University of Mumbai

Program: **Electronics Engineering**
Curriculum Scheme: **Rev2016**
Examination: **BE** Semester **VII**
Course Code: **ELX701** and Course Name**: Instrumentation System Design**

Time: 2 hours 30 minutes   Max. Marks: 80

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Q1. Choose the correct option for following questions. All the Questions are compulsory and carry equal marks

Question Number	**Correct Option (Enter either 'A' or 'B' or 'C' or 'D')**
Q1.	B
Q2.	A
Q3.	C
Q4	C
Q5	D
Q6	B
Q7	D
Q8.	D
Q9.	C
Q10.	C

Q2(20 Marks Each)	**Solve any Four out of Six** **5 marks each** ***Please delete the instruction shown in front of every sub question***
A	Distinguish between installed and inherent flow characteristics.
B	Draw circuit diagram of a basic RC band-pass filter. Sketch its frequency response clearly showing the expressions for cut-off frequencies.
C	Describe any two discontinuous controller modes.
D	What are two PLC operation modes? Describe both modes in brief.
E	List any five SAMA symbols. Draw clear symbol with brief description.
F	Write a short note on SCADA.

A. Difference between installed and inherent characteristics:

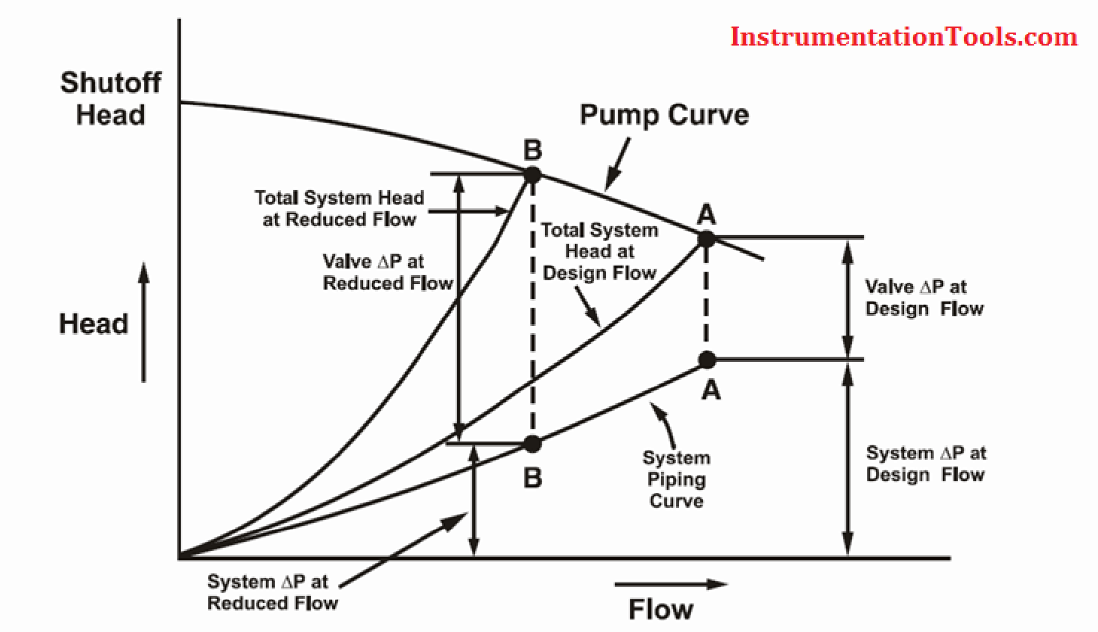
(Explanation = 03 Marks, Diagrams = 02 Marks)

The inherent flow characteristics do not reflect the actual performance of the valve as installed. The ideal condition of constant valve pressure drop (ΔP) is unlikely to be true and the 'operating' characteristics will have deviation from the inherent characteristics and is termed the "Installed Flow Characteristics".

The deviation in the characteristics depends on the pressure drop variation across the control valve, as the control valve operates from minimum flow at its initial travel position to its maximum flow at its fully opened position.

The variations in pressure drop across the valve can be attributed to two basic causes:

The pump characteristic which results in an increase in pump head as the flow is reduced; and The reduction in line losses as the flow is reduced, causing more and more of the pump head to appear across the valve.
Control Valve DP Curve



In a pipeline carrying fluid, the dynamic system pressure (Ps) is made up of two components:

1) the pressure drop across the control valve (Pv) and 2) the pressure drop along the pipeline (PL), excluding any fixed static or elevation pressure head component. It is given by:

PS = Pv + PL

In the pump curve above, the point “A” is the point where the system resistance curve crosses the pump characteristic curve and indicates the operating conditions (flow and head). As the valve modulates to the closed position; the resistance to the system flow that the valve provides (valve pressure drop) will increase by shifting from point “A” towards point “B”. This increasing resistance will use more of the head in the system, as well as decrease system flow.

Pressure drop across the control valve increases ($\Delta Pv - \uparrow$). The change in pressure drop across the valve can be attributed to two basic causes:

1) the pump characteristic, which results in an increase in pump head as the flow is reduced, and

2) the reduction in line losses as the flow is reduced, causing more and more of the pump head to appear across the valve. The amount that the pump head will increase with a decrease in system flow will depend upon the operating characteristics of the pump. A pump with a steep characteristic will produce a considerable increase in pressure head as the system resistance is increased. However, a flat characteristic pump will produce a relatively constant, high pressure head for any system flow. The relatively constant pressure would be preferable from a control standpoint.

Pressure loss in the pipeline reduces (ΔPL – ↓). This is because the decrease in system flow will result in a decrease in pressure drop along the pipeline and is proportional to the square root of the flow rate.

This indicates that the pressure drop across the valve in the system is not constant and it varies with flow and other changes in the system. This has a significant impact on the actual installed valve flow characteristic. The deviation from the inherent flow characteristic is a function of a property called Valve Authority. It is defined as the ratio of the full flow valve pressure drop to the system pressure drop (including the valve)

Control Valve Equation

N = Valve Authority

ΔPv = Pressure drop across the control valve

ΔPL = Pressure drop due to pipeline friction losses

ΔPS = System pressure drop = $\Delta Pv + \Delta PL$

When "N" approaches 1.0, then ΔPL is almost zero and ΔPv approaches ΔPs. This satisfies the requirement for the definition of valve inherent characteristics.

Distortion occurs when "N" falls from 1.0. This is the situation when the pipeline system pressure drop (ΔPs) is not concentrated at the control valve alone but well distributed along the pipeline. An inherently equal % characteristics control valve operating under such condition will behave like a linear valve and an inherently linear characteristics control valve will behave like a quick-opening control valve.

The effect of these system variables can be minimized by keeping the relative change in valve pressure drop as small as possible.

When the total flow is low, control valve pressure drop tends to be large fraction of the total system pressure loss; but at high flows this may not be true. A good design will respond well over the full range of conditions, hence it is important to pick the right characteristic for your system and size the valve for the right amount of pressure drop.

For good control, it is nice to take a fairly large pressure drop across a control valve. This way it will have a big influence on the total system, making the operators and control engineers happy. However, design engineers will worry that increasing pressure drop will tend to increase pumping and other operating costs. Compromise is necessary.

As a rule of thumb, design the system and size the valve so that 25 to 33% (1/3rd) of the total system pressure drop (including the valve) is taken across the control valve, with a minimum of 10-15 psig.

B. Draw circuit diagram of a basic RC band-pass filter. Sketch its frequency response clearly showing the expressions for cut-off frequencies.

