Electronic Measurements and Instruments (4331102) - Summer 2023 Solution

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Question 1(a) [3 marks]

Illustrate steps to minimize that all type of systematic error.

Solution

Steps to minimize systematic errors:

Table 1. Steps to Minimize Systematic Errors

Step	Description
1. Calibration	Periodically calibrate instruments against standard references
2. Correction	Apply correction factors or offset values
3. Control	Maintain constant environmental conditions (temperature, humidity)
4. Technique	Use proper measurement techniques and procedures
5. Equipment	Select appropriate instruments with required accuracy

Mnemonic

"CCCTS: Calibrate, Correct, Control, Technique, Select"

Question 1(b) [4 marks]

Define: Resolution, Precision, Sensitivity and Accuracy.

Solution

Table 2. Measurement Characteristics Definitions

Term	Definition
Resolution	The smallest change in input that can be detected by the instrument
Precision	Consistency or repeatability of measurements with minimal random error
Sensitivity	The ratio of change in output to the change in input ($\Delta O/\Delta I$)
Accuracy	Closeness of measured value to the true or accepted standard value

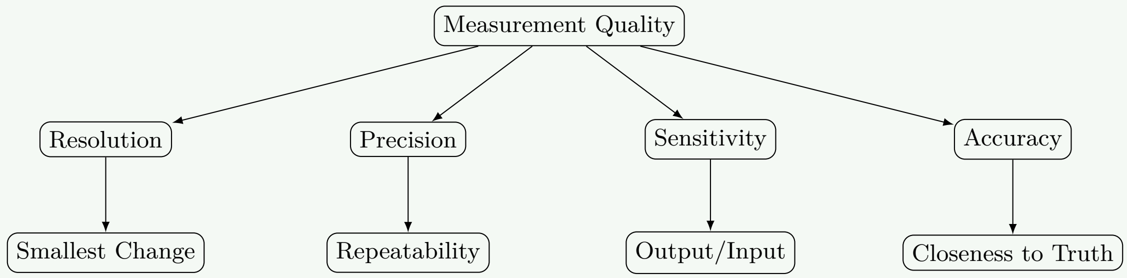


Figure 1. Measurement Characteristics

Mnemonic

"RSPA: Resolve Signals Precisely and Accurately"

Question 1(c) [7 marks]

Explain a principle of Q Meter and Working of practical Q Meter.

Solution

Principle:

- Based on series resonance where $Q = X_L/R$ or X_C/R at resonance
- Measures voltage magnification at resonance condition

Working of practical Q meter:

Table 3. Components of Practical Q Meter

Component	**Function**
Oscillator	Generates variable frequency signal (50kHz to 50MHz)
Work coil	Inductor under test (connected in series with calibrated capacitor)
Capacitor	Variable calibrated capacitor for resonance tuning
VTVM	Measures resonant voltage across capacitor
Shunt resistor	Monitors current through the circuit

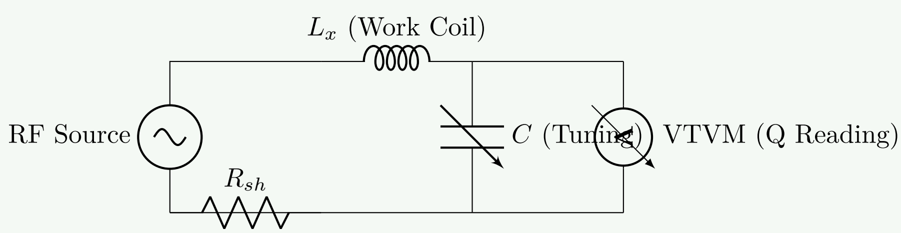


Figure 2. Practical Q Meter

- **Q factor calculation**: $Q = V_2/V_1$ where V_2 is voltage across capacitor and V_1 is the applied voltage
- **Resonance indication**: Maximum voltage across capacitor indicates resonance

Mnemonic

"VOCAL: Voltage ratio at resonance Oscillator Creates Amplification to measure coiL quality"

Question 1(c OR) [7 marks]

Explain Wheatstone bridge and derive equation for balanced condition. State application and limitation of Wheatstone bridge.

Solution

Wheatstone bridge is a network used to measure unknown resistance with high precision.

