Electronic Measurements and Instruments (4331102) - Summer 2024 Solution

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Question 1(a) [3 marks]

Define following term: (1) Accuracy (2) precision (3) Reproducibility

Solution

- **Accuracy**: Closeness of measured value to the true value of measured quantity.
- **Precision**: Ability of an instrument to reproduce the same output for repeated applications of same input under identical conditions.
- **Reproducibility**: Degree of agreement between results of measurements of same quantity when measured under changed conditions (different method, observer, or time).

Mnemonic

"APR: Accurate-to-truth, Precise-repeats, Reproduce-under-change"

Question 1(b) [4 marks]

Explain construction of RTD Transducer with necessary diagram in detail. Also list application of it.

Solution

RTD (Resistance Temperature Detector) is a temperature sensor that operates on the principle that electrical resistance of metals changes with temperature.

Diagram:

Figure 1. RTD Construction Block Diagram

- **Sensing Element**: Pure platinum, nickel, or copper wire wound around ceramic core.
- **Lead Wires**: Connect RTD to measuring circuit.
- **Support**: Provides mechanical stability to sensing element.
- **Protective Sheath**: Protects sensing element from external environment.

Applications of RTD:

- Temperature measurement in process industries.
- Food processing temperature monitoring.
- HVAC systems.
- Medical equipment.

Mnemonic

"RTD: Resistance Temperature Detector - Precise Temperature Measurement"

Question 1(c) [7 marks]

Explain working of Maxwell's Bridge with circuit diagram. List its advantages, disadvantages and applications.

Solution

Maxwell's Bridge is used to measure unknown inductance in terms of known capacitance and resistance.
Circuit Diagram:

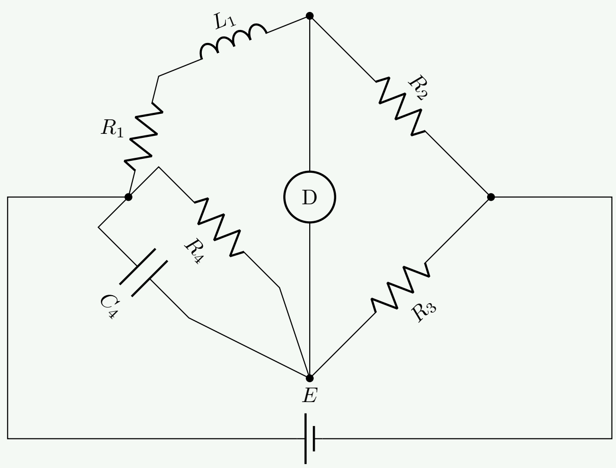


Figure 2. Maxwell's Inductance Capacitance Bridge

Working: At balance condition: $L_1 = C_4 \times R_2 \times R_3$
When the bridge is balanced, the detector shows zero current. The unknown inductance L_1 is calculated using above equation, where C_4 is known capacitance and R_2, R_3 are known resistances.

Table 1. Maxwell's Bridge Parameters

Parameter	Value
Balance Equation	$L_1 = C_4 \times R_2 \times R_3$
Quality Factor	$Q = \omega L_1/R_1 = \omega C_4 R_3$

Advantages:
- High accuracy for medium Q inductors.
- Balance equations are independent of frequency.
- Simple calculation for inductance.

Disadvantages:
- Not suitable for low Q inductor measurement.
- Requires variable standard capacitor.
- Affected by stray capacitance.

Applications:
- Measuring inductance in laboratories.
- Calibration of inductance standards.
- Testing of inductive components.

Mnemonic

"Maxwell's Magic: Inductance equals Capacitance times Resistance squared"

Question 1(c) OR [7 marks]

Explain working of Wheatstone bridge with circuit diagram for balance condition. List its advantages, disadvantages, and applications.

Solution

Wheatstone bridge is used to measure unknown resistance by comparing it with known resistance values.
Circuit Diagram:

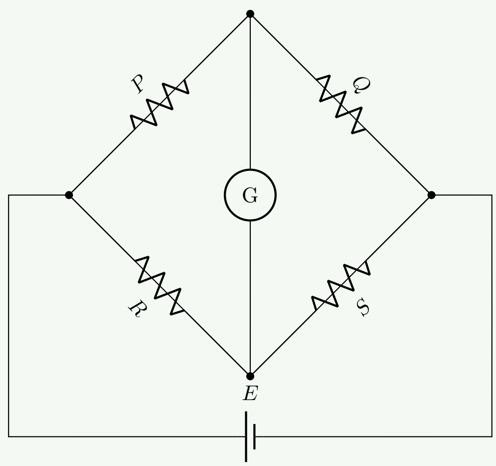


Figure 3. Wheatstone Bridge Circuit

Working: At balance condition: $P/Q = R/S$ or $R = S \times (P/Q)$
When bridge is balanced, galvanometer shows zero deflection. Unknown resistance R is calculated using the ratio of other resistances.