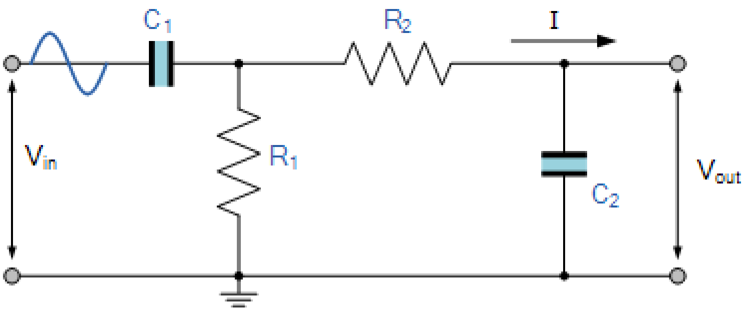
(Explanation = 03 Marks, Diagrams = 02 Marks)

Band Pass Filters can be used to isolate or filter out certain frequencies that lie within a particular band or range of frequencies. The cut-off frequency or ƒc point in a simple RC passive filter can be accurately controlled using just a single resistor in series with a non-polarized capacitor, and depending upon which way around they are connected, we have seen that either a Low Pass or a High Pass filter is obtained.

One simple use for these types of passive filters is in audio amplifier applications or circuits such as in loudspeaker crossover filters or pre-amplifier tone controls. Sometimes it is necessary to only pass a certain range of frequencies that do not begin at 0Hz, (DC) or end at some upper high frequency point but are within a certain range or band of frequencies, either narrow or wide.

By connecting or "cascading" together a single Low Pass Filter circuit with a High Pass Filter circuit, we can produce another type of passive RC filter that passes a selected range or "band" of frequencies that can be either narrow or wide while attenuating all those outside of this range. This new type of passive filter arrangement produces a frequency selective filter known commonly as a Band Pass Filter or BPF for short.

Band Pass Filter Circuit



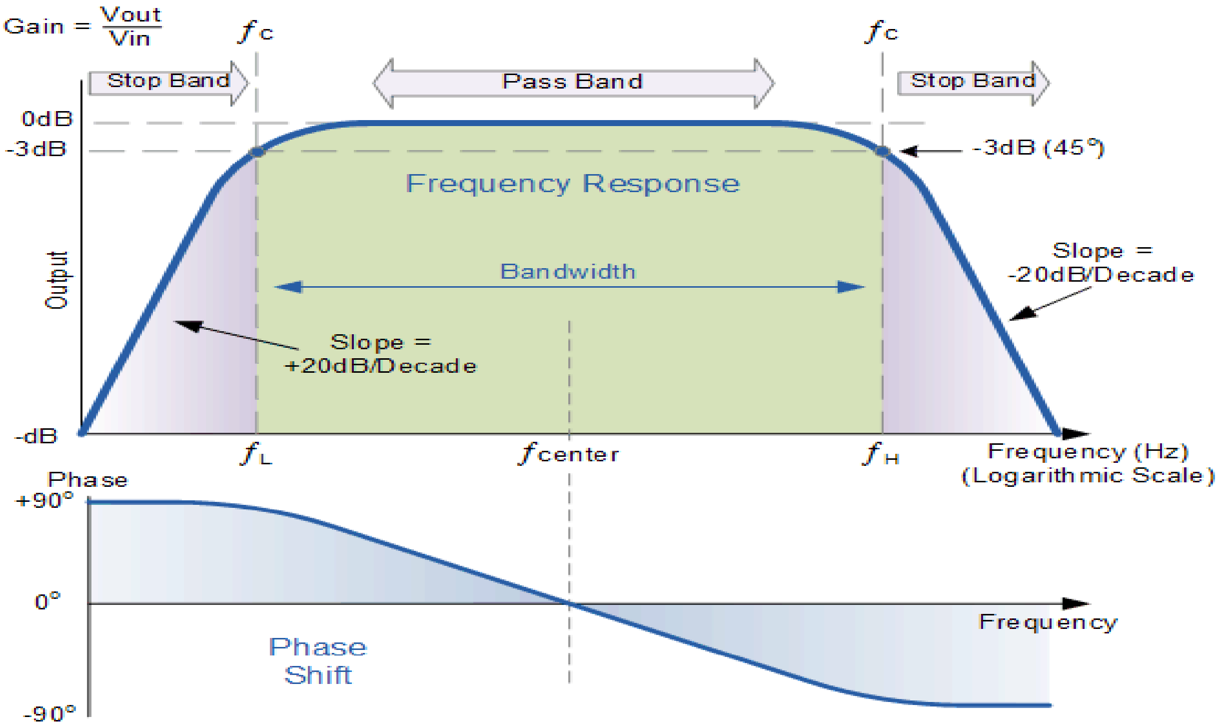
Unlike the low pass filter which only pass signals of a low frequency range or the high pass filter which pass signals of a higher frequency range, a Band Pass Filters passes signals within a certain "band" or "spread" of frequencies without distorting the input signal or introducing extra noise. This band of frequencies can be any width and is commonly known as the filters Bandwidth.

Bandwidth is commonly defined as the frequency range that exists between two specified frequency cut-off points (ƒc), that are 3dB below the maximum centre or resonant peak while attenuating or weakening the others outside of these two points.

Then for widely spread frequencies, we can simply define the term "bandwidth", BW as being the difference between the lower cut-off frequency (ƒcLOWER) and the higher cut-off frequency (ƒcHIGHER) points. In other words, BW = ƒH – ƒL. Clearly for a pass band filter to function correctly, the cut-off frequency of the low pass filter must be higher than the cut-off frequency for the high pass filter.

The “ideal” Band Pass Filter can also be used to isolate or filter out certain frequencies that lie within a particular band of frequencies, for example, noise cancellation. Band pass filters are known generally as second-order filters, (two-pole) because they have “two” reactive component, the capacitors, within their circuit design. One capacitor in the low pass circuit and another capacitor in the high pass circuit.

Frequency Response of a 2nd Order Band Pass Filter



band pass filter bode plot

The Bode Plot or frequency response curve above shows the characteristics of the band pass filter. Here the signal is attenuated at low frequencies with the output increasing at a slope of +20dB/Decade (6dB/Octave) until the frequency reaches the “lower cut-off” point ƒL. At this frequency the output voltage is again 1/√2 = 70.7% of the input signal value or -3dB (20*log(VOUT/VIN)) of the input.

The output continues at maximum gain until it reaches the “upper cut-off” point ƒH where the output decreases at a rate of -20dB/Decade (6dB/Octave) attenuating any high frequency signals. The point of maximum output gain is generally the geometric mean of the two -3dB value between the lower and upper cut-off points and is called the “Centre Frequency” or “Resonant Peak” value ƒr. This geometric mean value is calculated as being ƒr 2 = ƒ(UPPER) x ƒ(LOWER).

A band pass filter is regarded as a second-order (two-pole) type filter because it has “two” reactive components within its circuit structure, then the phase angle will be twice that of the previously seen first-order filters, ie, 180o. The phase angle of the output signal LEADS that of the input by +90o up to the centre or resonant frequency, ƒr point were it becomes “zero” degrees (0o) or “in-phase” and then changes to LAG the input by -90o as the output frequency increases.

The upper and lower cut-off frequency points for a band pass filter can be found using the same formula as that for both the low and high pass filters, For example.

cut-off frequency equation

$$fc = \frac{1}{2\pi RC} Hz$$

C. Describe any two discontinuous controller modes.

(Explanation = 03 Marks, Diagrams = 02 Marks)

1. **Two position (ON/OFF) Mode**

The most elementary controller mode is the two-position or ON/OFF controller mode. It is the simplest, cheapest, and suffices when its disadvantages are tolerable. The most general form can be given by:

$$P = 0\ \%\ ep < 0$$
$$100\ \%\ ep > 0$$

The relation shows that when the measured value is less than the setpoint (i.e. ep > 0), the controller output will be full (i.e. 100%), and when the measured value is more than the setpoint (i.e. ep < 0), the controller output will be zero (i.e. 0%).

