UNIT-3

1. What is feedback in electronics?

- In electronics, **feedback** refers to the process of taking a portion of the output signal of a circuit and feeding it back to the input. This feedback can be either positive or negative.

2. What is the difference between positive and negative feedback?

- **Positive Feedback:**
    - A portion of the output signal is fed back **in phase** with the input signal.
    - This can lead to **instability and oscillations**.
    - Used in oscillators to generate sustained oscillations.
- **Negative Feedback:**
    - A portion of the output signal is fed back **180 degrees out of phase** with the input signal.
    - This improves amplifier performance by:
        - **Reducing gain variations:** Makes the amplifier less sensitive to changes in component values or temperature.
        - **Increasing bandwidth:** Allows the amplifier to amplify a wider range of frequencies.
        - **Reducing distortion:** Minimizes nonlinear distortion in the output signal.
        - **Improving linearity:** Makes the amplifier's response more linear.
        - **Increasing input and output impedance:** Can improve the matching of the amplifier to the source and load.

3. How does negative feedback affect the gain of an amplifier?

- Negative feedback **reduces the overall gain** of the amplifier.
- The closed-loop gain (with feedback) is significantly lower than the open-loop gain (without feedback).

4. How does negative feedback affect the bandwidth of an amplifier?

- Negative feedback **increases the bandwidth** of an amplifier. This means the amplifier can amplify a wider range of frequencies with minimal distortion.

5. How does negative feedback affect the input impedance of an amplifier?

- Negative feedback generally **increases the input impedance** of an amplifier.

6. How does negative feedback affect the output impedance of an amplifier?

- Negative feedback generally **decreases the output impedance** of an amplifier.

7. What are the main applications of negative feedback in amplifiers?

- **Improving stability:** Reduces the tendency of amplifiers to oscillate, making them more stable.
- **Reducing distortion:** Minimizes nonlinear distortion in the amplifier output.

- **Increasing linearity:** Makes the amplifier's response more linear, resulting in a more accurate reproduction of the input signal.
- **Improving impedance matching:** Improves both input and output impedance, leading to better power transfer and reduced signal loss.

8. What is an oscillator?

- An oscillator is an electronic circuit that generates a continuous, periodic output signal without any external input signal.

9. What are the conditions for sustained oscillations? (Barkhausen Criterion)

- For sustained oscillations in an oscillator circuit, two conditions must be met:
  - **Loop Gain:** The loop gain (product of the amplifier gain and the feedback factor) must be equal to or greater than unity ($|A\beta| \geq 1$).
  - **Phase Shift:** The total phase shift around the feedback loop must be 0 degrees or an integer multiple of 360 degrees.

10. What is an RC phase shift oscillator?

- An RC phase shift oscillator uses a series of RC stages (resistors and capacitors) to provide the necessary phase shift (180 degrees) for oscillation.
- The amplifier provides an additional 180-degree phase shift, meeting the Barkhausen criteria.

11. What is a Wien bridge oscillator?

- The Wien bridge oscillator uses a bridge circuit consisting of two resistors and two capacitors.
- At the oscillation frequency, the bridge is balanced, and the output of the amplifier is fed back to the input.

12. What are LC oscillators?

- LC oscillators use a combination of inductors (L) and capacitors (C) in the feedback network to determine the oscillation frequency.
- Examples include Hartley oscillator and Colpitts oscillator.

13. What is a crystal oscillator?

- A crystal oscillator utilizes the piezoelectric property of a quartz crystal.
- When a voltage is applied to the crystal, it vibrates at its resonant frequency.
- This mechanical vibration is converted back into an electrical signal by the crystal, which is then amplified and fed back to the crystal, sustaining oscillations.

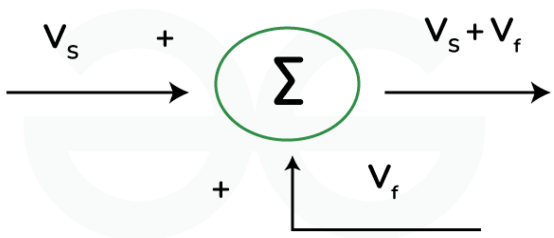
14. What are the advantages of crystal oscillators?

- **High frequency stability:** Very precise and stable frequency.
- **Low phase noise:** Minimal fluctuations in the output signal.
- **Compact size:** Relatively small and easy to integrate.

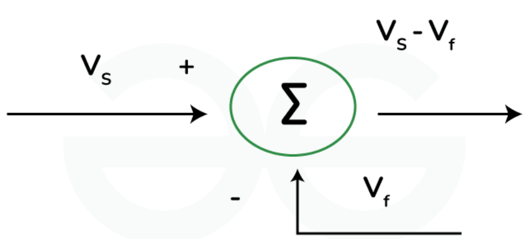
Long Answer Questions

1. Explain the concept of feedback in electronic circuits. Discuss the different types of feedback and their effects on amplifier performance.

- **Feedback:** In electronics, feedback refers to the process of taking a portion of the output signal of a circuit and feeding it back to the input.
- **Types of Feedback:**
  - **Positive Feedback:**
    - A portion of the output signal is fed back in phase with the input signal.
    - Can lead to instability and oscillations.



  - **Negative Feedback:**
    - A portion of the output signal is fed back 180 degrees out of phase with the input signal.



Improves amplifier performance by:

- Reducing gain variations
- Increasing bandwidth
- Reducing distortion
- Improving linearity
- Increasing input and output impedance

2. Derive the expressions for the gain, bandwidth, input impedance, and output impedance of an amplifier with negative feedback. Discuss the significance of these modifications.

- **Gain with Negative Feedback:**
  - $\mathbf{A_f = A / (1 + A\beta)}$
    - Where:
      - $\mathbf{A_f}$ is the closed-loop gain
      - A is the open-loop gain
      - β is the feedback factor

- **Bandwidth with Negative Feedback:**
  - Bandwidth increases with negative feedback.
- **Input Impedance with Negative Feedback:**
  - $\mathbf{Z_{in(f)} = Z_{in} / (1 + A\beta)}$
    - Where:
      - $\mathbf{Z_{in(f)}}$ is the input impedance with feedback
      - $\mathbf{Z_{in}}$ is the input impedance without feedback
- **Output Impedance with Negative Feedback:**
  - $\mathbf{Z_{out(f)} = Z_{out} / (1 + A\beta)}$
    - Where:
      - $\mathbf{Z_{out(f)}}$ is the output impedance with feedback
      - $\mathbf{Z_{out}}$ is the output impedance without feedback
- **Significance of Modifications:**
  - **Reduced Gain:** While the overall gain decreases, the gain becomes more stable and less sensitive to variations in component values or temperature.
  - **Increased Bandwidth:** This improves the amplifier's ability to amplify higher frequencies.
  - **Improved Input and Output Impedance:** These modifications can better match the amplifier to the source and load, respectively, leading to better power transfer and reduced distortion.

3. Discuss the various applications of negative feedback in amplifiers, such as improving stability, reducing distortion, and increasing linearity.

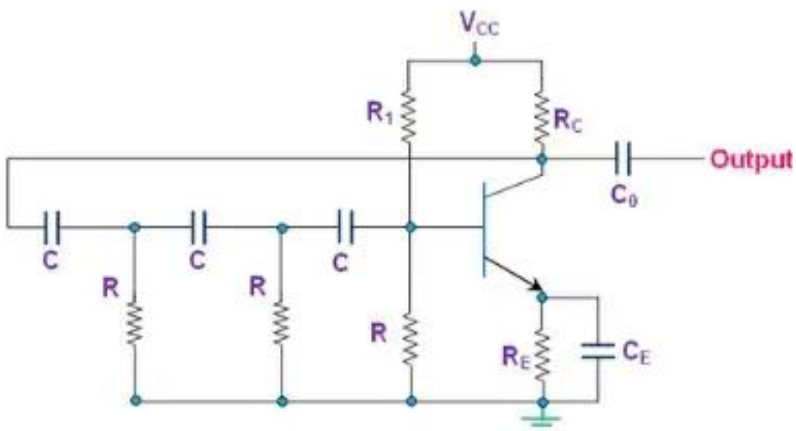
- **Improving Stability:** Negative feedback reduces the tendency of amplifiers to oscillate, making them more stable.
- **Reducing Distortion:** By reducing the gain and increasing linearity, negative feedback minimizes nonlinear distortion in the amplifier output.
- **Increasing Linearity:** Negative feedback helps to linearize the amplifier's response, resulting in a more accurate reproduction of the input signal.
- **Improving Impedance Matching:** As mentioned earlier, negative feedback can improve both input and output impedance, leading to better power transfer and reduced signal loss.

