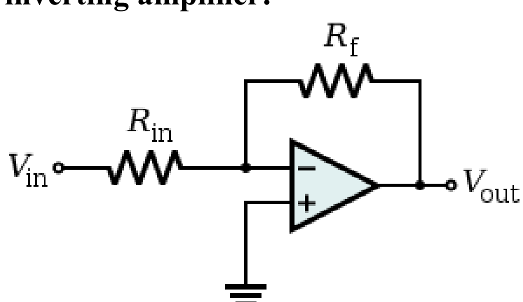
MODEL ANSWER

SUMMER– 18 EXAMINATION

Subject Title: Industrial InstrumentationSubject Code:- **17414**

Important Instructions to examiners:

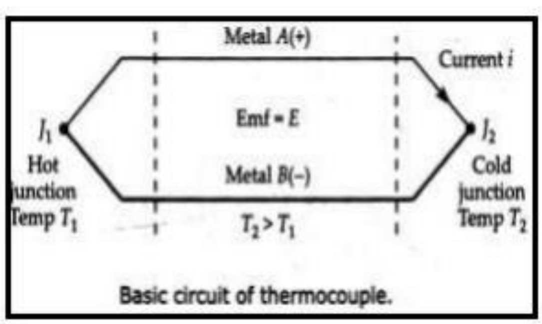
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q.1	**A)**	**Attempt any ten:**	**20 Marks**
	a)	**Draw circuit diagram for inverting amplifier using IC 741.**	**2 Marks**
	Ans:	**Circuit diagram for inverting amplifier:**  $$\text{Gain (Av)} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$	**2M**
	b)	**Define :** **i) Accuracy ii) Linearity.**	**2 Marks**
	Ans:	1. **Accuracy:** The degree of exactness (closeness) of a measurement compared to the expected (desired) value. **OR** It is the ability of a device or a system to respond to a true value of a measured variable under reference conditions. **OR** Closeness with which the instrument reading approaches the true value of the	**1M**

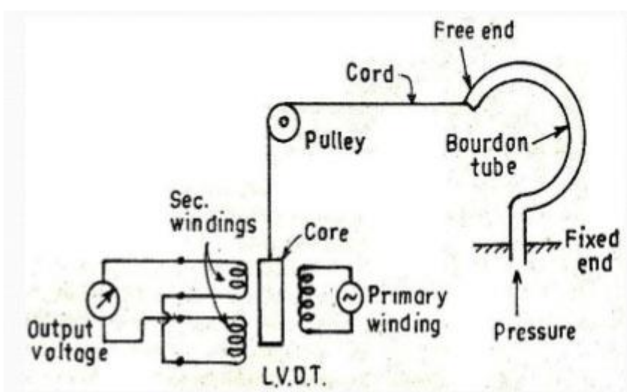
		quantity being measured is known as accuracy. 2. **Linearity:** **Linearity** is defined as the ability to reproduce the input characteristics symmetrically and this can be expressed by the equation y= mx+c Where y is the output is the input is the slope and c is the intercept.	**1M**
	c)	**Define :** **1) Dynamic error ii) Settling time.**	**2 Marks**
	Ans:	1. **Dynamic error:** It is the difference between the true value of the quantity (under measurement) changing with time and the value indicated by the measurement system if no static error is assumed. 2. **Settling time:** It is the time required for the output of any system to reach and stay within a specified tolerance band.	**1M** **1M**
	d)	**Compare primary and secondary transducer (any two points).**	**2 Marks**
	Ans:	(see table below)	**1M each**

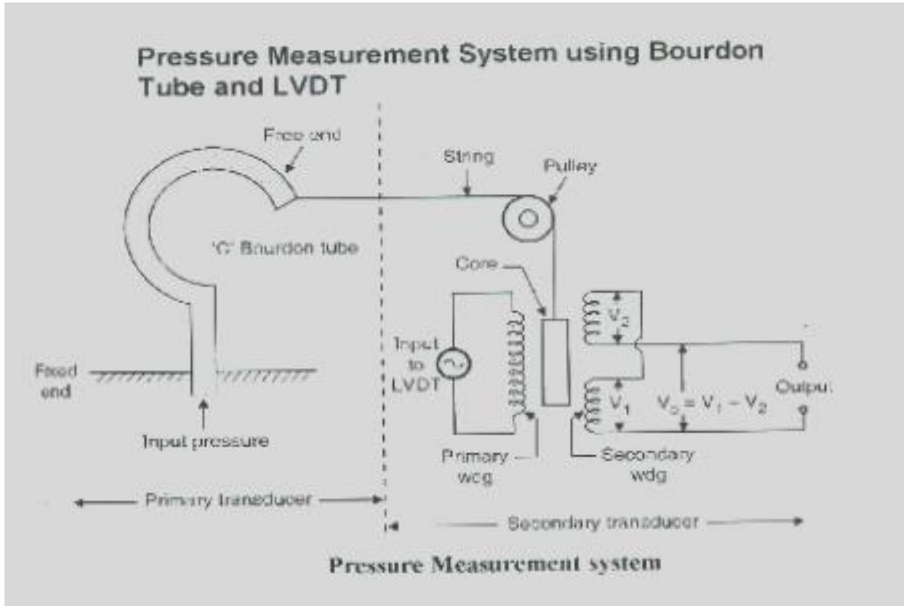
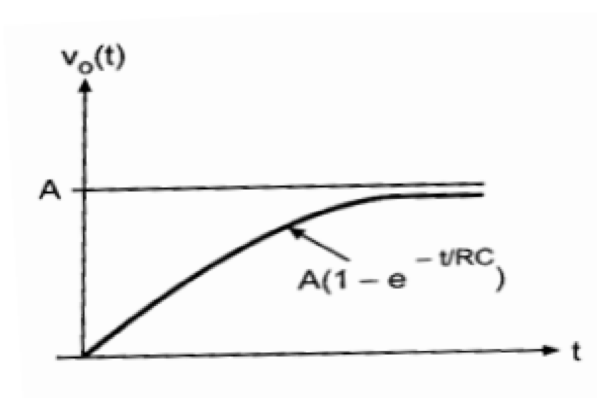
Primary transducer	Secondary transducer
The device which converts physical quantity into a mechanical displacement is called primary transducers.	The device that converts the mechanical form into an electrical form is called secondary transducers.
Ex: Bourdon tube acting as a primary transducer senses the pressure and converts the pressure into displacement.No output is given to the input of the bourdon tube.So it is called primary transducer. Mechanical device can act as a primary transducer	**Ex:**The output of the Bourdon tube is given to the input of the LVDT.There are two stages of transduction, firstly the pressure is converted into a displacement by the Bourdon tube,then the displacement is converted into analog voltage by LVDT.Here LVDT is called secondary transducer. Electrical device can act as a secondary transducer.

	e)	**State working principle of thermocouple.**	**2 Marks**
	Ans:		



		Note:Diagram is optional **Working principle of thermocouple.** When heat is applied to junction (hot junction) of the two dissimilar metals, an emf is generated which can be measured at the other junction (cold junction). The two dissimilar metals form an electric circuit, and current flows as a result of the generated emf. This current will continue to flow as long as T1>T2.	**2M**
	f)	**State any four criteria for selection of transducer.**	**2 Marks**
	Ans:	Transducer is a device which transforms energy from one form to another. The following points should be considered while selecting a transducer for particular application. 1. Operating range 2. Operating principle 3. Sensitivity 4. Accuracy 5. Frequency response and resonant frequency 6. Errors 7. Environmental compatibility 8. Usage and ruggedness. 9. Electrical aspect. 10. Stability and Reliability 11. Loading effect 12. Static characteristics 13. General selection criteria	**½ M each(Any four)**
	g)	**List any four applications of rotary encoder.**	**2 Marks**
	Ans:	**Applications of rotary encoder:** 1. Aerospace industry 2. Material Handling 3. Packaging industry 4. Textiles industry 5. Timber products 6. Metal forming and fabrication 7. Foods and beverage industry 8. Printing industry 9. Linear measurement 10. X-Y Positioning	**½ M each(Any four)**
	h)	**State two examples of passive transducer.**	**2 Marks**
	Ans:	**Examples of passive transducer:** 1. LDR 2. Thermistor 3. Strain Gauge 4. Resistive transducers. 5. Inductive transducers.	**1M each(Any two)**