Neutral Zone : In practical implementation of the two-position controller, there is an overlap as ep increases through zero or decreases through zero. In this span, no change in the controller output occurs which is illustrated in Fig. 1

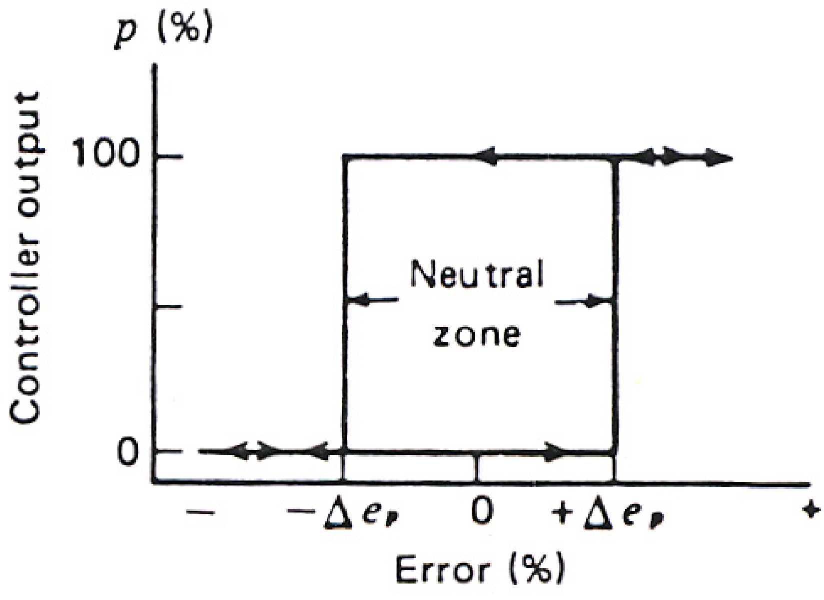


Fig. 1 Two-position controller action with neutral zone.

It can be observed that, until an increasing error changes by Δep above zero, the controller output will not change state. In decreasing, it must fall Δep below zero before the controller changes to 0%. The range 2Δep is referred to as neutral zone or differential gap.

Two-position controllers are purposely designed with neutral zone to prevent excessive cycling. The existence of such a neutral zone is an example of desirable hysteresis in a system.

2. **Multiposition Mode**

   It is the logical extension of two-position control mode to provide several intermediate settings of the controller output. This discontinuous control mode is used in an attempt to reduce the cycling behaviour and overshoot and undershoot inherent in the two-position mode. This control mode can be preferred whenever the performance of two-position control mode is not satisfactory. The general form of multiposition mode is represented by

$$p = p_i \quad e_p > e_i \quad i = 1, 2, \ldots, n$$

As the error exceeds certain set limits $\pm e_i$, the controller output is adjusted to present values p_i.

Three-position Control Mode: One of the best example for multiposition control mode is three position control mode, which can be expressed in the following analytical form:

$$P = 100\% \quad e_p > +e_1$$
$$= 50\% \quad -e_1 < e_p < +e_1$$
$$= 0\% \quad e_p < -e_1$$

As long as the error is between $+e_1$ and $-e_1$ of the setpoint, the controller stays at some nominal setting indicated by a controller output of 50%. If the error exceeds the set point by $+e_1$ or more, then the output is increased to 100%. If it is less than the setpoint by $-e_1$ or more, the controller output is reduced to zero. Figure 2, illustrates three-position mode graphically.

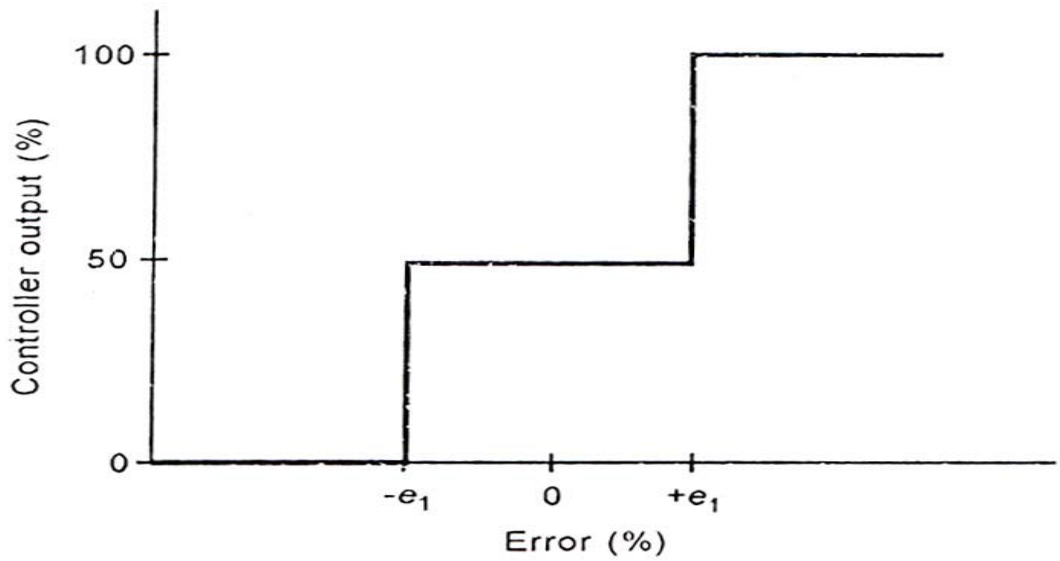


Fig. 2. Three-position controller action

The three-position control mode usually requires a more complicated final control element, because it must have more than two settings. Fig. 2. shows the relationship between the error and controller output for a three-position control. The finite time required for final control element to change from one position to another is also shown. The graph shows the overshoot and undershoots of error around the upper and lower setpoints. This is due to both the process lag time and controller lag time, indicated by the finite time required for control element to reach new setting.

Fig.

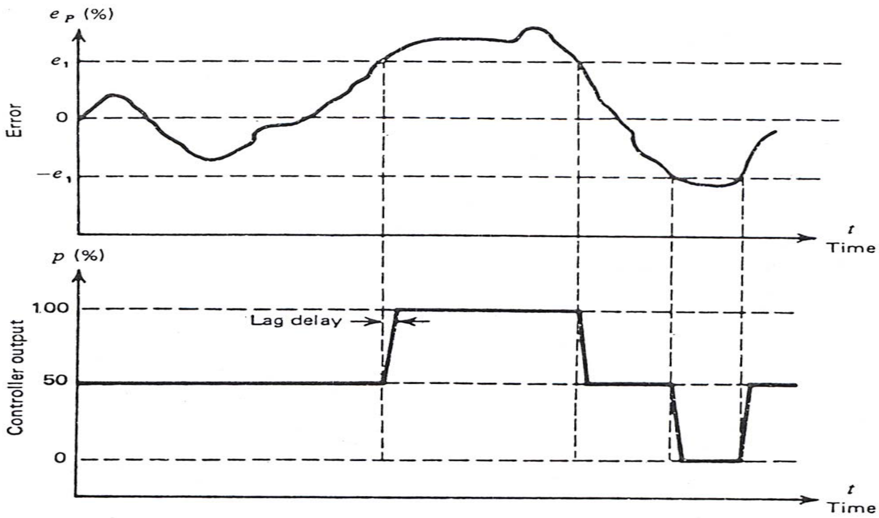


Fig. 3. Relationship between error and three-position controller action, including the effects of lag.

D. What are two PLC operation modes? Describe the modes in brief.

(Explanation = 05 Marks)

There are two modes of operation for the PLC processors first one is the program mode and the next type is the different variations of RUN mode, the numbers of modes in PLC would change according to the manufacturers.

PROGRAM MODE

In this mode, new programs are entered, and this mode is also used to edit or update the program and is also used to upload or download files, document programs. If the PLC is in this mode all the PLC outputs are forced off and the ladder I/O sequence is halted.

RUN MODE

This mode in the PLC is used to RUN the user program, so while doing this the input devices are monitored, and also the energy devices are energized as per the requirement. The processor will put into the RUN mode after entering all the instructions into the PLC program.

