flows through detector.
- Values of L and R calculated using balance equations.

Advantages:

- **High accuracy**: Good for medium value inductors (Q between 1 and 10).
- **Independent balance**: Resistance and inductance balanced separately.

Mnemonic

"MILL - Maxwell's Inductance is Like L = R2R3C"

Question 2(c) [7 marks]

Draw the block diagram of a Successive Approximation type Digital Voltmeter (DVM) and explain its working.

Solution

Successive Approximation DVM converts analog input to digital output using binary search algorithm.

Block Diagram:

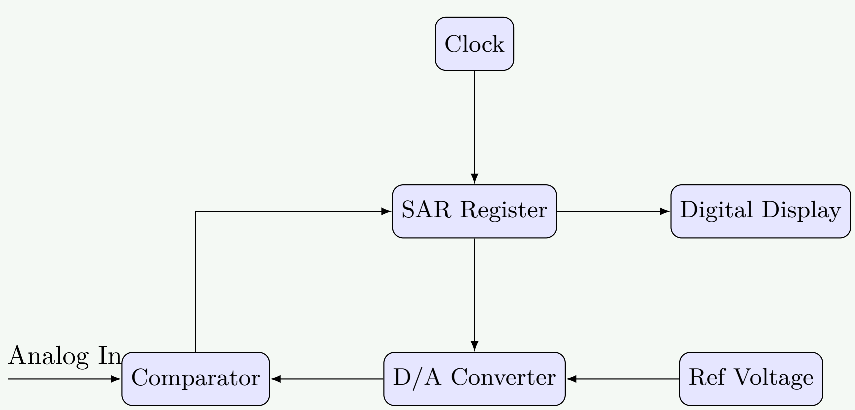

Figure 6. Successive Approximation DVM

Working:

1. **Signal conditioning**: Scales input voltage.
2. **Sample & Hold**: Captures instantaneous input value.
3. **SAR (Successive Approximation Register)**: Performs binary search.
4. **DAC**: Converts digital value to analog.
5. **Comparator**: Compares input with DAC output.
6. **Digital Display**: Shows final digital value.

Example Conversion: 4-bit conversion of 9V (range 0-15V): 8V (1000) $<$ 9V (Keep 1) $\rightarrow$ 12V (1100) $>$ 9V (Change to 0) $\rightarrow$ 10V (1010) $>$ 9V (Change to 0) $\rightarrow$ 9V (1001) $=$ 9V (Keep 1). Result: 1001.
Advantages:
- **Fast conversion**: Fixed time.
- **Good accuracy**: Suitable for most applications.

Mnemonic

"SHARP - Sample, Hold, Approximate, Register stores, Present result"

Question 2(a) OR [3 marks]

State and explain the working principle of PMMC instruments.

Solution

PMMC (Permanent Magnet Moving Coil) instruments operate based on electromagnetic principles.
Working Principle: When current flows through a coil placed in a magnetic field, a torque is produced causing the coil to rotate proportionally to the current ($T \propto I$).
Diagram:

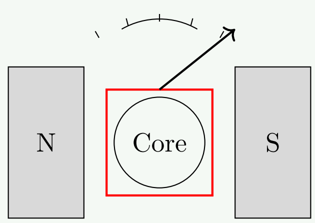

Figure 7. PMMC Construction

Key Components:
- **Permanent magnet**: Creates strong measuring field.
- **Moving coil**: Carries current, produces torque.
- **Control springs**: Provide restoring torque.
- **Pointer**: Indicates reading.

Mnemonic

"PMMC - Permanent Magnet Makes Coil turn when Current flows"

Question 2(b) OR [4 marks]

Draw and explain Schering bridge.

Solution

Schering Bridge measures capacitance and dissipation factor.
Circuit Diagram:

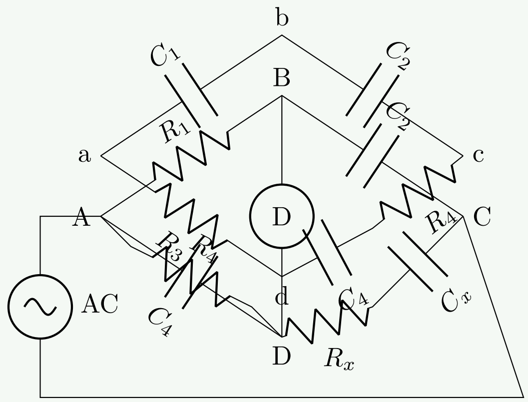

Figure 8. Schering Bridge

Balance Equations:
- Unknown Capacitance $C_x = C_2(\frac{R_1}{R_4})$
- Unknown Resistance $R_x = R_4(\frac{C_4}{C_2})$
- Dissipation Factor $D = \omega C_x R_x = \omega C_4 R_4$

Applications: Capacitor testing, Insulation testing.

Mnemonic

"SCAN - Schering Capacitance And taN delta measured together"

Question 2(c) OR [7 marks]

Draw and explain Dual slope integrating type DVM.

Solution

Block Diagram:

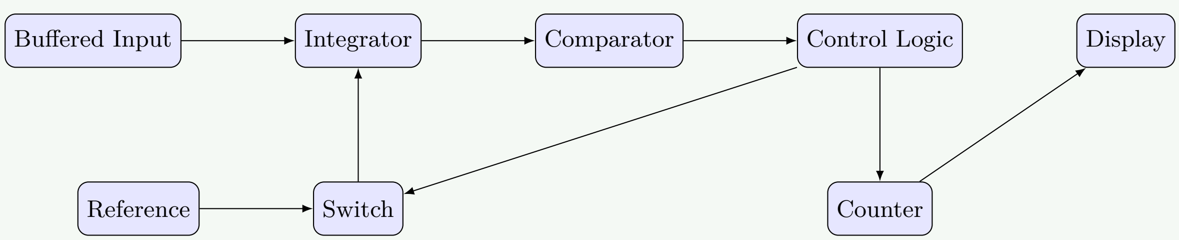

Figure 9. Dual Slope DVM

Working Principle:
- **First phase (T1)**: Integrates input signal for fixed time. Output ramps up.

$$V_{out} = -\frac{1}{RC}\int V_{in}dt$$

- **Second phase (T2)**: Integrates reference voltage (opposite polarity) until output hits zero. Output ramps down.

$$T_2 = T_1 \times (\frac{V_{in}}{V_{ref}})$$

Advantages: Excellent noise rejection (integrates out 50Hz hum if T1 is multiple of 20ms), High accuracy.

Mnemonic

"FIRE - First Integrate input, then Integrate Reference, until Equal to zero"

Question 3(a) [3 marks]

What is the importance of delay line and trigger circuit in a CRO?

Solution

Delay Line:
- **Purpose**: Delays signal to vertical plates.
- **Benefit**: Allows viewing of the leading edge of the signal that triggered the sweep.

Trigger Circuit:
- **Purpose**: Initiates horizontal sweep at a specific point on the waveform.
- **Benefit**: Ensures a stable, stationary display of repetitive waveforms.

Table 5. Delay vs Trigger

Component	Purpose	Benefit
Delay Line	Delays signal path	Shows complete waveform including trigger point
Trigger Circuit	Initiates sweep	Creates stable display with synchronized timing

Mnemonic

"DT-SS - Delay To See Signal, Trigger Stops Screen drift"

Question 3(b) [4 marks]

Explain the internal structure and working of a Cathode Ray Tube (CRT) with a neat diagram.

Solution

Cathode Ray Tube (CRT) converts electrical signals into visual display.
Structure Diagram:

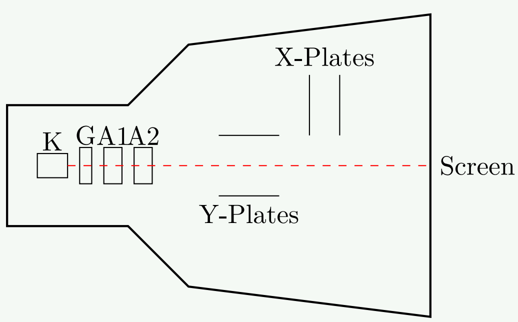

Figure 10. CRT Construction

Working:
1. **Electron Gun**: Generates (Cathode), controls (Grid), focuses (Anodes) electron beam.
2. **Deflection System**: Bends beamp vertically (Y-plates) and horizontally (X-plates).
3. **Screen**: Phosphor coating glows when struck by electrons.

