

## Question 1(a) [3 marks]

Illustrate steps to minimize that all type of systematic error.

Answer:

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"

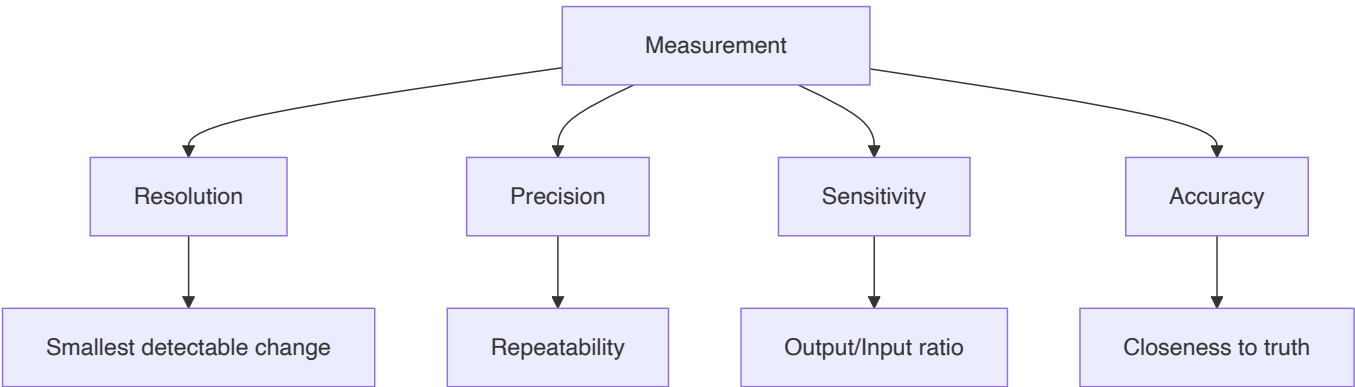
## Question 1(b) [4 marks]

Define: Resolution, Precision, Sensitivity and Accuracy.

Answer:

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

Diagram:



**Mnemonic:** "RSPA: Resolve Signals Precisely and Accurately"

## Question 1(c) [7 marks]

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

**Answer:**

Q Meter operates on the resonance principle to measure quality factor (Q) of coils and capacitors.

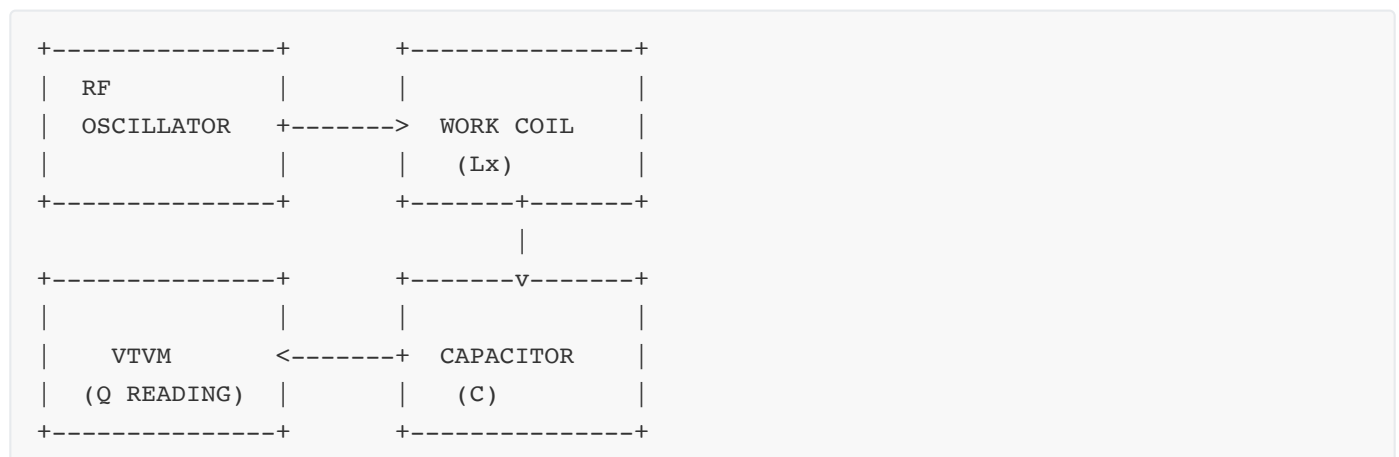
**Principle:**

- 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:**

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

**Diagram:**



- **Q factor calculation:**  $Q = V_2/V_1$  where  $V_2$  is voltage across capacitor and  $V_1$  is the applied voltage
- **Applications:** Testing RF components, coil quality measurement
- **Resonance indication:** Maximum voltage across capacitor indicates resonance

**Mnemonic:** "VOCAL: Voltage ratio at resonance Oscillator Creates Amplification to measure coil quality"

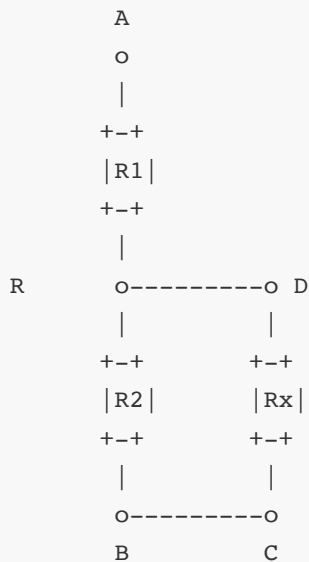
## Question 1(c OR) [7 marks]

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

**Answer:**

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

**Circuit diagram:**



G = Galvanometer

Rx = Unknown resistance

**Balanced condition equation derivation:**

- At balance, no current flows through galvanometer
- Potential at point D = Potential at point B
- Voltage across  $R_1$  = Voltage across  $R_x$
- Voltage across  $R_2$  = Voltage across  $R_3$

Therefore:

- $(R_1/R_2) = (R_x/R_3)$
- $R_x = R_3(R_1/R_2)$

**Applications:**

Application	Description
Precision resistance measurement	Accurate measurement of unknown resistors
Temperature sensing	When used with RTD or thermistor
Strain measurement	With strain gauges for stress analysis
Transducer interface	Converting physical quantities to electrical signals

Limitations:

Limitation	Description
Low resistance measurement	Poor accuracy for very low resistances ( $<1\Omega$ )
Sensitivity	Limited by galvanometer sensitivity
Range	Limited range of measurement (typically $1\Omega$ to $100k\Omega$ )
Contact resistance	Affects accuracy in low resistance measurements

Mnemonic: "BEAR: Balance Equation at Arms Ratio"

Question 2(a) [3 marks]

Differentiate between moving iron and moving coil type instruments.