		6. Photoconductive 7. Capacitive transducers. 8. Magnetoresistive 9. Thermoresistive 10. Electroresistive 11. RTD	
	i)	**State two examples of active transducer.**	**2 Marks**
	Ans:	**Examples of active transducer:** 1. Thermocouple 2. photovoltaic cells (solar cells) 3. Piezoelectric crystals. 4. Thermoelectric 5. Magnetostrictive 6. Electrokinetic	**1M each(Any two)**
	j)	**State any four functions of data acquisition system.**	**2 Marks**
	Ans:	**Functions of data acquisition system.** 1. Handling of analog signals 2. Relates to the process of collecting the input data in digital form,as rapidly, accurately, completely and economically as necessary. 3. Making the measurement of electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound 4. Converting the data to digital form and handling it 5. Internal programming and control 6. Connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution.	**½ M each (Any four)**
	k)	**Draw circuit diagram for measurement of pressure using Bourdon tube and LVDT.**	**2 Marks**
	Ans:	**Circuit diagram for measurement of pressure using Bourdon tube and LVDT:**  **OR**	**2M**

			
	l)	**List any four drawbacks of LVDT.**	**2 Marks**
	Ans:	**Drawbacks of LVDT.** 1. Large primary voltage produces distortion in output. 2. Temperature affects the performance. 3. Sensitive to stray magnetic field. 4. Large displacements are required for differential output 5. It has residual voltage	**2M**
Q 2	**A)**	**Attempt any four of the following :**	**16 Marks**
	a)	**With mathematical expression describe dynamic response of first order system.**	**4 Marks**
	Ans:	**Note: Dynamic response of first order system for other standard signals also should be considered** The response of first order for step input signal is shown in fig. 	**2M**

The T.F. of First order system is ,

$$\frac{V_0(s)}{V_i(s)} = \frac{1}{1 + sRC}$$

For Unit Step input $V_i(s) = \frac{1}{s}$

$$\text{So, } V_0(s) = \frac{1}{s(1+sRC)} = \frac{A'}{s} + \frac{B'}{1+sRC}$$

Where : A' = 1 and B' = - RC

$$Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC} = \frac{1}{s} - \frac{1}{s} + \frac{1}{RC}$$

Taking Laplace inverse,

$$Vo(t) = 1 - e^{\frac{-t}{RC}} \quad => Css + ct(t)$$

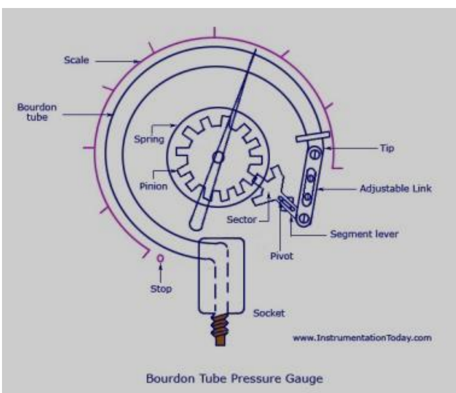
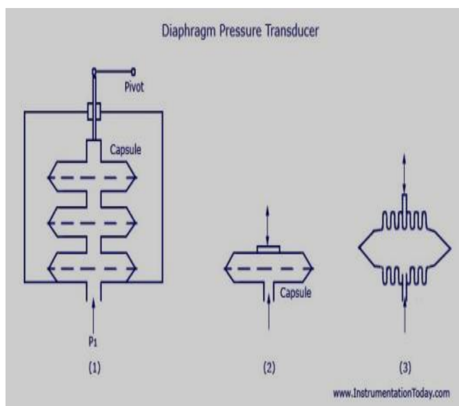
$$Css = 1 \text{ and } ct(t) = - e^{\frac{-t}{RC}}$$

The response is purely exponential

2M

b) **Give comparison of Bourdon tube and Diaphragm.** **4 Marks**

Ans: **4M (Any four)**

Sr. No	Bourdon tube	Diaphragm.
1.		
2.	Gear drive connects dial reading	No gears inside the diaphragm pressure gauge
3.	Increased gap between gear and arm affect accuracy	Shock resistant and good accuracy

4.	Not sudden pressure endurable	sudden pressure endurable
5.	Need to fill glycerin/oil to gauge	No need to fill glycerin/oil to gauge
6.	It takes more time to measure pressure and Expensive	Users save time and money
7.	Large range of pressure measurement	Small range of pressure measurement

c) **List materials used for any four thermocouple along with their temperature range.** **4 Marks**

Ans: **1 M each(Any four)**

TYPE	Material	Temperature Range
E	Chromel/Constantan	-18 to +315/315 to 870
K	Chromel/Alumel	-18 TO +276/276 to 1000
J	Iron/Constantan	-18 TO +276/276 to 760
R	Platinum/Platinum 13% Rhodium	0 to 1000
S	Platinum/Platinum 13% Rhodium	450 to 1500
T	Copper/Constantan	-200 to 400

d) **With neat diagram explain working of Ratiometric conversion.** **4 Marks**

Ans: **Diagram:** **2M**

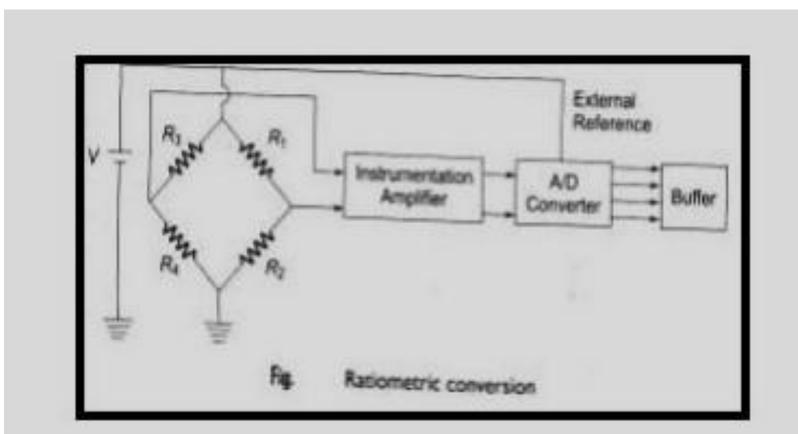


Fig. Ratiometric conversion

2M

Working of Ratiometric conversion.

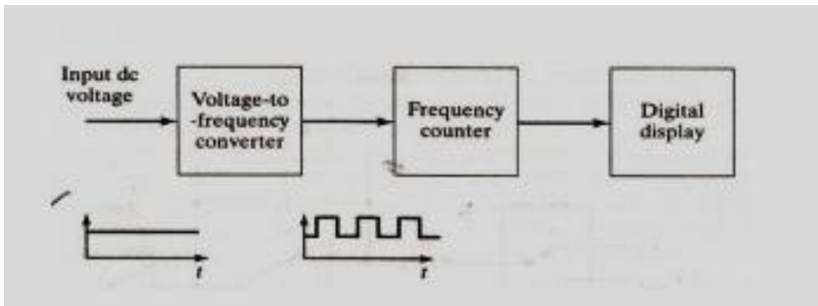
It is a signal conditioning method applicable with DAS. It includes an analog voltage divider to which an excitation voltage is given as the input. The output of it is given to an instrumentation amplifier and then to A to D converter. The output voltage of the divider is the ratio of the amplifier output voltage and the excitation voltage. Thus by this method the output of the signal amplifier will be a voltage proportional to the input parameter only and independent of the input excitation voltage. Hence the system

		accuracy improves since variation in the excitation voltage does not affect the sensitivity of the system	
	e)	**Explain working of integrating type ADC.**	**4 Marks**
	Ans:	**Types of integrating type ADC.**	

1. Single slope/Voltage to frequency or integrating type A/D converter
2. Dual slope integrating type A/D converter

Single slope/Voltage to frequency or integrating type A/D converter:

Diagram:



2 M

Explanation:

An analog voltage can be converted to digital form, by producing pulses whose frequency is proportional to the analog voltage. These pulses are counted by a counter for a fixed duration and the reading of the counter will be proportional to the frequency of the pulses and hence, to the analog voltage.