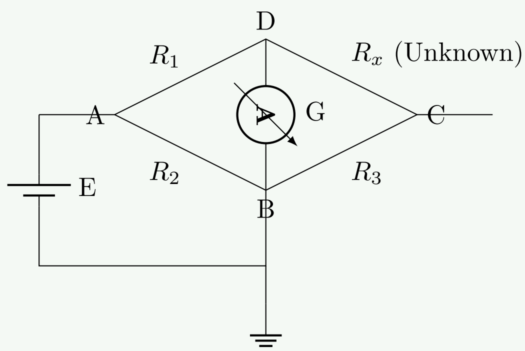


Figure 3. Wheatstone Bridge

Balanced Condition Derivation:

- At balance, no current flows through galvanometer ($I_G = 0$)
- Potential at point D = Potential at point B
- Voltage drop across R_1 = Voltage drop across R_2 ($I_1R_1 = I_2R_2$)
- Voltage drop across R_x = Voltage drop across R_3 ($I_1R_x = I_2R_3$)

Dividing the equations:

$$\frac{I_1R_1}{I_1R_x} = \frac{I_2R_2}{I_2R_3} \implies \frac{R_1}{R_x} = \frac{R_2}{R_3} \implies R_x = R_3\left(\frac{R_1}{R_2}\right)$$

Applications & Limitations:

Table 4. Wheatstone Bridge Applications and Limitations

Application	**Limitation**
Precision resistance measurement	Poor accuracy for low resistances ($< 1\Omega$)
Transducer interface (Strain gauge, RTD)	Limited by galvanometer sensitivity
Temperature measurement	Contact resistance affects accuracy

Mnemonic

"BEAR: Balance Equation at Arms Ratio"

Question 2(a) [3 marks]

Differentiate between moving iron and moving coil type instruments.

Solution

Table 5. Comparison: Moving Iron vs PMMC Instruments

Parameter	Moving Iron (MI)	Moving Coil (PMMC)
Principle	Magnetic attraction/repulsion	EM force on conductor
Scale	Non-uniform (crowded at start)	Uniform (linear)
Supply	AC and DC	DC only
Accuracy	Lower $(1 - 2.5\%)$	Higher $(0.1 - 1\%)$
Damping	Air friction	Eddy current
Power	Higher consumption	Lower consumption

Mnemonic

"IRON-COIL: Iron Repulsion Non-uniform; Coil Current Linear"

Question 2(b) [4 marks]

Draw the construction diagram of clamp on Ammeter and explain in detail.

Solution

Construction Diagram:

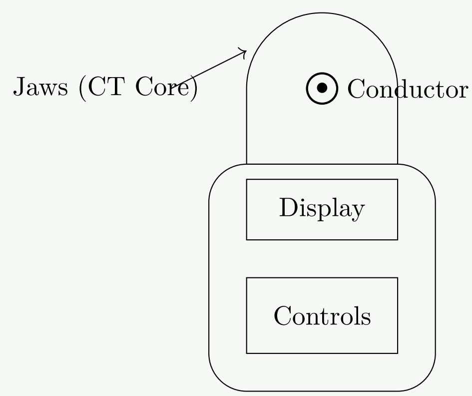


Figure 4. Clamp-on Ammeter

Working:

- **Transformer Principle**: The current-carrying conductor acts as a single-turn primary winding of a transformer.
- **Core & Secondary**: The clamp jaws form the magnetic core required for flux path. A secondary winding inside the casing picks up the induced current.
- **Measurement**: The induced secondary current is proportional to the primary current, which is processed and displayed.
- **Non-intrusive**: Allows current measurement without breaking the circuit.

Mnemonic

"CLASP: Conductor-Loop Amperes Sensed by Primary-secondary"

Question 2(c) [7 marks]

Describe working and advantages of Integrating type DVM with suitable diagram.