Answer:

Parameter	Moving Iron Instrument	Moving Coil Instrument
Operating principle	Magnetic attraction or repulsion	Electromagnetic force on current-carrying conductor
Scales	Non-uniform scale	Uniform scale
Accuracy	Lower (1-2.5%)	Higher (0.1-1%)
Frequency range	Works for both AC and DC	Only DC (unless rectified)
Damping	Air friction damping	Eddy current damping
Power consumption	Higher	Lower

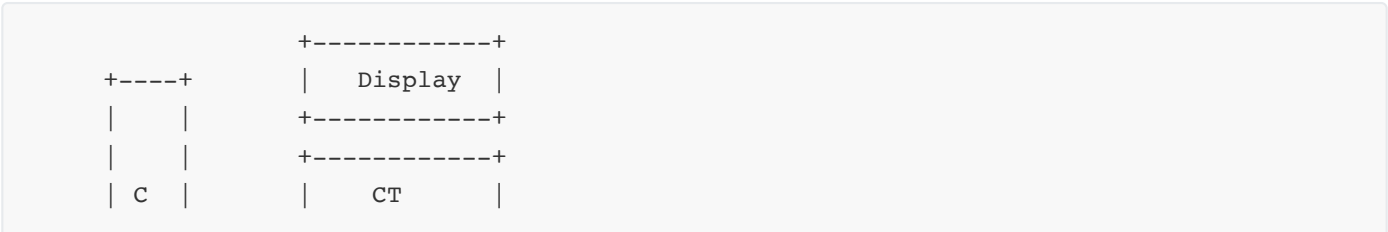
Mnemonic: "IRON-COIL: Iron uses Repulsion with Non-uniform scale; COIL uses Current with Organized, Improved, Linear scale"

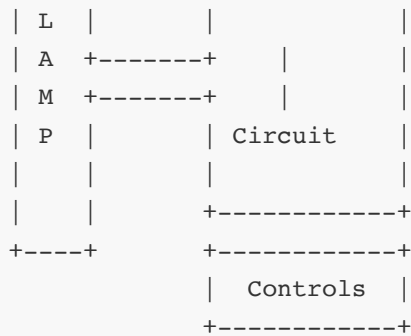
Question 2(b) [4 marks]

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

Answer:

Construction diagram of clamp-on ammeter:





### Components and working:

- **Core:** Split laminated ferromagnetic core that can be opened/closed
- **Coil:** Secondary winding wrapped around the core
- **Conductor:** Primary conductor (current to be measured) passes through the core
- **Measurement circuit:** Processes induced current and displays reading
- **Spring mechanism:** For easy opening and closing of the jaw

**Working principle:** Based on transformer principle where conductor acts as single-turn primary winding, creating magnetic flux proportional to current.

**Mnemonic:** "CLASP: Conductor-Loop Amperes Sensed by Primary-secondary relationship"

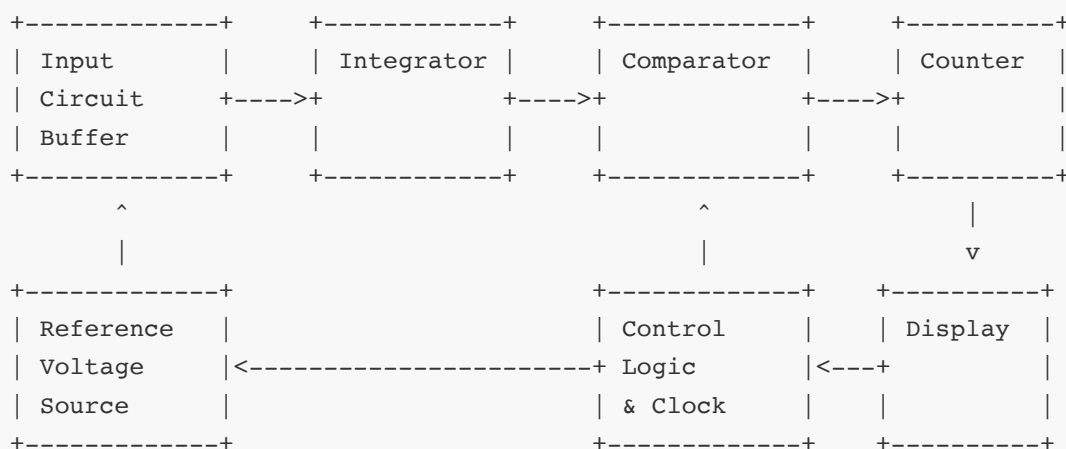
## Question 2(c) [7 marks]

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

**Answer:**

Integrating-type Digital Voltmeter converts analog voltage to digital value using dual-slope integration.

**Block diagram:**



**Working principle:**

Phase	Description
1. Run-up	Unknown input voltage is integrated for fixed time $T_1$
2. Run-down	Reference voltage (opposite polarity) is integrated until output returns to zero
3. Measurement	Time $T_2$ of run-down is proportional to input voltage
4. Display	Digital value based on $T_2/T_1 \times V_{ref}$ is displayed

**Advantages:**

- **Noise rejection:** Excellent rejection of power line noise (50/60Hz)
- **Accuracy:** Highly accurate (0.005% to 0.05%)
- **Resolution:** High resolution (up to 6½ digits)
- **Stability:** Less affected by component tolerances
- **Common mode rejection:** High CMRR

**Mnemonic:** "RISES: Ramp Integration Samples and Eliminates Spikes"

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

**Differentiate between Digital Voltmeter over Analog Voltmeter.**

**Answer:**

Parameter	Digital Voltmeter	Analog Voltmeter
Display	Numeric display (digits)	Pointer movement on scale
Reading error	No parallax error	Subject to parallax error
Resolution	Higher (limited by number of digits)	Limited by scale divisions
Accuracy	Better (typically 0.05% to 0.5%)	Lower (typically 1% to 3%)
Output	Can provide digital output for interfacing	No direct digital output
Power requirement	Requires power supply	Can be passive (PMMC type)

**Mnemonic:** "DAPPER: Digital Accuracy and Precise readings; Parallax Error in Reading analog"

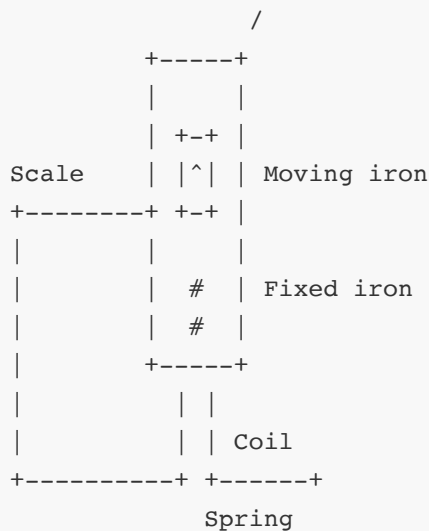
## Question 2(b OR) [4 marks]

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

**Answer:**

**Construction diagram of moving iron meter:**

+-----+ Pointer



### Working principle and components:

- **Coil:** Creates magnetic field proportional to current
- **Iron vanes:** Two soft iron pieces (one fixed, one movable)
- **Movement:** Magnetic repulsion between similarly magnetized iron pieces
- **Control:** Spring provides opposing torque
- **Damping:** Air friction damping mechanism
- **Scale:** Non-uniform scale due to non-linear magnetic force

### Types:

- Attraction type: Works on magnetic attraction principle
- Repulsion type: Works on magnetic repulsion principle

**Mnemonic:** "MIRROR: Magnetic Interaction Requires Repulsion/attraction Of Related iron pieces"

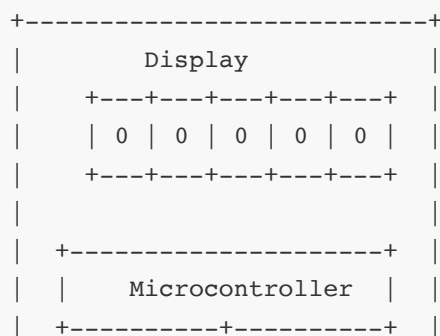
## Question 2(c OR) [7 marks]

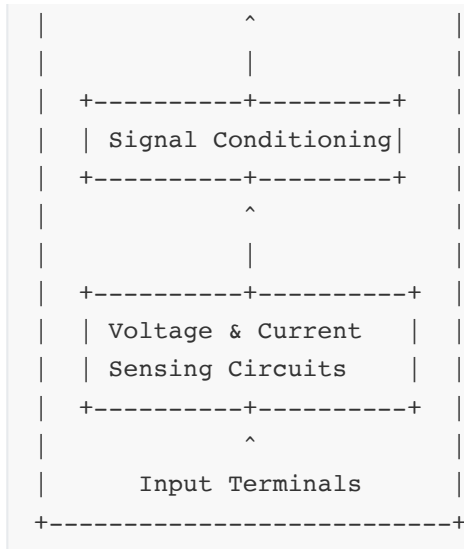
**Describe construction diagram of Energy meter and explain in detail.**

**Answer:**

Electronic energy meter measures electrical energy consumption in kilowatt-hours.

