ID: 11461

NAME: ASFANDYAR AWAIS

COURSE: ELECTRONIC CIRCUIT DESIGN

INSTRUCTOR: ENHGINEER MUJTABA EHSAN

ANSWER Q1(a):

DARLINGTON CONNECTION:

-The main feature is that the composite transistor acts as a single unit with a current gain that is the product of the current gains of the individual transistors

-Provides high current gain than a single BJT

-The connection is made using two separate transistors having current gains of β_1 and β_2

So, the current gain $\beta_D = \beta_1\beta_2$

If $\beta_1 = \beta_2 = \beta$

The Darlington connection

provides a current gain of $\beta_D = \beta^2$

ANSWER Q1(b):

SOLUTION:

Line Reg = 0.062/4.5*100 = 1.37%

Line Reg = (0.062/40*100)/4.5 = 0.034 %v

Answer 2:

Colpitts Oscillator is a type of LC oscillator which falls under the category of Harmonic Oscillator and was invented by Edwin Colpitts in 1918. Figure 1 shows a typical Colpitts oscillator with a tank circuit in which an inductor L is connected in parallel to the serial combination of capacitors C_1 and C_2 (shown by the red enclosure).

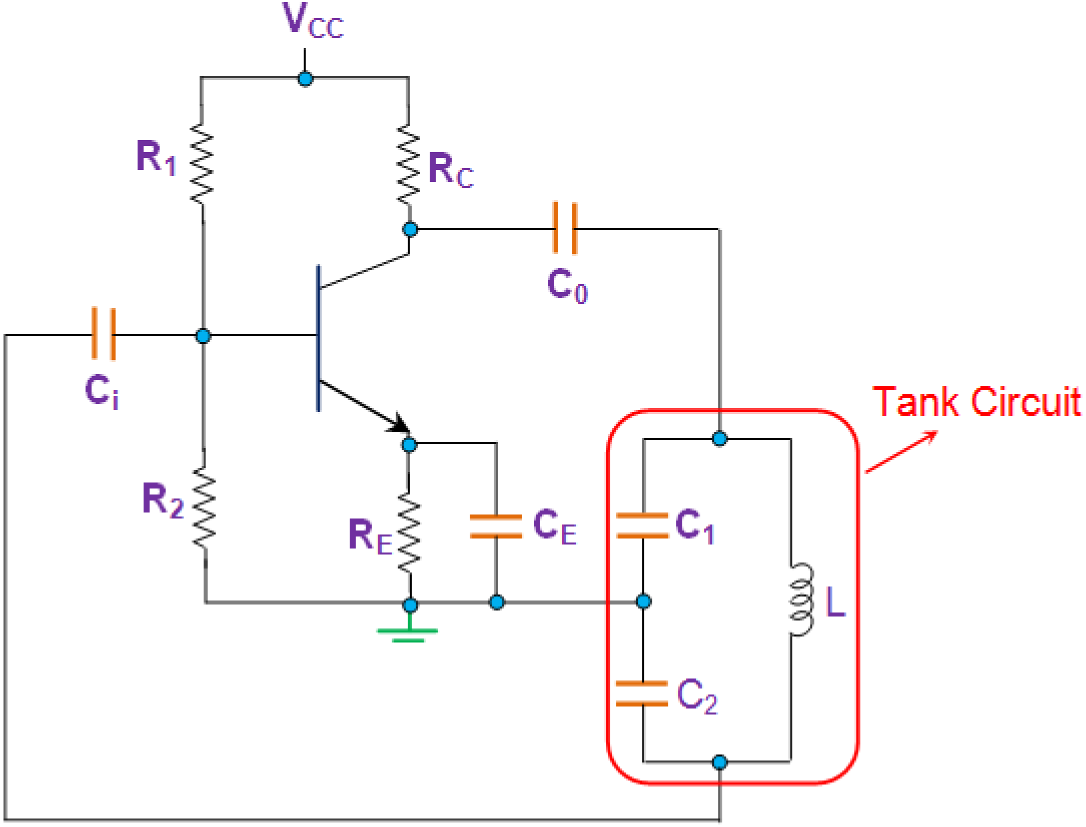


Figure 1 Colpitts Oscillator

Other components in the circuit are the same as that found in the case of common-emitter CE which is biased using a voltage divider network i.e. R_C is the collector resistor, R_E is the emitter resistor which is used to stabilize the circuit and the resistors R_1 and R_2 form the voltage divider bias network. Further, the capacitors C_i and C_o are the input and output decoupling capacitors while the emitter capacitor C_E is the bypass capacitor used to bypass the amplified AC signals.

Here, as the power supply is switched ON, the transistor starts to conduct, increasing the collector current I_C due to which the capacitors C_1 and C_2 get charged. On acquiring the maximum charge feasible, they start to discharge via the inductor L. During this process, the electrostatic energy stored in the capacitor gets converted into magnetic flux which in turn is stored within the inductor in the form of electromagnetic energy. Next, the inductor starts to discharge which charges the capacitors once again. Likewise, the cycle continues which gives rise to the oscillations in the tank circuit.

Further the figure shows that the output of the amplifier appears across C_1 and thus is in-phase with the tank circuit's voltage and makes-up for the energy lost by re-supplying it. On the other hand, the voltage feedback to the transistor is the one obtained across the capacitor C_2, which means the feedback signal is out-of-phase with the voltage at the transistor by 180°. This is due to the fact that the voltages developed across the capacitors C_1 and C_2 are opposite in polarity as the point where they join is grounded. Further, this signal is provided with an additional phase-shift of 180° by the transistor which results in a net phase-shift of 360° around the loop, satisfying the phase-shift criterion of Barkhuizen principle.

At this state, the circuit can effectively act as an oscillator producing sustained oscillations by carefully monitoring the feedback ratio given by (C_1 / C_2). The frequency of such a Colpitts

Oscillator depends on the components in its tank circuit and is given by

$$F = \frac{1}{2\pi\sqrt{LC_{eff}}}$$

Where, the C_{eff} is the effective capacitance of the capacitors expressed as

$$\frac{C_1C_2}{C_1 + C_2}$$

As a result, these oscillators can be tuned either by varying their inductance or the capacitance. However the variation of L does not yield a smooth variation. Hence they are usually tuned by varying the capacitances which are generally ganged, due to which a change in any one of them changes both of them. Nevertheless, the process is tedious and requires special large-valued capacitor. Thus, the Colpitts oscillators are seldom preferred in the applications where in the frequency varies but are more popular as fixed frequency oscillators due to their simple design. Further they offer better stability in comparison with the Hartley Oscillators as they are exempted from the mutual inductance effect present in-between the two inductors of the latter case.

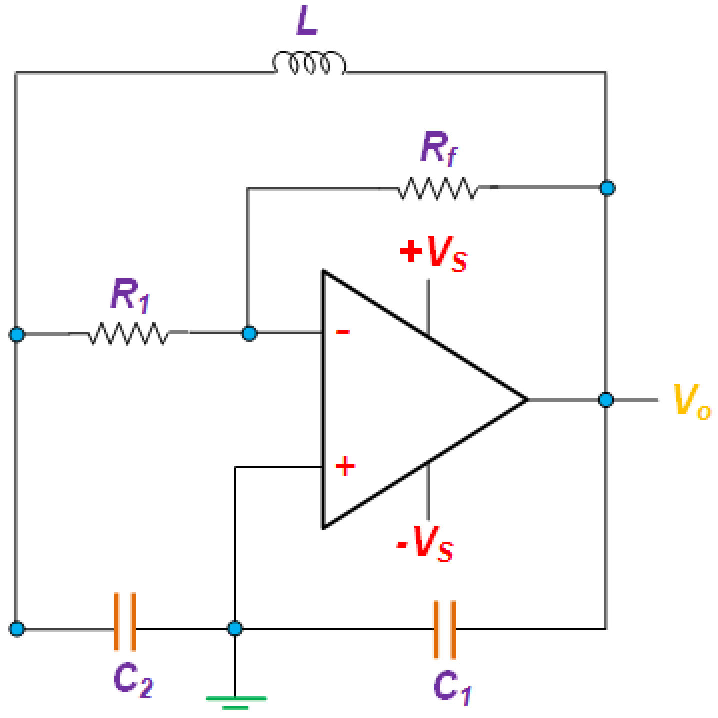


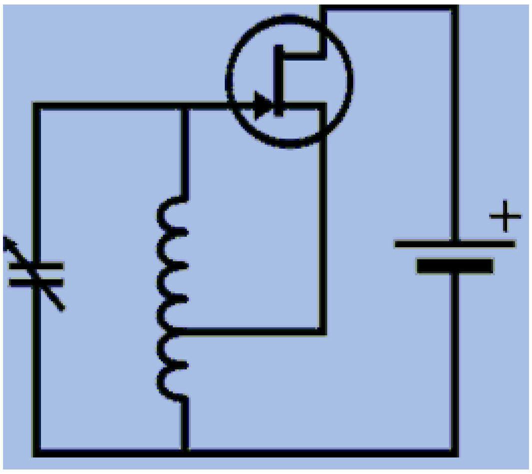
Figure 2 Colpitts Oscillator Using an Op-Amp

Apart from the BJT-based Colpitts Oscillator shown, they are also realizable using valves or FET (Field Effect Transistor) or Op-Amp. Figure 2 shows such a Colpitts oscillator which uses an Op-Amp in inverting configuration in its amplifier section while the tank circuit remains similar to that in the case of Figure 1. This kind of circuit functions almost analogous to that of the one explained earlier. However, here the gain of the oscillator can be adjusted individually just by using the feedback resistor R_f, as the gain of the inverting amplifier is given as $-R_f / R_1$. From this, it can be noted that, in this case, the gain of the circuit is less dependent on the circuit elements of the tank circuit.

Typically, the operating frequency of the Colpitts oscillators ranges from 20 KHz to 300 MHz. However they can even be used for microwave applications as their capacitors provide low reactance path for the high-frequency signals. This results in better frequency stability as well as a better sinusoidal output waveform. Moreover, they are also extensively used as surface acoustical wave (SAW) resonators, sensors and in mobile and communication systems.

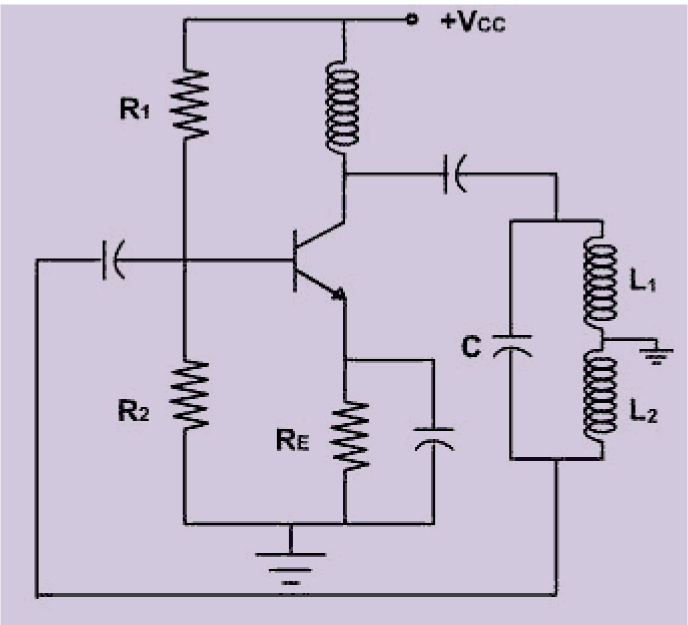
HARTLEY OSCILLATORS

Hartley oscillator is inductively coupled, variable frequency oscillators where the oscillator may be a series or shunt fed. Hartley oscillators is the advantage of having one tuning capacitor and one center-tapped inductor. This processor simplifies the construction of a Hartley oscillator circuit.



The circuit diagram of a Hartley oscillator is shown in the below figure. An NPN transistor connected in a common emitter configuration works as the active device in amplifier stage. R1 and R2 are biasing resistors and RFC is the radio frequency choke, which provides the isolation between AC and DC operation.

At high frequencies, the reactance value of this choke is very high, hence it can be treated as an open circuit. The reactance is zero for DC condition, hence causes no problem for DC capacitors. The CE is the emitter bypass capacitor and RE is also be a biasing resistor. The CC1 and CC2 are the coupling capacitors.



Hartley Oscillator Circuit

When the DC supply (Vcc) is given to the circuit, the collector current starts raising and begins with the charging of the capacitor C. Once capacitor C is fully charged, it starts discharging through L1 and L2 and again starts charging.

This back-and-fourth voltage waveform is a sine wave which is a small and leads with its negative alteration. It will eventually die out unless it is amplified.

Now the transistor comes into the picture. The sine wave generated by the tank circuit is coupled to the base of the transistor through the capacitor CC1.

Since the transistor is configured as common-emitter, it takes the input from tank circuit and inverts it to a standard sine wave with a leading positive alteration.

Thus the transistor provides amplification along with inversion to amplify and correct the signal generated by the tank circuit. The mutual inductance between L1 and L2 provides the feedback of energy from collector-emitter circuit to the base-emitter circuit.

The frequency of oscillations in this circuit is

$$f_o = 1/ (2\pi \sqrt{(L_{eq} C)})$$

Where Leq is the total inductance of coils in the tank circuit is given as

$$L_{eq} = L_1 + L_2 + 2M$$

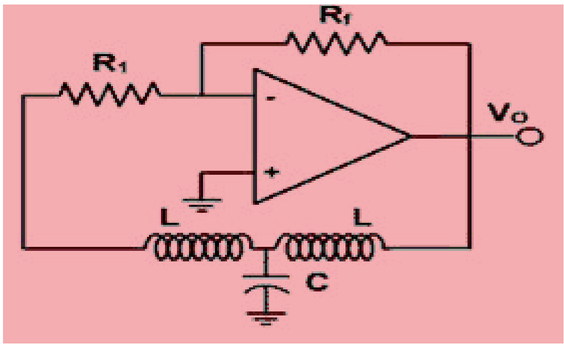
For a practical circuit, if L1 = L2 = L and the mutual inductance are neglected, then the frequency of oscillations can be simplified as

$$f_o = 1/ (2\pi \sqrt{(2 L C)})$$

Hartley Oscillator Circuit Using Op-Amp

The Hartley oscillator can be implemented by using an operational amplifier and its typical arrangement is shown in the below figure. This type of circuit facilitates the gain adjustment by using feedback resistance and input resistance.

In transistorized Hartley oscillator, the gain depending up on the tank circuit elements like L1 and L2 whereas in Op-amp oscillator gain is less depends on the tank circuit elements and hence provides greater frequency stability.



Hartley Oscillator using Op-Amp

The operation of this circuit is similar to the transistor version of the Hartley oscillator. The sine wave is generated by the feedback circuit and it’s coupled with the op-amp section. Then this wave is stabilized and inverted by the amplifier.

The frequency of an oscillator is varied by using a variable capacitor in the tank circuit, keeping the feedback ratio and the amplitude of the output is constant for over a frequency range. The frequency of oscillations for this type of oscillator is the same as the above-discussed oscillator and is given as

$$f_o = 1/ (2\pi \sqrt{(L_{eq} C)})$$

Where: $L_{eq} = L1 + L2 + 2M$

Or

$L_{eq} = L1 + L2$

To generate the oscillation from this circuit, the amplifier gain must and should be selected greater than or at least equal to the ratio of two inductances.

$$Av = L1 / L2$$

If the mutual inductance exists between L1 and L2 because the common core of these two coils, then the gain becomes

$$Av = (L1 + M) / (L2 + M)$$

Advantages

- Instead of two separate coils L1 and L2, a single coil of bare wire can be used and the coil grounded at any desired point along with it.
- By using a variable capacitor or by making core movable (varying the inductance), the frequency of oscillations can be varied.
- Very few components are needed, including either two fixed inductors or a tapped coil.
- The amplitude of the output remains constant over the working frequency range.

Disadvantages

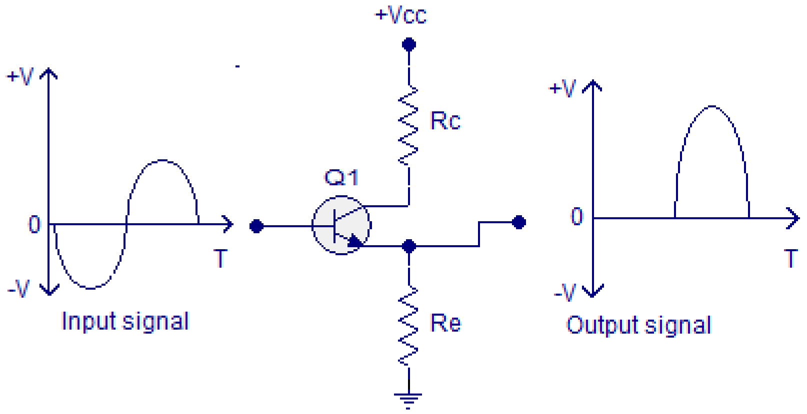
- It cannot be used as a low-frequency oscillator since the value of inductors becomes large and the size of the inductors becomes large.
- The harmonic content in the output of this oscillator is very high and hence it is not suitable for the applications which require a pure sine wave.

Applications

- The Hartley oscillator is to produce a sine wave with the desired frequency
- Hartley oscillators are mainly used as radio receivers. Also note that due to its wide range of frequencies, it is the most popular oscillator
- The Hartley oscillator is Suitable for oscillations in RF (Radio-Frequency) range, up to 30MHZ

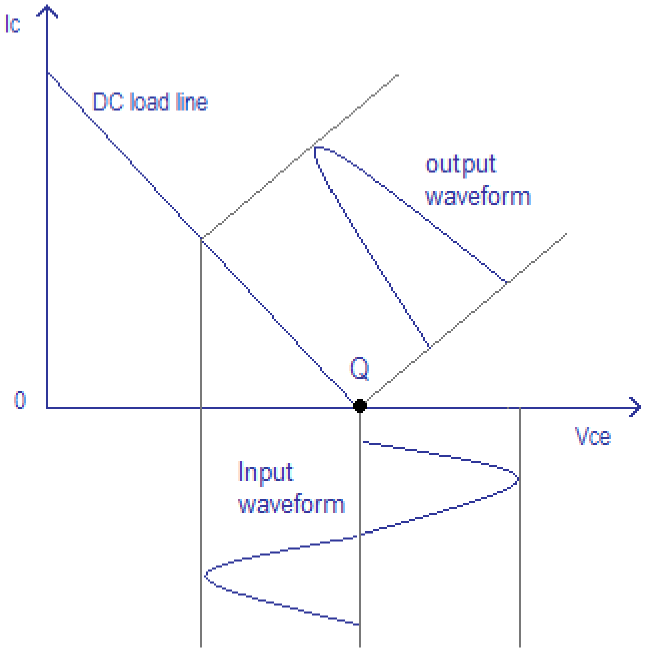
ANSWERQ3(A):

Class B amplifier is a type of power amplifier where the active device (transistor) conducts only for one half cycle of the input signal. That means the conduction angle is 180° for a Class B amplifier. Since the active device is switched off for half the input cycle, the active device dissipates less power and hence the efficiency is improved. Theoretical maximum efficiency of Class B power amplifier is 78.5%. The schematic of a single ended Class B amplifier and input , output waveforms are shown in the figure below.