Test mode

This mode is used after editing or creating a program to test the PLC program before the program is used for real applications like industrial automation etc. In this mode, the new program is tested with the inputs without energizing any output. We can include many types of test mode in a single-step test mode, which directs the processor to execute a single rung or a group of rungs. There is a mode called single scan test mode, which can execute a single processor operating scan or cycle. The other test mode is continuous scan test mode which would direct the process to run the program continuously in order to do the troubleshooting.

Remote mode

The remote mode will be very useful to control the PLC remotely, so by using this mode, we can select the program run mode by using a computer connected to the PLC. This mode will be very useful if the controller is not inaccessible locations.

Monitor mode

In this mode, the CPU will be running and the I/O will be processed in the same way as in the RUN mode, and also the CPU operation status can be monitored. The bits can be force-set or reset, the set values and present values of the timer and the counter instructions can be modified. The present values of the word data can be modified. This mode is usually used for the adjustments in the system during the trial operation.

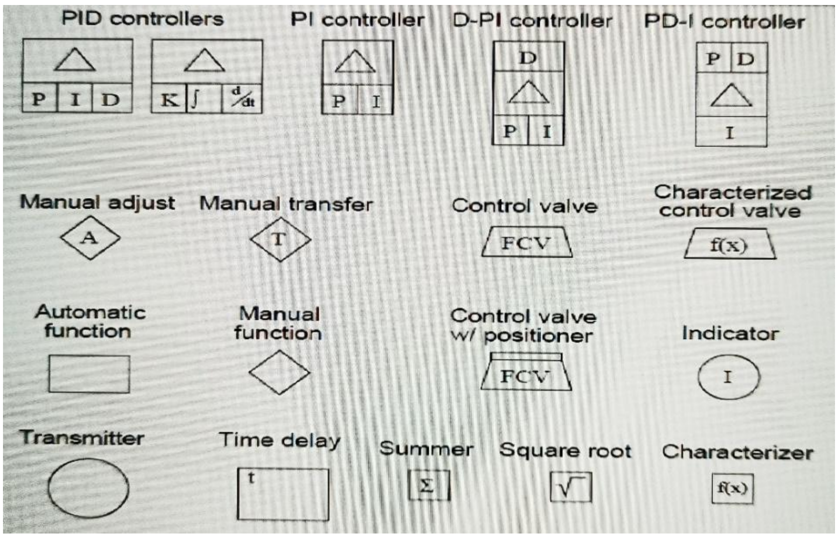
The operating modes would describe the CPU behavior at a particular point in time. It is very useful to know the CPU operating mode during the startup of the program, controller testing, and also for troubleshooting.

If the CPU is in stop mode then it would check that module that is set by default addressing exists or not and it would send the I/O's to the predefined initial status. In the stop mode, the user program won't be executed.

In the start-up mode, a distinction is made between the start-up types like the warm restart, hot restart, and cold restart. During the RUN mode, the CPU will execute the user program and it would update the inputs and outputs, Error messages, and service interrupts. In the HOLD mode, the program processing is stopped and we can check the user program. If the CPU is not ready for operation, then it could be due to a power supply problem or it could be because of a fault in the CPU.

E. List any five SAMA symbols. Draw clear symbol with brief description.

(Explanation of each symbol =01 mark each)



Explain any five symbols out of the above enlisted.

F. Write a short note on SCADA.

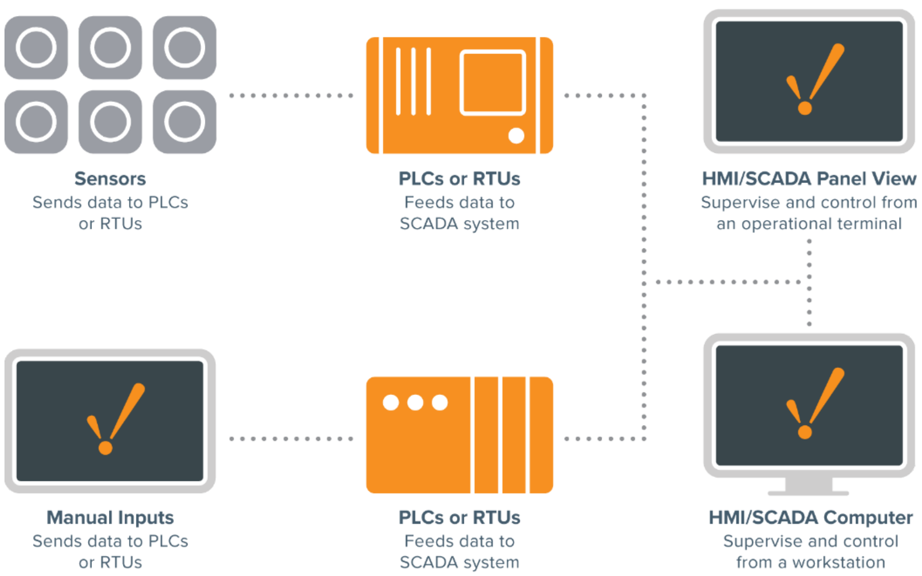
(Explanation = 03 Marks, Diagram = 02 Marks)

Supervisory control and data acquisition (SCADA) is a system of software and hardware elements that allows industrial organizations to:

- Control industrial processes locally or at remote locations
- Monitor, gather, and process real-time data
- Directly interact with devices such as sensors, valves, pumps, motors, and more through human-machine interface (HMI) software
- Record events into a log file

SCADA systems are crucial for industrial organizations since they help to maintain efficiency, process data for smarter decisions, and communicate system issues to help mitigate downtime.

The basic SCADA architecture begins with programmable logic controllers (PLCs) or remote terminal units (RTUs). PLCs and RTUs are microcomputers that communicate with an array of objects such as factory machines, HMIs, sensors, and end devices, and then route the information from those objects to computers with SCADA software. The SCADA software processes, distributes, and displays the data, helping operators and other employees analyze the data and make important decisions.



Modern SCADA Systems

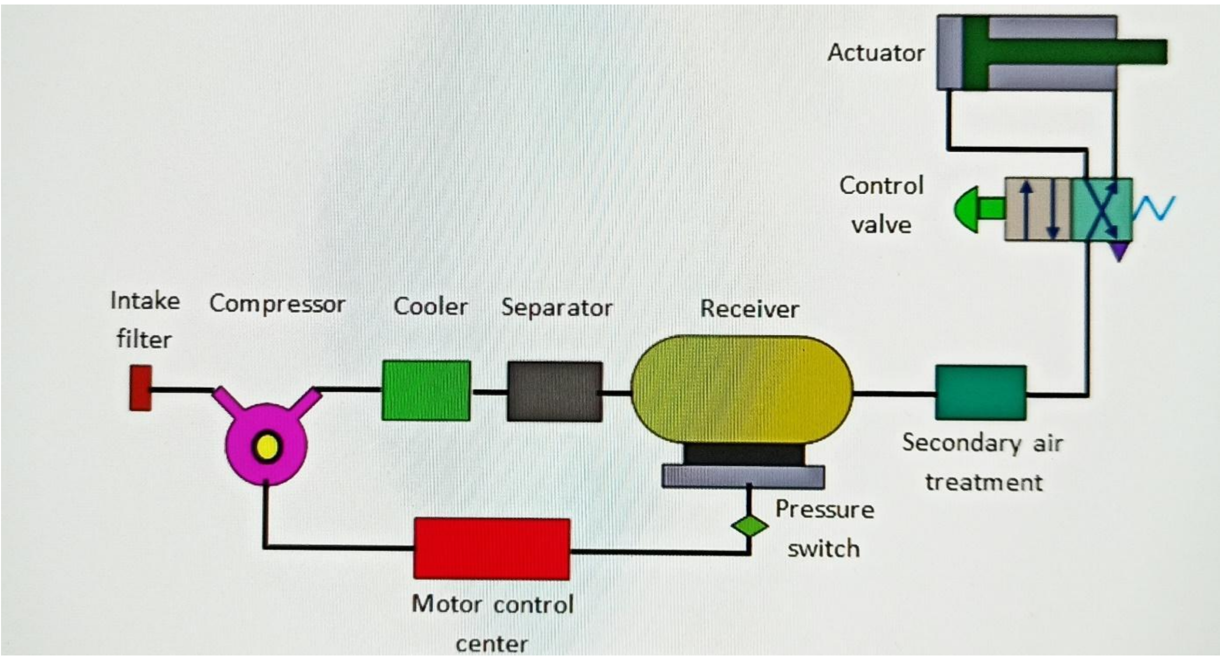
Modern SCADA systems allow real-time data from the plant floor to be accessed from anywhere in the world. This access to real-time information allows governments, businesses, and individuals to make data-driven decisions about how to improve their processes. Without