**Construction diagram:**





### Components and working:

Component	Function
Voltage sensor	Potential transformer or resistive divider to measure voltage
Current sensor	Current transformer or shunt resistor to measure current
Multiplier	Multiplies instantaneous voltage and current values
Integrator	Integrates power over time to calculate energy
Microcontroller	Processes signals and calculates energy consumption
Display	LCD or LED to show consumption in kWh
Pulse LED	Blinks at a rate proportional to power consumption

### Working principle:

1. Voltage and current are sensed by respective sensors
2. Signals are multiplied to obtain instantaneous power
3. Power is integrated over time to calculate energy
4. Energy is displayed as kilowatt-hours (kWh)

**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.**

**Answer:**

Lissajous patterns on oscilloscope screen help measure frequency ratio and phase difference.

**Frequency measurement:**



- Apply reference signal to X-axis and unknown signal to Y-axis
- Frequency ratio = Number of tangent points on Y-axis / Number of tangent points on X-axis
- Frequency of unknown = Frequency of reference  $\times$  Frequency ratio

Pattern	Frequency Ratio (Y:X)
	1:1
	2:1
	n:m

#### Phase angle measurement:

- If both frequencies are equal, phase angle ( $\phi$ ) can be measured
- $\phi = \sin^{-1}(A/B)$  where A = minor axis and B = major axis of ellipse

**Mnemonic:** "LIPS: Lissajous Indicates Phase and Signal frequency"

## Question 3(b) [4 marks]

**Explain Graticules in CRO also Explain its types.**

**Answer:**

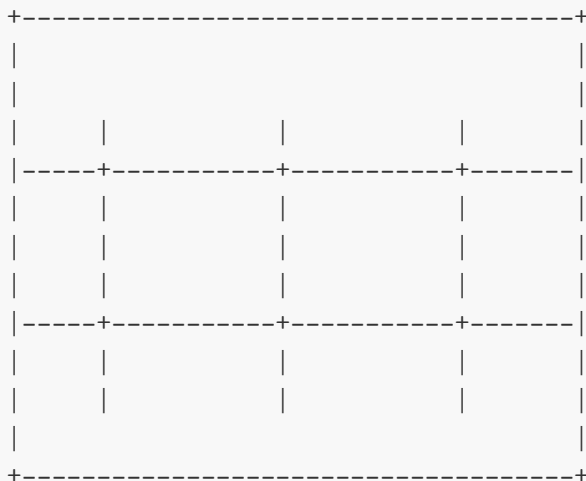
Graticules are reference markings on CRO screen for measurements.

Graticule Type	Description	Application
<b>Internal graticule</b>	Markings inside CRT glass	Eliminates parallax error
<b>External graticule</b>	Plastic overlay on screen	Replaceable, economical
<b>Electronic graticule</b>	Generated electronically	Digital storage oscilloscopes

#### Standard graticule features:

- $10 \times 8$  divisions typically
- Center lines darker for reference
- Small hash marks for subdivisions
- Percentage markings (rise time)

**Diagram:**



**Mnemonic:** "GRID: Graticule References for Intensity and Distance"

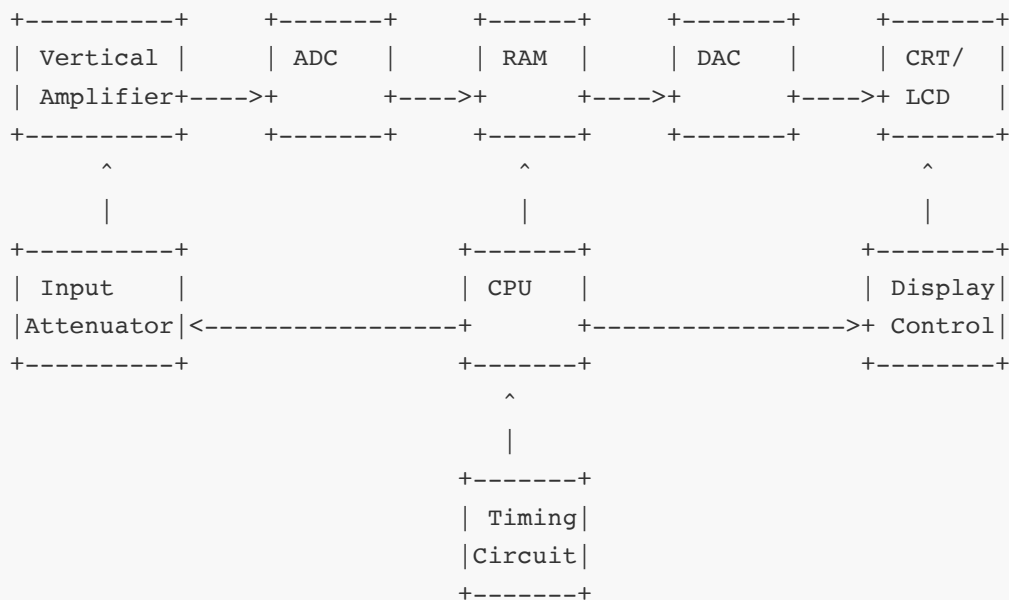
## Question 3(c) [7 marks]

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

**Answer:**

Digital Storage Oscilloscope (DSO) converts analog signals to digital for storage and processing.

**Block diagram:**



**Working principle:**

1. **Signal acquisition:** Analog signal is sampled at high speed
2. **A/D conversion:** Continuous signal converted to discrete digital values
3. **Storage:** Digital values stored in memory
4. **Processing:** Microprocessor analyzes stored data

5. **Display:** Data converted back to analog for display or shown directly on LCD

#### Advantages of DSO:

Advantage	Description
Pre-trigger viewing	Can see signal before trigger event
Single-shot capture	Can capture transient events
Waveform storage	Can save waveforms for later analysis
Signal processing	Advanced mathematical operations on signals
Automated measurements	Automatic parameter measurements
Digital interfaces	Can transfer data to computers

**Mnemonic:** "SAMPLE: Storage And Memory Processes Live Events"

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

**Differentiate between CRO and DSO.**

**Answer:**

Parameter	Analog CRO	Digital Storage Oscilloscope
Signal processing	Real-time analog	Digitized and stored
Storage capability	None (phosphor persistence only)	Can store waveforms in memory
Bandwidth	Typically higher for same price range	Limited by sampling rate
Pre-trigger view	Not possible	Available
Single-shot events	Difficult to capture	Easily captured
Signal analysis	Basic measurements only	Advanced mathematical analysis