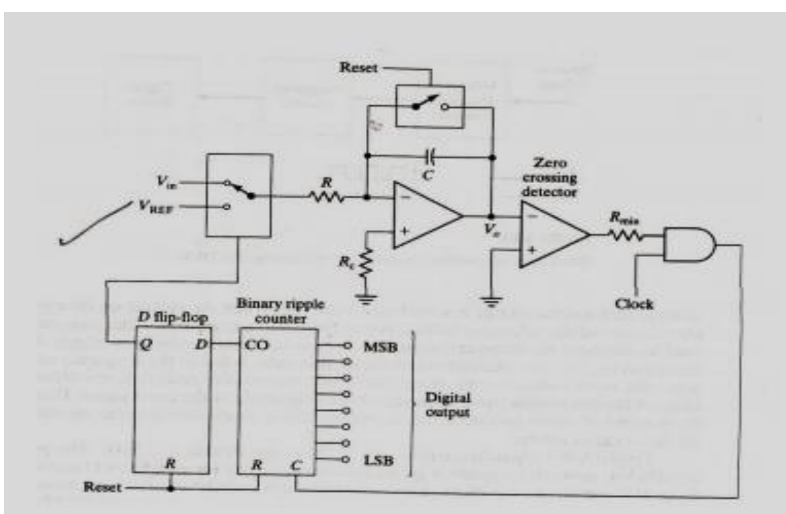
Voltage-to-frequency converter In these types of A/D converters, the voltage is converted (by a voltage-to-frequency converter) into a set of pulses repetition rate (or frequency) is proportional to the magnitude of the input. The pulses are counted by an electronic counter similar to the way the number of wavelengths was counted by the time-interval counter in the ramp-type DVM.

2M

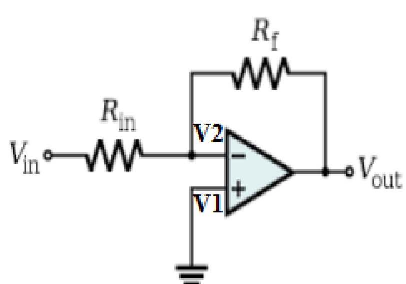
OR

Dual slope Integration A/D converter

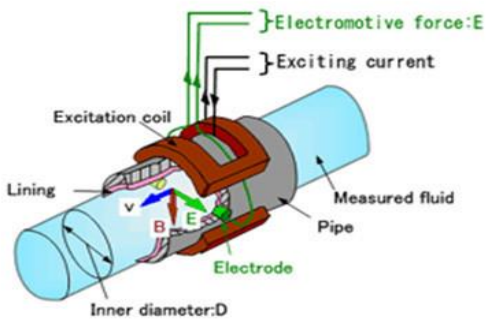
Diagram:

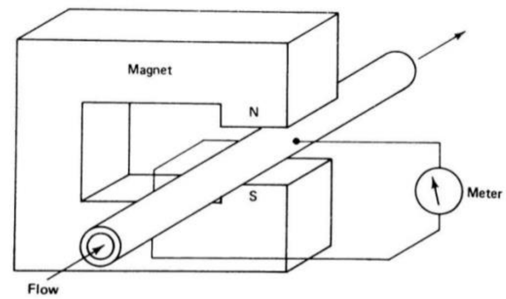


2M

		Explanation: In this ADC, an unknown analog voltage and a known reference voltage are converted into equivalent time periods using an integrator, These time periods are measured by the counter. This circuit is called dual slope ADC because the analog voltage and reference voltage are converted to ramp signals of different slopes by the integrator. The dc voltage to be converted by the dual-slope converter, Vin, is fed to an integrator, which produces a ramp waveform output, The ramp signal starts at zero and creases for a fixed time interval, T1 equal to the maximum count of the multiplied by the clock frequency. An 8-bit counter operating at 1 MHz would there by cause T1 to be 8 µs. The slope of the ramp is proportional to the magnitude of Vin. The end of the interval, T1 the carry-out (CO) bit of the ripple counter causes the switch to move to the -VREF position. In this position, a constant current (- V_{REFI} R) begins to discharge capacitor C. The ripple counter is reset to zero there is a Co. The count continues until the zero crossing detector switches state as result of capacitor C being discharged. The counter is stopped by the zero crossing detector, and the resultant count is proportional to the input voltage. In the following derivation it is important to observe that t, is independent of the value of Rand C. $V_{charging} = V_{discharging}$ $\frac{i_{charging} T_1}{C} = \frac{i_{discharging} t_r}{C}$ $\frac{V_{input}}{R} T_1 = \frac{V_{REF}}{R} t_r$ $V_{input} = V_{REF} \frac{t_r}{T_1}$	**2M**
	f)	**Explain in brief concept of virtual ground.**	**4 Marks**
	Ans:	**<u>In ideal op-amp gain (A) is infinity...</u>** A=Vo/Vin, which means Vo/Vin=infinity then Vin=0 , As V1-V2=0 in an op-amp V1=V2 (V1 isgrounded). So, V1=0(actual ground) and V2=0(virtual ground). When one terminal is grounded the other terminal is assumed to be at ground potential. **Diagram:**  That is virtual ground concept of op-amp.	**2M** **2M**

Q. 3		**Attempt any four of the following :**	**16 Marks**
	a)	**Explain the working principle of electromagnetic flow meter.**	**4 Marks**
	Ans:	**Diagram**:	**2M**



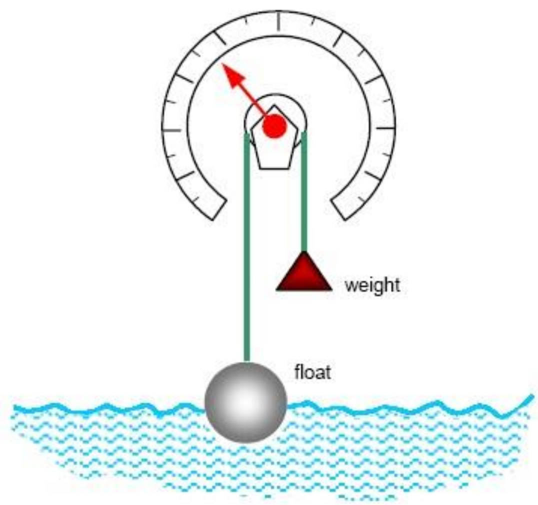
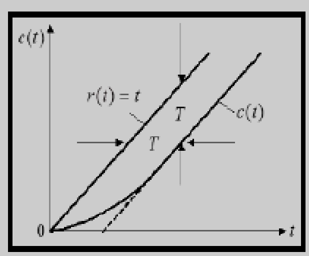
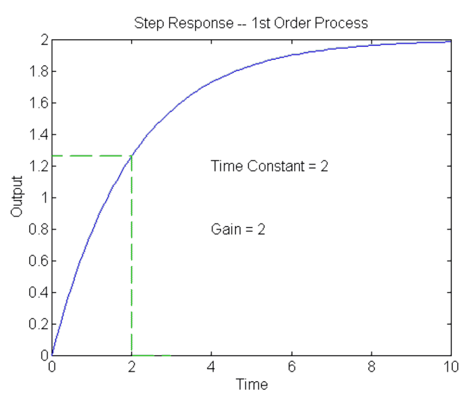