Mnemonic

"EFADS - Electrons Fly, Anodes Direct, Screen shows signals"

Question 3(c) [7 marks]

Explain the working of a Cathode Ray Oscilloscope (CRO) with the help of a block diagram and describe the function of each block.

Solution

Block Diagram:

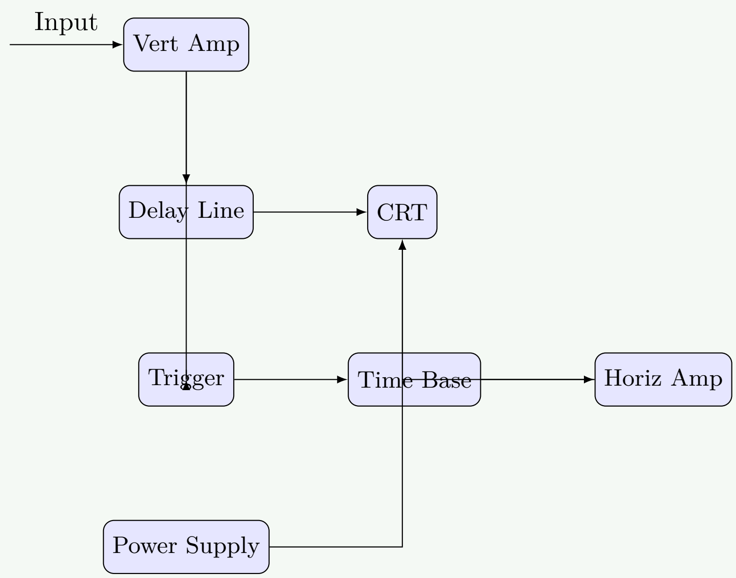

Figure 11. CRO Block Diagram

Functions:

- **Vertical Amplifier**: Amplifies weak signals for vertical deflection.
- **Delay Line**: Synchronizes signal arrival with sweep start.
- **Trigger Circuit**: Synchronizes sweep with signal frequency.
- **Time Base**: Generates sawtooth wave for horizontal sweep.
- **Horizontal Amplifier**: Amplifies sweep signal.
- **CRT**: Displays the waveform.

Mnemonic

"VATH-CDS - Vertical Attenuates Then amplifies, Horizontal Creates Deflection Sweep"

Question 3(a) OR [3 marks]

Give the differences between Cathode Ray Oscilloscope (CRO) and Digital Storage Oscilloscope (DSO).

Solution

Table 6. CRO vs DSO

Parameter	CRO	DSO
Signal Processing	Analog	Digital (ADC conversion)
Storage	None (Real-time)	Stores waveforms indefinitely
Bandwidth	Limited	Higher possible
Analysis	Basic	Advanced (FFT, Auto measure)

Key Differences:
- DSO can freeze and store waveforms.
- DSO can capture single-shot transient events.
- DSO provides direct digital readout of parameters.

Mnemonic

"DSO-MAPS - Digital Storage Oscilloscope Measures, Analyzes, Processes, Stores signals"

Question 3(b) OR [4 marks]

Explain how frequency and phase angle can be determined with the help of CRO.

Solution

Frequency Measurement:
1. Measure time period T (horizontal distance of 1 cycle $\times$ Time/div).
2. Frequency $f = 1/T$.

Phase Angle Measurement:
1. Display two signals.
2. Measure time difference Δt between zero crossings.
3. Measure period T.
4. Phase $\phi = (\frac{\Delta t}{T}) \times 360°$.

Diagram:

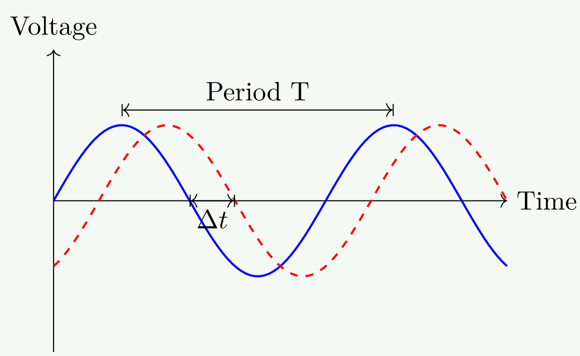

Figure 12. Phase Shift Measurement

Mnemonic

"FPL - Frequency = Period's Length reciprocal"

Question 3(c) OR [7 marks]

Draw the block diagram of a Digital Storage Oscilloscope (DSO) and explain the function of each block.