Table 2. Wheatstone Bridge Components

Component	Function
P, Q, S	Known resistances
R	Unknown resistance
G	Galvanometer (detector)
E	DC voltage source

Advantages:
- High accuracy in resistance measurement.
- Simple construction and operation.
- Wide range of resistance measurement.

Disadvantages:
- Cannot measure very low or very high resistances.
- Requires battery as power source.
- Temperature effects on resistors cause errors.

Applications:
- Precise resistance measurement.
- Strain gauge measurements.
- Temperature sensing using RTDs.
- Transducer applications.

Mnemonic

"When WheatStone Balances: Product of opposites are equal ($P \times S = Q \times R$)"

Question 2(a) [3 marks]

Compare moving iron and moving coil type instruments.

Solution

Table 3. Moving Iron vs Moving Coil Instruments

Characteristic	Moving Iron Type	Moving Coil Type
Principle	Magnetic attraction/repulsion	Electromagnetic force
Scale	Non-uniform (Cramped at beginning)	Uniform
Damping	Air friction damping (Poor)	Eddy current damping (Good)
Accuracy	Less accurate (2-5%)	High accuracy (0.1-2%)
Frequency range	DC and AC	DC only (without rectifier)
Power consumption	High	Low
Cost	Less expensive	More expensive

Mnemonic

"IMAP-CAD: Iron-Magnetic-AC-Poor damping, Coil-Accurate-DC-Damped well"

Question 2(b) [4 marks]

Explain working and construction of successive approximation type DVM with necessary diagram.

Solution

Successive Approximation type Digital Voltmeter (DVM) converts analog voltage to digital value using binary search technique.

Block Diagram:

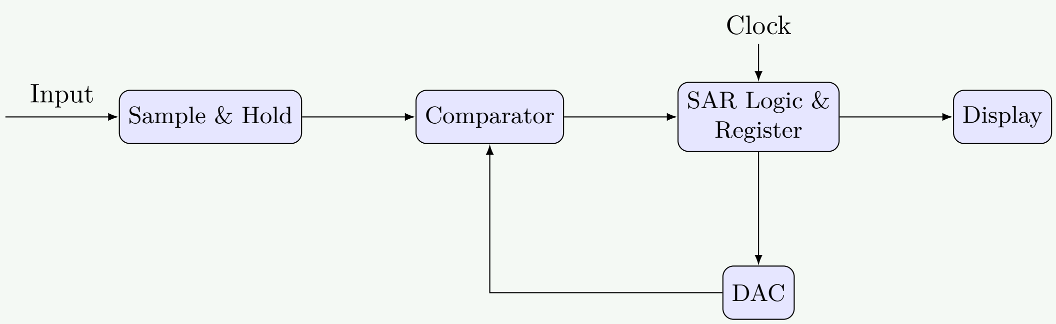


Figure 4. Successive Approximation DVM

Working:

- Sample & Hold circuit captures input voltage.
- SAR sets MSB to 1, other bits to 0.
- DAC converts digital word to analog voltage.
- Comparator compares DAC output with input voltage.

- If DAC output > Input, bit is reset to 0; otherwise kept 1.
- Process repeats for next bit until all bits are tested.
- Final digital word represents input voltage.

Advantages:

- Medium conversion speed (10-100 μs).
- Good resolution and accuracy.
- Moderate cost.

Mnemonic

"SAR DVM: Sample-And-Register by Digital-Voltage-Matching"

Question 2(c) [7 marks]

1- A moving coil ammeter reading up to 10 amperes has a resistance of 0.02 ohm. How this instrument could be adopted to read current up to 1000 amperes?
2- A moving coil voltmeter reading up to 200 mV has a resistance of 5 ohms. How this instrument can be adopted to read voltage up to 300 volts?

Solution

Part 1: Ammeter Range Extension
To extend ammeter range from 10A to 1000A, a shunt resistor is connected in parallel with the meter.
Diagram:

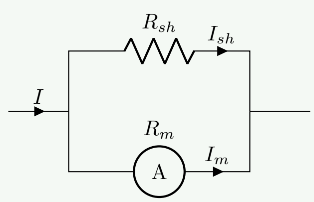


Figure 5. Ammeter with Shunt

Calculation:

- Original meter resistance $(R_m) = 0.02\ \Omega$
- Original full-scale current $(I_m) = 10$ A
- Desired full-scale current $(I) = 1000$ A
- Current through shunt $(I_{sh}) = I - I_m = 1000 - 10 = 990$ A
- Voltage across meter = Voltage across shunt
- $I_m \times R_m = I_{sh} \times R_{sh}$
- $R_{sh} = \frac{10\times0.02}{990} = \frac{0.2}{990} = 0.000202\Omega$

Part 2: Voltmeter Range Extension
To extend voltmeter range from 200mV to 300V, a multiplier resistor is connected in series with the meter.
Diagram:

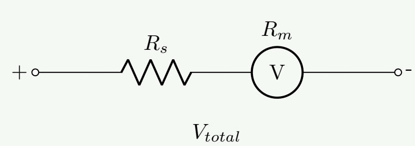


Figure 6. Voltmeter with Multiplier

Calculation:

- Original meter resistance $(R_m) = 5\ \Omega$
- Original full-scale voltage $(V_m) = 200$ mV $= 0.2$ V
- Desired full-scale voltage $(V) = 300$ V
- Series resistance $(R_s) = R_m \times (\frac{V}{V_m} - 1)$

- $R_s = 5 \times (\frac{300}{0.2} - 1) = 5 \times (1500 - 1) = 5 \times 1499 = 7495\Omega$

Mnemonic

"ShuntSeries: Shunt-for-Current, Series-for-Voltage"

Question 2(a) OR [3 marks]

Explain working and construction of Clamp on Meter with necessary diagram.