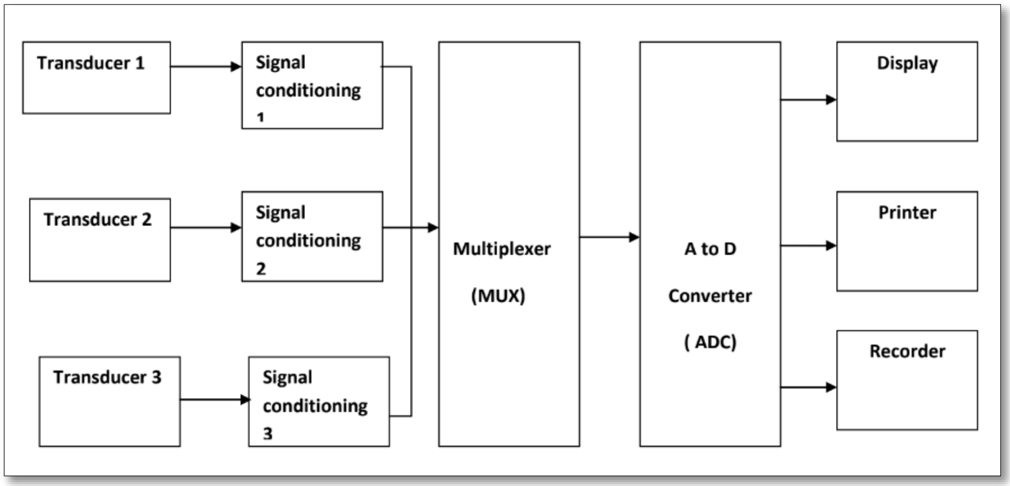
OR

Working Principle:

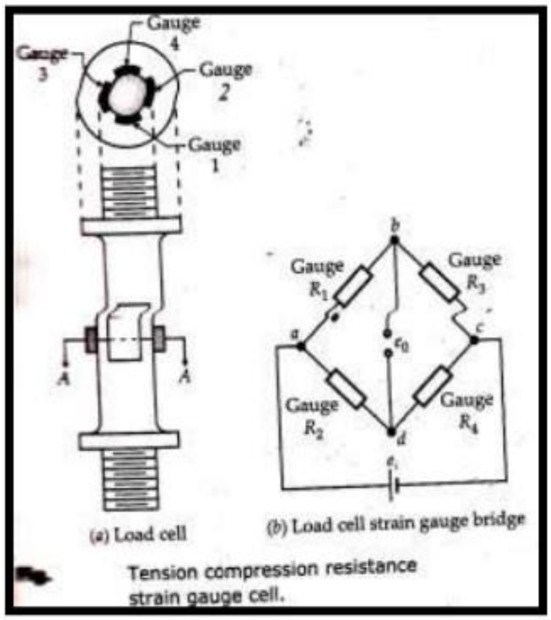
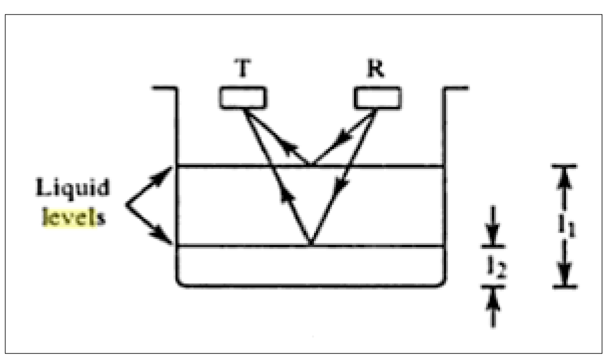
- The electromagnetic flow meter uses Faraday's Law of electromagnetic induction to measure the process flow. **2M**
- When an electrically conductive fluid flows in the pipe, an electrode voltage E is induced between a pair of electrodes placed at right angles to the direction of magnetic field.
  Under Faraday's law of induction, moving conductive liquids inside of a magnetic field generates an electromotive force (voltage) in which the pipe inner diameter, magnetic field strength, and average flow velocity are all proportional. In other words, the flow velocity of liquid moving in a magnetic field is converted into electricity.
- (E is proportional to V × B × D)
- The electrode voltage E is directly proportional to the average fluid velocity V.

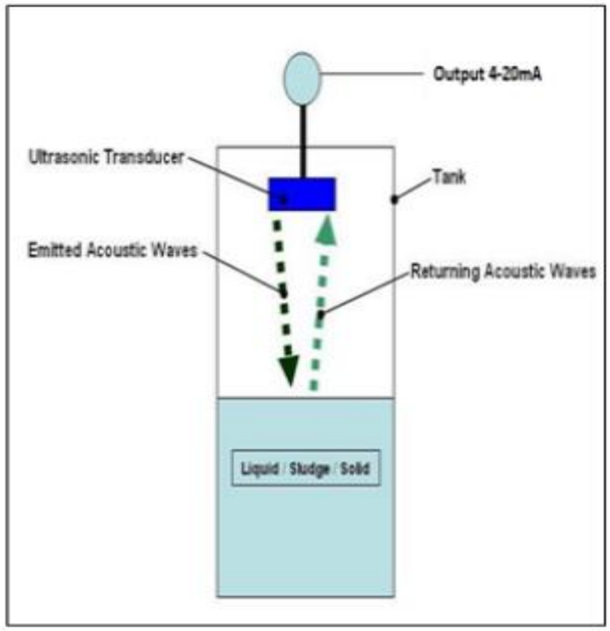
	b)	**Explain how level is measured by using float?**	**4 Marks**
	Ans:	• The float displaces its own weight in the liquid in which it floats. • It will sink into the liquid until a volume of liquid is displaced that is equal in weight to that of the float. • When the specific gravity of the liquid and the cross-sectional area of the float remain constant, the float rises and falls with the level. So, the float will assume a constant relative position with the level and its position is a direct indication of level. • The amount of liquid displaced by variable displacers depends on how deeply the device is submerged in the liquid. With variable displacement devices, the amount of displacement varies with the level of the liquid. • The span of the displacer is the distance that the displacer will respond to the forces of buoyancy. • Buoyant force depends on the amount of liquid displaced and the density of the liquid.	**2M**

		Digram: 	**2M**
	c)	**Draw the response of first order instrument to** **i) Ramp input ii) step input.**	**4 Marks**
	Ans:	**Ramp input response to first order instrument:** **02M**  **Figure:- Response of ramp** **Step input response to first order instrument:** 	**2M** **2M**
	d)	**Draw block diagram of Data Acquisition System (DAS). Write function of each block.**	**4 Marks**

	Ans:	**Block Diagram:** 	**2M**
		Functions: A data acquisition (DAQ) system is used for the measurement and processing of plant Signal data before it is displayed on the operator desk or permanently recorded. Block diagram of a PC (computer) based data acquisition is shown in figure. • It consists of individual transducers (sensors) for measurement of physical plant Parameters (such as temperature, pressure, flow, etc.). • After measurement, the transducer data is fed to the signal conditioning device to bring the signal level up to a sufficient value to make it useful for conversion, processing, indicating and recording. Signal conditioner is used to amplify, modify or select certain portion of signals. • The output of the signal conditioner is fed to the multiplexing (telemetry) device With the help of multiplexing all individual signal data (called lower bandwidth • Communication channels) are combined and transmitted over a higher bandwidth channel. At the receiving end, de-multiplexing recovers the original lower bandwidth channels. It scans across a number of analog signals and time-sharing them sequentially into a single analog output channel. • The multiplexed data is converted into digital signal with the help of analog-to-Digital converter. • The converted digital signals are fed to the computer for further processing, Mathematical computation, storage, etc. The final and processed data is either displayed on electronic digital display panel or recorded on magnetic media And/or chart recorders.	**2 M**
	e)	**Give Comparison of Active and Passive Filter (any four points).**	**4 Marks**
	Ans:	**Consider other relevant points.**	**1M each any four points**

Passive Filter	Active Filter
• It uses passive elements R,L& C. • Output is less than input.	• It uses R,L & C with active devices like op-amp.