Single ended Class B amplifier www.circuitstoday.com

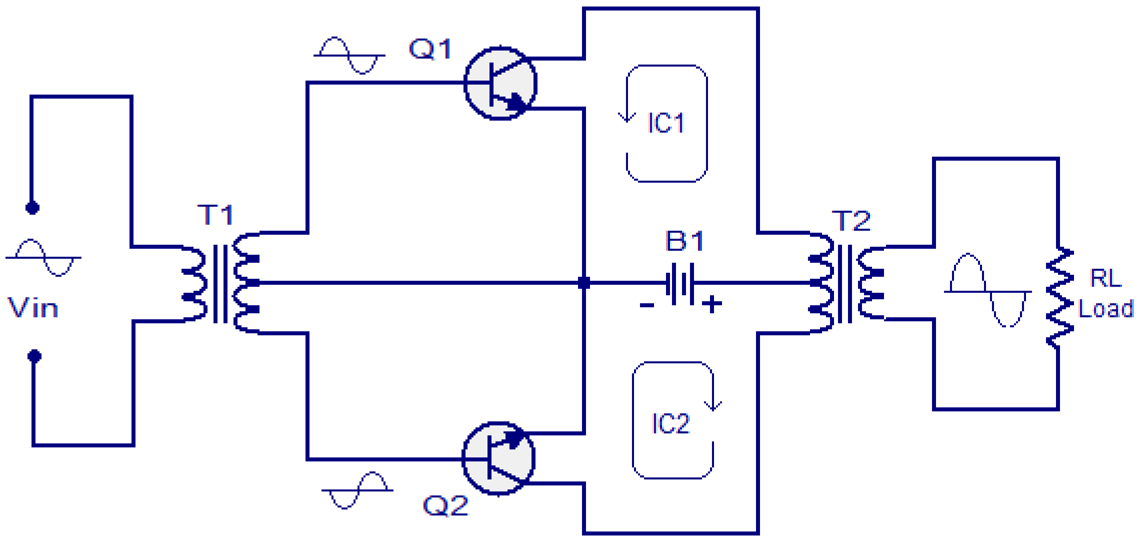
From the above circuit it is clear that the base of the transistor Q1 is not biased and the negative half cycle of the input waveform is missing in the output. Even though it improves the power efficiency, it creates a lot of distortion. Only half the information present in the input will be available in the output and that is a bad thing.Single ended Class B amplifiers are not used in present day practical audio amplifier application and they can be found only in some earlier gadgets. Another place where you can find them is the RF power amplifiers where the distortion is not a matter of major concern. Anyway, Class C amplifiers are more often used in RF power amplifier applications. Output characteristics of a single ended Class B power amplifier is shown in the figure below.



Class B power amplifier output characteristics wwww.circuitstoday.com

One way to realize a practical Class B amplifier is to use a pair of active devices (transistors) arranged in push-pull mode where one transistor conducts one half cycle and the other transistor conducts the other half cycle. The output from both transistors are then combined together to get a scaled replica of the input. But there is a snag – there must be some way to split the input wave form to feed the individual transistors and there must be some way to put together the output of the individual transistors. Transformer coupling is solution for this problem and such amplifiers are called transformer coupled Class B amplifiers.

Transformer coupled Class B amplifier.



Transformer coupled Class B amplifier

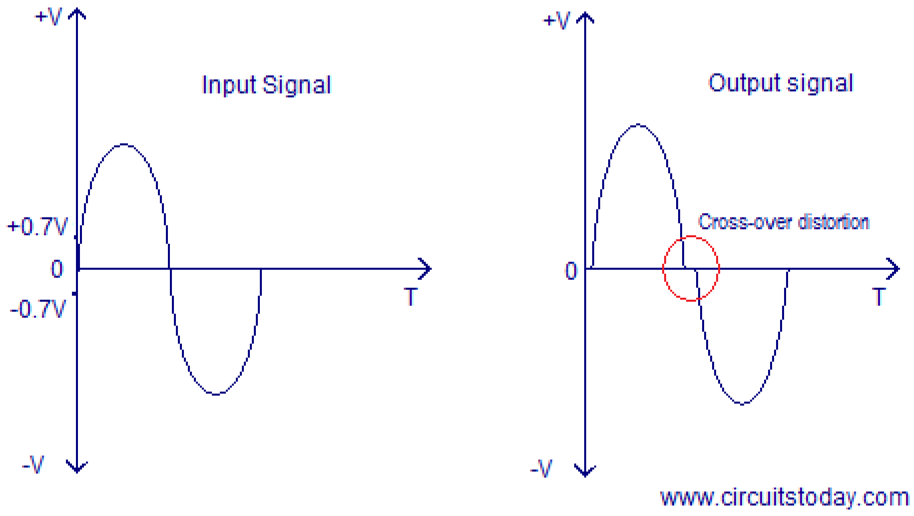
www.circuitstoday.com

The circuit diagram of a simple transformer coupled class B power amplifier is shown in the figure above. Transistor Q1 and Q2 are the active elements. The transformer T1 reproduces the input signal into two copies which are 180° out of phase. From the above figure you can see that the transistor Q1 amplifies the positive half of the input signal and transistor Q2 amplifies the negative half of the input signal. Current flow path of the two transistors are also depicted in the above figure. The amplified two halves are joined together by the transformer T2. If an ideal transformer is used the DC components of the collector current of each transistors will flow in opposite directions through the transformer primary and they will cancel each other. That means there is no core saturation and there will be no DC components in the output.

Since the transistors are not biased they remains OFF when there is no input signal and no current flows through the load. Each transistor starts conduction only when the amplitude of the input signal goes above the base-emitter voltage (Vbe) of the transistor which is about 0.7 V. This improves the efficiency but creates a problem called cross-over distortion.

Cross over distortion.

Since the active elements start conduction only after the input signal amplitude has risen above 0.7V, the regions of the input signal where the amplitude is less than 0.7V will be missing in the output signal and it is called cross over distortion. The schematic representation of cross-over distortion is shown in the figure below. In the figure, you can see that the regions of the input waveform which are under 0.7V are missing in the output waveform.



Advantages of Class B amplifier.

- High efficiency when compared to the Class A configurations.
- Push-pull mechanism avoids even harmonics.
- No DC components in the output (in ideal case).

Disadvantages of Class B amplifier.

- The major disadvantage is the cross-over distortion.
- Coupling transformers increases the cost and size.
- It is difficult to find ideal transformers.
- Transformer coupling causes hum in the output and also affects the low frequency response.
- Transformer coupling is not practical in case of huge loads.

ANSWERQ3(b):

Basically, there are two types of Voltage regulators: Linear voltage regulator and Switching voltage regulator.

- There are two types of Linear voltage regulators: Series and Shunt.
- There are three types of Switching voltage regulators: Step up, Step down and Inverter voltage regulators.

Linear Regulator

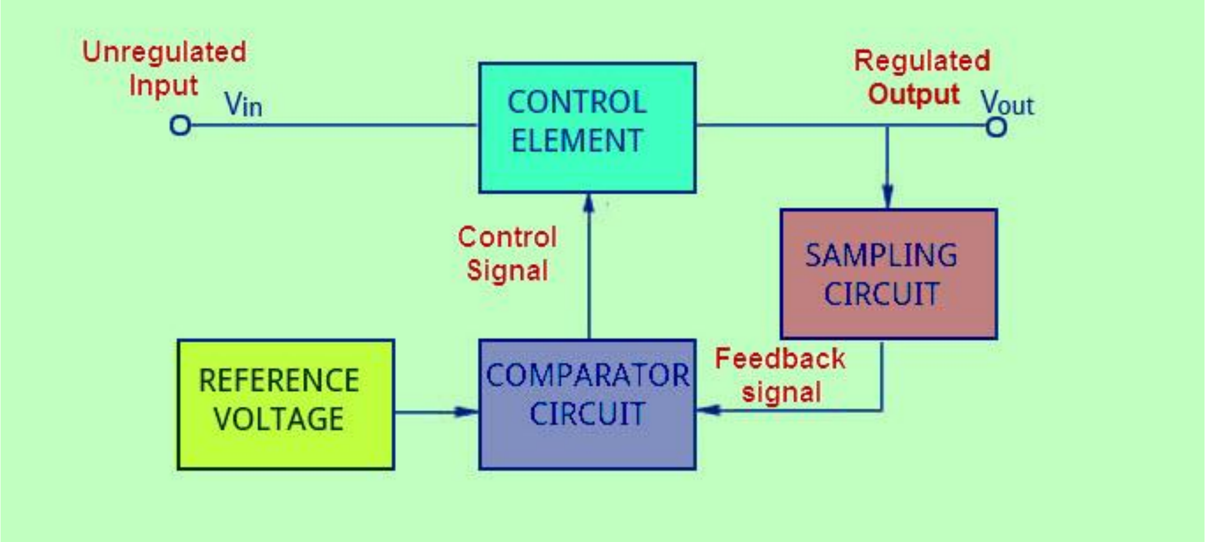
Linear regulator acts as a voltage divider. In the Ohmic region, it uses FET. The resistance of the voltage regulator varies with load resulting in constant output voltage.

Advantages of a linear voltage regulator
- Gives a low output ripple voltage
- Fast response time to load or line changes
- Low electromagnetic interference and less noise

Disadvantages of the linear voltage regulator
- Efficiency is very low
- Requires large space – heatsink is needed
- Voltage above the input cannot be increased

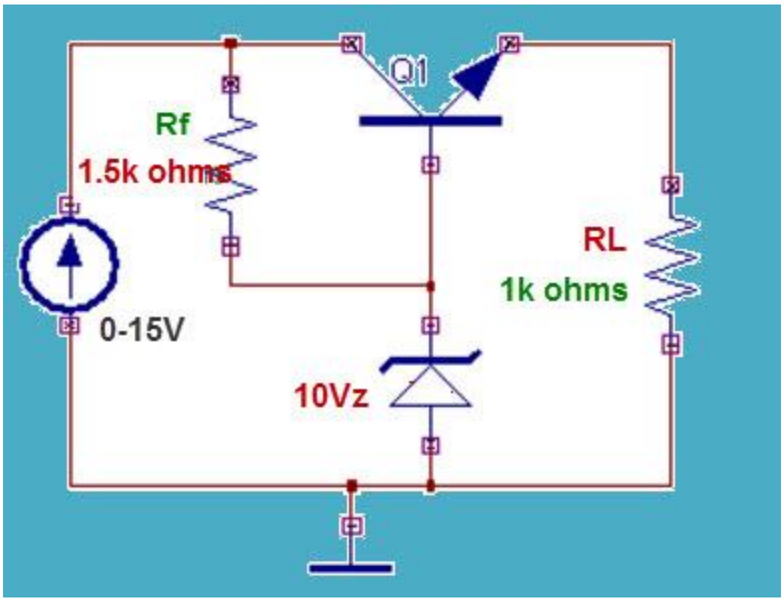
Series Voltage Regulator

A series voltage regulator uses a variable element placed in series with the load. By changing the resistance of that series element, the voltage dropped across it can be changed. And, the voltage across the load remains constant.



Series Voltage Regulator

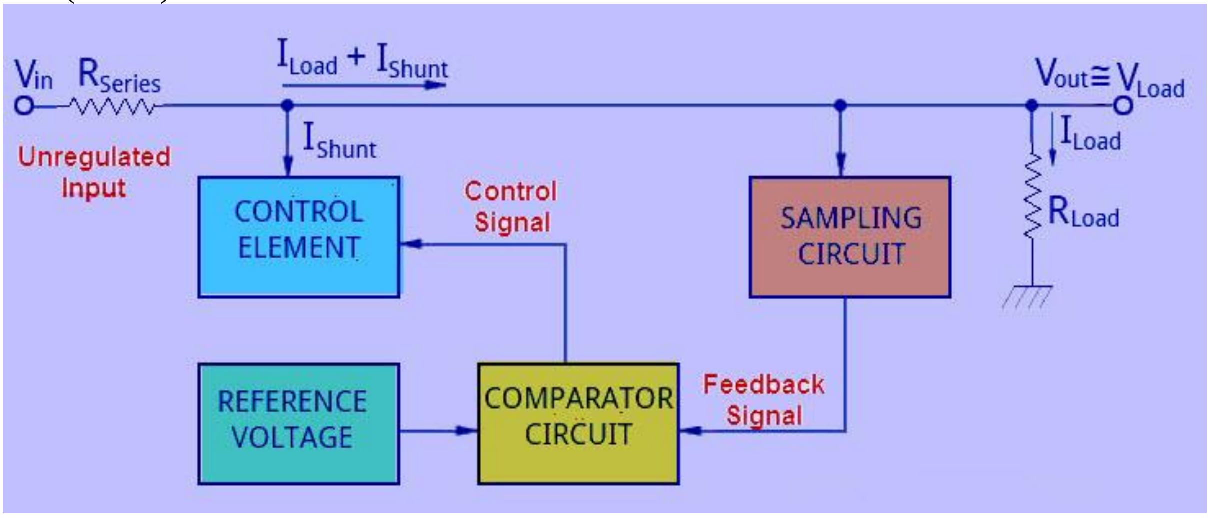
The amount of current drawn is effectively used by the load; this is the main advantage of the series voltage regulator. Even when the load does not require any current, the series regulator does not draw full current. Therefore, a series regulator is considerably more efficient than shunt voltage regulator.



Series Voltage Regulator Circuit

Shunt Voltage Regulator

A shunt voltage regulator works by providing a path from the supply voltage to ground through a variable resistance. The current through the shunt regulator has diverted away from the load and flows uselessly to the ground, making this form usually less efficient than the series regulator. It is, however, simpler, sometimes consisting of just a voltage-reference diode, and is used in very low-powered circuits wherein the wasted current is too small to be of concern. This form is very common for voltage reference circuits. A shunt regulator can usually only sink (absorb) current.