Solution

Digital Storage Oscilloscope (DSO) digitizes analog signals for storage and analysis.
Block Diagram:

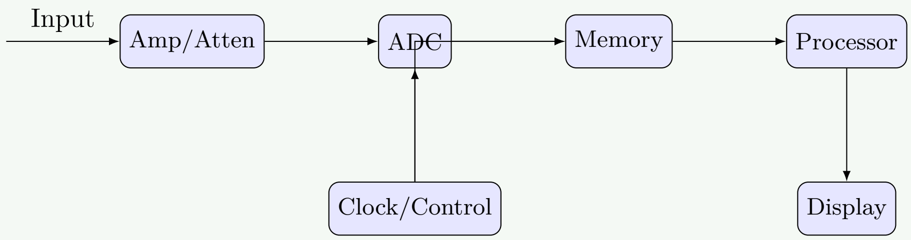

Figure 13. DSO Block Diagram

Functions:
- **Attenuator**: Scales input.
- **ADC**: Sampling and digitization.
- **Memory**: Stores digital samples.
- **Processor**: Reconstructs waveform, performs maths.
- **Display**: Shows signal on LCD.

Advantages: Single-shot capture, Pre-trigger view, Mathematical analysis.

Mnemonic

"AADPD - Attenuate Analog, Digitize, Process, Display the signal"

Question 4(a) [3 marks]

Give the classification of different types of transducers.

Solution

Classification:
- **Based on Energy**:
  - **Active**: Self-generating (e.g., Thermocouple).
  - **Passive**: External power driven (e.g., LVDT, Strain Gauge).
- **Based on Principle**:
  - **Resistive**: Potentiometer, Strain Gauge.
  - **Capacitive**: Variable capacitance pressure sensor.
  - **Inductive**: LVDT.
- **Based on Output**: Primary vs Secondary.

Mnemonic

"APRCI - Active/Passive, Resistive/Capacitive/Inductive are key categories"

Question 4(b) [4 marks]

Explain the construction and working of a strain gauge.

Solution

Strain Gauge: Measures mechanical strain by changing resistance.
Construction: Grid of fine wire or foil on a backing material.

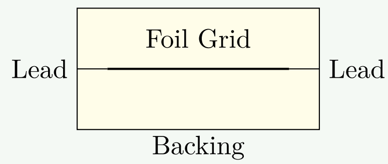

Figure 14. Bonded Strain Gauge

Working:
- When stretched (tension), length increases, area decreases → Resistance Increases.
- When compressed, length decreases → Resistance Decreases.
- $\frac{\Delta R}{R} = GF \times \epsilon$ (where GF = Gauge Factor, ϵ = Strain).

Mnemonic

"GRID - Gauge Resistance Increases with Deformation"

Question 4(c) [7 marks]

Explain the Linear Variable Differential Transducer (LVDT) with its construction, working, advantages, and applications.

Solution

LVDT measures linear displacement.
Diagram:

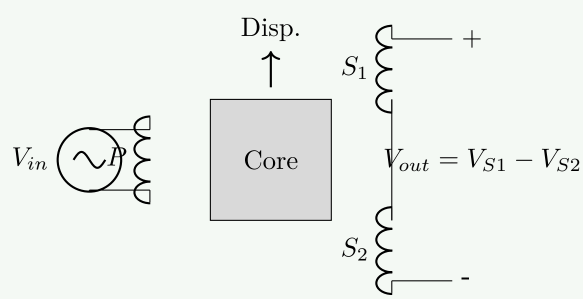

Figure 15. LVDT Construction

Working:
- AC excites Primary. Flux links to S1 and S2 via Core.
- **Null Position**: Core center. $V_{S1} = V_{S2} \rightarrow V_{out} = 0$.
- **Displacement**: Core moves up $\rightarrow V_{S1} > V_{S2}$. Moves down $\rightarrow V_{S2} > V_{S1}$.

Advantages: Infinite resolution, Frictionless (Long life), Robust. **Applications**: Displacement measurement, Pressure sensors, CNC.