**Mnemonic:** "ASPAD: Analog Shows Present; Digital Archives Data"

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

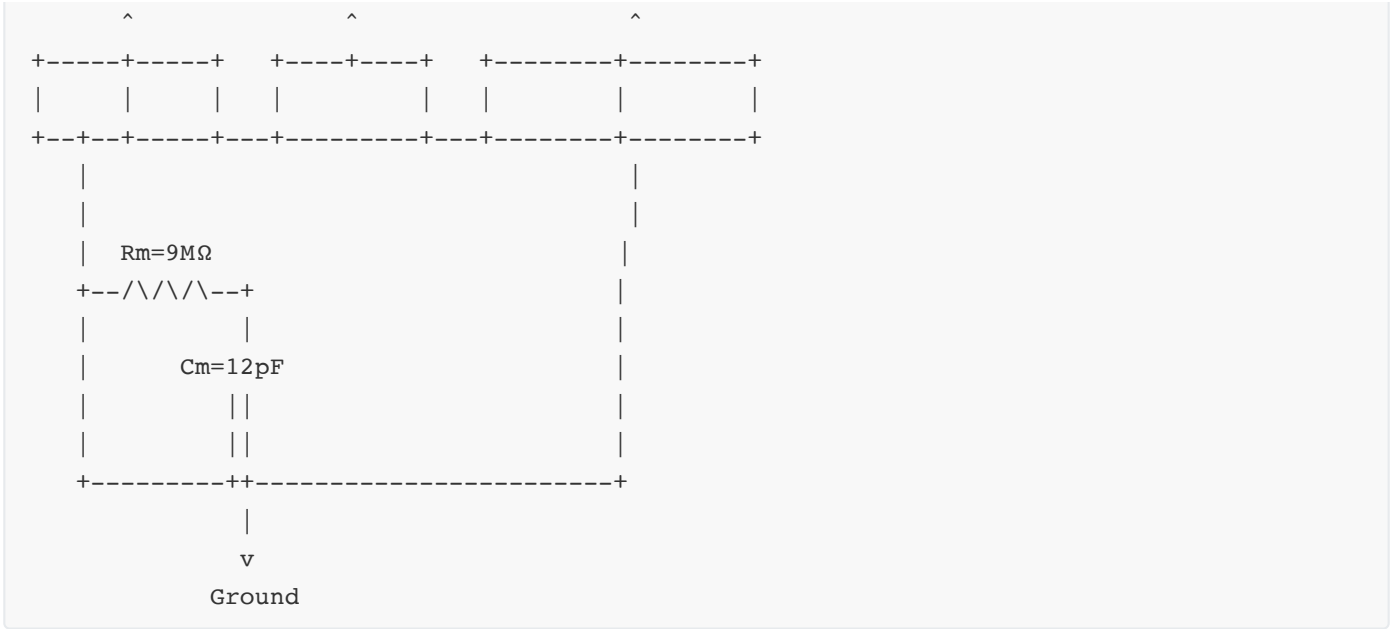
**Explain structure of 10:1 Probes in detail.**

**Answer:**

10:1 probe reduces signal amplitude by 10 times to extend oscilloscope range.

**Structure:**

Probe tip	Cable	Compensation
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Components:

Component	Description
Probe tip	Metal contact point that touches circuit
Ground clip	Reference connection to circuit ground
Compensation network	RC circuit for frequency compensation
Probe body	Insulated housing for components
Cable	Low-capacitance coaxial cable
Connector	BNC connector for oscilloscope input

Working principle:

- Forms voltage divider with oscilloscope input ( $9\text{M}\Omega$  probe +  $1\text{M}\Omega$  scope = 10:1 division)
- Compensating capacitor ensures flat frequency response
- Reduces circuit loading effect by increasing effective input impedance

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

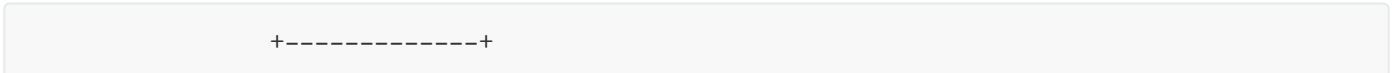
Question 3(c OR) [7 marks]

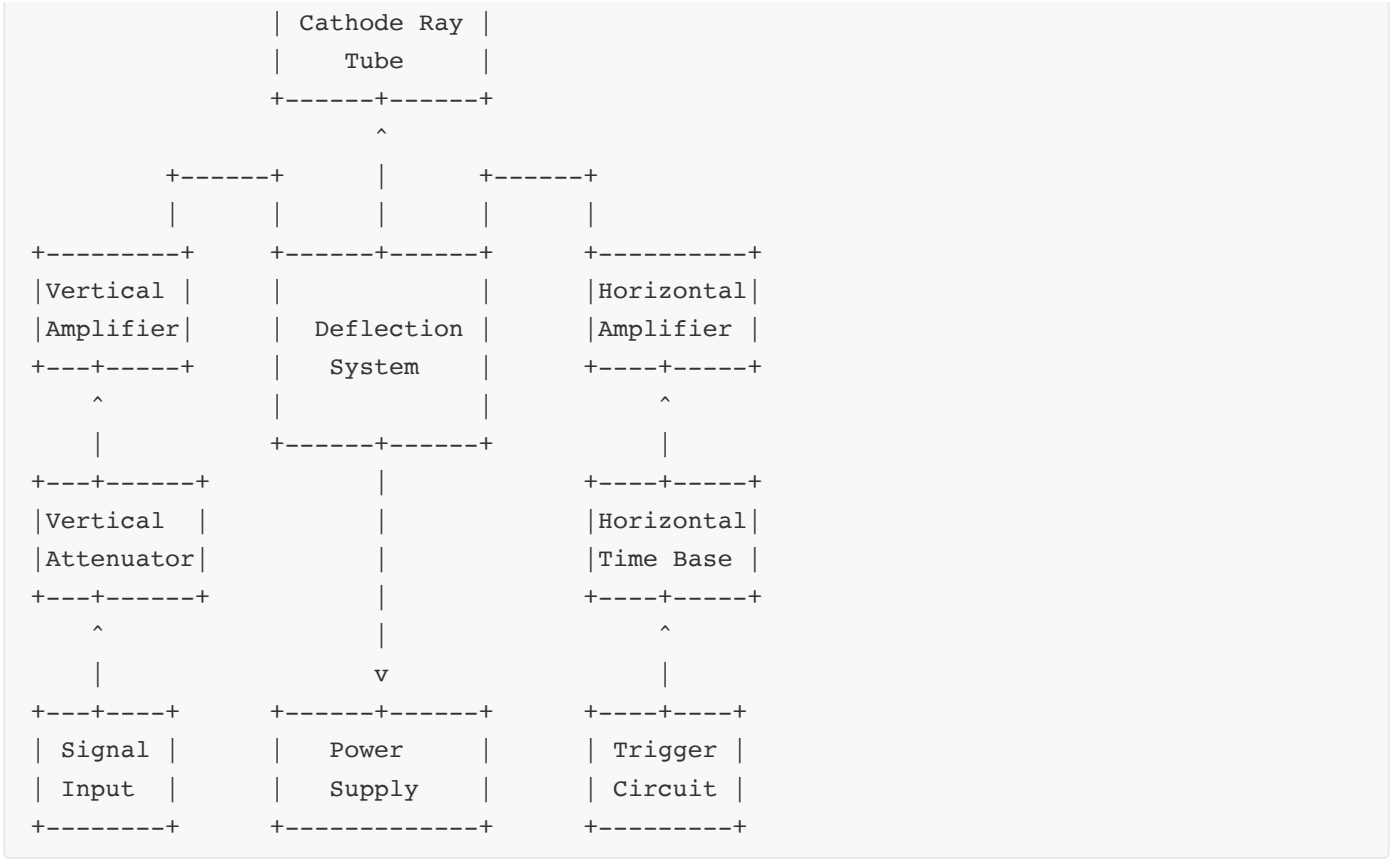
Describe Block diagram, working and application of CRO.