Solution

Integrating DVM uses dual-slope integration to measure voltage, effectively canceling out noise.
Block Diagram:

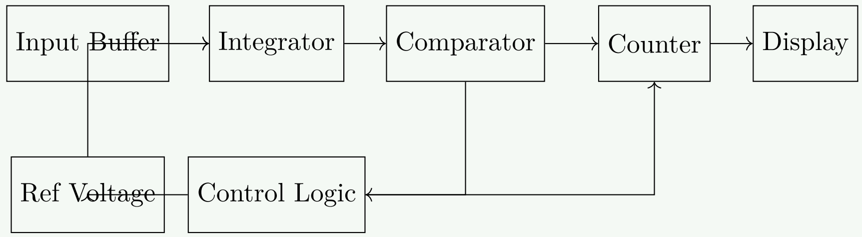


Figure 5. Integrating DVM

Working Principle:

1. **Run-up**: Unknown voltage V_{in} charges the integrator capacitor for a fixed time period T_1.
2. **Run-down**: A reference voltage V_{ref} of opposite polarity discharges the capacitor until it reaches zero. Time taken is T_2.
3. **Measurement**: Since charge up = charge down, $V_{in}T_1 = V_{ref}T_2 \implies V_{in} = V_{ref}\frac{T_2}{T_1}$.

Advantages:

- High noise rejection (esp. mains frequency).
- High accuracy and resolution.
- Good stability and linearity.

Mnemonic

"RISES: Ramp Integration Samples and Eliminates Spikes"

Question 2(a OR) [3 marks]

Differentiate between Digital Voltmeter over Analog Voltmeter.

Solution

Table 6. Comparison: Digital vs Analog Voltmeter

Parameter	**Digital Voltmeter**	**Analog Voltmeter**
Display	Numeric digits (LCD/LED)	Pointer on scale
Parallax Error	None	Possible
Resolution	High (depends on digits)	Limited by scale
Accuracy	High (0.05%)	Lower ($1 - 3\%$)
Output	BCD/Digital output available	None

Mnemonic

"DAPPER: Digital Accuracy and Precise readings; Parallax Error Removed"

Question 2(b OR) [4 marks]

Draw the construction diagram of Moving iron type Meter and explain in detail.

Solution

Construction:

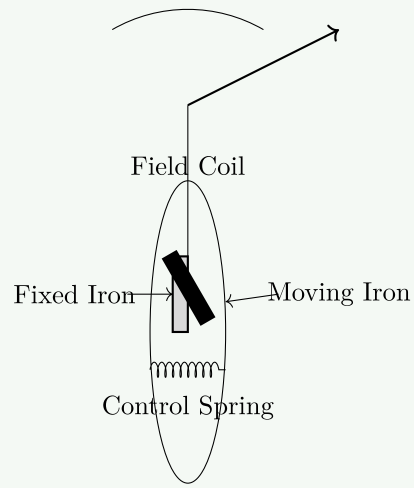


Figure 6. Repulsion Type MI Instrument

Explanation:

- Consists of a fixed coil carrying current.
- Two soft iron pieces: one fixed to the coil frame, one movable attached to spindle.
- When current flows, both irons are magnetized with same polarity.
- Repulsion occurs, moving the spindle and pointer.
- Control torque provided by spring; damping by air friction piston.

Mnemonic

"MIRROR: Magnetic Interaction Requires Repulsion Of Related irons"

Question 2(c OR) [7 marks]

Describe construction diagram of Energy meter and explain in detail.

Solution

Electronic energy meter measures kWh consumption.

Block Diagram:

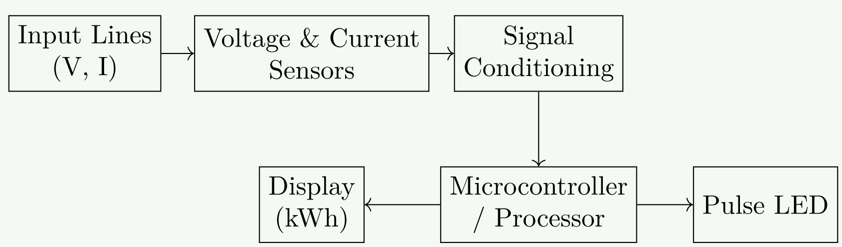


Figure 7. Electronic Energy Meter

Working:

- **Sensing**: Voltage divider and shunt/CT sense voltage and current.
- **Multiplication**: Instantaneous V and I are multiplied to get Power (P).
- **Integration**: Power is integrated over time ($\int Pdt$) to get Energy.
- **Display**: Result is stored and shown on LCD in kWh. Pulse LED blinks proportional to consumption.

