Electronic Basics #17: Oscillators || RC, LC, Crystal

Introduction to Oscillators

An **oscillator** is an electronic circuit that generates a **continuous, periodic waveform** without requiring an external input signal. It converts **DC power** into an **AC signal** and is used in applications such as **timing circuits, communication systems, frequency generation, and signal processing**.

Oscillators are broadly classified into:

- **Linear (Harmonic) Oscillators** – Use feedback networks to generate **sine waves** (e.g., LC, RC, and crystal oscillators).
- **Relaxation Oscillators** – Use **charging and discharging** of components to produce **non-sinusoidal waveforms**, such as rectangular or triangular waves.

RC Oscillators

RC oscillators use a **resistor-capacitor (RC) network** for frequency determination and are typically used for **low-frequency applications** (up to a few MHz).

- **Working Principle**:
    - The capacitor **charges and discharges** through the resistor, generating a phase shift.
    - A feedback amplifier (e.g., an **op-amp or transistor**) sustains the oscillations.
- **Common Types**:
    - **Phase Shift Oscillator** – Uses three RC sections to produce a **180° phase shift** for feedback.
    - **Wien Bridge Oscillator** – Provides a **stable sine wave** output, commonly used in audio applications.

The **frequency** of an RC oscillator is given by:

$f=12\pi RC$

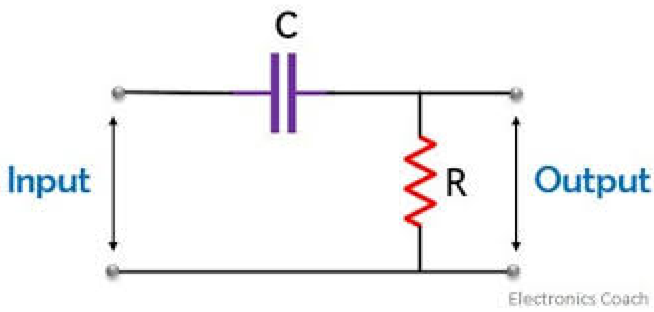

Fig17.1: RC Oscillator Circuit Diagram

LC Oscillators

LC oscillators use an **inductor (L) and capacitor (C) tank circuit** to generate **high-frequency oscillations**. They are widely used in **radio transmitters, receivers, and RF circuits**.

- **Working Principle**:
    - Energy oscillates between the **magnetic field of the inductor** and the **electric field of the capacitor**.
    - A transistor or amplifier provides **feedback** to maintain oscillations.
- **Common Types**:
    - **Colpitts Oscillator** – Uses a capacitor voltage divider for feedback.
    - **Hartley Oscillator** – