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Sub: Electronic Circuit Design

Module: Final Exam

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Question 2:

The Hartley Oscillator

The Hartley Oscillator design uses two inductive coils in series with a parallel capacitor to form its resonance tank circuit producing sinusoidal oscillations

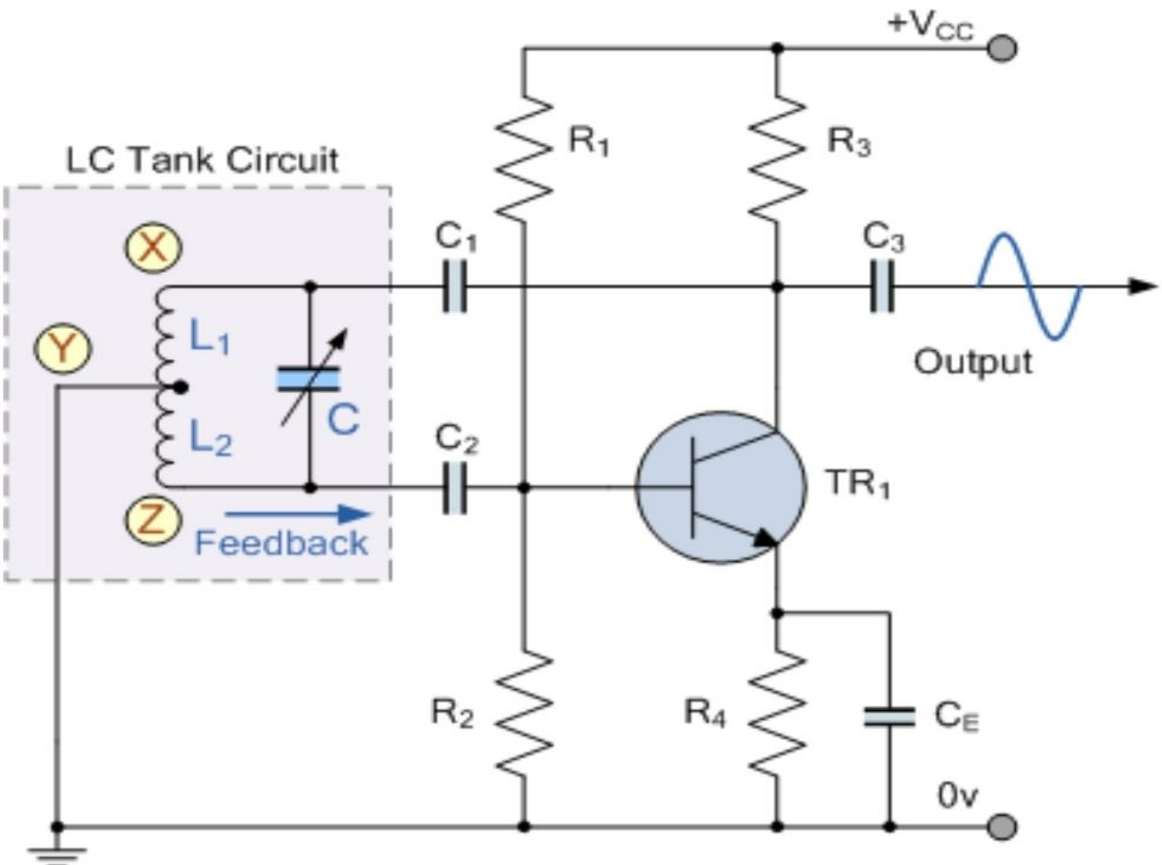
In the Hartley Oscillator the tuned LC circuit is connected between the collector and the base of a transistor amplifier. As far as the oscillatory voltage is concerned, the emitter is connected to a tapping point on the tuned circuit coil.

The feedback part of the tuned LC tank circuit is taken from the centre tap of the inductor coil or even two separate coils in series which are in parallel with a variable capacitor.

The Hartley circuit is often referred to as a split-inductance oscillator because coil L is centre-tapped. In effect, inductance L acts like two separate coils in very close proximity with the current flowing through coil section XY induces a signal into coil section YZ below.

An Hartley Oscillator circuit can be made from any configuration that uses either a single tapped coil (similar to an autotransformer) or a pair of series connected coils in parallel with a single capacitor as shown below

Basic Hartley Oscillator Design



When the circuit is oscillating, the voltage at point X (collector), relative to point Y (emitter), is 180^{o} out-of-phase with the voltage at point Z (base) relative to point Y. At the frequency of oscillation, the impedance of the Collector load is resistive and an increase in Base voltage causes a decrease in the Collector voltage.

Thus there is a 180^{o} phase change in the voltage between the Base and Collector and this along with the original 180^{o} phase shift in the feedback loop provides the correct phase relationship of positive feedback for oscillations to be maintained.

The amount of feedback depends upon the position of the “tapping point” of the inductor. If this is moved nearer to the collector the amount of feedback is increased, but the output taken between the Collector and earth is reduced and vice versa. Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitors act as DC-blocking capacitors.

The Hartley Oscillator Summary

Then to summarise, the Hartley oscillator consists of a parallel LC resonator tank circuit whose feedback is achieved by way of an inductive divider. Like most oscillator circuits, the Hartley oscillator exists in several forms, with the most common form being the transistor circuit above.

This *Hartley Oscillator* configuration has a tuned tank circuit with its resonant coil tapped to feed a fraction of the output signal back to the emitter of the transistor. Since the output of the transistors emitter is always “in-phase” with the output at the collector, this feedback signal is positive. The oscillating frequency which is a sine-wave voltage is determined by the resonance frequency of the tank circuit.

The Colpitts Oscillator

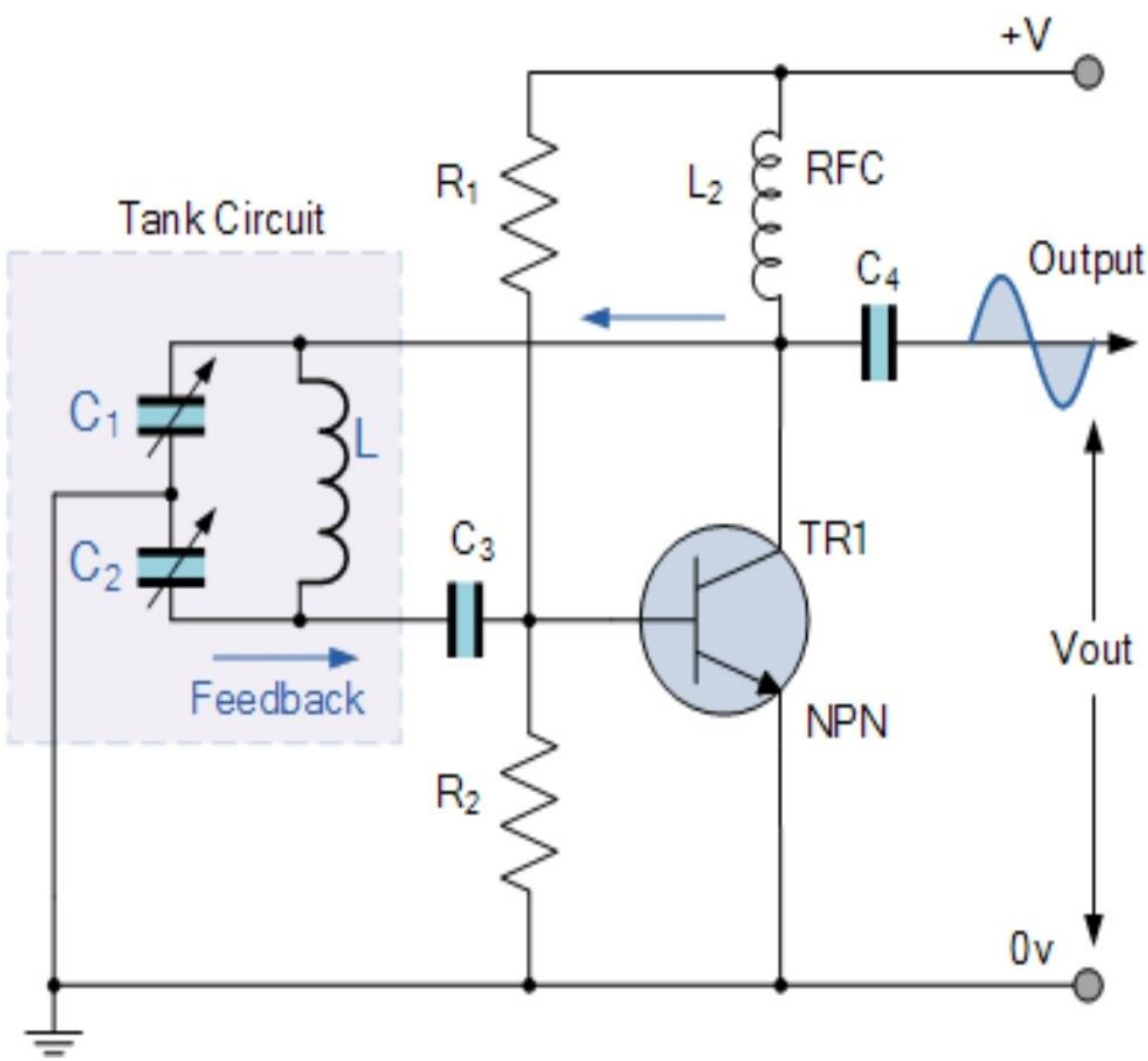
The Colpitts Oscillator design uses two centre-tapped capacitors in series with a parallel inductor to form its resonance tank circuit producing sinusoidal oscillations

The Colpitts oscillator uses a capacitive voltage divider network as its feedback source. The two capacitors, C1 and C2 are placed across a single common inductor, L as shown. Then C1, C2 and L form the tuned tank circuit with the condition for oscillations being: $X_{C1} + X_{C2} = X_L$, the same as for the Hartley oscillator circuit.

The advantage of this type of capacitive circuit configuration is that with less self and mutual inductance within the tank circuit, frequency stability of the oscillator is improved along with a more simple design.

As with the Hartley oscillator, the Colpitts oscillator uses a single stage bipolar transistor amplifier as the gain element which produces a sinusoidal output. Consider the circuit below.

Basic Colpitts Oscillator Circuit



The emitter terminal of the transistor is effectively connected to the junction of the two capacitors, C1 and C2 which are connected in series and act as a simple voltage divider. When the power supply is firstly applied, capacitors C1 and C2 charge up and then discharge through the coil L. The oscillations across the capacitors are applied to the base-emitter junction and appear in the amplified at the collector output.

Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the additional capacitors act as a DC-blocking bypass capacitors. A radio-frequency choke (RFC) is used in the collector circuit to provide a high reactance (ideally open circuit) at the frequency of oscillation, (fr) and a low resistance at DC to help start the oscillations.

The required external phase shift is obtained in a similar manner to that in the Hartley oscillator circuit with the required positive feedback obtained for sustained undamped oscillations. The amount of feedback is determined by the ratio of C1 and C2. These two capacitances are generally "ganged" together to provide a constant amount of feedback so that as one is adjusted the other automatically follows.

Colpitts Oscillator Summary

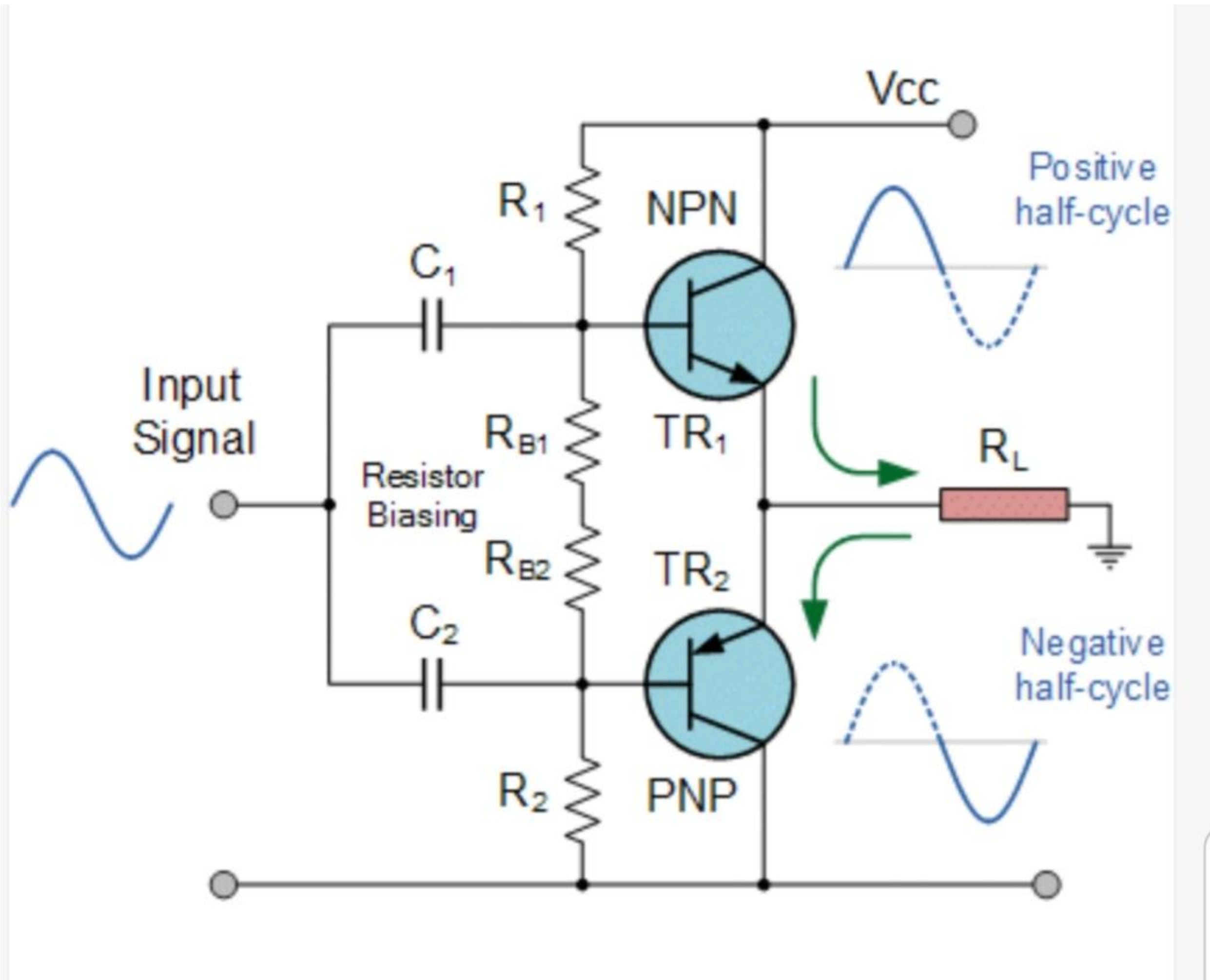
Then to summarise, the **Colpitts Oscillator** consists of a parallel LC resonator tank circuit whose feedback is achieved by way of a capacitive divider. Like most oscillator circuits, the Colpitts oscillator exists in several forms, with the most common form being similar to the transistor circuit above.

The centre tapping of the tank sub-circuit is made at the junction of a "capacitive voltage divider" network to feed a fraction of the output signal back to the emitter of the transistor. The two capacitors in series produce a 180^o phase shift which is inverted by another 180^o to produce the required positive feedback. The oscillating frequency which is a purer sine-wave voltage is determined by the resonance frequency of the tank circuit.

Question:3(a)

Class B Amplifier

Class-B Amplifiers use two or more transistors biased in such a way so that each transistor only conducts during one half cycle of the input waveform



[redacted]

To improve the full power efficiency of the previous Class A amplifier by reducing the wasted power in the form of heat, it is possible to design the power amplifier circuit with two transistors in its output stage producing what is commonly termed as a **Class B Amplifier** also known as a **push-pull amplifier** configuration.

Push-pull amplifiers use two “complementary” or matching transistors, one being an NPN-type and the other being a PNP-type with both power transistors receiving the same input signal together that is equal in magnitude, but in opposite phase to each other. This results in one transistor only amplifying one half or 180° of the input waveform cycle while the other transistor amplifies the other half or remaining 180° of the input waveform cycle with the resulting “two-halves” being put back together again at the output terminal.

Then the conduction angle for this type of amplifier circuit is only 180° or 50% of the input signal. This pushing and pulling effect of the alternating half cycles by the transistors gives this type of circuit its amusing “push-pull” name, but are more generally known as the **Class B Amplifier**

Idea for class B Amplifier

The **Class B Amplifier** has the big advantage over their Class A amplifier cousins in that no current flows through the transistors when they are in their quiescent state (ie, with no input signal), therefore no power is dissipated in the output transistors or transformer when there is no signal present unlike Class A amplifier stages that require significant base bias thereby dissipating lots of heat – even with no input signal present.

So the overall conversion efficiency (η) of the amplifier is greater than that of the equivalent Class A with efficiencies reaching as high as 70% possible resulting in nearly all modern types of push-pull amplifiers operated in this Class B mode.

Question 3(b)

Types of Voltage Regulators

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.

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

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.

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.

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.

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.

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/Step Down (Boost/Buck)

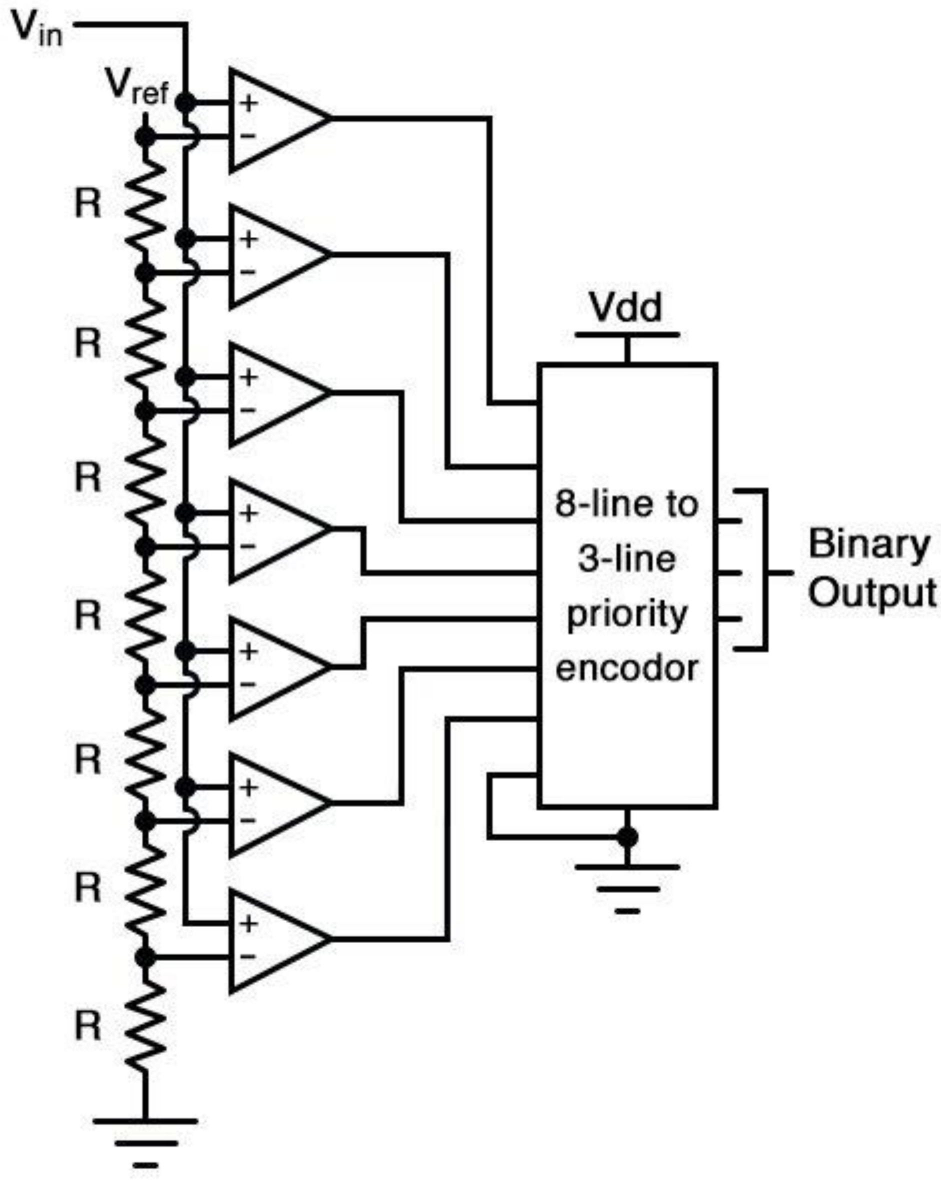
It is also called Voltage inverter. By using this configuration, it is possible to raise, lower or invert the voltage as per the requirement.

- 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

Question:4

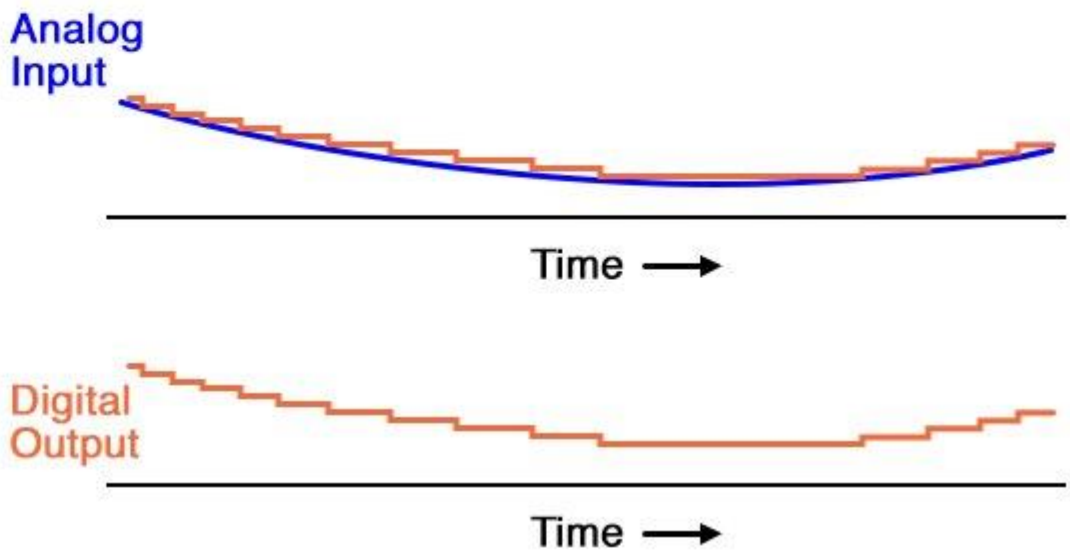
1.Flash ADC

Also called the *parallel* A/D converter, this circuit is the simplest to understand. It is formed of a series of comparators, each one comparing the input signal to a unique reference voltage. The comparator outputs connect to the inputs of a priority encoder circuit, which then produces a binary output. The following illustration shows a 3-bit flash ADC circuit:

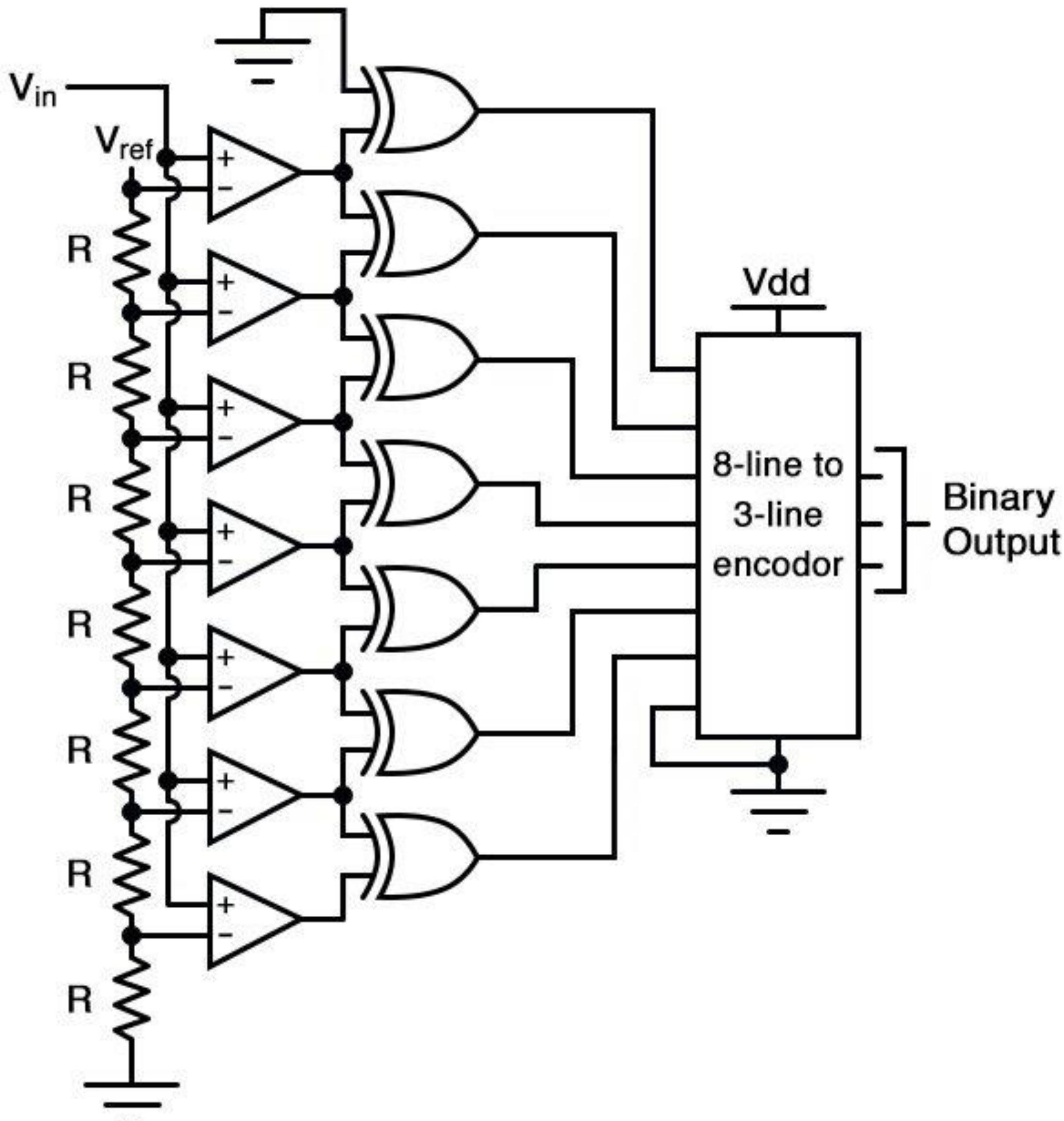


V_{ref} is a stable reference voltage provided by a precision voltage regulator as part of the converter circuit, not shown in the schematic. As the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state. The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs.

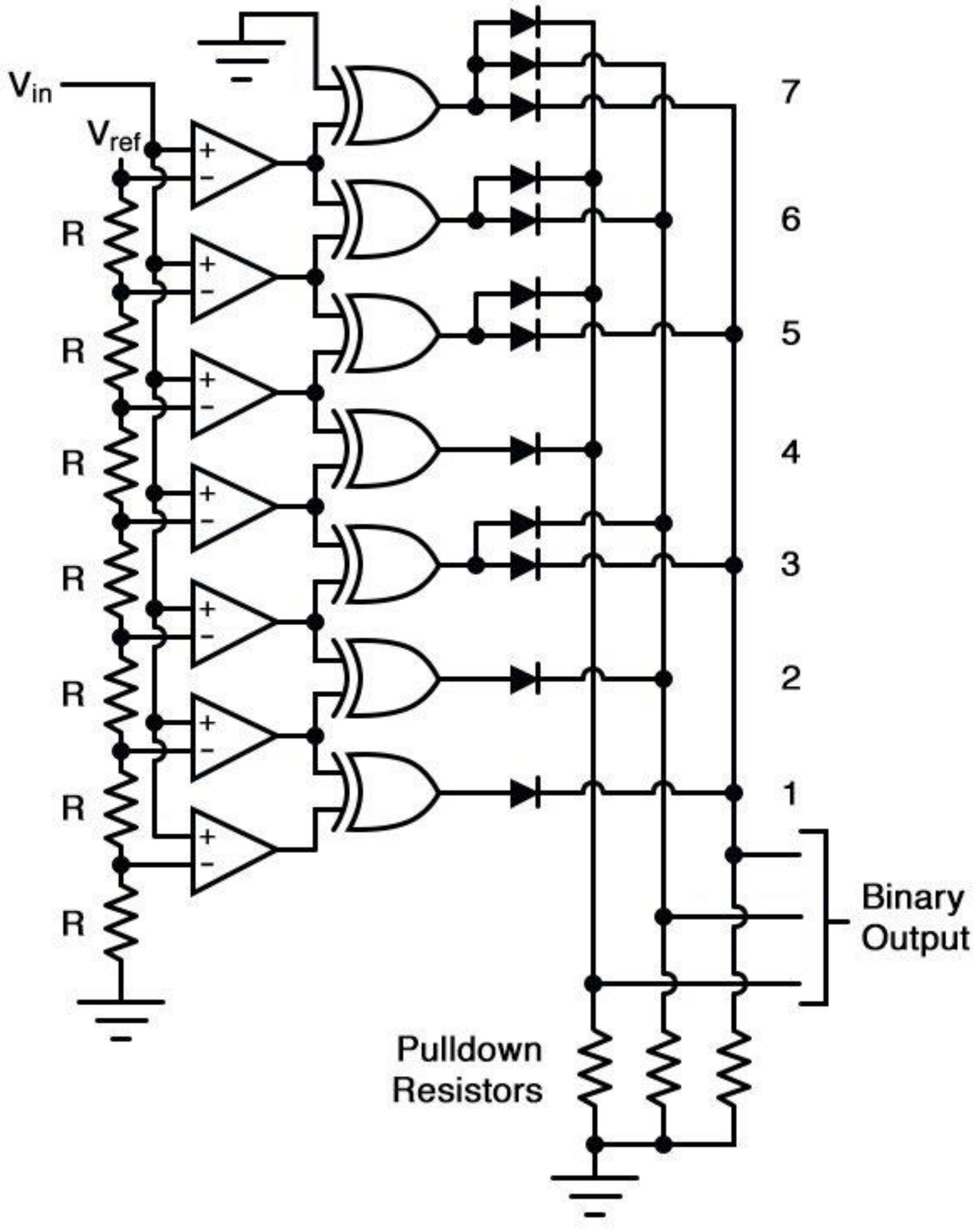
When operated, the flash ADC produces an output that looks something like this:



For this particular application, a regular priority encoder with all its inherent complexity isn't necessary. Due to the nature of the sequential comparator output states (each comparator saturating "high" in sequence from lowest to highest), the same "highest-order-input selection" effect may be realized through a set of Exclusive Or gate allowing the use of a simpler, non-priority encoder:



And, of course, the encoder circuit itself can be made from a matrix of diode demonstrating just how simply this converter design may be constructed:



Not only is the flash converter the simplest in terms of operational theory, but it is the most efficient of the ADC technologies in terms of speed, being limited only in comparator and gate propagation delays. Unfortunately, it is the most component-intensive for any given number of output bits.

This three-bit flash ADC requires seven comparators. A four-bit version would require 15 comparators. With each additional output bit, the number of required comparators doubles.

Considering that eight bits is generally considered the minimum necessary for any practical ADC (255 comparators needed!), the flash methodology quickly shows its weakness. An additional advantage of the flash converter, often overlooked, is the ability for it to produce a non-linear output.

With equal-value resistors in the reference voltage divider network, each successive binary count represents the same amount of analog signal increase, providing a proportional response. For special applications, however, the resistor values in the divider network may be made non-equal.

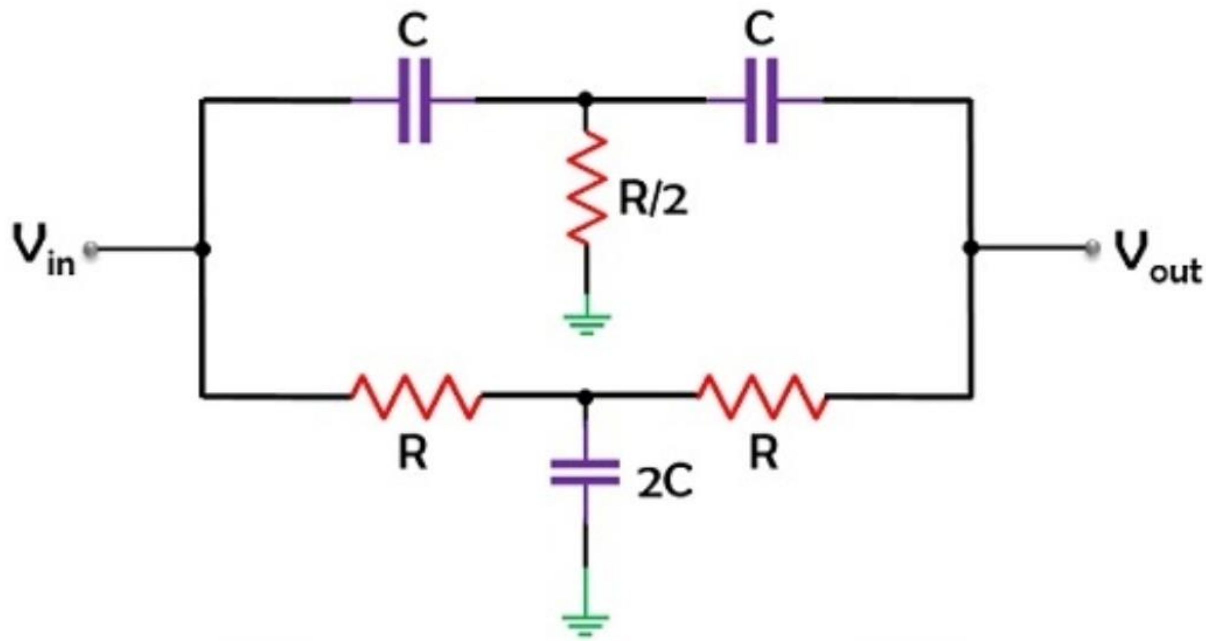
This gives the ADC a custom, nonlinear response to the analog input signal. No other ADC design is able to grant this signal-conditioning behavior with just a few component value changes.