Mnemonic

"LVDT-MAPS - Linear Variable Differential Transformer Measures Accurately Position"

Question 4(a) OR [3 marks]

State any three uses of PH sensors.

Solution

Uses of PH Sensors:
1. **Water Treatment**: Ensuring neutral PH for drinking water.
2. **Agriculture**: Soil PH testing for crop health.
3. **Medical**: Blood PH monitoring.
4. **Industrial**: Process control in chemical plants.

Mnemonic

"WAM - Water quality control, Agriculture soil testing, Medical diagnostics"

Question 4(b) OR [4 marks]

Explain the construction and working of a capacitive transducer.

Solution

Capacitive Transducer: Works on principle of changing capacitance.

$$C = \frac{\epsilon A}{d}$$

Diagram:

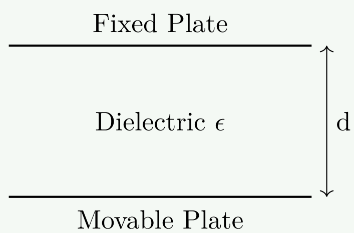

Figure 16. Variable Separation Capacitive Transducer

Methods of Transduction:
1. **Change in Distance (d)**: Diaphragm moves plate. Used in microphones, pressure sensors.
2. **Change in Area (A)**: Plates slide relative to each other.
3. **Change in Dielectric (ϵ)**: Liquid level sensors.

Mnemonic

"CAD - Capacitance changes with Area, Distance, or Dielectric variations"

Question 4(c) OR [7 marks]

Describe absolute optical encoder and its A, B, C waveform outputs with proper illustration.

Solution

Absolute Optical Encoder: Measures angular position digitally.
Construction:
- **Code Disc**: Transparent/Opaque segments in tracks (Binary/Gray code).
- **Light Source**: LEDs.
- **Sensor**: Photodiodes detect light passing through.

Diagram:

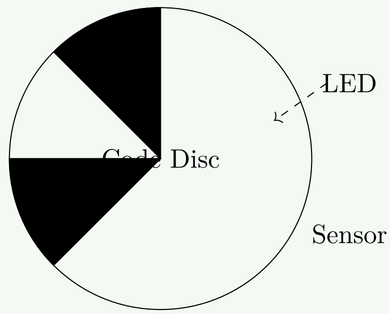

Figure 17. Optical Encoder Disc

Outputs:

1. **A & B Channels**: Quadrature signals (90° phase shift) to determine direction.
2. **C Channel (Index)**: One pulse per revolution (Reference).

Waveforms:

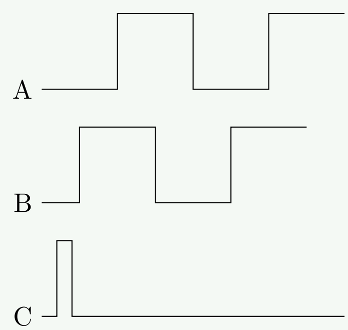

Figure 18. Quadrature Outputs

Mnemonic

"ABC-PDP - Absolute encoder tracks A, B, C Provide Direction, Position, and reference pulse"

Question 5(a) [3 marks]

Describe the working principle of a basic frequency counter.

Solution

Frequency Counter measures frequency of an input signal by counting events over a precise time interval.

Working Principle:

1. Count number of cycles/pulses of input signal.
2. Divide by the precise gate time.
3. Display resulting frequency ($f = N/T$).

Block Diagram:

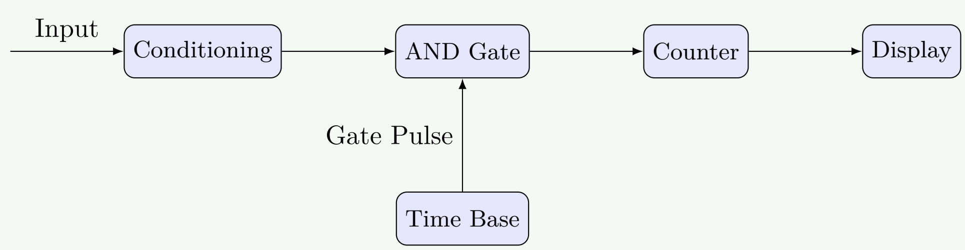

Figure 19. Basic Frequency Counter

Mnemonic

"CTPG - Count The Pulses, Gate the time"

Question 5(b) [4 marks]

Draw the diagram of of an energy meter and explain its working principle.