Solution

Clamp on Meter (Current Clamp) measures current without breaking the circuit by using electromagnetic induction.

Diagram:

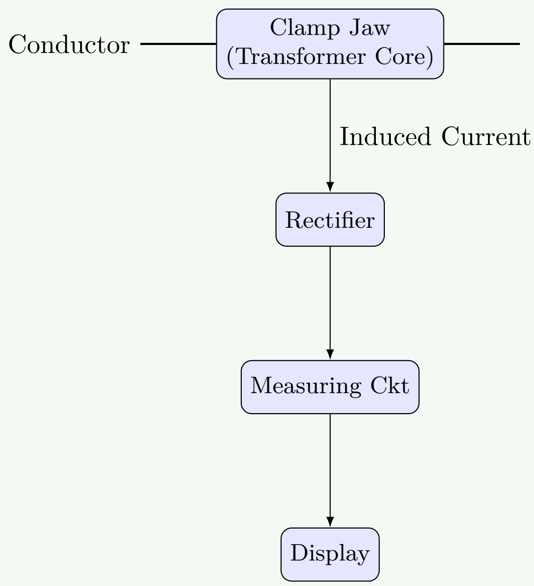


Figure 7. Clamp Meter Block Diagram

Construction & Working:

- **Clamp Jaw**: Split core transformer that can be opened to encircle conductor. Acts as secondary.
- **Current Transformer**: Converts primary current (in conductor) to proportional secondary current.
- **Rectifier**: Converts AC to DC for measurement circuit.
- **Measuring Circuit**: Processes signal and calculates current value.
- **Display**: Shows measured current value.

When a current-carrying conductor passes through the clamp jaw, it induces current in the secondary winding proportional to primary current, which is then measured.

Mnemonic

"CLAMP: Current-Loop Amplifies Magnetic Proportionally"

Question 2(b) OR [4 marks]

Explain working of PMMC instruments with necessary diagram.

Solution

PMMC (Permanent Magnet Moving Coil) instruments operate on the principle of electromagnetic force on current-carrying conductor in magnetic field.

Diagram:

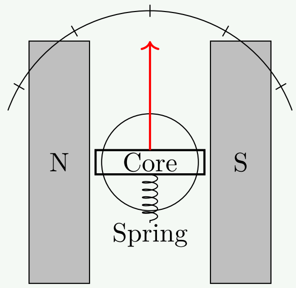


Figure 8. PMMC Construction

Working:

- Current flows through rectangular coil placed in magnetic field.
- Electromagnetic force produces torque proportional to current ($T_d \propto I$).
- Spring provides controlling torque ($T_c \propto \theta$).
- Pointer deflects until $T_d = T_c$, so $\theta \propto I$.
- Damping system prevents oscillations.

Components:

- Permanent magnet creates strong magnetic field.
- Soft iron core concentrates magnetic flux.
- Moving coil carries current to be measured.
- Control springs provide restoring force.
- Damping system (air or eddy current) reduces oscillations.

Mnemonic

"PMMC: Permanent Magnet Makes Current-proportional movement"

Question 2(c) OR [7 marks]

Draw the block diagram, working and construction of Integrating type DVM with necessary diagram and waveform.

Solution

Integrating type DVM (Digital Voltmeter) converts analog voltage to digital value by integrating the input over a fixed time.

Block Diagram:

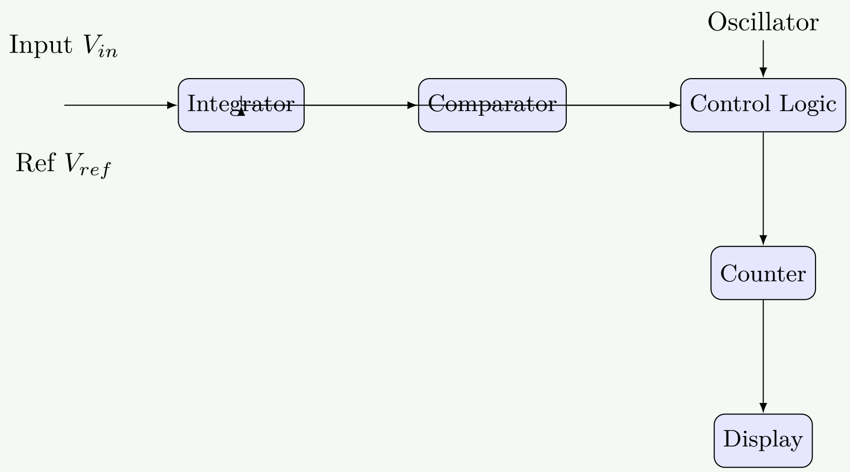


Figure 9. Integrating DVM (Dual Slope)