Mnemonic

"WATTAGE: Work And Time Tracked As Generated Electrical energy"

Question 3(a) [3 marks]

Apply Lissajous pattern for frequency measurement and Phase angle measurement.

Solution

Lissajous patterns are formed on CRO X-Y mode.

Frequency Measurement:

- $f_y/f_x = \frac{\text{Tangents on Horizontal}}{\text{Tangents on Vertical}}$
- Circle/Ellipse = 1:1 ratio.
- Figure 8 = 2:1 ratio.

Phase Measurement (1:1 ratio):

- Pattern is an ellipse.
- $\sin\phi = A/B$
- A: Intercept on Y-axis (center to intersection).
- B: Max deflection on Y-axis.
- Circle = 90°, Line = 0° or 180°.

Mnemonic

"LIPS: Lissajous Indicates Phase and Signal frequency"

Question 3(b) [4 marks]

Explain Graticules in CRO also Explain its types.

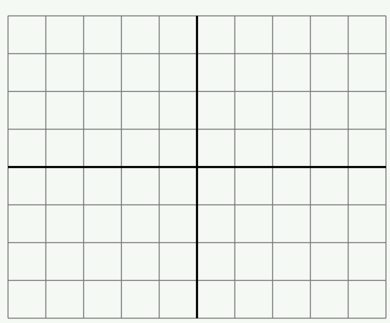
Solution

Graticules are the grid lines on the CRO screen for measurement.

Types:

Table 7. Types of CRO Graticules

Type	Feature
Internal	Etched inside CRT faceplate. No parallax error.
External	Plastic sheet overlay. Cheap, easily changeable, but parallax error exists.
Electronic	Generated by electron beam. Very accurate, no parallax.



Standard 8x10 div Graticule

Figure 8. CRO Graticule

Mnemonic

"GRID: Graticule References for Intensity and Distance"

Question 3(c) [7 marks]

Describe Construction, Block diagram, working and advantage of Digital storage oscilloscope (DSO).

Solution

Block Diagram:

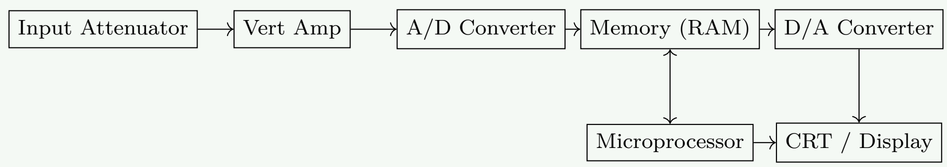


Figure 9. DSO Block Diagram

Working:
1. Analog signal is sampled and digitized by ADC.
2. Digital data stored in memory (RAM).
3. Microprocessor processes data (measurements, math).
4. Data converted back to analog (DAC) or directly driven to display.

Advantages:
- Storage of waveforms (indefinite time).
- Pre-trigger viewing.
- Capture of single-shot/transient events.
- Direct digital measurements (V, t, f).
- PC connectivity.

Mnemonic

"SAMPLE: Storage And Memory Processes Live Events"

Question 3(a OR) [3 marks]

Differentiate between CRO and DSO.

Solution

Table 8. Comparison: CRO vs DSO

Feature	CRO (Analog)	DSO (Digital)
Processing	Real-time Analog	Digital sampling
Storage	None (Phosphor persistence)	Digital Memory
Bandwidth	Higher for price	Limited by Sample Rate
Transients	Cannot capture well	Easily captures
Pre-trigger	No	Yes

Mnemonic

"ASPAD: Analog Shows Present; Digital Archives Data"

Question 3(b OR) [4 marks]

Explain structure of 10:1 Probes in detail.