Question:5(a)

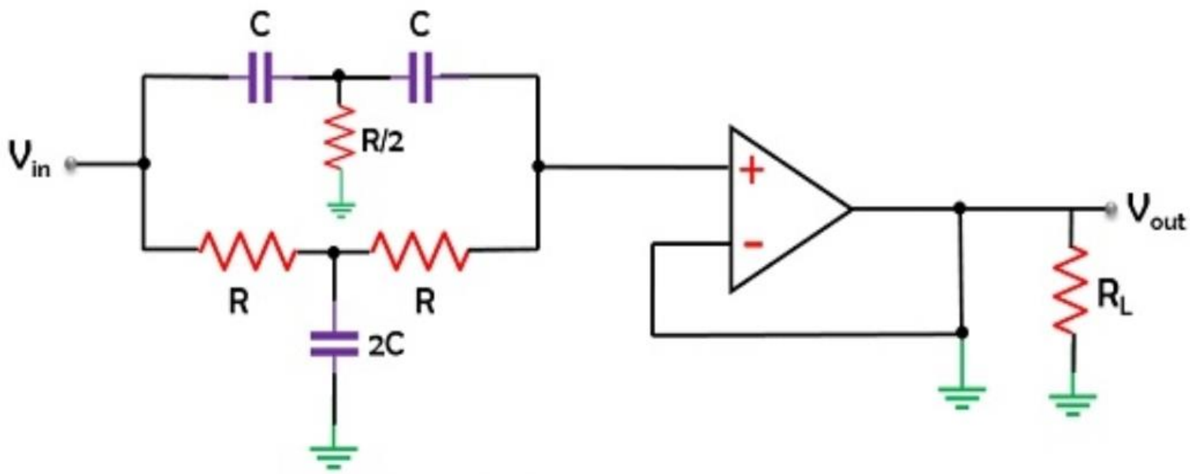
Difference Between Active and Passive Filter

The major difference between active and passive filter is that an active filter uses active components like **transistor and op-amp** for the filtering of electronic signals. As against, a passive filter uses passive components like **resistor, inductor and capacitor** to generate a signal of a particular band.

Another major difference between the two is that an active filter needs an external source of power for its operation. While no external source is needed in case of passive filters



Circuit of Passive Filter



Circuit of Active Filter

Question:5(b)

Difference between active filters and passive filters

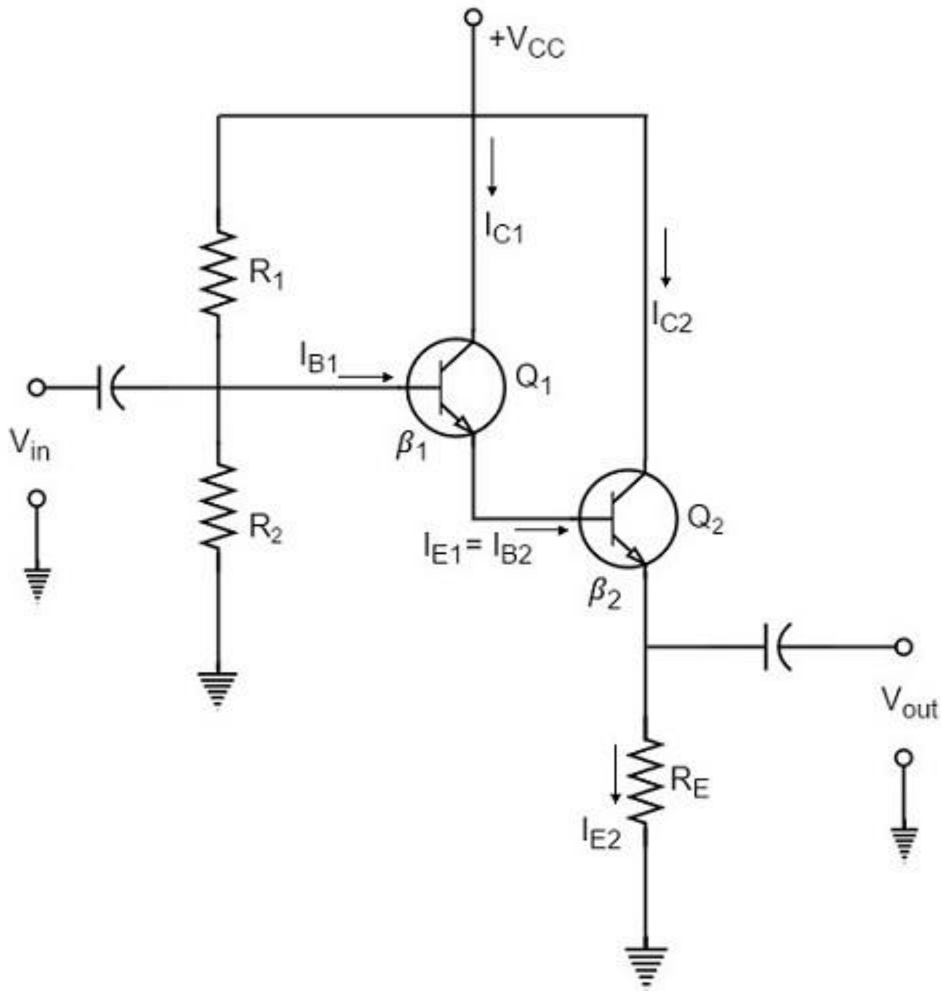
- Active filters need outside sources for their operation, while passive filters do not need any outside source for their operation.
- Active filters have the capability of amplifying filter output, while passive filters consume the power of the input signal and cannot amplify the output signal.
- Passive filters are designed using capacitors, resistors, and inductors, while active filters do not use inductors in their design. This results in a compact design of active filters as compared to passive filters.
- Active filters are costlier than passive filters due to extra added active elements and external power required to operate an active element. However, passive filters can also be costlier if high accuracy and compactness are required.
- Active filters have bandwidth limitations due to the involvement of active elements, which operate properly in only specific frequency ranges. Outside these frequency ranges, their performance degrades, resulting in an unreliable response of the active filter at higher frequencies. However, passive filters have no such limitations and output is reliable at even very high frequencies.
- Due to the involvement of fewer elements, passive filters are less complex and easy to design as compared to the equivalent active filters.