SCADA software, it would be extremely difficult if not impossible to gather sufficient data for consistently well-informed decisions.
Also, most modern SCADA designer applications have rapid application development (RAD) capabilities that allow users to design applications relatively easily, even if they don't have extensive knowledge of software development.
The introduction of modern IT standards and practices such as SQL and web-based applications into SCADA software has greatly improved the efficiency, security, productivity, and reliability of SCADA systems.
SCADA software that utilizes the power of SQL databases provides huge advantages over antiquated SCADA software. One big advantage of using SQL databases with a SCADA system is that it makes it easier to integrate into existing MES and ERP systems, allowing data to flow seamlessly through an entire organization.
Historical data from a SCADA system can also be logged in a SQL database, which allows for easier data analysis through data trending.

Q3 (20 Marks Each)	**Solve any Two Questions out of Three** **10 marks each**
A	Draw the basic pneumatic system and describe its components.
B	What are the criteria for selecting controller mode for a given process? Describe the ratio controller with clearly specifying the types of processes for which it is used.
C	Draw and explain cascade control. Discuss about the advantages of cascade control.

A. Draw the basic pneumatic system and describe its components.

(Explanation = 06 Marks, Diagram = 04 Marks)



the common parts of a pneumatic system:

Check Valves. These are one-way valves that are installed to the hose, which connects the compressor to the buffer tank. They let the compressed air gather in the buffer tanks, but prevent backflow into the compressor tank.

Compressor. It is a mechanical device that increases the pressure of air by reducing its volume. This is a pump powered by gas or electricity. It compresses the air to a higher PSI (pounds per square inch). Compressors have a tank connected to store the air before it's released into the pneumatic track. An air compressor is a specific type of gas compressor.

Regulators and gauges. These are equipment that is connected to the compressor or compressor tank. To release air into the pneumatic track, the regulator is electrically or mechanically triggered. Gauges are also electric or mechanic measuring instruments. They let the computer system or operator to regulate and check the PSI of the air inside the compressor.

Accumulator or buffer tank. Buffer tanks are secondary storage units for the compressed air that came from the compressor. They are storing the high-PSI compressed air for the pneumatic actuators. These tanks help in preventing irregular airflow surges in the actuators, allowing the compressor cycle to maximise its shutoff timing. They also allow the compressor to be in the exact distance from the actuators in projects.

Feed lines. These are hoses that move the pressurised air through the pneumatic system. The largest diameter hoses are installed to handle the PSI. These large hoses allow the pressurised air to travel faster, eliminating the airflow backups.

Actuators. These are the components of the pneumatic system that do the hard work. Many types of actuators are powered by pressurised air. The most frequently used are cylinder and plunge. The pressurised air is released into the cylinder to make a piston move forward as the air is forced to the chamber.

These are some of the main components of a pneumatic system. To fully understand the system, you need to know how every component works. Knowing their specific functions will help in preventing problems during work.

B. Explain process reaction curve and Ziegler Nichols methods in brief.

(Each method explanation with suitable diagrams = 05 Marks each)

1. Reaction Curve Technique (Process reaction method)

- This is basically an open loop technique of tuning.
- Here the process is assumed to be a stable first order system with time delay.
- The closed loop system is broken as shown in Fig.2; a step input is applies at , output is measured at *b*.
- In fact, a bias input may be necessary so that the plant output initially becomes close to the nominal value.
- The step input is superimposed on this bias value.

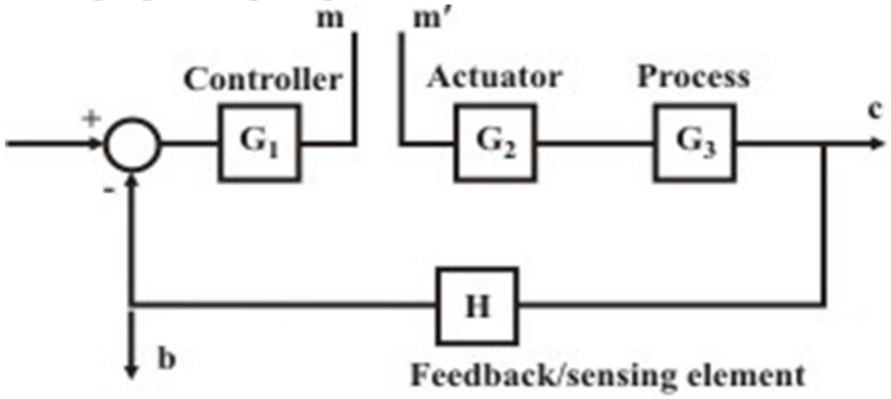


Fig. 2 Reaction curve technique for controller tuning.

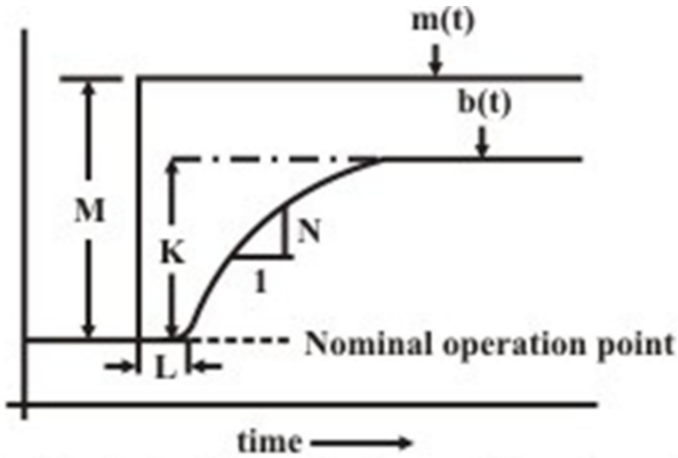


Fig. 3 Input and output plots under the condition shown in Fig. 1.

M,L and K are measured. Let us define the following terms corresponding to Fig. 2:

Slope = N,
Time Constant T=K/N
Lag Ratio R=L/T
Then, the recommended optimum settings, for P, P-I and P-I-D controller are as follows:

Optimum settings

P-Control: $$K_p = \frac{M}{NL}(1+\frac{R}{3})$$

P-I Control: $$K_p = \frac{M}{NL}(\frac{9}{10}+\frac{R}{12}); \qquad \tau_i = L\left(\frac{30+3R}{9+20R}\right)$$

P-I-D Control: $$K_p = \frac{M}{NL}(\frac{4}{3}+\frac{R}{4}); \qquad \tau_i = L\left(\frac{32+6R}{13+8R}\right)$$

$$\tau_d = L\left(\frac{4}{11+2R}\right)$$

Zeigler-Nichols method:

Zeigler-Nichols proposed closed-loop methods for tuning the PID controller. Those are the continuous cycling method and damped oscillation method. Procedures for both methods are the same but oscillation behavior is different. In this, first, we have to set the p-controller constant, Kp to a particular value while Ki and Kd values are zero. Proportional gain is increased till the system oscillates at a constant amplitude.

Gain at which system produces constant oscillations is called ultimate gain (Ku) and the period of oscillations is called the ultimate period (Pc). Once it is reached, we can enter the values of P, I, and D in the PID controller by Zeigler-Nichols table depends on the controller used like P, PI or PID, as shown below.