Waveforms:

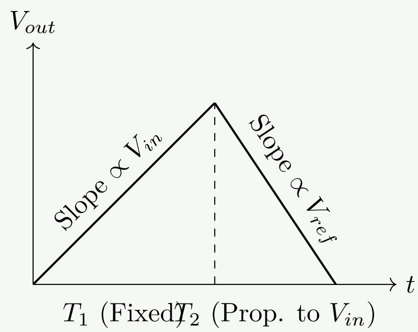


Figure 10. Dual Slope Waveforms

Working:

- **Phase 1**: Integrate unknown voltage (V_{in}) for fixed time T_1. Capacitor charges.
- **Phase 2**: Integrate known reference voltage (V_{ref}) of opposite polarity until output reaches zero. Capacitor discharges.
- **Phase 3**: Counter counts clock pulses during phase 2 (T_2).
- $V_{in} = V_{ref} \times (T_2/T_1)$.

Advantages:

- High noise rejection.
- Good accuracy.
- Automatic zero adjustment.

Mnemonic

"Integrate-twice: Up with unknown, Down with reference"

Question 3(a) [3 marks]

In CRO What is the value of unknown DC voltage, if a straight line below x-axis is obtained with a displacement of 4cm and volt/div knob = 3V. calculate the unknown voltage Vdc.

Solution

Calculation:

- Displacement = 4 cm (below x-axis)

- Volt/div setting = 3 V/div
- Direction = Below x-axis (negative voltage)

$$V_{dc} = -(\text{Displacement} \times \text{Volt/div})$$
$$V_{dc} = -(4 \text{ cm} \times 3 \text{ V/div})$$
$$V_{dc} = -12 \text{ V}$$

Therefore, the unknown DC voltage is **-12 V**.

Mnemonic

"voltage = Deflection $\times Scale''$

Question 3(b) [4 marks]

Draw internal structure of CRT. Explain in short.

Solution

CRT (Cathode Ray Tube) is the display device used in analog oscilloscopes.
Diagram:

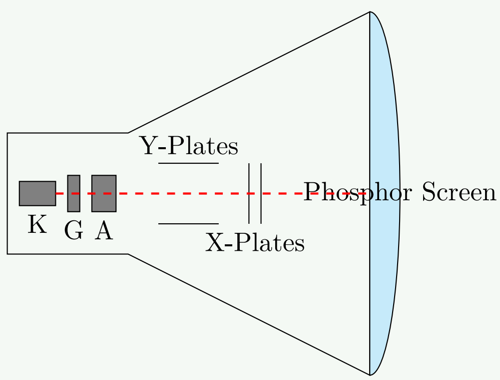


Figure 11. Internal Structure of CRT

Components:
- **Electron Gun**: Consists of heater, cathode, control grid, and anodes; produces electron beam.
- **Focusing System**: Focuses electron beam into sharp point using electrostatic lenses.
- **Deflection System**: Deflects electron beam horizontally and vertically using deflection plates.
- **Phosphor Screen**: Converts electron energy to visible light.
- **Glass Envelope**: Vacuum-sealed container housing all components.

Working:
- Electron gun emits electrons.
- Focusing system narrows electron beam.
- Deflection plates move beam across screen.
- Beam strikes phosphor screen creating visible trace.

Mnemonic

"GFDS: Gun-Focus-Deflect-Screen"

Question 3(c) [7 marks]

Explain Construction, Block diagram, working and advantage of DSO with necessary diagram.

Solution

Digital Storage Oscilloscope (DSO) converts analog signals to digital form and stores them for display and analysis.
Block Diagram:

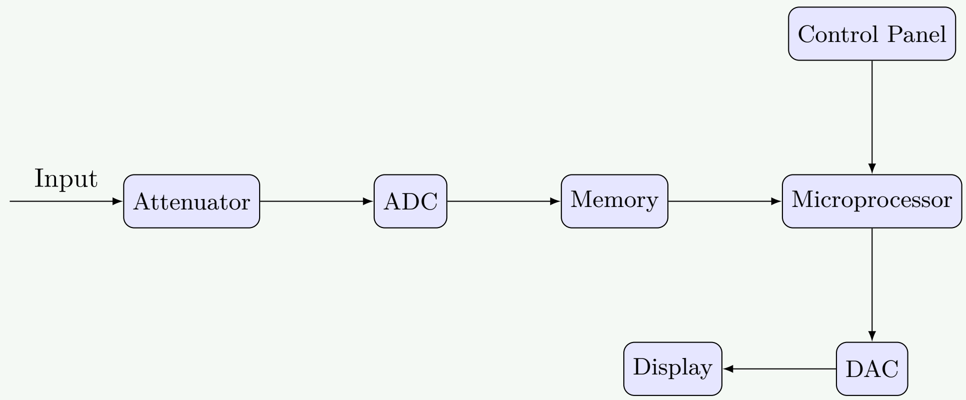


Figure 12. Digital Storage Oscilloscope Block Diagram

Construction and Working:
- **Input Stage**: Attenuator/amplifier conditions signal.
- **ADC**: Converts analog signal to digital at sampling rate.
- **Memory**: Stores digital samples.
- **Microprocessor**: Controls operation and processes data.
- **DAC**: Converts digital data back to analog for display.
- **Display**: Shows waveform.