		• Gain is less. • Suitable for high frequencies. No need of voltage sources. | • Gain can be adjusted. • Suitable for low frequencies. Requires voltage sources.	
	f)	**Explain how force is measured using load cell.**	**4 Marks**
	Ans:		**2M**
		Strain gauge along with elastic member combination which is used for weighing is called as load –cell. **Load** cell utilizes an elastic member as the primary transducer and strain gauge as secondary transducers. Strain gauges may be attached to any elastic member, on which there exists a suitable plane area to accommodate them. This arrangement then used to measure load applied to deform or deflect the member, to produce detectable outputs.	**2 M**
Q. 4		**Attempt any two of the following :**	**16 Marks**
	a)	**Draw and explain the working principle of ultrasonic level measurement system. Also give advantages, disadvantages and applications of it.**	**8 Marks**
	Ans:	**Diagram:**  **OR**	**2M**



Working principle:

1. It operates by generating an ultrasonic wave or pulse and measuring a time it takes for the echo to return.
2. There are two way of measurement of liquid level:
    - Doppler Type **3M**
    - Time difference type
3. The ultrasonic waves generated by transmitter and directed towards the liquid surface in the tank which is to be measure.
4. These waves get reflected from the surface of the liquid and are received by the receiver.
5. The time take by the wave is a measure of the distance travelled by the wave. Therefore the time't' between transmitting and receiving a wave is proportional to the distance 'd' between ultrasonic set and surface of the liquid in the tank.
6. As the distance 'H' between ultrasonic set and the bottom of the tank is fixed time 't' is measure of level 'l'

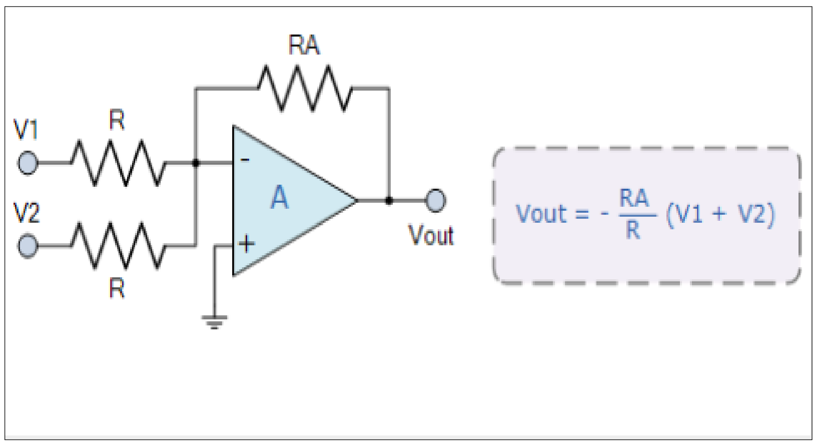
Advantages: (any two)

1. Non-contact type level measurement technique.
2. There is no moving parts.
3. The output is unaffected by changes in composition, density, electrical conductivity of process fluid. **1M**

Disadvantages: (any two)

1) Temperature compensation is essential.
2) Accuracy may get affected by the dirt, contamination, solid suspensions in process fluids.
3) Ultrasonic Transmitter is subject to many interferences so as strength of the signal may dilute. **1M**
4) Ultrasonic level measurement devices do not work satisfactorily in areas

		involving vacuum or high pressure conditions **Application:** 1. It is used in a nuclear power factory to ensure enough water to be turned into steam. 2. It can be used to control the flow rate by means of detecting level of process fluid in tank. 3. It is used to measure level of tank of height more than 50 feet.	**1M**
	b)	**Draw and explain working of adder and subtractor using op-amp.**	**8 Marks**
	Ans:	**Diagram(adder)**	**2M**

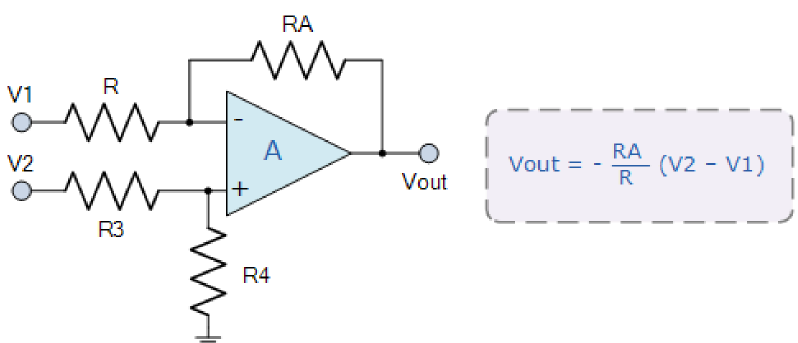


Explanation : **2M**

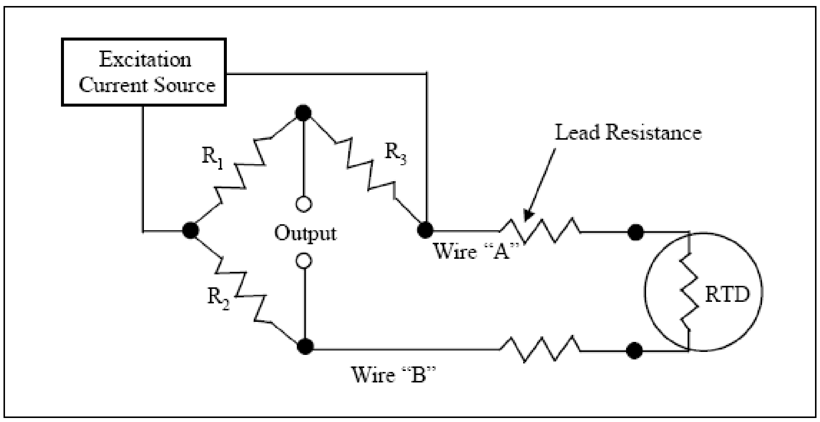
The Adder, also called a summing amplifier, produces an inverted output voltage which is proportional to the sum of the input voltages V1 and V2. More inputs can be summed. If the input resistors are equal in value (R1 = R2 = R) then the summed output voltage is as given and the gain is +1. If the input resistors are unequal then the output voltage is a weighted sum and becomes:

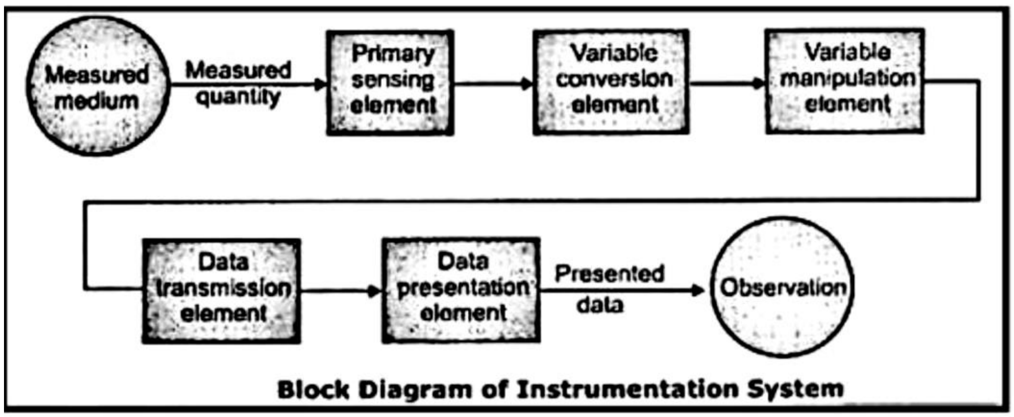
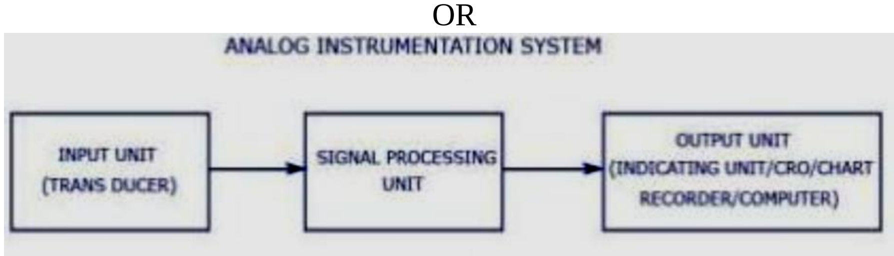
Vout= $-(V1(\frac{RA}{R1}) + V2(\frac{RA}{R2}))$