Shunt Voltage Regulator

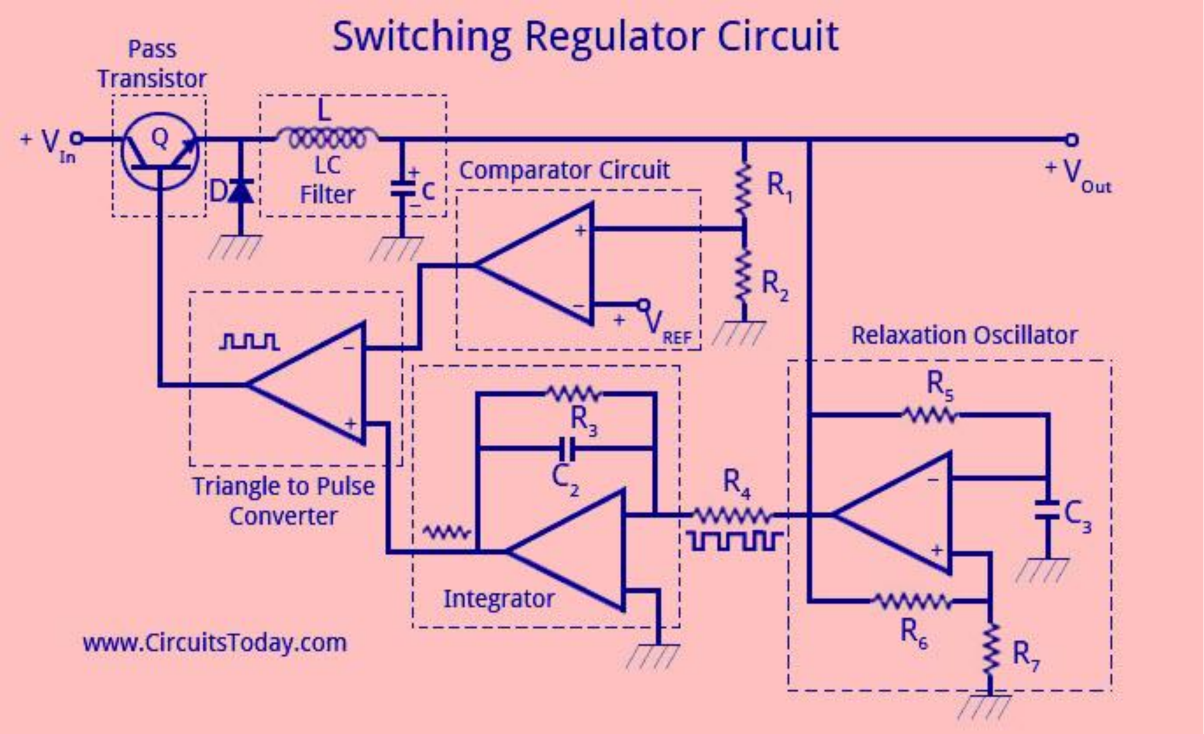
Applications of Shunt Regulators

Shunt regulators are used in:

- Low Output Voltage Switching Power Supplies
- Current Source and Sink Circuits
- Error Amplifiers
- Adjustable Voltage or Current Linear and Switching Power Supplies
- Voltage Monitoring
- Analog and Digital Circuits that require precision references
- Precision current limiters

Switching Voltage Regulator

A switching regulator rapidly switches a series device on and off. The switch’s duty cycle sets the amount of charge transferred to the load. This is controlled by a feedback mechanism similar to that of a linear regulator. Switching regulators are efficient because the series element is either fully conducting or switched off because it dissipates almost no power. Switching regulators are able to generate output voltages that are higher than the input voltage or of opposite polarity, unlike linear regulators.



Switching Voltage Regulator

The switching voltage regulator switches on and off rapidly to alter the output. It requires a control oscillator and also charges storage components.

In a switching regulator with Pulse Rate Modulation varying frequency, constant duty cycle and noise spectrum imposed by PRM vary; it is more difficult to filter out that noise.

A switching regulator with Pulse Width Modulation, constant frequency, varying duty cycle, is efficient and easy to filter out noise.
In a switching regulator, continuous mode current through an inductor never drops to zero. It allows the highest output power. It gives better performance.
In a switching regulator, discontinuous mode current through the inductor drops to zero. It gives better performance when the output current is low.

Switching Topologies

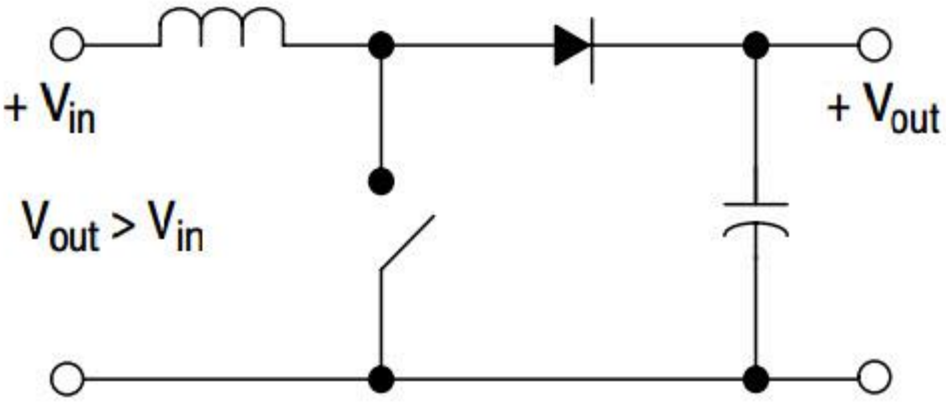
It has two types of topologies: Dielectric isolation and Non- isolation.

Non –Isolation: It is based on small changes in Vout/ Vin. Examples are Step Up voltage regulator (Boost) – Raises input voltage; Step Down (Buck) – lowers input voltage; Step up/ Step Down (boost/ buck) Voltage regulator – Lowers or raises or inverts the input voltage depending on the controller; Charge pump – It provides multiples of input without using inductor.
Dielectric – Isolation: It is based on radiation and intense environments.
Advantages of Switching Topologies
The main advantages of a switching power supply are efficiency, size, and weight. It is also a more complex design, which is capable of handling higher power efficiency. Switching voltage regulator can provide output, which is greater than or less than or that inverts the input voltage.

Disadvantages of Switching Topologies
- Higher output ripple voltage
- Slower transient recovery time
- EMI produces very noisy output
- Very expensive

Step-Up Voltage Regulator

Step-up switching converters also called boost switching regulators, provide a higher voltage output by raising the input voltage. The output voltage is regulated, as long as the power is drawn is within the output power specification of the circuit. For driving strings of LEDs, Step up Switching voltage regulator is used.



Step Up Voltage Regulator

Assume Lossless circuit Pin= Pout (input and output powers are same)

Then $V_{in}\ I_{in} = V_{out}\ I_{out}$,

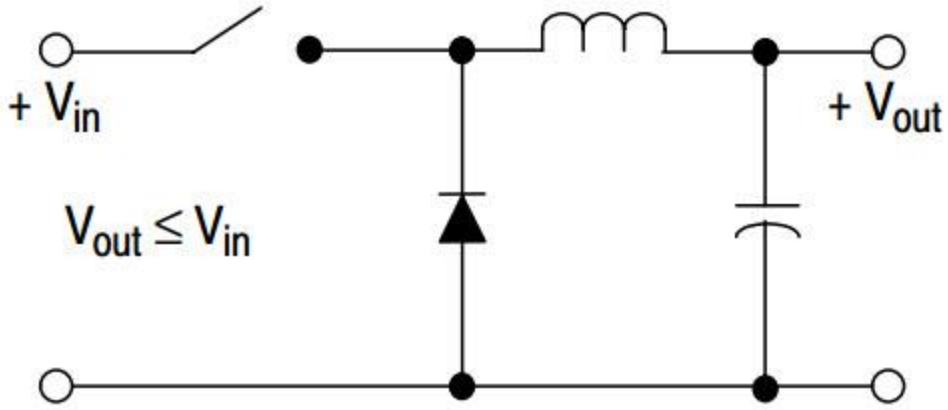
$I_{out} / I_{in} = (1\text{-}D)$

From this, it is inferred that in this circuit

- Powers remain the same
- Voltage increases
- Current decreases
- Equivalent to DC transformer

Step Down (Buck) Voltage Regulator

It lowers the input voltage.