Type of Controller	K_p	T_i	T_d
P	$0.5\ K_{cr}$	∞	0
PI	$0.45\ K_{cr}$	$1/1.2\ P_{cr}$	0
PID	$0.6\ K_{cr}$	$0.5\ P_{cr}$	$0.125\ P_{cr}$

C. Draw and explain cascade control. Discuss about the advantages of cascade control.

(Explanation = 05 Marks, Diagrams = 05 Marks)

Consider the heat exchange process shown in Fig. 1.

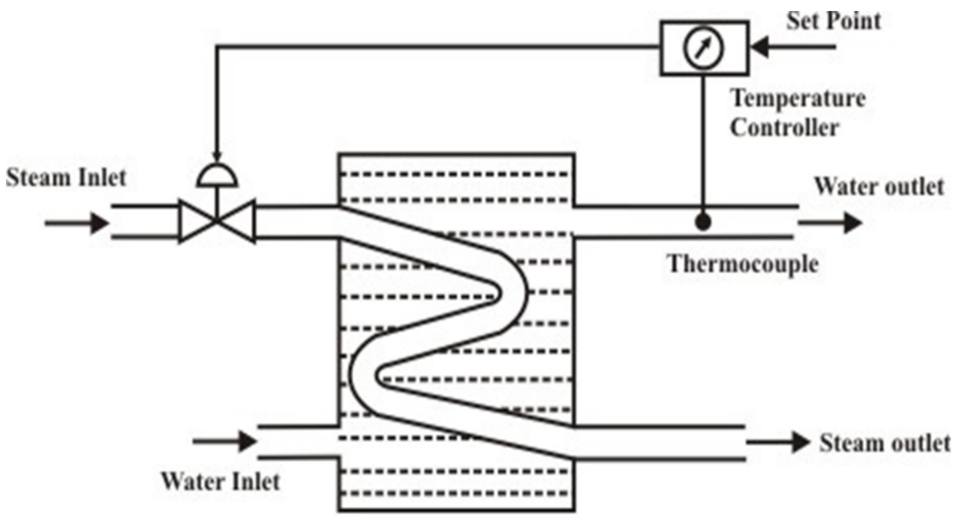


Fig. 1 Feedback temperature control of a heat exchanger

- Steam is used to heat the water in the heat exchanger.
- Feedback temperature controller is used to compare the water outlet temperature with the set point and control the steam flow rate by opening or closing the control valve.
- However due to the change in upstream steam pressure Pi, the steam flow rate may change, though the control valve is at the same position.
- This will affect the amount of heat exchanged and the temperature at the water outlet.
- It will take some time to detect the change in temperature and take subsequent corrective action.
- In a cascade control, this problem can be overcome by measuring the disturbance (change in flow rate in steam due to upstream pressure variation and a corrective action is taken to maintain constant flow rate of steam.
- There is an additional controller (flow controller) whose set point is decided by the temperature controller.
- The schematic arrangement of cascade control is shown in Fig.2. its block diagram is shown in Fig.3.
- Clearly, there are two control loops – outer and inner, and two controllers. The set point of the inner loop controller is decided by the outer loop primary controller.

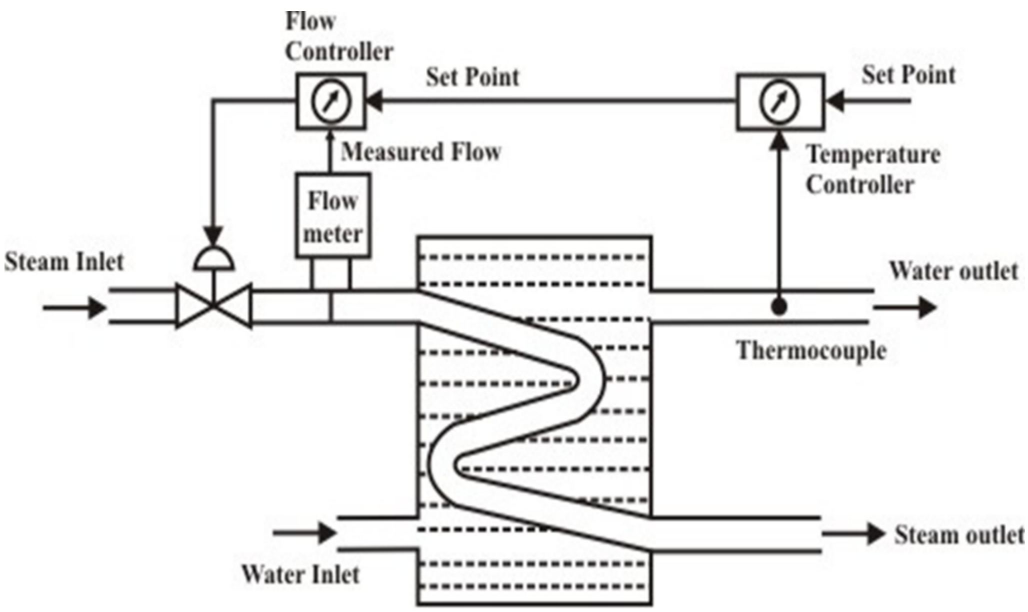


Fig. 2 Cascade Control

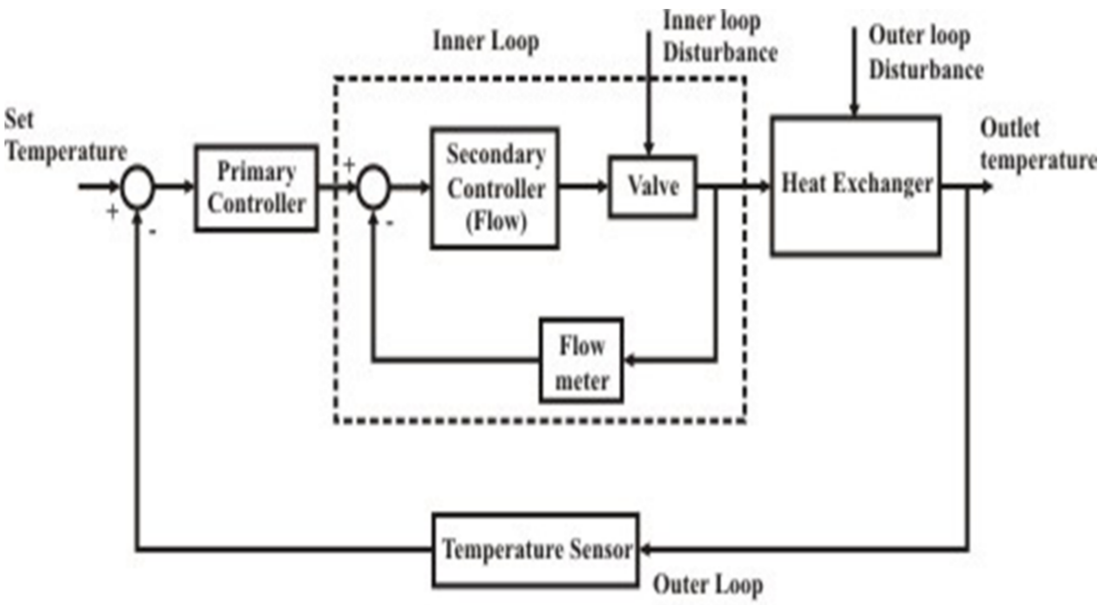


Fig. 3 Block diagram of a Cascade Control System

There are two major functions of cascade control: (1) to eliminate the effect of some disturbances, and (2) to improve the dynamic performance of the control loop.

It is evident from Fig. 3, that the effect of disturbances arising within the inner loop (or secondary loop, as it is called sometimes) is corrected by the secondary controller, before it can influence the output, and the primary controller takes care of the other disturbances in the outer loop. As a result, the transient response of the overall system improves.

There are few other advantages of cascade control.