Answer:

CRO (Cathode Ray Oscilloscope) displays and measures electrical signals.

Block diagram:





**Working principle:**

- 1. **Electron beam generation:** CRT produces focused electron beam
- 2. **Vertical deflection:** Y-plates deflect beam proportional to input signal
- 3. **Horizontal deflection:** X-plates sweep beam across screen
- 4. **Triggering:** Synchronizes sweep with input signal
- 5. **Display:** Beam strikes phosphor screen creating visible trace

**Applications of CRO:**

Application	Description
Waveform analysis	Visualize signal shape and characteristics
Frequency measurement	Measure time period and calculate frequency
Phase measurement	Compare phase relationship between signals
Voltage measurement	Measure signal amplitude
Component testing	Check behavior of electronic components
Transient analysis	Observe fast-changing events

**Mnemonic:** "VIEW: Voltage Inspection and Electrical Waveform observation"

**Question 4(a) [3 marks]**

**Differentiate RTD and Thermistor.****Answer:**

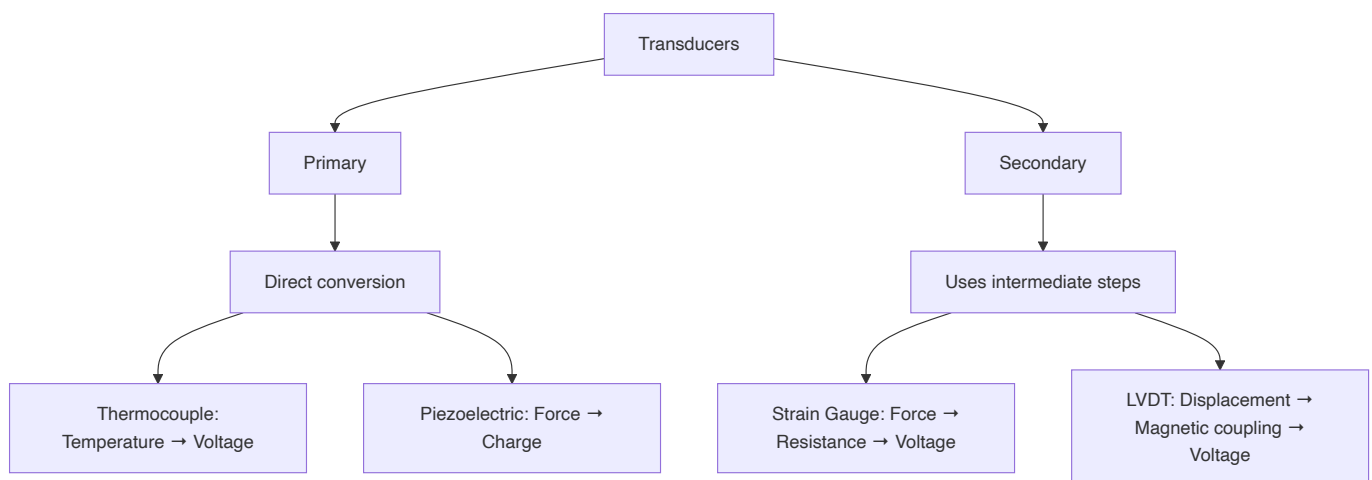
Parameter	RTD (Resistance Temperature Detector)	Thermistor
Material	Pure metals (Pt, Ni, Cu)	Semiconductor materials
Resistance-temp relation	Linear (positive)	Highly non-linear (usually negative)
Temperature range	-200°C to 850°C	-50°C to 300°C
Sensitivity	Lower (0.4%/°C)	Higher (4%/°C)
Accuracy	Higher	Lower
Cost	Higher	Lower
Response time	Slower	Faster

**Mnemonic:** "METAL-SEMI: Metal Elements Temperature-Linear vs. SEMIconductor Exponential Measurement Instrument"

**Question 4(b) [4 marks]****Give and explain two example of primary and Secondary transducer.****Answer:**

Type	Examples	Explanation
<b>Primary Transducers</b>		
1. Thermocouple	Directly converts temperature difference to voltage using Seebeck effect	Two dissimilar metals generate voltage proportional to temperature difference
2. Piezoelectric crystal	Directly converts mechanical force to electrical charge	Quartz crystal develops charge proportional to applied pressure
<b>Secondary Transducers</b>		
1. Strain gauge	Requires intermediate conversion; change in dimension alters resistance	Mechanical strain → resistance change → electrical signal
2. LVDT	Requires intermediate conversion; displacement changes magnetic coupling	Mechanical displacement → magnetic coupling → electrical signal

**Diagram:**



**Mnemonic:** "PIDS: Primary Is Direct; Secondary is Stepwise"

## Question 4(c) [7 marks]

**Describe Thermocouple with working principle, types and application.**

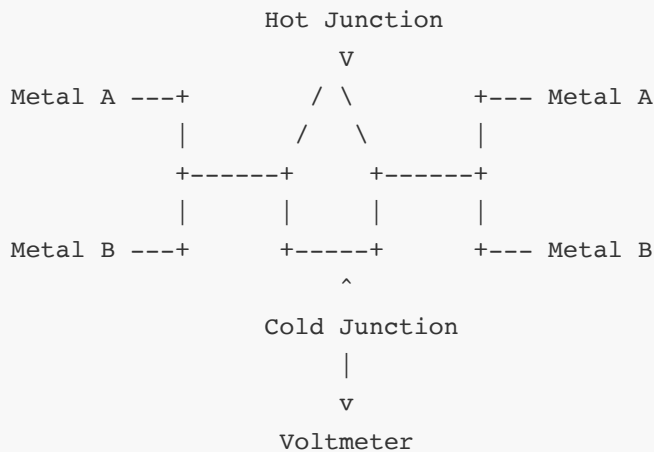
**Answer:**

Thermocouple is a temperature sensor based on the Seebeck effect.

**Working principle:**

- When two dissimilar metals are joined, a voltage is generated proportional to temperature difference

- Seebeck effect: Temperature gradient creates electromotive force

**Diagram:****Types of thermocouples:**

Type	Materials	Temperature Range	Application
Type J	Iron-Constantan	-40°C to 750°C	General purpose, reducing atmosphere
Type K	Chromel-Alumel	-200°C to 1350°C	Oxidizing atmosphere, high temperatures
Type T	Copper-Constantan	-200°C to 350°C	Low temperature, food industry
Type E	Chromel-Constantan	-200°C to 900°C	Highest sensitivity, cryogenics
Type R/S	Platinum-Rhodium	0°C to 1600°C	High temperature, laboratory standards

**Applications:**

- Industrial temperature measurement
- Furnace and kiln temperature control
- Chemical processing
- Food processing
- Automotive engine sensors
- Medical equipment

**Mnemonic:** "STEVE: Seebeck Thermoelectric Effect Verifies Elevated temperatures"

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

**Demonstrate working and principle Semiconductor Temperature Sensor LM35.**

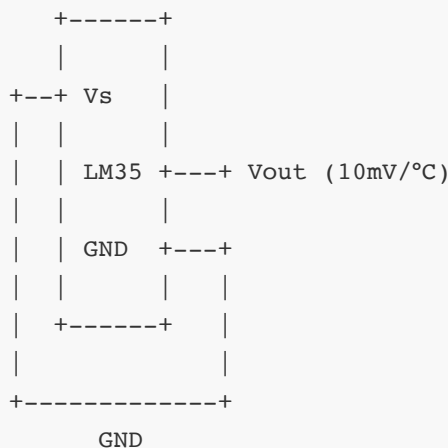


**Answer:**

LM35 is a precision integrated-circuit temperature sensor that provides output voltage proportional to temperature.