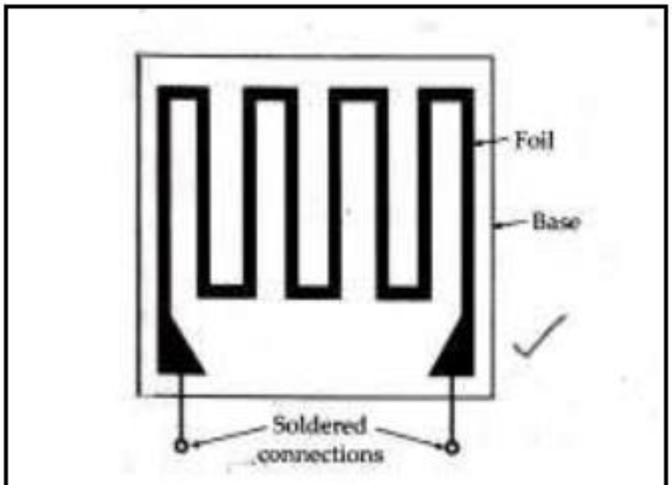
Diagram(Substractor): **2M**



Explanation :

		The Substractor also called a differential amplifier, uses both the inverting and non-inverting inputs to produce an output signal which is the difference between the two input voltages V1 and V2allowing one signal to be subtracted from another. More inputs can be added to be subtracted if required. If resistances are equal (R = R3 and RA = R4) then the output voltage is as given and the voltage gain is +1. If the input resistance are unequal the circuit becomes a differential amplifier producing a negative output when V1 is higher than V2 and a positive output when V1 is lower than V2.	**2M**
	c)	**Draw and explain temperature measurement using RTD. State its advantages and disadvantages.**	**8 Marks**
	Ans:	**Diagram:**  **Explanation:** A Resistance Thermometer or Resistance Temperature Detector is a device which used to determine the temperature by measuring the resistance of pure electrical wire. This wire is referred to as a temperature sensor. If we want to measure temperature with high accuracy, RTD is the only one solution in industries. It has good linear characteristics over a wide range of temperature. The variation of resistance of the metal with the variation of the temperature is given as, $R_t = R_0[1 + (t - t_0) + \beta(t - t_0)^2 + \cdots\cdots]$ Where, Rt and R0 are the resistance values at t°C and t_0°C temperatures. α and β are the constants depends on the metals. In this RTD, the change in resistance value is very small with respect to the temperature. So, the RTD value is measured by using a bridge circuit. By supplying the constant electric current to the bridge circuit and measuring the resulting voltage drop across the resistor, the RTD resistance can be calculated. Thereby, the temperature can be also determined. This temperature is determined by converting the RTD resistance value using a calibration expression. **Advantages : (any two)** • Linear over wide operating range • Wide temperature operating range • High temperature operating range • Good stability at high temperature	**2M** **2M** **2M**

		Disadvantages: (any two) • Low sensitivity • Affected by shock and vibration • Requires three or four-wire operation •	**2M**
Q.5	**A)**	**Attempt any two of the following :**	**16 Marks**
	a)	**Draw the generalized block diagram of instrumentation system. Explain the function of eachblock.**	**8 Marks**
	Ans:	 **Fig. Block diagram of instrumentation system**	**4M**
		Primary Sensing Element: primary sensing element of system is that which first receives energy from the measured medium and produces an output depending in some way on the value of measured quantity. Variable Conversion Element: A variable conversion element merely converts the output signal of the primary sensing element into a more suitable variable or condition useful to the function of the instruments. Variable Manipulation Element: It manipulates the signal represented by some physical variable, to perform the intended task of an instrument. In the manipulation process, the physical nature of the signal is preserved. Data Transmission Element: It transmits the data from one element to other element. Data presentation Element: It performs the translation function, such as the simple indication of a pointer moving over a scale or recording of a pen moving over a chart. OR  The Primary Element/Transducer: The input receives the quantity whose value is to be measured and is converted into its proportional incremental electrical signal such as voltage, current, resistance change, inductance or even capacitance. Thus, the changed	**4M**

		variable contains the information of the measured variable. Such a functional element or device is called a transducer. The Secondary Element/Signal Processing Unit :The output of the transducer is provided to the input of the signal processing unit. This unit amplifies the weak transducer output and is filtered and modified to a form that is acceptable by the output unit. Thus this unit may have devices like: amplifiers, filters, analog to digital converters, and so on. The Final Element/Output Unit: The output from the signal processing unit is fed to the input of the output unit. The output unit measures the signal and indicates the value to the reader. The indication may be either through: an indicating instrument, a CRO, digital computer, and so on	
	b)	**Describe construction of bounded metal foil strain gauge and explain its operation.**	**8 Marks**
	Ans:	 Figure Bonded metal foil gauge. Explanation:- Metal foil strain gauges use identical or similar materials to wire stain gauges and are used today for most general-purpose stress analysis applications and for many transducers. Foil type gauges have a much greater heat dissipation capacity as compared with wire wound strain gauges on account of their grater surface area for the same volume. For this reason, they can be used for higher operating temperature range. Also the large surface area leads to better bonding. The sensing elements of foil gauges are formed from sheets less than 0.005mm thick by photo-etching process, which allow greater flexibility with regards to shape.	**4M** **4M**
	c)	**Describe the resistive method for liquid level measurement. Write its advantages and disadvantages.**	**8 Marks**
	Ans:		**2M**

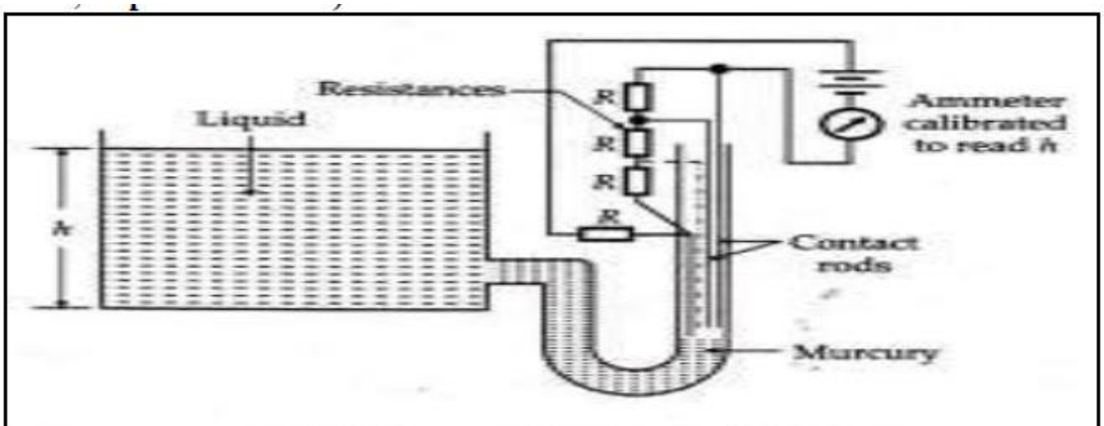


Fig. Measurement of level of liquids by resistive method.

2M

Explanation:- (02M) **2M**

This method uses mercury as a conductor. A number of conduct rods are placed at various liquid levels. As head h increases, the rising level of mercury above the datum, shorts successive resistors R and increases the value of h directly.

Advantages

1. Direct reading is possible
2. Simple
3. cost-effective measuring principle **2M**
4. Multi-point detection with one process connection

Disadvantages.

1. The liquid being measured must be conductive in nature.
2. The sensor tips deteriorate over time and can need periodic cleaning to keep them from fouling
3. Deposition of contaminate will give error in reading

Q.6	**A)**	**Attempt any four of the following :**	**16 Marks**
	a)	**Define absolute pressure and gauge pressure. State the different units for pressure measurement.**	**4 Marks**
	Ans:	Definition:	**1M each**

Definition:

Absolute pressure: Absolute pressure is defined as actual total pressure including atmospheric pressure actin On a surface.