Advantages of DSO:
- Signal storage capability for later analysis.
- Pre-trigger viewing of signal.
- Single-shot signal capture.
- Automatic measurements and calculations.
- Waveform processing (FFT, averaging, etc.).
- Digital interfacing (USB, Ethernet).

Mnemonic

"SAMPLE: Store-Analyze-Measure-Process-Link-Examine"

Question 3(a) OR [3 marks]

In CRO vertical displacement for peak is = 1cm and volt/div knob = 10mV. Find peak value and RMS value of voltage.

Solution

Calculation:
- Vertical displacement (peak) = 1 cm
- Volt/div setting = 10 mV/div

Peak value (V_p) = Displacement × Volt/div

$$V_p = 1 \text{ cm} \times 10 \text{ mV/div} = 10 \text{ mV}$$

For sinusoidal waveform: RMS value $(V_{rms}) = V_p \div \sqrt{2}$

$$V_{rms} = 10 \text{ mV} \div 1.414 = 7.07 \text{ mV}$$

Therefore, **peak value = 10 mV** and **RMS value = 7.07 mV**.

Mnemonic

"Peak-to-RMS: Divide by root-2"

Question 3(b) OR [4 marks]

Explain CRO Screen in detail.

Solution

CRO (Cathode Ray Oscilloscope) screen displays waveforms and provides measurement references.
Diagram:

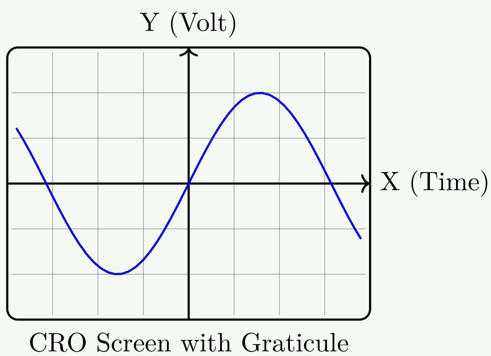


Figure 13. CRO Screen

Components:
- **Phosphor Coating**: Converts electron energy to visible light.
- **Graticule**: Grid pattern for measurements (typically 8×10 divisions).
- **X-Axis**: Represents time (horizontal).
- **Y-Axis**: Represents voltage (vertical).
- **Center Point**: Reference for measurements (0,0).

Screen Features:
- **Divisions**: Subdivisions for precise reading.
- **Intensity Control**: Adjusts brightness of display.
- **Focus Control**: Sharpens displayed trace.
- **Scale Illumination**: Illuminates graticule.

Mnemonic

"PAXED: Phosphor-Axes-X-time-Y-amplitude-Equal-Divisions"

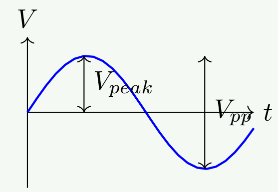
Question 3(c) OR [7 marks]

Explain Measurement of Voltage, Frequency, Time delay and Phase angle using CRO with necessary diagram.

Solution

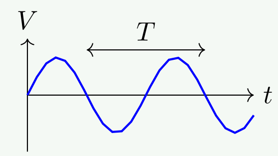
CRO can measure various electrical parameters accurately.

1. Voltage Measurement:



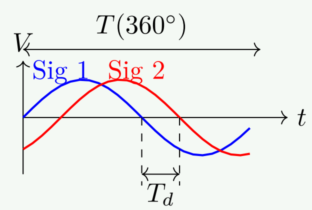
- Count vertical divisions of waveform.
- Multiply by V/div setting.
- Amplitude = Vertical divisions × V/div.

2. Frequency Measurement:



- Measure time period (T) between similar points.
- Frequency $f = 1/T$.
- T = Horizontal divisions × Time/div.

3. Time Delay & 4. Phase Angle Measurement:



- **Time Delay**: Measure horizontal distance (T_d) between corresponding points of two signals.
- **Phase Angle**:
  - Measure time period (T) of one complete cycle.
  - Measure time delay (T_d).
  - Phase angle $\phi = (T_d/T) \times 360°$.

Mnemonic

"VFTP: Vertical-Frequency-Time-Phase"

Question 4(a) [3 marks]

Compare active and passive transducers.