- A strong (high gain) inner loop reduces the sensitivity and nonlinearity of the plant in the closed loop. The outer loop therefore experiences less parameter perturbations.

- Cascading makes the use of feed-forward control more systematic. In the heat exchanger example (Fig.2) it is possible to measure the water flow and add feed-forward compensation to the flow controller. This would improve the speed of response to fluctuation in water flow, which is a disturbance.
- Cascade control often makes it possible to use simpler control action than what could be needed for a single controller. Though the number of tunable parameters is more in cascade control, a systematic tuning procedure (inner to outer) is available.
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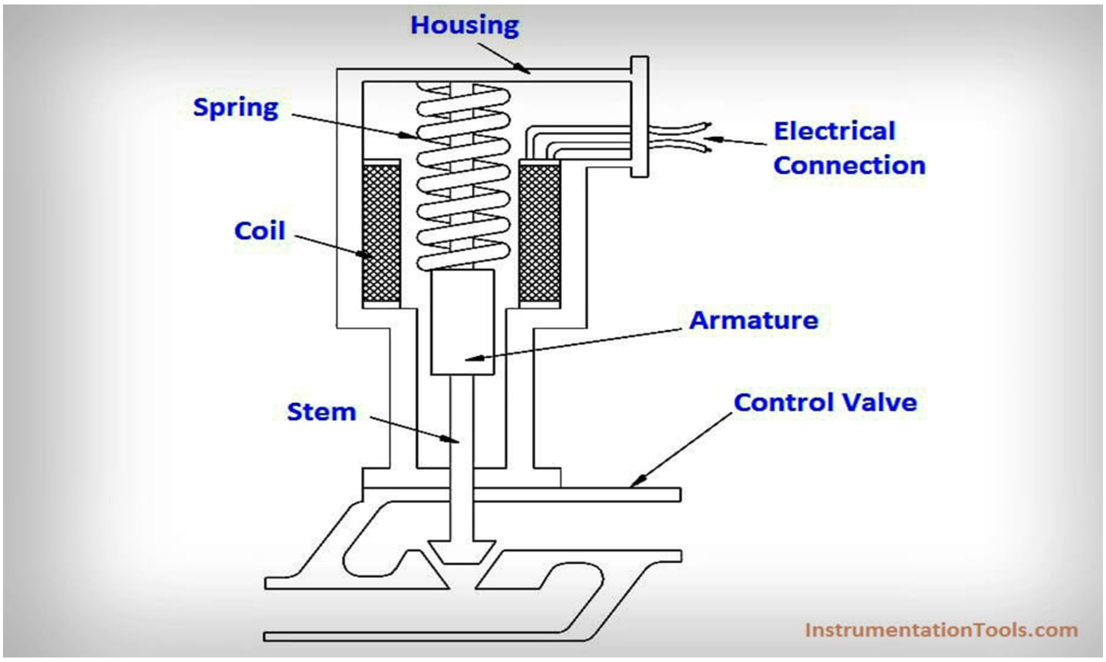
Q4(20 Marks Each)	Solve any two 10 Marks each
A	What is Solenoid? Explain its working in brief.
B	Explain the working of active band pass filter.
C	Explain working of pinch valve with advantages and disadvantages. Discuss about selection criteria and field of applications.

A. What is Solenoid? Explain its working in brief.

(Explanation = 05 Marks, Diagrams = 05 Marks)

A solenoid is a long piece of wire which is wound in the shape of a coil. When the electric current passes through the coil it creates a relatively uniform magnetic field inside the coil.

The solenoid can create a magnetic field from electric current and this magnetic field can be used to generate a linear motion with the help of a metal core. This simple device can be used as an electromagnet, as an inductor or as a miniature wireless receiving antenna in a circuit.



A solenoid is a coil of wire in a corkscrew shape wrapped around a piston, often made of iron. As in all electromagnets, a magnetic field is created when an electric current passes through the wire. Electromagnets have an advantage over permanent magnets in that they can

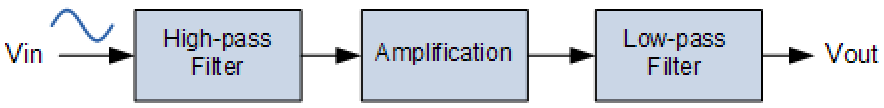
be switched on and off by the application or removal of the electric current, which is what makes them useful as switches and valves and allows them to be entirely automated.
Like all magnets, the magnetic field of an activated solenoid has positive and negative poles that will attract or repel material sensitive to magnets. In a solenoid, the electromagnetic field causes the piston to either move backward or forward, which is how motion is created by a solenoid coil.
When current flows through the coil, a magnetic field forms around the coil. The magnetic field attracts the armature toward the centre of the coil. As the armature moves upward, the spring collapses and the valve opens. When the circuit is opened and current stops flowing to the coil, the magnetic field collapses. This allows the spring to expand and shut the valve.

A major advantage of solenoid actuators is their quick operation. Also, they are much easier to install than pneumatic or hydraulic actuators.

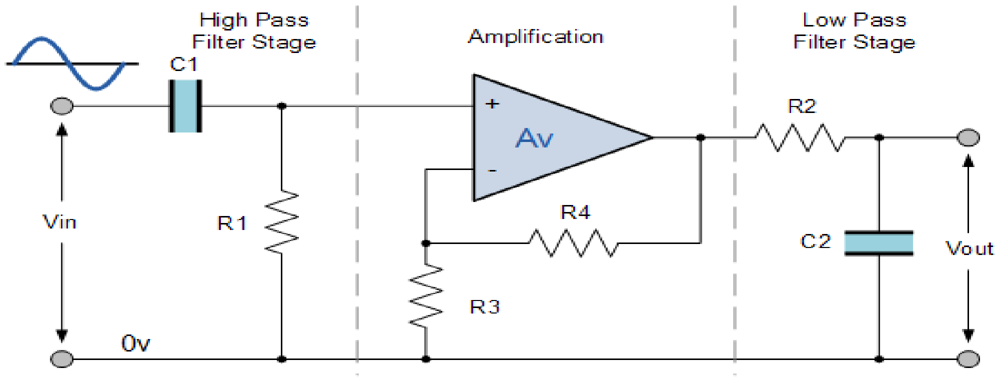
However, solenoid actuators have two disadvantages:

- They have only two positions: fully open and fully closed.
- They don't produce much force, so they usually only operate relatively small valves.

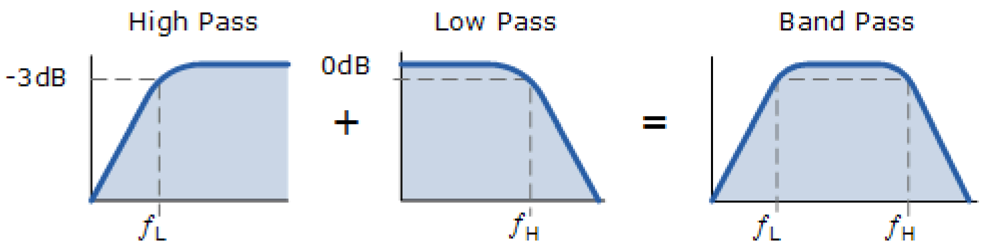
B. Explain the working of active band pass filter.
(Explanation = 05 Marks, Diagrams = 05 Marks)
Simple Active Band Pass Filter can be easily made by cascading together a single Low Pass Filter with a single High Pass Filter as shown.