PAbsolute= PAtmospheric + PGauge

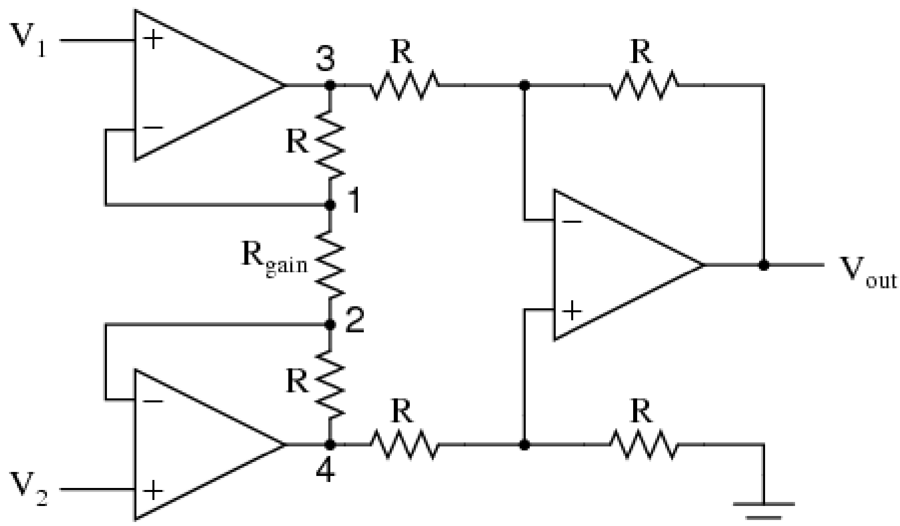
Gauge pressure:

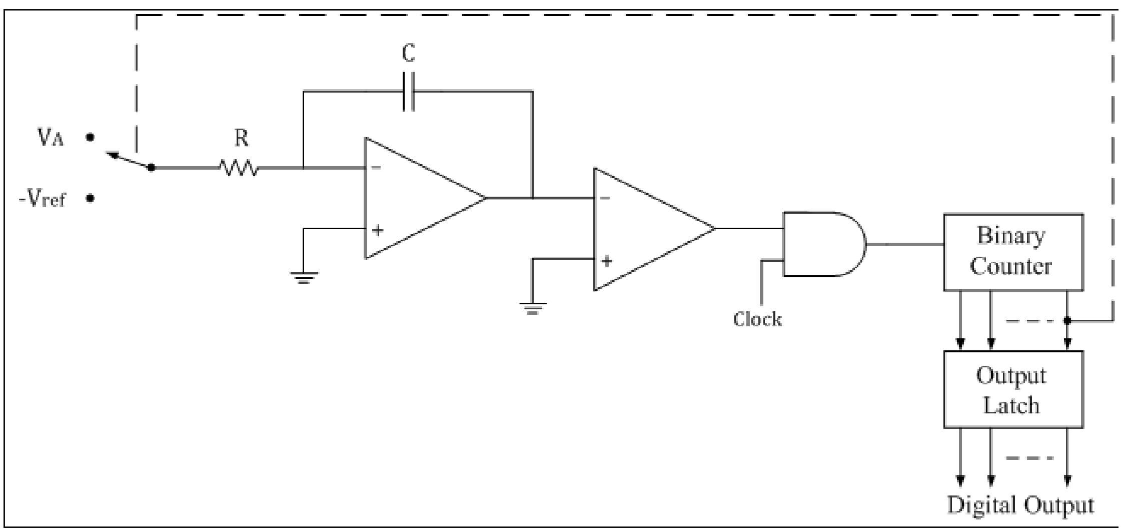
Gauge pressure is defined as the difference between absolute pressure and atmospheric pressure.

Gauge pressure= PAbsolute – Patmospheric

Units for pressure measurement.

- Pascal (Newtons per meter square) with various prefixes
- Pounds per square inch
- atmosphere (used for comparisons to sea level)
- inches of mercury (aviation, altimeter setting)

		• mm of mercury column (blood pressure) • inches of water • Barmillibar (weather) • Torr	
	b)	**Explain the need of cold junction compensation.**	**4 Marks**
	Ans:	Cold junction Compensation Thermocouples require some form of temperature reference to compensate for the cold junctions. The most common method is to measure the temperature at the reference junction with a direct-reading temperature sensor. This process is called cold-junction compensation (CJC). Because the purpose of CJC is to compensate for the known temperature of the cold junction, another less-common method is forcing the junction from the thermocouple metal to copper metal to a known temperature, such as 0 ºC, by submersing the junction in an ice-bath, and then connecting the copper wire from each junction to a voltage measurement device.	**4M**
	c)	**Draw and explain instrumentation amplifier using 3 op amps.**	**4 Marks**
	Ans:	Explanation:- It is beneficial to be able to adjust the gain of the amplifier circuit without having to change more than one resistor value, as is necessary with the previous design of differential amplifier. The so-called instrumentation builds on the last version of differential amplifier to give us that capability: Diagram:-  Figure:- Instrumentation amplifier This intimidating circuit is constructed from a buffered differential amplifier stage with three new resistors linking thetwo buffer circuits together. Consider all resistors to be of equal value except for Rgain. The negative feedback of theupper-left op-amp causes the voltage at point 1 (top of Rgain) to be equal to V1. Likewise, the voltage at point 2 (bottomof Rgain) is held to a value equal to V2. This establishes a voltage drop across Rgain equal to the voltage differencebetween V1 and V2. That voltage drop causes a current through Rgain, and since the feedback loops of the two input op amps draw no	**2M** **2M**

		current, that same amount of current through Rgain must be going through the two "R" resistors above andbelow it. This produces a voltage drop between points 3 and 4 equal to: $V_{3\text{-}4} = (V_2 - V_1)(1 + \frac{2R}{R_{gain}})$ The regular differential amplifier on the right-hand side of the circuit then takes this voltage drop between points 3 and4, and amplifies it by a gain of 1 (assuming again that all "R" resistors are of equal value). Though this looks like acumbersome way to build a differential amplifier, it has the distinct advantages of possessing extremely high inputimpedances on the V1 and V2 inputs (because they connect straight into the non-inverting inputs of their respective opamps),and adjustable gain that can be set by a single resistor. Manipulating the above formula a bit, we have a general expression for overall voltage gain in the instrumentation amplifier: $A_V = (1 + \frac{2R}{R_{gain}})$ Though it may not be obvious by looking at the schematic, we can change the differential gain of the instrumentationamplifier simply by changing the value of one resistor: Rgain. Yes, we could still change the overall gain by changingthe values of some of the other resistors, but this would necessitate balanced resistor value changes for the circuit toremain symmetrical. Please note that the lowest gain possible with the above circuit is obtained with Rgain completelyopen (infinite resistance), and that gain value is 1.	
	d)	**With neat diagram explain working of Dual slope integrator ADC.**	**4 Marks**
	Ans:	 Dual slope Integration A/D converter In this ADC, an unknown analog voltage and a known reference voltage are converted into equivalent time periods using an integrator, These time periods are measured by the counter. This circuit is called dual slope ADC because the analog voltage and reference voltage are converted to ramp signals of different slopes by the integrator. **OR**	**2M** **2M**

Operation:

The binary counter is initially reset to 0000; the output of integrator reset to 0V and the input to the ramp generator or integrator is switched to the unknown analog input voltage VA.

The analog input voltage VA is integrated by the inverting integrator and generates a negative ramp output. The output of comparator is positive and the clock is passed through the AND gate. This results in counting up of the binary counter.

The negative ramp continues for a fixed time period t1, which is determined by a count detector for the time period t1. At the end of the fixed time period t1, the ramp output of integrator is given by

$\therefore VS=-VA/RC\times t1$

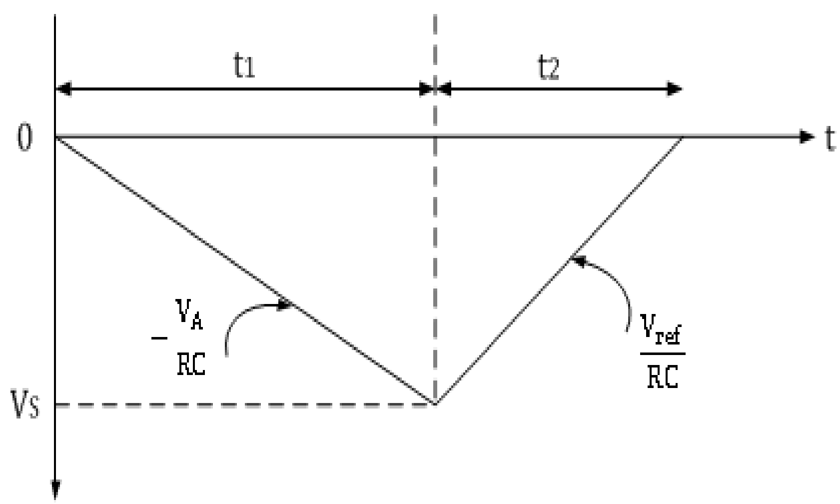
When the counter reaches the fixed count at time period t1, the binary counter resets to 0000 and switches the integrator input to a negative reference voltage –Vref.