Solution

10:1 probe attenuates signal by factor of 10 to increase input impedance and reduce loading.
Structure:

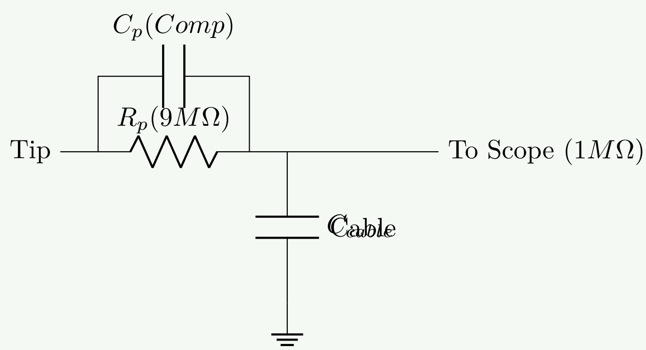


Figure 10. 10:1 Probe Circuit

Details:
- Contains a 9 MΩ resistor in series with the scope's 1 MΩ input.
- Total resistance = 10 MΩ. Voltage division ratio = 10:1.
- Adjustable capacitor compensates for cable capacitance to ensure flat frequency response.

Mnemonic

"TAPER: Ten-to-one Attenuation Preserves and Extends Range"

Question 3(c OR) [7 marks]

Describe Block diagram, working and application of CRO.

Solution

Block Diagram:

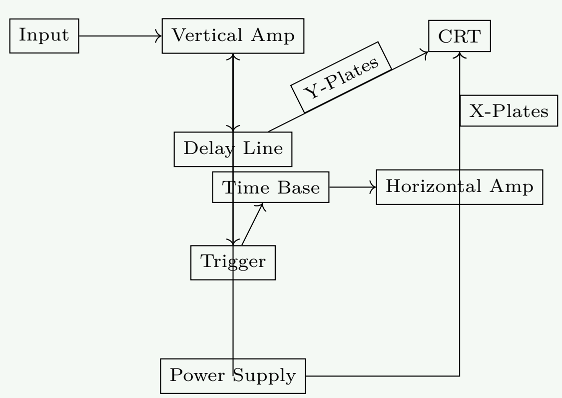


Figure 11. CRO Block Diagram

Working:
- **Vertical System**: Amplifies signal for Y-deflection.
- **Horizontal System**: Generates sawtooth wave (Time Base) for X-sweep.
- **Trigger**: Synchronizes sweep with signal start.
- **CRT**: Displays the trace.

Applications: Voltage, frequency, phase measurement, waveform observation.

Mnemonic

"VIEW: Voltage Inspection and Electrical Waveform observation"

Question 4(a) [3 marks]

Differentiate RTD and Thermistor.

Solution

Table 9. Comparison: RTD vs Thermistor

Parameter	RTD	Thermistor
Material	Pure Metal (Pt, Ni)	Semiconductor
Coeff (α)	Positive (PTC)	Usually Negative (NTC)
Linearity	Linear	Highly Non-linear
Range	Wide (-200°C to 850°C)	Medium (-50°C to 300°C)
Sensitivity	Low (0.4%/°C)	High (4%/°C)

Mnemonic

"METAL-SEMI: Metal Linear vs Semi Non-linear"

Question 4(b) [4 marks]

Give and explain two example of primary and Secondary transducer.

Solution

Table 10. Primary vs Secondary Transducers

Primary Transducer	Secondary Transducer
Thermocouple: Converts temp directly to voltage.	**LVDT**: Converts displacement to voltage (requires excitation).
Piezoelectric: Converts force directly to charge.	**Strain Gauge**: Resistance changes with strain (needs bridge to read voltage).

Explanation:
- **Primary**: Direct conversion from physical to electrical quantity.
- **Secondary**: Requires an intermediate stage or external power to produce electrical signal.

Mnemonic

"PIDS: Primary Is Direct; Secondary is Stepwise"

Question 4(c) [7 marks]

Describe Thermocouple with working principle, types and application.

Solution

Principle (Seebeck Effect): When two dissimilar metals are joined at two junctions kept at different temperatures, an EMF is generated proportional to the temperature difference.
Construction:

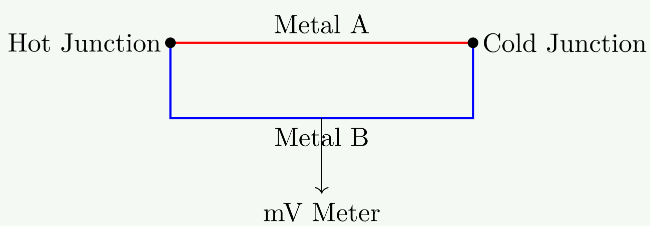


Figure 12. Thermocouple

Types:

- **Type J**: Iron-Constantan (-40 to $750°C$)
- **Type K**: Chromel-Alumel (-200 to $1350°C$) - Most common.
- **Type T**: Copper-Constantan (Low temp).
- **Type R/S**: Platinum-Rhodium (High temp/Precision).