**Principle:**

- Based on the predictable change in base-emitter voltage ( $V_{BE}$ ) of a transistor with temperature
- Output voltage linearly proportional to Celsius temperature ( $10\text{mV}/^\circ\text{C}$ )

**Circuit diagram:****Working characteristics:**

- Linear output:  $10\text{mV}/^\circ\text{C}$  ( $0.01\text{V}/^\circ\text{C}$ ) scale factor
- Range:  $-55^\circ\text{C}$  to  $+150^\circ\text{C}$
- Accuracy:  $\pm 0.5^\circ\text{C}$  (typical)
- Low self-heating:  $0.08^\circ\text{C}$  in still air
- Low impedance output:  $0.1\Omega$  for  $1\text{mA}$  load

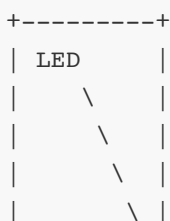
**Mnemonic:** "LOTUS: Linear Output Temperature Units from Semiconductor"

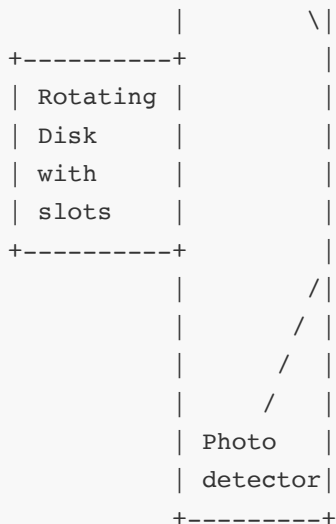
**Question 4(b OR) [4 marks]**

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

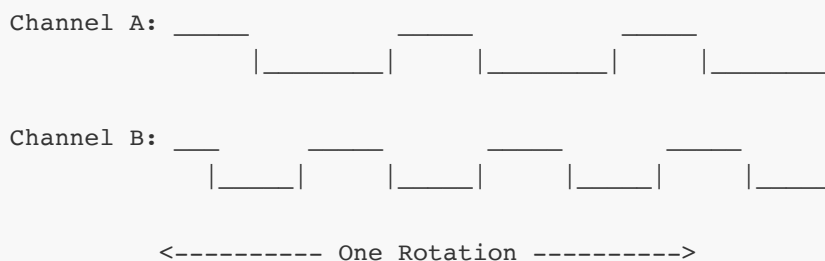
**Answer:**

Incremental optical encoder generates pulses as shaft rotates to measure position, speed, and direction.

**Construction:**



### Output waveform:



### Working principle:

- Light source (LED) shines through slotted disk
- Photodetectors receive light pulses as disk rotates
- Two output channels (A and B) are 90° out of phase
- Direction determined by which channel leads
- Resolution depends on number of slots on disk

**Mnemonic:** "PADS: Pulses from A and Determine Speed"

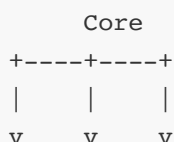
## Question 4(c OR) [7 marks]

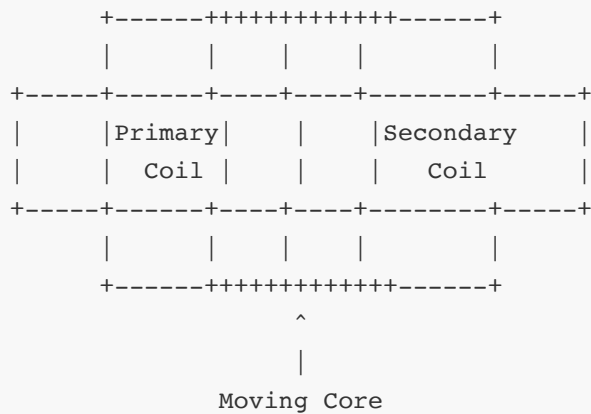
**Describe construction, operation of LVDT with advantages, disadvantages and application.**

**Answer:**

LVDT (Linear Variable Differential Transformer) is an electromechanical transducer that converts linear displacement into electrical signal.

**Construction:**



**Operation:**

1. AC excitation applied to primary coil
2. Magnetic flux couples to secondary coils
3. Core position determines differential voltage output
4. Null position: Equal voltage in both secondaries
5. Movement: Voltage increases in one secondary, decreases in other

**Advantages:**

Advantage	Description
Frictionless	No mechanical contact between core and coils
Infinite resolution	Analog output with no quantization
Robustness	Long operational life, high reliability
Null position stability	Highly stable reference position
High sensitivity	Small displacements can be measured

**Disadvantages:**

Disadvantage	Description
AC excitation required	Needs AC power source
Temperature sensitive	Output varies with temperature
Position limited	Measurement range is limited
Bulky	Larger size compared to other sensors

**Applications:**

- Machine tool positioning
- Hydraulic and pneumatic systems

- Aircraft and missile systems
- Automated manufacturing
- Structural testing

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

## Question 5(a) [3 marks]

**Describe working of Pressure measurement using Capacitive transducer.**

**Answer:**

Capacitive pressure transducer uses changes in capacitance to measure pressure.

**Working principle:**

- Pressure deforms diaphragm, changing distance between capacitor plates
- Capacitance inversely proportional to distance ( $C = \epsilon_0 \epsilon_a A/d$ )
- Change in capacitance is measured and converted to pressure reading

**Diagram:**



**Application:** Industrial process monitoring, atmospheric pressure measurement, liquid level sensing

**Mnemonic:** "CAPS: Capacitance Alters as Pressure Shifts"

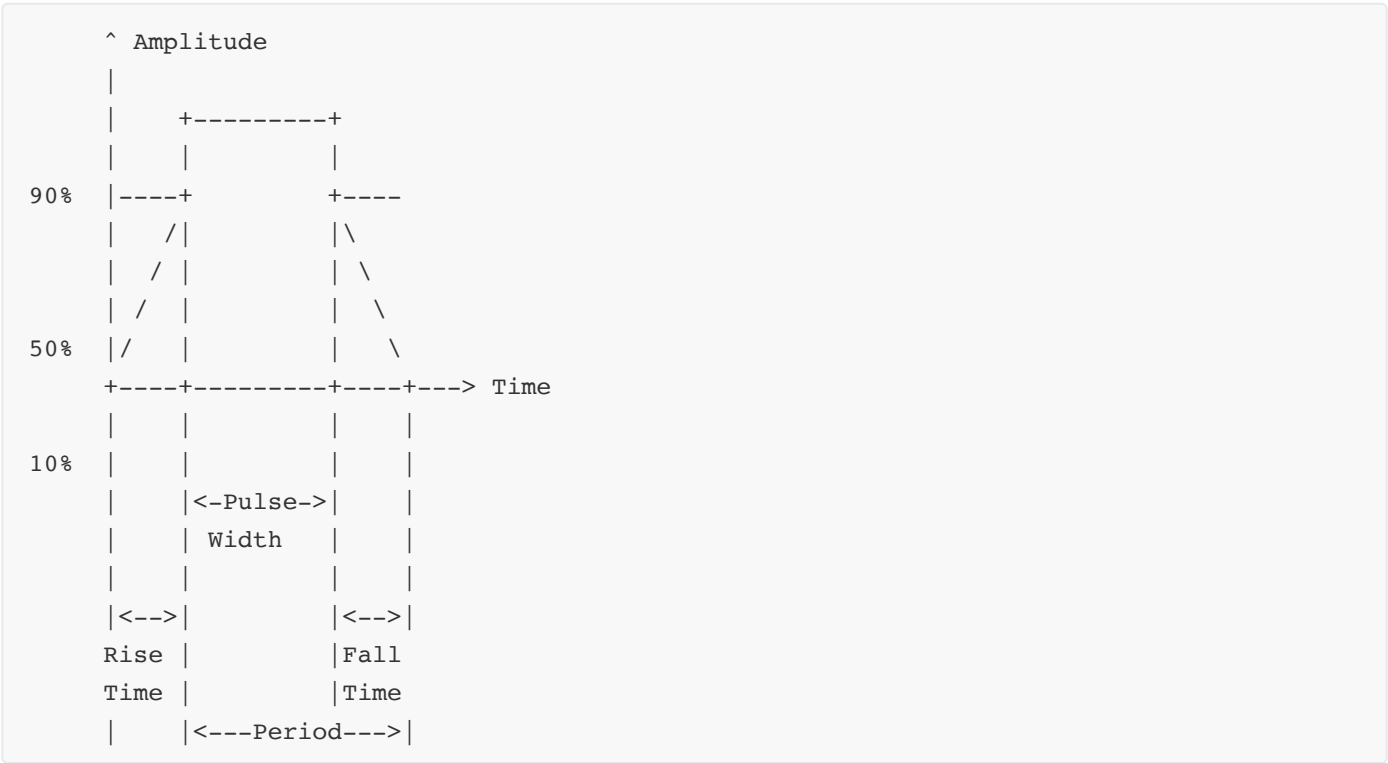
## Question 5(b) [4 marks]