The cut-off or corner frequency of the low pass filter (LPF) is higher than the cut-off frequency of the high pass filter (HPF) and the difference between the frequencies at the -3dB point will determine the "bandwidth" of the band pass filter while attenuating any signals outside of these points. One way of making a very simple Active Band Pass Filter is to connect the basic passive high and low pass filters we look at previously to an amplifying op-amp circuit as shown

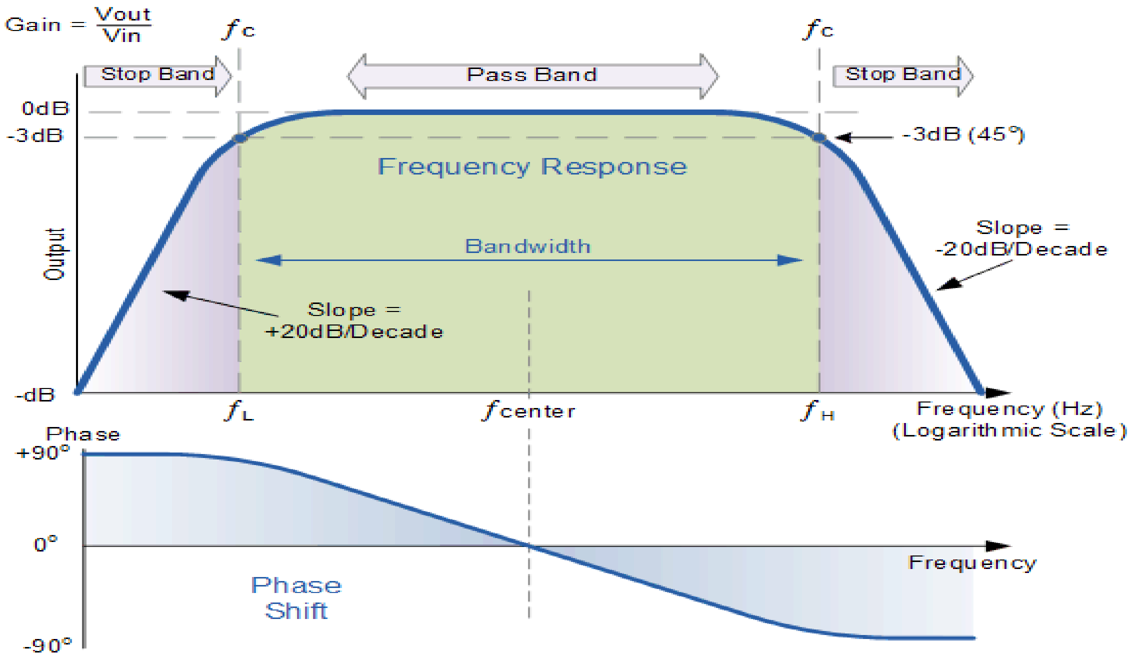


This cascading together of the individual low and high pass passive filters produces a low "Q-factor" type filter circuit which has a wide pass band. The first stage of the filter will be the high pass stage that uses the capacitor to block any DC biasing from the source. This design has the advantage of producing a relatively flat asymmetrical pass band frequency response with one half representing the low pass response and the other half representing high pass response as shown.



The higher corner point (ƒH) as well as the lower corner frequency cut-off point (ƒL) are calculated the same as before in the standard first-order low and high pass filter circuits. Obviously, a reasonable separation is required between the two cut-off points to prevent any interaction between the low pass and high pass stages. The amplifier also provides isolation between the two stages and defines the overall voltage gain of the circuit. The bandwidth of the filter is therefore the difference between these upper and lower -3dB points. For example, suppose we have a band pass filter whose -3dB cut-off points are set at 200Hz and 600Hz. Then the bandwidth of the filter would be given as: Bandwidth (BW) = 600 – 200 = 400Hz.

The normalised frequency response and phase shift for an active band pass filter will be as follows.

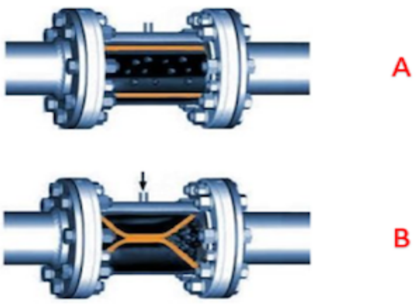


While the above passive tuned filter circuit will work as a band pass filter, the pass band (bandwidth) can be quite wide and this may be a problem if we want to isolate a small band of frequencies. Active band pass filter can also be made using inverting operational amplifier.

So by rearranging the positions of the resistors and capacitors within the filter we can produce a much better filter circuit as shown below. For an active band pass filter, the lower cut-off -3dB point is given by $ƒC1$ while the upper cut-off -3dB point is given by $ƒC2$.

C. *Explain working of pinch valve with advantages and disadvantages. Discuss about selection criteria and field of applications.*
(Explanation with diagram = 04 Marks, Advantages & disadvantages = 03 Marks, Selection Criteria = Field of Application = 03)

A pinch valve consists of three major components: a housing, an internal rubber sleeve (orange section in Figure 2) and end connections. The rubber sleeve is fitted into the housing from inlet to outlet and is the only component that comes in contact with the media. The end connections are bolted, screwed or threaded at each end to provide support and connection to the valve. The valve is open in a normal position (un-pressurized) as seen in Figure 2.A. When the pressurized air is applied to the valve, it pushes down the rubber sleeve, creating a pinching effect as seen in Figure 2.B. When the rubber sleeve is completely pinched, the flow is obstructed, and the valve is closed. Unlike the conventional valves like ball or gate valves where particles can get trapped around the ball or discs, the rubber sleeve in a pinch valve is able to trap the particles around it, providing an excellent shut off. When the external air pressure is no longer applied to the rubber sleeve, the elastic rebounding property of it along with the force of the flowing media fully opens the valve. The fully opened valve provides free flow passage to the media preventing the valve from clogging or blockage. The media also only comes into contact with the rubber sleeve, allowing the media to be isolated, no contamination, and no damage any other components.



When the abrasive media strikes the rubber sleeve, it absorbs the impact and deflects it back to the media. This resilient property helps the rubber sleeve wear at a much slower rate and gives it a longer service life than metal surfaces.

Advantages

A pinch valve has a unique design, which provides it with the following advantages:

- Great to use with abrasive and corrosive media
- Straight flow path and no clogging by the media
- Minimum turbulence and friction
- Keeps media free from contamination
- Easy replacement of the rubber sleeves and a low maintenance cost
- Excellent sealing properties
- Quick opening and closing time
- Low energy consumption

Disadvantages

The few disadvantages of pinch valves are:

- Due to elastomeric property of the sleeve, the valve is not suitable for high temperature application.
- High pressure differential can cause the rubber sleeve to collapse or deform causing the valve to not open fully.
- The valve is not suitable for vacuum applications as suction inside the valve may lead the sleeve to collapse.

Selection criteria

Following criteria should be considered while selecting a pinch valve for your application:

1. Material: The valve body material should be lightweight for easy handling, but it does not need to be compatible with the media since they do not come in contact. The rubber sleeve, however, should be given careful consideration because it is the only component that comes in contact with the media. The rubber sleeve material may include natural rubber, NBR (nitrile), EPDM (ethylene propylene diene monomer), silicon, food quality rubber, etc. The material should have good abrasion resistance to avoid damage by the media.
2. Pressure: To prevent a failure to open/close, the following pressure differentials need to be taken into account:
   - Opening:The operating pressure needs to be greater than the control pressure. Control pressure is typically 0 bar when opening. If the pressure differential is not big enough, the operating pressure will not be able to open the sleeve.
   - Closing:The control pressure needs to be greater than the operating pressure. If the pressure differential is not big enough, the control pressure will not be able to overcome the operating pressure in pushing the sleeve in to close the valve.

   Max Control Pressure = Operating Pressure + Max Pressure Differential

3. Temperature: Ensure that the valve materials can withstand the minimum and maximum operating temperature requirement of your application.
4. Certification: Depending upon your application, certification may be required for safety and no contamination of the media (i.e. food grade, drinking water, etc.).

Field of application

Pinch valves are increasingly being used in industrial applications due to their advantages. Some of the industries using pinch valves include:

- Food and beverage industries
- Pharmaceutical industry
- Chemical industry
- Cement industry
- Bulk and solid handling industry
- Ceramic industry
- Plastic industry
- Wastewater industry