Applications: Furnaces, Gas turbines, Engines, Industrial temp monitoring.

Mnemonic

"STEVE: Seebeck Thermoelectric Effect Verifies Elevated temperatures"

Question 4(a OR) [3 marks]

Demonstrate working and principle Semiconductor Temperature Sensor LM35.

Solution

Principle: Integrated circuit sensor where output voltage is linearly proportional to Centigrade temperature (10 mV/°C).
Features:

- Calibrated directly in Celsius.
- Linear +10.0 mV/°C scale factor.
- Range: $-55°$ to $+150°C$.

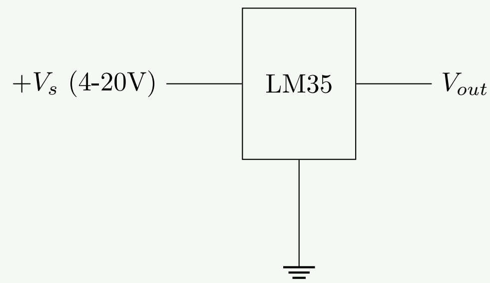


Figure 13. LM35 Connection

Mnemonic

"LOTUS: Linear Output Temperature Units from Semiconductor"

Question 4(b OR) [4 marks]

Describe incremental type of Optical encoder with it's output waveform.

Solution

Optical encoder measures position/speed using light pulses.
Construction:

- Rotating disk with slots.
- LED source and Photodetector.
- As disk rotates, beam is interrupted, generating pulses.

Output Waveform:

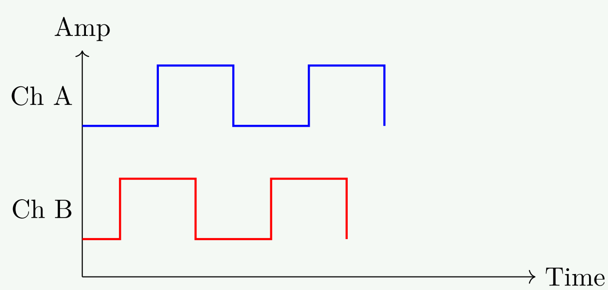


Figure 14. Quadrature Output

Offset allows direction detection.

Mnemonic

"PADS: Pulses from A and Determine Speed"

Question 4(c OR) [7 marks]

Describe construction, operation of LVDT with advantages, disadvantages and application.

Solution

LVDT (Linear Variable Differential Transformer) measures linear displacement.
Construction:

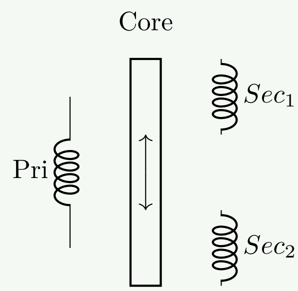


Figure 15. LVDT Schematic

Operation: AC applied to Primary. Core position varies flux linkage to Secondaries (S_1, S_2). Output $V_{out} = V_{s1} - V_{s2}$. Null at center.
Pros: Frictionless, infinite resolution, robust.
Cons: AC required, temp sensitive.
App: Displacement, pressure measurement.

Mnemonic

"MOVE-AC: Magnetic Output Varies with Exact Armature Core"

Question 5(a) [3 marks]

Describe working of Pressure measurement using Capacitive transducer.

Solution

Principle: Pressure deforms a diaphragm, changing the distance (d) between capacitor plates, thus changing capacitance ($C \propto 1/d$).

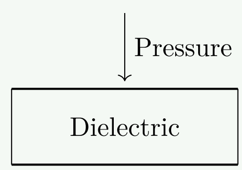


Figure 16. Capacitive Pressure Sensor

Mnemonic

"CAPS: Capacitance Alters as Pressure Shifts"

Question 5(b) [4 marks]

Define rise time, fall time, Pulse width and duty cycle.