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

**Answer:**

Parameter	Definition
Rise Time	Time taken for pulse to rise from 10% to 90% of its maximum amplitude
Fall Time	Time taken for pulse to fall from 90% to 10% of its maximum amplitude
Pulse Width	Time interval between 50% amplitude points on rising and falling edges
Duty Cycle	Ratio of pulse width to total period, expressed as percentage

Diagram:



Mnemonic: "RPFD: Rise Pulses, Fall Determines"

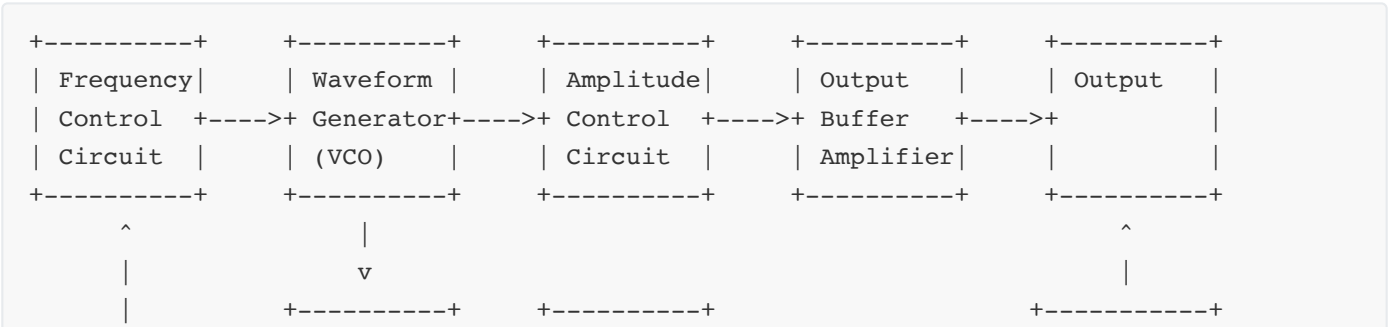
## Question 5(c) [7 marks]

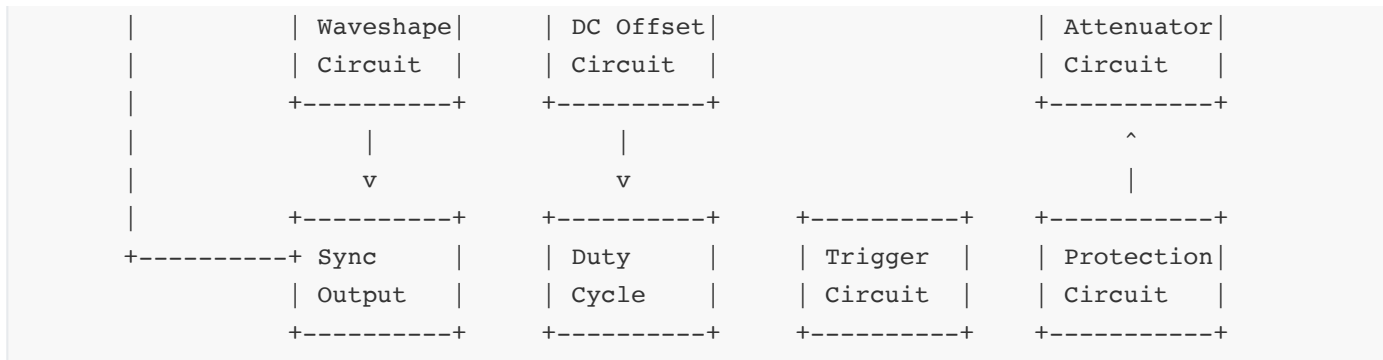
Discuss Function generator block diagram.

Answer:

Function generator produces various waveforms over a range of frequencies.

Block diagram:





### Function and operation of each block:

Block	Function
<b>Frequency Control</b>	Sets the operating frequency using variable capacitor/resistor network
<b>Waveform Generator</b>	Voltage-controlled oscillator producing basic waveform (usually triangle)
<b>Waveshape Circuit</b>	Converts triangle wave to sine/square waves through shaping circuits
<b>Amplitude Control</b>	Adjusts output amplitude of the generated waveform
<b>DC Offset</b>	Adds DC bias to shift the waveform up or down from zero reference
<b>Output Buffer</b>	Provides low output impedance for proper loading
<b>Attenuator</b>	Controls final output level with calibrated steps
<b>Protection Circuit</b>	Protects output from short circuits or overload

### Output waveforms:

Waveform	Generation Method
Sine	Shaped from triangle wave using non-linear shaping circuit
Square	Derived from triangle wave using comparator
Triangle	Basic output from integrator circuit
Ramp	Modified triangle wave with different rise/fall times
Pulse	Square wave with variable duty cycle

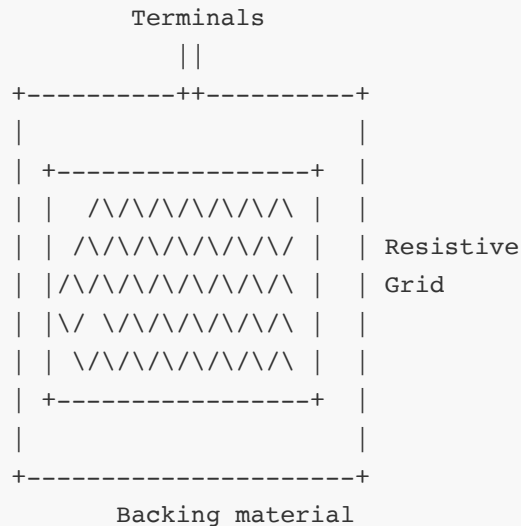
**Mnemonic:** "FASTEST: Frequency Amplitude Shaping Together Ensures Signal Types"

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

**Discuss Working, construction of strain gauge.**

**Answer:**

Strain gauge converts mechanical deformation to electrical resistance change.