Question:1(a)

Darlington

The term Darlington transistor is named from its inventor's name Sidney Darlington. The Darlington transistor is made up of two PNP or NPN BJTs by connecting together. The emitter of the PNP transistor is connected to the base of the other PNP transistor to create a sensitive transistor with high current gain used in many applications where switching or amplification is crucial. The transistor pair in the Darlington transistor can be formed with two separately connected BJTs. As we know that, transistor is used a switch as well as an amplifier, the BJT can be used to operate as an ON/OFF switch. Darlington Transistor

In order to achieve some increase in the overall values of circuit current gain and input impedance, two transistors are connected as shown in the following circuit diagram, which is known as **Darlington** configuration.



As shown in the above figure, the emitter of the first transistor is connected to the base of the second transistor. The collector terminals of both the transistors are connected together.

Biasing Analysis

Because of this type of connection, the emitter current of the first transistor will also be the base current of the second transistor. Therefore, the current gain of the pair is equal to the product of individual current gains i.e.,

$$\beta=\beta_1\beta_2$$

A high current gain is generally achieved with a minimum number of components.

As two transistors are used here, two V_{BE} drops are to be considered. The biasing analysis is otherwise similar for one transistor.

Voltage across R_2,

$$V_2=V_{CC}R_1+R_2\times R_2$$

Voltage across R_E,

$$V_E=V_2-2V_{BE}$$

Current through R_E,

$$I_{E2}=V_2-2V_{BE}R_E$$

Since the transistors are directly coupled,

$$I_{E1}=I_{B2}$$

Now

$$I_{B2}=I_{E2}\beta_2$$

Therefore

$$I_{E1}=I_{E2}\beta_2$$

Which means

$$I_{E1}=I_{E1}\beta_2$$

We have

$$I_{E1}=\beta_1 I_{B1} \text{ since } I_{E1}\cong I_{C1}$$

Hence, as

$$I_{E2}=I_{E1}\beta_2$$

We can write

$$I_{E2}=\beta_1\beta_2 I_{B1}$$

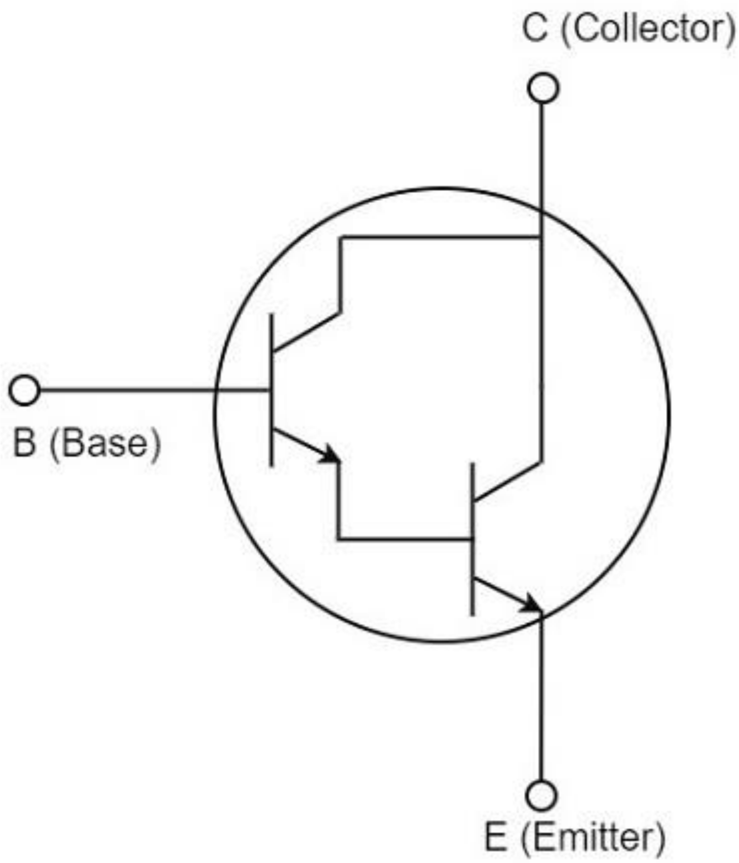
Therefore, Current Gain can be given as

$$\beta=I_{E2}I_{B1}=\beta_1\beta_2 I_{B1}I_{B1}=\beta_1\beta_2$$

Input impedance of the darling ton amplifier is

$$Z_{in}=\beta_1\beta_2 R_E \text{..... neglecting } r'_e$$

In practice, these two transistors are placed in a single transistor housing and the three terminals are taken out of the housing as shown in the following figure.



This three terminal device can be called as **Darling ton transistor**. The darling ton transistor acts like a single transistor that has high current gain and high input impedance.

Characteristics

The following are the important characteristics of Darling ton amplifier.

- Extremely high input impedance (MΩ).
- Extremely high current gain (several thousands).
- Extremely low output impedance (a few Ω).

Question 1(b)

Q. 1 (b)

Sol: Line Reg $= \frac{0.062}{4.5} \times 100\% = 1.377\%$

&

Line Reg $= \frac{0.062}{\frac{40}{4.5}} \times 100\% = 0.034\%$