Solution

Electronic Energy Meter measures electrical energy consumption in kWh.
Block Diagram:

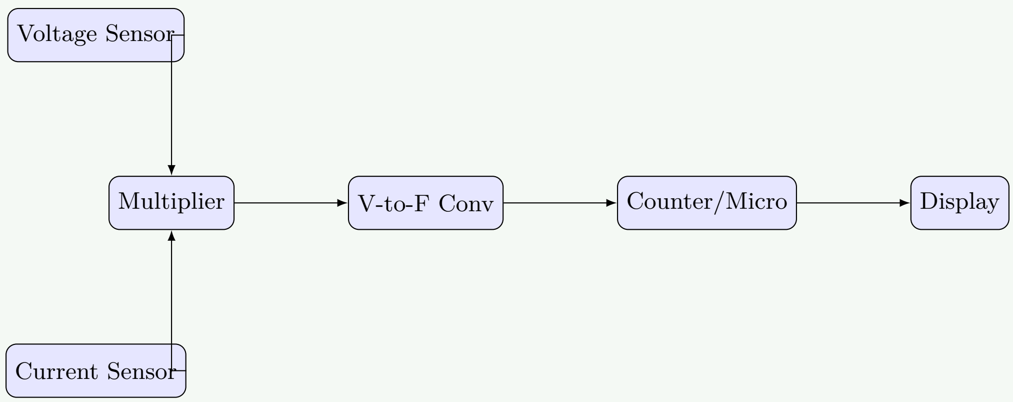

Figure 20. Energy Meter Block Diagram

Working:

- Voltage and Current sensed and multiplied to get Instantaneous Power.
- Power converted to frequency (pulses) by VFC.
- Counter accumulates pulses (Energy = Power × Time).
- Display shows kWh.

Mnemonic

"VCPI - Voltage and Current are multiplied, Pulses Indicate energy used"

Question 5(c) [7 marks]

Briefly explain the working principle and functions of a function generator. Describe its front panel controls and explain how it is used to test electronic circuits with suitable examples.

Solution

Function Generator: Generates different waveforms (Sine, Square, Triangle) with adjustable parameters.
Block Diagram:

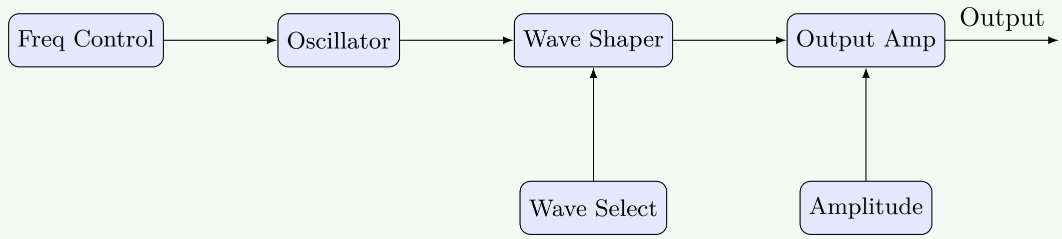

Figure 21. Function Generator

Controls:
- **Frequency**: Sets output frequency (e.g., 0.1Hz - 20MHz).
- **Amplitude**: Sets peak-to-peak voltage.
- **Function**: Selects Sine, Square, Triangle.
- **Offset**: Adds DC component.

Testing Example (Amplifier):
1. Connect FG sine wave to Amp input.
2. Vary frequency.
3. Observer output on CRO to measure Gain and Bandwidth.

Mnemonic

"FAWOD - Frequency, Amplitude, Waveform, Offset, Duty cycle are key controls"

Question 5(a) OR [3 marks]

Describe the working of a spectrum analyzer.