Now the ramp generator starts with the initial value –Vs and increases in positive direction until it reaches 0V and the counter gets advanced. When Vs reaches 0V, comparator output becomes negative (i.e. logic 0) and the AND gate is deactivated. Hence no further clock is applied through AND gate. Now, the conversion cycle is said to be completed and the positive ramp voltage is given by

$\therefore VS=Vref/RC\times t2$

Where Vref & RC are constants and time period t2 is variable.

The dual ramp output waveform is shown below.



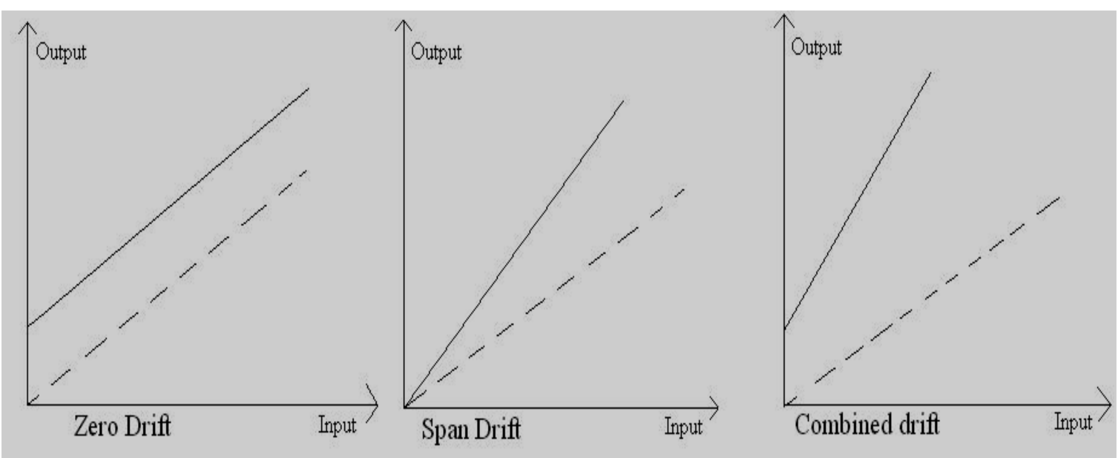
Since ramp generator voltage starts at 0V, decreasing down to –Vs and then increasing up to 0V, the amplitude of negative and positive ramp voltages can be equated as follows.

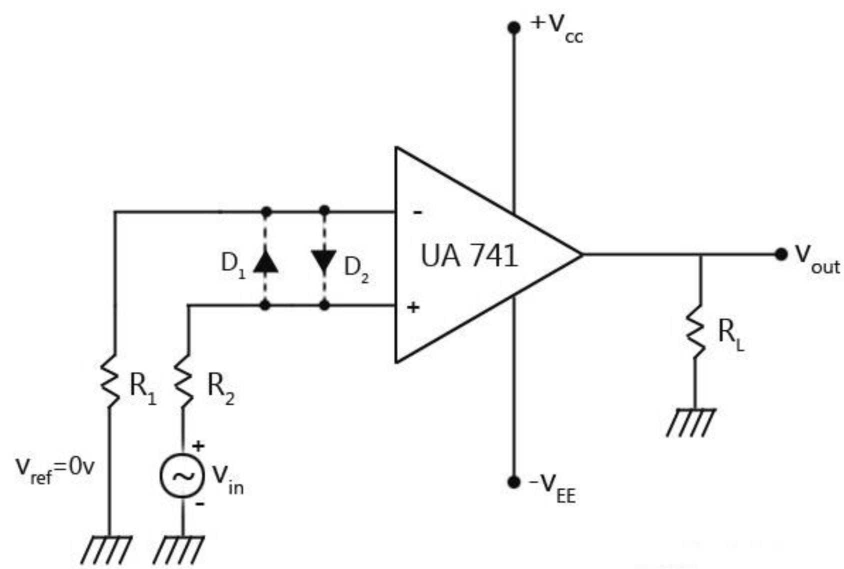
$\therefore Vref/RC\times t2=-VA/RC\times t1$

$\therefore t2=-t1\times VA/Vref$

$\therefore VA=-Vref\times t1/t2$

Thus the unknown analog input voltage VA is proportional to the time period t2, because Vref is a known reference voltage and t1 is the predetermined time period.

		The actual conversion of analog voltage VA into a digital count occurs during time t2. The binary counter gives corresponding digital value for time period t2. The clock is connected to the counter at the beginning of t2 and is disconnected at the end of t2. Thus the counter counts digital output as Digital output=(counts/sec) t2 ∴Digital output=(counts/sec)[t1×VA/Vref] For example, consider the clock frequency is 1 MHz, the reference voltage is -1V, the fixed time period t1 is 1ms and the RC time constant is also 1 ms. Assuming the unknown analog input voltage amplitude as VA = 5V, during the fixed time period t1 , the integrator output Vs is ∴VS=-VA/RC×t1=(-5)/1ms×1ms=-5V During the time period t2, ramp generator will integrate all the way back to 0V. ∴t2=VS/Vref ×RC=(-5)/(-1)×1ms=5ms=5000μs Hence the 4-bit counter value is 5000, and by activating the decimal point of MSD seven segment displays, the display can directly read as 5V.	
	e)	**Define :** **i) Hysteresis** **ii) Drift**	**4 Marks**
	Ans:	**i. Hysteresis:** Hysteresis is due to magnetic effects of the metals. It gives the relation between field current and the output voltage. The magnetization of ferromagnetic substances due to a varying magnetic field lags behind the field. This effect is called hysteresis, and the term is used to describe any system in whose response depends not only on its current state, but also upon its past history. **ii. Drift:**The gradual shift in the indication or record of the instrument over an extended period of time, during which the true value of the variable does not change is referred to as drift.  Fig. Types of Drift	**2M**

	f)	Draw the diagram of zero crossing detector using op-amp and explain its working.	**4 Marks**
	Ans:	Zero Crossing Detector Using UA 741 op-amp IC 	**2M**
		The zero crossing detector circuit is an important application of the op-amp comparator circuit. It can also be called as the sine to square wave converter. Anyone of the inverting or non-inverting comparators can be used as a zero-crossing detector. The reference voltage with which the input voltage is to be compared, must be made zero (Vref = 0V). An input sine wave is given as Vin. These are shown in the circuit diagram and input and output waveforms of an inverting comparator with a 0V reference voltage. As shown in the waveform, for a reference voltage 0V, when the input sine wave passes through zero and goes in positive direction, the output voltage Vout is driven into negative saturation. Similarly, when the input voltage passes through zero and goes in the negative direction, the output voltage is driven to positive saturation. The diodes D1 and D2 are also called clamp diodes. They are used to protect the op-amp from damage due to increase in input voltage. They clamp the differential input voltages to either +0.7V or -0.7V. In certain applications, the input voltage may be a low frequency waveform. This means that the waveform only changes slowly. This causes a delay in time for the input voltage to cross the zero-level. This causes further delay for the output voltage to switch between the upper and lower saturation levels. At the same time, the input noises in the op-amp may cause the output voltage to switch between the saturation levels. Thus zero crossing are detected for noise voltages in addition to the input voltage. These difficulties can be removed by using a regenerative feedback circuit with a positive feedback that causes	**2M** **(brief explanation)**

		the output voltage to change faster thereby eliminating the possibility of any false zero crossing due to noise voltages at the op-amp input.