4. Explain the Barkhausen criteria for sustained oscillations. Discuss the factors that determine the frequency of oscillation in an oscillator circuit.

- **Barkhausen Criteria:** For sustained oscillations in an oscillator circuit, two conditions must be met:
  - **Loop Gain:** The loop gain (product of the amplifier gain and the feedback factor) must be equal to or greater than unity ($|A\beta| \geq 1$).
  - **Phase Shift:** The total phase shift around the feedback loop must be 0 degrees or an integer multiple of 360 degrees.
- **Factors Determining Oscillation Frequency:**
  - **Component Values:** The values of resistors, capacitors, inductors, and other components in the oscillator circuit determine the frequency of oscillation.
  - **Feedback Network:** The design of the feedback network plays a crucial role in setting the oscillation frequency.

5. Analyze the operation of an RC phase shift oscillator. Derive the expression for the frequency of oscillation.

- **Operation:**
    - An RC phase shift oscillator uses a series of RC stages to provide the necessary phase shift (180 degrees) for oscillation.
    - The amplifier provides an additional 180-degree phase shift, meeting the Barkhausen criteria.



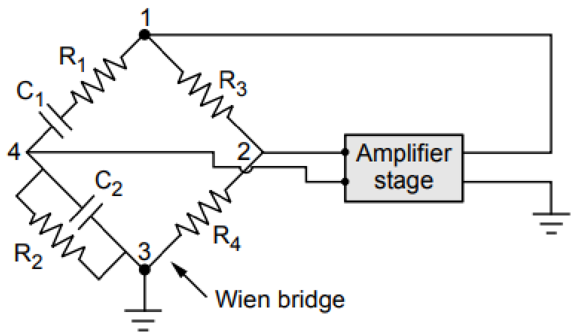
Here the collector resistor RC limits the collector current of the transistor, resistors R_1 and R (nearest to the transistor) form the voltage divider network while the emitter resistor R_E improves the stability. Next, the capacitors C_E and C_o are the emitter by-pass capacitor and the output DC decoupling capacitor, respectively. Further, the circuit also shows three RC networks employed in the feedback path.

This arrangement causes the output waveform to shift by 180^o during its course of travel from output terminal to the base of the transistor. Next, this signal will be shifted again by 180^o by the transistor in the circuit due to the fact that the phase-difference between the input and the output will be 180^o in the case of common emitter configuration. This makes the net phase-difference to be 360^o, satisfying the phase-difference condition.

- **Frequency of Oscillation:**
    - **$f = 1 / (2\pi RC\sqrt{6})$**
        - Where:
            - f is the frequency of oscillation
            - R is the resistance of each RC stage
            - C is the capacitance of each RC stage

6. Explain the working principle of a Wien bridge oscillator. Discuss the methods used to ensure stable oscillations.

- **Working Principle:**
    - The Wien bridge oscillator uses a bridge circuit consisting of two resistors and two capacitors.
    - At the oscillation frequency, the bridge is balanced, and the output of the amplifier is fed back to the input.