Solution

Spectrum Analyzer: Displays signal amplitude versus frequency.
Block Diagram:

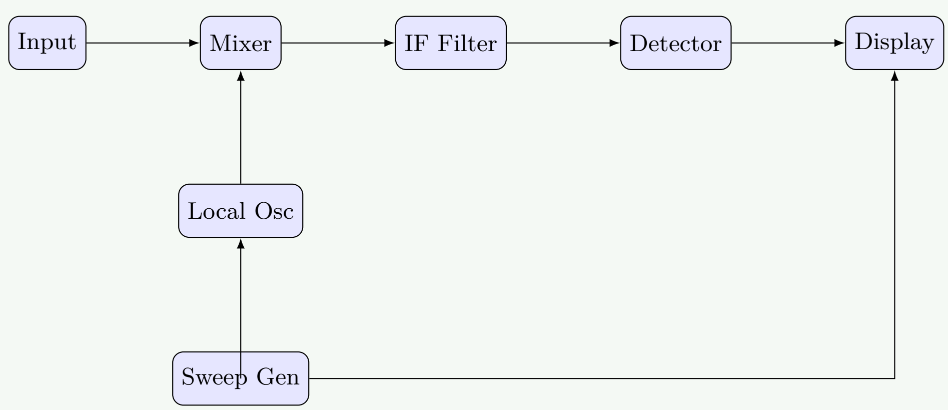

Figure 22. Spectrum Analyzer

Working:
- Superheterodyne principle.
- Sweep generator ramps LO frequency.
- IF filter passes specific component.
- Display plots Amplitude (Y) vs Frequency (X).

Mnemonic

"SAME - Spectrum Analyzer Maps signal Energy across frequencies"

Question 5(b) OR [4 marks]

Draw a neat diagram of a clamp-on meter and explain its working.

Solution

Clamp-on Meter: Non-contact current measurement.
Diagram:

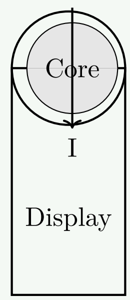

Figure 23. Clamp Meter

Working:
- Current carrying conductor acts as single-turn primary of transformer.
- Clamp core acts as magnetic core.
- Induces voltage in secondary coil inside meter.
- Voltage proportional to current.

Mnemonic

"CLIP - Clamp measures current, Lets magnetic Induction Produce voltage"

Question 5(c) OR [7 marks]

Explain the working principle of a digital IC tester. Describe its block diagram and explain how it is used to test the functionality of digital ICs with a suitable example.

Solution

Digital IC Tester: Verifies IC functionality by truth table comparison.
Block Diagram:

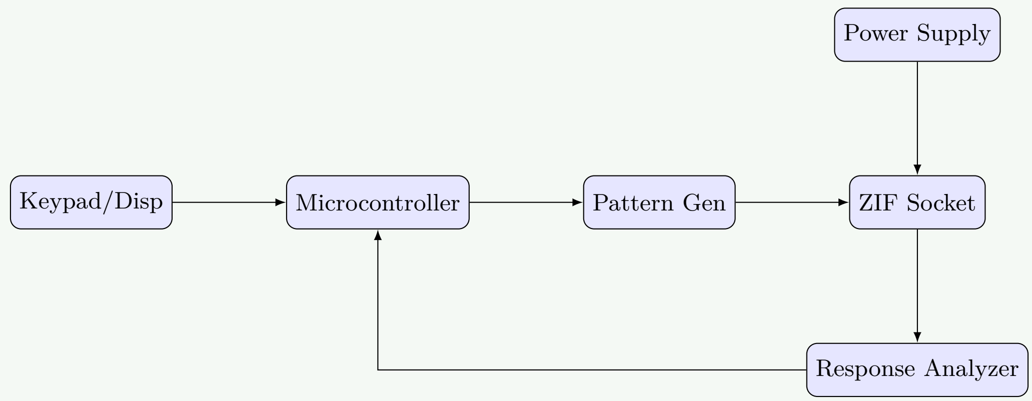

Figure 24. Digital IC Tester

Working:

1. **Test Pattern Memory**: Stores truth tables for various ICs.
2. **ZIF Socket**: Holds the IC under test.
3. **Pattern Generator**: Applies inputs (0s and 1s) to IC pins.
4. **Analyzer**: Reads outputs and compares with expected values.

Example (7400 NAND):

- Apply 0,0 → Expect 1.
- Apply 1,1 → Expect 0.
- If difference found → Fail. Else → Pass.

Mnemonic

"TEST - Test patterns Exercise all States, Then verify outputs"