Solution

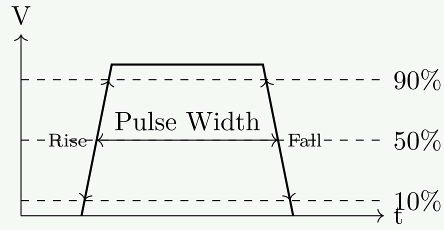


Figure 17. Pulse Characteristics

- **Rise Time**: 10% to 90% of max.
- **Fall Time**: 90% to 10% of max.
- **Pulse Width**: Width at 50%.
- **Duty Cycle**: (Pulse Width / Total Period) ×100%.

Mnemonic

"RPFD: Rise Pulses, Fall Determines"

Question 5(c) [7 marks]

Discuss Function generator block diagram.

Solution

Produces Sine, Square, Triangle waves.
Block Diagram:

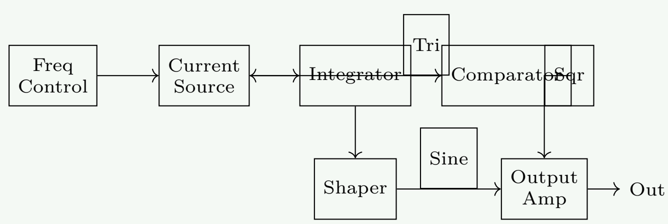


Figure 18. Function Generator

Working:
- Integrator + Comparator loop generates Triangle and Square.
- Sine shaper (diode network) converts Triangle to Sine.
- Output amplifier adjusts Amplitude and Offset.

Mnemonic

"FASTEST: Frequency Amplitude Shaping Together Ensures Signal Types"

Question 5(a OR) [3 marks]

Discuss Working, construction of strain gauge.

Solution

Construction: Fine wire grid on backing material. **Working:**

- Bonded to test object.
- Deformation changes length (l) and area (A), changing resistance $R = \rho l/A$.
- $\Delta R/R = G \times \epsilon$ (G = Gauge Factor, ϵ = Strain).

Mnemonic

"SERB: Strain Effects Resistance by Bonding"

Question 5(b OR) [4 marks]

Describe working of Digital IC tester with suitable diagrams.

Solution

Tests logic gates/ICs by applying truth table inputs and complying outputs.
Block Diagram:

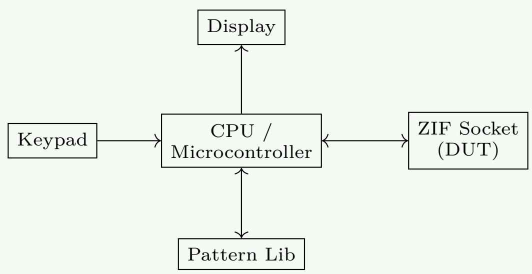


Figure 19. IC Tester

Working:

1. Select IC number.
2. CPU fetches test patterns from library.
3. Applies inputs to DUT pins.
4. Reads outputs and compares with expected.
5. Displays Pass/Fail.

Mnemonic

"PIPE: Pattern Input, Pin Examination"

Question 5(c OR) [7 marks]

Discuss working of Spectrum Analyzer with suitable diagrams.

Solution

Displays Amplitude vs Frequency.
Block Diagram (Swept Superheterodyne):

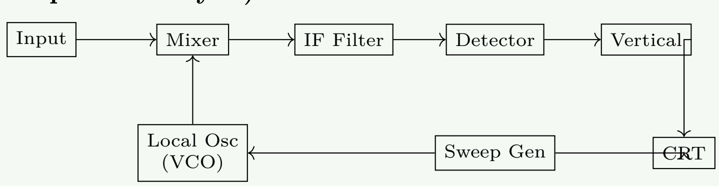


Figure 20. Spectrum Analyzer

Working:

- Sweep generator ramps LO frequency and drives X-axis.
- Mixer shifts input frequencies to IF.
- IF filter selects current frequency component.
- Detector recovers amplitude (Y-axis).

Mnemonic

"SHAFT: Sweep, Heterodyne, Analyze Frequency and Time"