<u>Basic Circuit of a Wien bridge Oscillator</u>

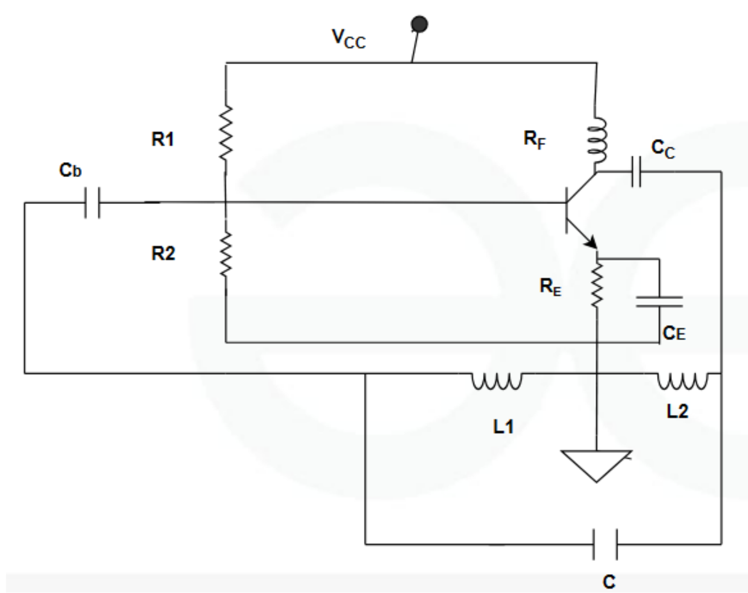
- **Methods to Ensure Stable Oscillations:**
  - **Automatic Gain Control (AGC):** A thermistor or a light-dependent resistor (LDR) is used to adjust the amplifier's gain to maintain stable oscillations.
  - **Nonlinear Feedback:** A nonlinear element (like a lamp) is used in the feedback path to stabilize the amplitude of oscillations.

7. Discuss the different types of LC oscillators (e.g., Hartley, Colpitts) and their applications.

Hartley Oscillator:

- Uses a tapped inductor in the feedback network.
- Applications: Radio frequency (RF) oscillators, local oscillators in receivers.

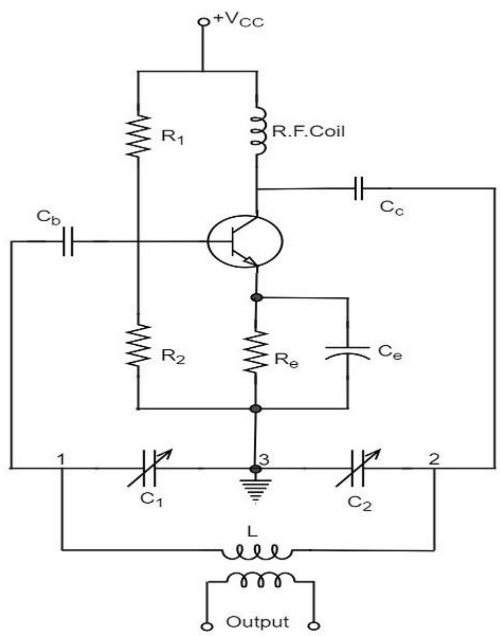
- Capacitor C starts charging, when the supply is given.
- The capacitor starts discharging, once it is fully charged and the charge stored in the form of electrostatic field energy flows to inductor L2 where it is stored in the form of magnetic field.



- There will be no current flow to L2, (when the charger is fully discharged) which decreases current value in L2. Due to this there is decrease in magnetic field strength which results in the vanishing of magnetic field inside the inductor. This variation induces an emf i.e. back emf.
- Due to this back emf the capacitor starts charging again and the magnetic field in L2 gets converted into electrostatic field again. This leads to the oscillations across L2. These oscillations (or distortions) and output are in phase.
- Therefore, oscillations from L2 are transferred to L1 but undergoes a phase shift of 180° (due to the ground provided between L1 and L2).
- This is given to the Bipolar junction transistor where phase shift or 180° again takes place (Thus total phase shift of 360°).
- Hence, the condition for an amplifier to work as an oscillator is satisfied in accordance with Barkhausen criteria.

Colpitts Oscillator:

  - Uses a tapped capacitor in the feedback network.
  - Applications: Similar to Hartley oscillators, often used in RF circuits.



When the collector supply is given, a transient current is produced in the oscillatory or tank circuit. The oscillatory current in the tank circuit produces a.c. voltage across C_1 which are applied to the base emitter junction and appear in the amplified form in the collector circuit and supply losses to the tank circuit.

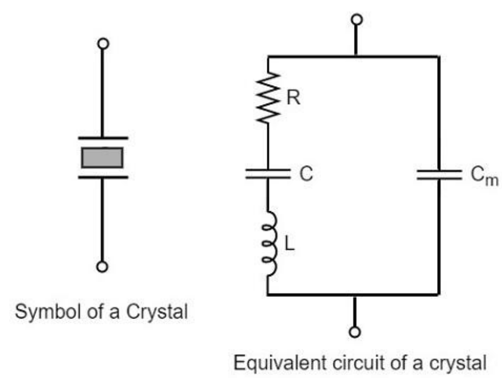
If terminal 1 is at positive potential with respect to terminal 3 at any instant, then terminal 2 will be at negative potential with respect to 3 at that instant because terminal 3 is grounded. Therefore, points 1 and 2 are out of phase by 180^o.

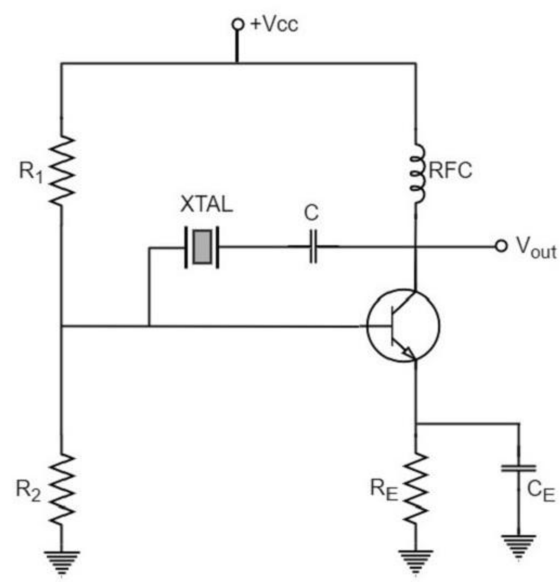
As the CE configured transistor provides 180^o phase shift, it makes 360^o phase shift between the input and output voltages. Hence, feedback is properly phased to produce continuous Undamped oscillations. When the **loop gain |βA| of the amplifier is greater than one, oscillations are sustained** in the circuit.

- **Crystal Oscillator:**
  - Uses a piezoelectric crystal (like quartz) as the frequency-determining element.
  - Highly stable frequency, low phase noise.
  - Applications: Clocks in computers, communication systems, and precision timing applications.

8. Explain the principle of operation of a crystal oscillator. Discuss its advantages and disadvantages compared to other types of oscillators.

- **Principle of Operation:**
  - A crystal oscillator utilizes the piezoelectric property of a quartz crystal.
  - When a voltage is applied to the crystal, it vibrates at its resonant frequency.
  - This mechanical vibration is converted back into an electrical signal by the crystal, which is then amplified and fed back to the crystal, sustaining oscillations.





<u>Crystal Oscillator</u>

In this circuit, the crystal is connected as a series element in the feedback path from collector to the base. The resistors R_1, R_2 and R_E provide a voltage-divider stabilized d.c. bias circuit. The capacitor C_E provides a.c. bypass of the emitter resistor and RFC (radio frequency choke) coil provides for d.c. bias while decoupling any a.c. signal on the power lines from affecting the output signal. The coupling capacitor C has negligible impedance at the circuit operating frequency. But it blocks any d.c. between collector and base.

The circuit frequency of oscillation is set by the series resonant frequency of the crystal and its value is given by the relation,

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

It may be noted that the changes in supply voltage, transistor device parameters etc. have no effect on the circuit operating frequency, which is held stabilized by the crystal.

- **Advantages:**
    - High frequency stability
    - Low phase noise
    - Compact size
- **Disadvantages:**
    - Limited frequency range
    - Can be more expensive than other types of oscillators.