Step Down Voltage Regulator

If input power is equal to output power, then

$P_{in} = P_{out}$; $V_{in}\ I_{in} = V_{out}\ I_{out}$,

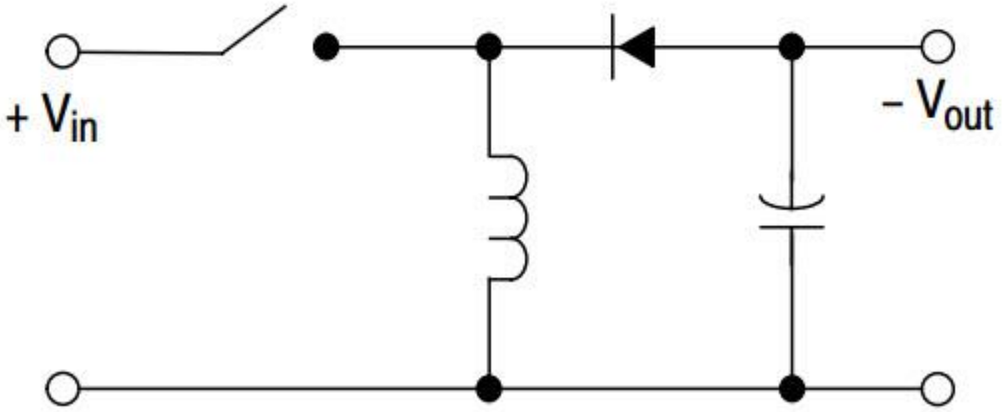
$I_{out} / I_{in} = V_{in} / V_{out} = 1/D$

Step down converter is equivalent to DC transformer wherein the turns ratio is in the range of 0-1.

Step Up/Step Down (Boost/Buck)

It is also called Voltage inverter. By using this configuration, it is possible to raise, lower or invert the voltage as per the requirement.

- The output voltage is of opposite polarity of the input.
- This is achieved by VL forward- biasing reverse-biased diode during the off times, producing current and charging the capacitor for voltage production during the off times
- By using this type of switching regulator, 90% efficiency can be achieved.



Step Up/Step Down Voltage Regulator

Alternator Voltage Regulator

Alternators produce the current that is required to meet a vehicle's electrical demands when the engine runs. It also replenishes the energy which is used to start the vehicle. An alternator has the ability to produce more current at lower speeds than the DC generators that were once used by most of the vehicles. The alternator has two parts

Alternator Voltage Regulator

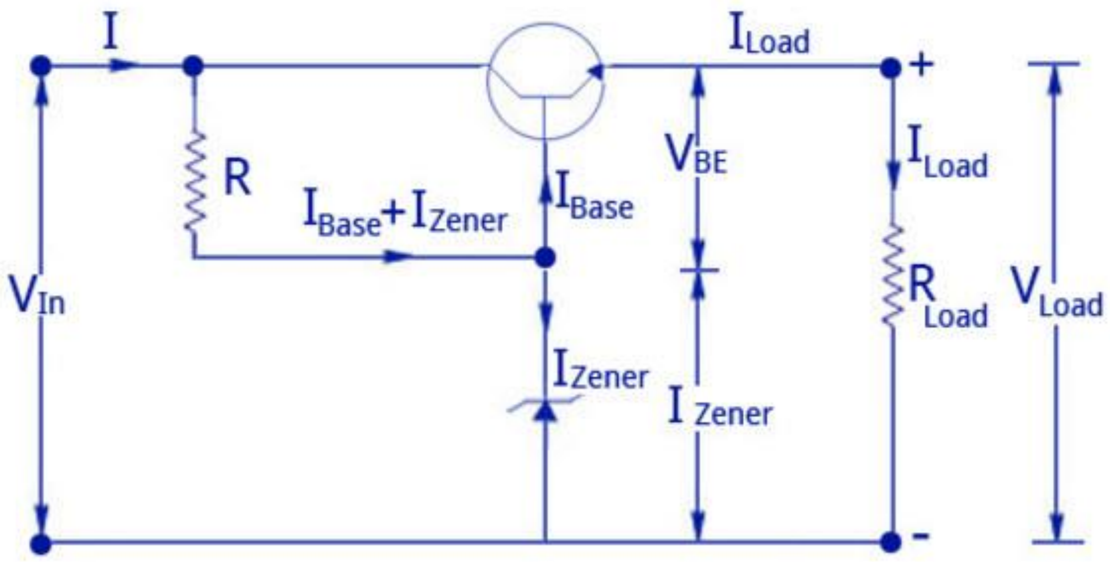
Stator – This is a stationary component, which does not move. It contains a set of electrical conductors wound in coils over an iron core.
Rotor / Armature – This is the moving component that produces a rotating magnetic field by anyone of the following three ways: (i) induction (ii) permanent magnets (iii) using an exciter.
Electronic Voltage Regulator

A simple voltage regulator can be made from a resistor in series with a diode (or series of diodes). Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn or changes in the input. When precise voltage control and efficiency are not important, this design may work fine.

Electronic Voltage Regulator

Transistor Voltage Regulator

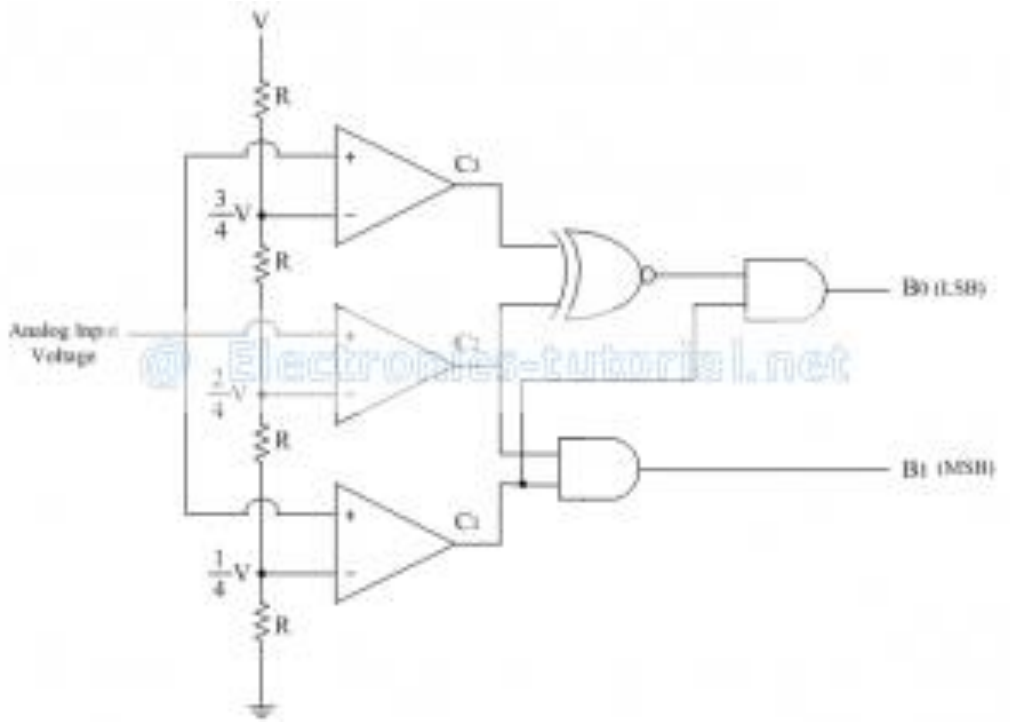
Electronic voltage regulators have an astable voltage reference source that is provided by the Zener diode, which is also known as reverse breakdown voltage operating diode. It maintains a constant DC output voltage. The AC ripple voltage is blocked, but the filter cannot be blocked. Voltage regulator also has an extra circuit for short circuit protection, and current limiting circuit, over-voltage protection, and thermal shutdown.