**Construction:****Working principle:**

- Based on piezoresistive effect: resistance changes with mechanical deformation
- When bonded to object, strain gauge deforms along with it
- Resistance increases with tension (elongation)
- Resistance decreases with compression (shortening)
- Resistance change is measured using bridge circuit

**Resistance change relation:**

- $\Delta R/R = GF \times \epsilon$
- Where:  $\Delta R$  = resistance change,  $R$  = initial resistance
- $GF$  = gauge factor (sensitivity),  $\epsilon$  = strain

**Materials used:**

- Foil: Constantan, Karma, Nichrome alloys
- Semiconductor: Silicon, Germanium for higher sensitivity

**Mnemonic:** "SERB: Strain Effects Resistance by Bonding"

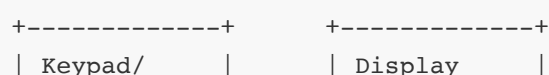
**Question 5(b OR) [4 marks]**

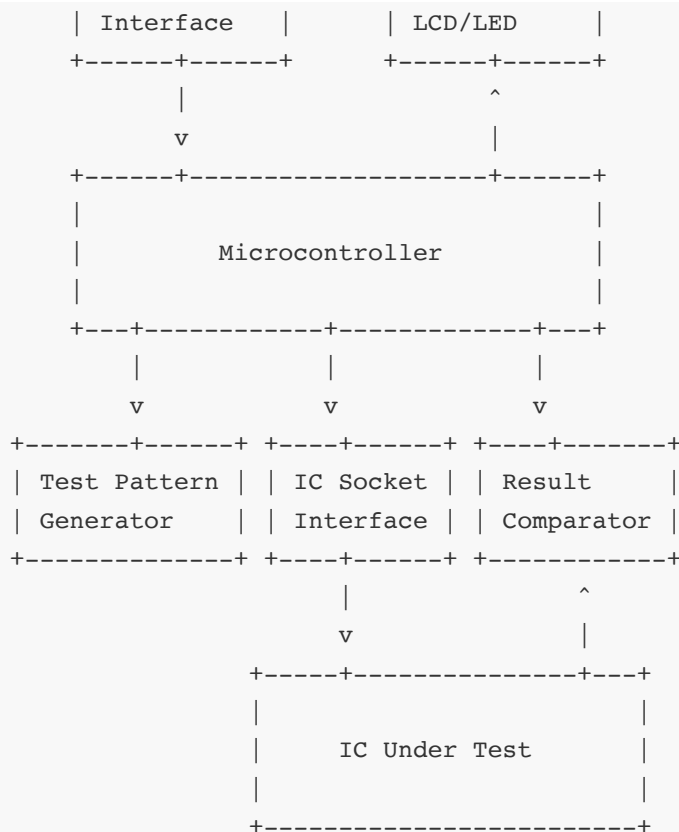
**Describe working of Digital IC tester with suitable diagrams.**

**Answer:**

Digital IC tester verifies functionality of integrated circuits by applying test patterns.

**Block diagram:**



**Working principle:**

1. IC is inserted into test socket
2. User selects IC type/number using keypad
3. Microcontroller loads appropriate test pattern
4. Test patterns applied to IC inputs
5. Output responses compared with expected values
6. Pass/Fail result displayed

**Features of digital IC tester:**

- Tests TTL, CMOS, HCMOS logic families
- Can identify unknown ICs by analyzing pin functions
- Performs functional and parametric tests
- Checks for static and dynamic characteristics

**Mnemonic:** "PIPE: Pattern Input, Pin Examination"

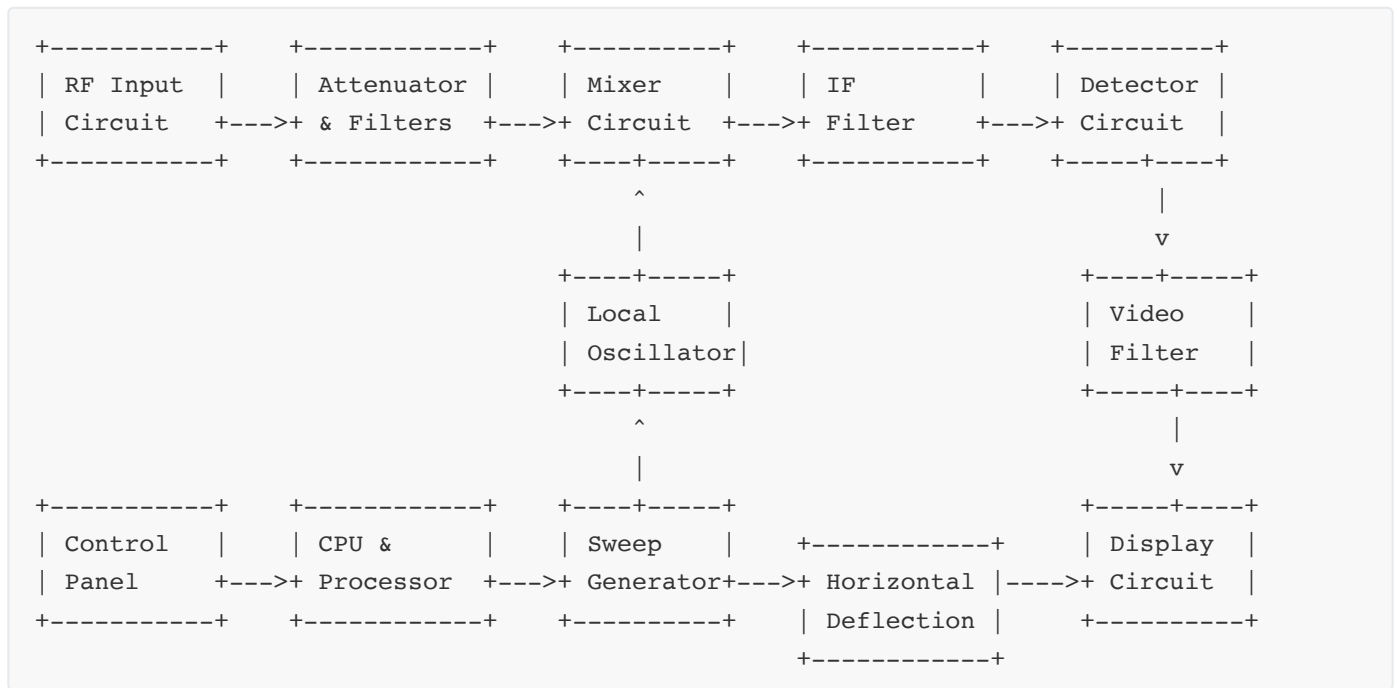
## Question 5(c OR) [7 marks]

**Discuss working of Spectrum Analyzer with suitable diagrams.**

**Answer:**

Spectrum analyzer displays signal amplitude versus frequency, showing frequency components.



**Block diagram:****Working principle:**

1. **Superheterodyne conversion:** Input signal mixed with local oscillator
2. **Frequency sweep:** Local oscillator sweeps across frequency range
3. **IF filtering:** Narrow bandpass filter selects frequency components
4. **Detection:** Amplitude of each frequency component is measured
5. **Display:** Amplitude vs. frequency plot shown on screen

**Types of spectrum analyzers:**

Type	Principle	Application
Swept-tuned	Superheterodyne with swept LO	RF and microwave signals
FFT (Fast Fourier Transform)	Digital conversion and FFT algorithm	Audio and low-frequency signals
Real-time	Combination of FFT with high-speed processing	Transient and dynamic signals

**Applications:**

- EMI/EMC testing
- Signal purity measurement
- Harmonic distortion analysis
- Communication system testing
- Modulation analysis

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