Solution

Table 4. Active vs Passive Transducers

Characteristic	Active Transducers	Passive Transducers
Power source	Self-generating (no external power)	Requires external power
Output	Generates energy from input	Modifies external energy
Examples	Thermocouple, Photovoltaic cell	Strain gauge, RTD, LVDT
Sensitivity	Generally lower	Generally higher
Response time	Faster	Slower
Cost	Usually less expensive	Usually more expensive
Complexity	Simpler	More complex

Mnemonic

"APE-GSR: Active-Produces-Energy, Gets-Signal-Requiring-power"

Question 4(b) [4 marks]

Explain Working of strain Gauge with necessary diagram in detail. Also list application of it.

Solution

Strain gauge converts mechanical deformation to electrical resistance change.
Diagram:

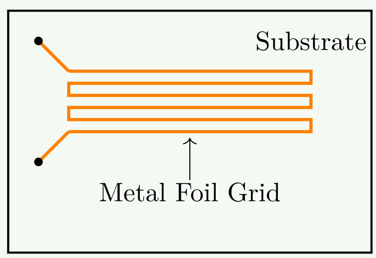


Figure 14. Strain Gauge Construction

Working:
- When a conductor is stretched, its length increases and cross-sectional area decreases.
- This causes an increase in electrical resistance: $\Delta R/R = GF \times \epsilon$.
- Where $\Delta R/R$ is fractional change in resistance, GF is gauge factor, ϵ is strain.

Applications:
- Load cells for weighing systems.
- Structural health monitoring.
- Pressure sensors.
- Torque measurement.
- Mechanical stress analysis.

Mnemonic

"STRAIN: Stretch-To-Resistance-Alteration-In-Narrow-conductor"

Question 4(c) [7 marks]

Explain Gas Sensor MQ2 with necessary diagram in detail.

Solution

MQ2 is a semiconductor gas sensor that detects combustible gases, smoke, and LPG.
Diagram:

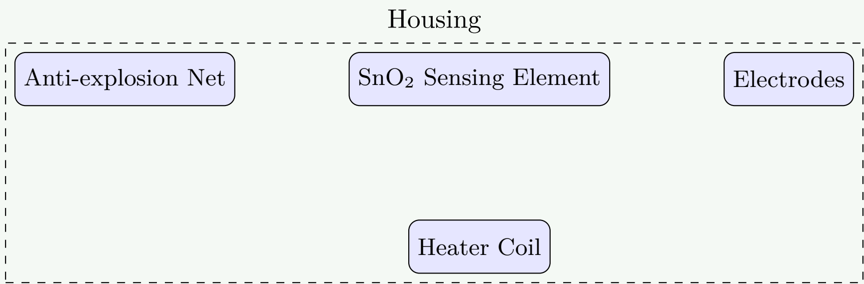


Figure 15. MQ2 Sensor Structure

Construction:

- **Sensing Element**: Tin dioxide (SnO_2) semiconductor.
- **Heater**: Maintains operating temperature (around 200-400°C).
- **Electrodes**: Measure resistance changes.
- **Housing**: Protects components and allows gas flow.

Working Principle:

- In clean air, sensor has high resistance.
- When combustible gases present, surface reactions occur.
- Electrons are released, decreasing resistance.
- Resistance decreases proportionally to gas concentration.

Circuit Connection:

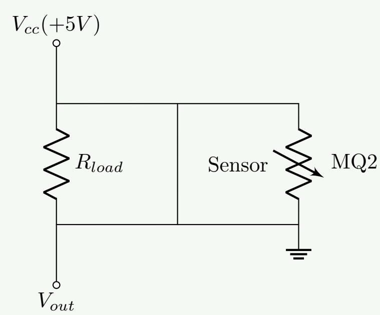


Figure 16. Basic MQ2 Circuit

Mnemonic

"MQ2: Measures Quick-leaks of 2+ gases (LPG, Propane)"

Question 4(a) OR [3 marks]

Compare primary and secondary transducers

Solution

Table 5. Primary vs Secondary Transducers

Characteristic	Primary Transducers	Secondary Transducers
Definition	Directly convert physical quantity to electrical signal	Convert output of primary transducer to usable form
Function	First stage of conversion	Second stage of conversion
Examples	Thermocouple, Photocell, Piezoelectric	Amplifiers, ADCs, Signal conditioners
Input	Physical parameter	Output from primary transducer
Output	Electrical signal	Modified electrical signal
Location	At sensing point	May be remote from primary transducer
Accuracy	Affects overall system accuracy	Further processes already converted signal

Mnemonic

"PS-FLIP: Primary-Senses, Secondary-Further-Level-Improves-Processing"

Question 4(b) OR [4 marks]

Explain Capacitive Transducer with necessary diagram in detail. Also list application of it.

Solution

Capacitive transducer converts physical displacement into capacitance change which is then converted to electrical signal.

Diagram:

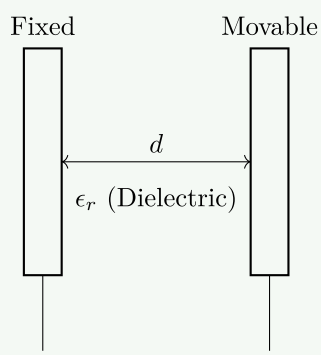


Figure 17. Capacitive Transducer Principle

Working:

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

Where ϵ_0 is permittivity of free space, ϵ_r is relative permittivity, A is area, d is distance.