Transistor Voltage Regulator

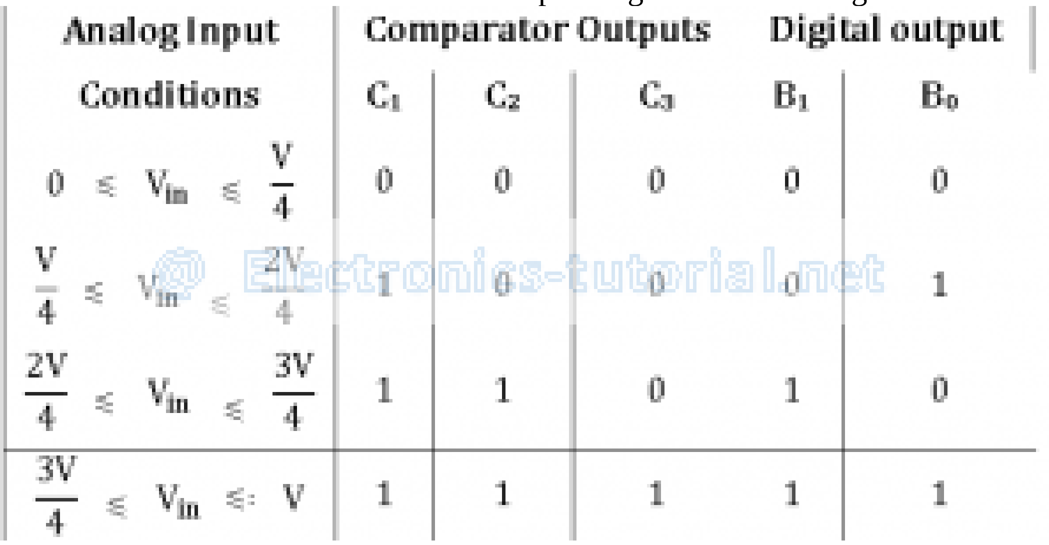
ANSWER Q4:

Flash Type ADC is based on the principle of comparing analog input voltage with a set of reference voltages.
To convert the analog input voltage into a digital signal of n-bit output, (2^n – 1) comparators are required.
The following figure shows 2- bit flash type ADC



The three op-amps are used as comparators. The non-inverting inputs of all the three comparators are connected to the analog input voltage. The inverting terminals are connected to a set of reference voltages (V/4), (2V/4) and (3V/4) respectively which are obtained using a

resistive divider network and power supply +V.
The output of the comparator is in positive saturation(i.e. logic 1), when voltage at non-inverting terminal is greater than voltage at inverting terminal and is in negative saturation otherwise.
The following table shows the comparator outputs for different ranges of analog input voltages and their corresponding digital outputs.



Analog Input Conditions	Comparator Outputs			Digital output	
	C_1	C_2	C_3	B_1	B_0
$0 \le V_{in} \le \frac{V}{4}$	0	0	0	0	0
$\frac{V}{4} \le V_{in} \le \frac{2V}{4}$	1	0	0	0	1
$\frac{2V}{4} \le V_{in} \le \frac{3V}{4}$	1	1	0	1	0
$\frac{3V}{4} \le V_{in} \le V$	1	1	1	1	1

Consider first condition, where analog input voltage VA is less than (V/4). In this case, the voltage at the non-inverting terminals of all the three comparators is less than the respective voltages at inverting terminals and hence the comparator outputs are C1C2C3 = 000. This comparator outputs are applied to the further coding circuit to get the digital outputs as B1B0 = 00
Similarly the digital outputs are calculated for other three conditions also.

Advantages:
1) It is the fastest type of ADC because the conversion is performed simultaneously through a set of comparators, hence referred as flash type ADC. Typical conversion time is 100ns or less.
2) The construction is simple and easier to design.

Disadvantages:
1) It is not suitable for higher number of bits.
2) To convert the analog input voltage into a digital signal of n-bit output, (2^n – 1) comparators are required. The number of comparators required doubles for each added bit.

ANSWER Q5(a):

Difference between High Pass and Low Pass Filter

The major difference between high pass and low pass filter is the range of frequency which they pass. If we talk about high pass filter, so it is a circuit which allows the high frequency to pass through it while it will block low frequencies. On the contrary, low pass filter is an electronic circuit which allows the low frequency to pass through it and blocks the high-frequency signal.
Comparison Chart

PARAMETERS	HIGH PASS FILTER	LOW PASS FILTER
Definition	It is a circuit which allows the frequencies above cut off frequency to pass through it.	It is a circuit which allows the frequency below cut off frequency to pass through it.
Circuit Architecture	It consists of Capacitor followed by a resistor.	It consists of resistor followed by capacitor.
Significance	It is significant when the distortion due to low frequency signal such as noise is to be removed.	It is significant in removing aliasing effect.
Operating Frequency	Higher than the cut off frequency.	Lower than the cut off frequency.
Applications	In audio amplifiers, low noise amplifiers etc.	In communications circuit as anti-aliasing filter.

ANSWER Q5(b):

Definition of Active Filter

Active filters are those filter circuits that are designed using transistor and op-amp as their basic components. Along with these elements circuits of active filters also contain resistor and capacitor, but not inductors.

Definition of Passive Filter

Passive filters are the filter circuits that are formed using only resistor, inductor and capacitor as their major components. As no amplifying element is present in it thus passive filters offer low signal gain.

Basis for Comparison	Active Filter	Passive Filter
Composed of	Active components like op-amp, transistor etc.	Passive components like resistor, inductor and capacitor etc.
Cost	High	Comparatively low.
Circuit complexity	More complex	Less complex than active filter.
Weight	Low	Comparatively bulkier due to presence of inductors.
Q factor	High	Very low in comparison to active filters.
External power supply	Required	Not required
Sensitivity	More sensitive	Comparatively less sensitive.