Capacitance changes by:

- Varying distance between plates (d).
- Varying overlap area of plates (A).
- Varying dielectric constant (ϵ_r).

Applications:

- Pressure sensors.
- Displacement measurements.
- Level indicators.
- Humidity sensors.
- Touch screens.

Mnemonic

"CAPACITIVE: Change-Area-Plates-And-Change-In-Thickness-Impacts-Value-Electrically"

Question 4(c) OR [7 marks]

Explain LVDT Transducer operation, construction with necessary diagram in detail. Also list advantage, disadvantage and application of LVDT.

Solution

LVDT (Linear Variable Differential Transformer) is an electromagnetic transducer that converts linear displacement to electrical signal.
Diagram:

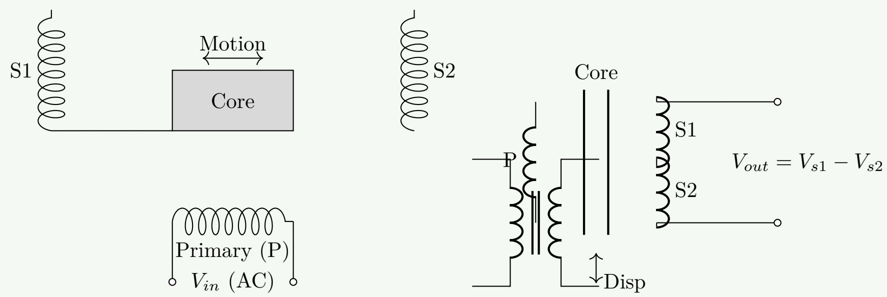


Figure 18. LVDT Schematic

Construction:
- **Primary Coil**: Center coil excited by AC source.
- **Secondary Coils**: Two coils connected in series opposition.
- **Core**: Ferromagnetic material that moves with measured displacement.
- **Housing**: Protects the coil assembly.

Working:
- AC excitation applied to primary coil.
- At null position (center), equal voltages induced in S1, S2 ($V_{out} = 0$).
- Moving core towards S1 increases V_{s1}, decreasing V_{s2} ($V_{out} = V_{s1} - V_{s2}$).
- Phase indicates direction.

Advantages: Non-contact, High resolution, Robust. **Disadvantages:** AC source needed, Costly. **Applications:** Position feedback, Robotics, Aircraft control.

Mnemonic

"LVDT: Linear-Variation-Detected-Through electromagnetic induction"

Question 5(a) [3 marks]

Explain working of Thermocouple sensor with necessary diagram in detail.

Solution

Thermocouple is a temperature sensor based on the Seebeck effect.
Diagram:

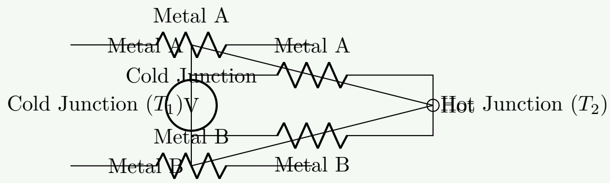


Figure 19. Thermocouple Circuit

Working:

- Two dissimilar metals joined at two points.
- Temperature difference $(T_2 - T_1)$ creates Seebeck voltage (EMF).
- $E \propto (T_2 - T_1)$.

Mnemonic

"THC: Temperature-produces Hot-junction Current"

Question 5(b) [4 marks]

Explain working of Digital IC tester with necessary diagram in detail.

Solution

Digital IC Tester tests functionality of digital ICs by applying test vectors.

Block Diagram:

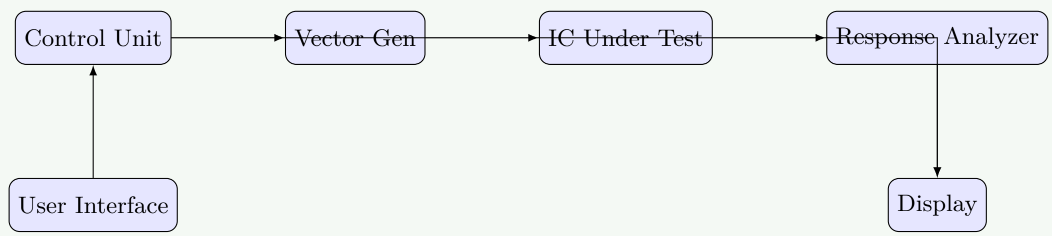


Figure 20. IC Tester Block Diagram

Working:

- **Control Unit**: Manages testing process.
- **Vector Generator**: Applies input patterns to IC pins.
- **IC Under Test**: The component being verified.
- **Response Analyzer**: Compares output with expected truth table.
- **Display**: Shows PASS/FAIL.

Mnemonic

"VECTOR: Verify-Each-Circuit-Through-Output-Response"

Question 5(c) [7 marks]

Explain working of function generator with necessary diagram in detail.

Solution

Function generator produces different waveforms (sine, square, triangle).
Block Diagram:

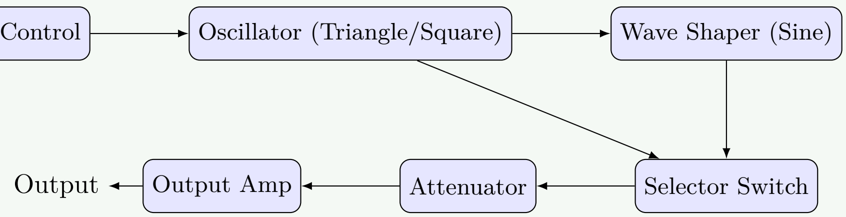


Figure 21. Function Generator Block Diagram

Working:

- **Oscillator**: Generates basic Triangle and Square waves.
- **Wave Shaper**: Converts Triangle to Sine wave using diode shaping.
- **Selector**: Selects desired waveform.
- **Attenuator/Amp**: Controls amplitude and output impedance.

Mnemonic

"FAST: Frequency-Amplitude-Signal-Type control"

Question 5(a) OR [3 marks]

Explain working of PH sensor with necessary diagram in detail.

Solution

PH sensor measures hydrogen ion concentration.
Diagram:

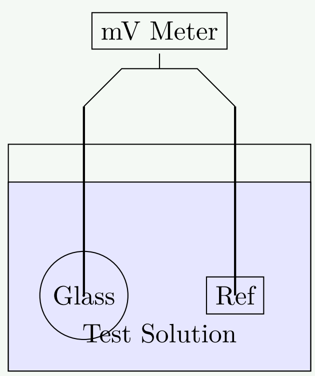


Figure 22. pH Measurement System

Working:

- Glass electrode contains buffer solution.
- Potential difference develops across glass membrane due to H^+ ion difference.
- Voltage is proportional to pH (59.16 mV/pH).

Mnemonic

"pH-MVH: Potential-of-Hydrogen Measured by Voltage per Hydrogen-ion concentration"

Question 5(b) OR [4 marks]

Describe working of Spectrum Analyzer with necessary diagram in detail

Solution

Spectrum Analyzer displays signal amplitude vs. frequency.
Block Diagram:

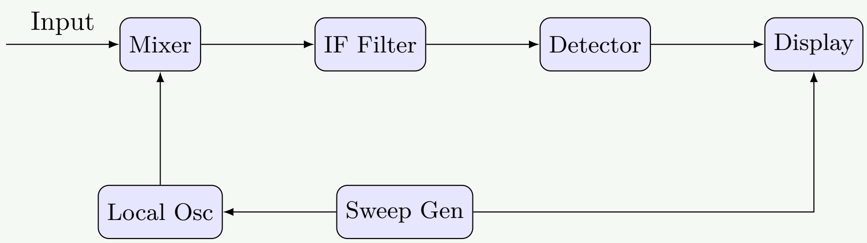


Figure 23. Spectrum Analyzer Block Diagram

Working:
- **Mixer**: Mixes input with swept Local Oscillator (LO).
- **IF Filter**: Selects specific frequency component.
- **Detector**: Converts IF magnitude to DC (Y-axis).
- **Sweep Gen**: Sweeps LO frequency and drives X-axis.

Mnemonic

"SAFE-D: Signal-Amplitude-Frequency-Evaluation-Display"

Question 5(c) OR [7 marks]

Explain working of basic frequency counter with necessary diagram in detail

Solution

Frequency counter measures frequency by counting cycles in a fixed time.
Block Diagram:

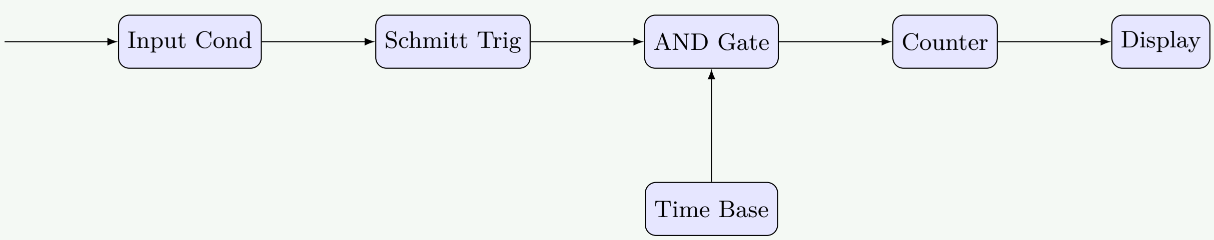


Figure 24. Frequency Counter Block Diagram

Working:
- **Input Conditioning**: Shapes signal.
- **Schmitt Trigger**: Converts to square pulses.
- **Time Base**: Opens Main Gate for precise time (T).
- **Counter**: Counts pulses (N) when gate is open.
- Frequency $f = N/T$.

Mnemonic

"COUNT: Cycles-Over-Unit-time-Numerically-Tallied"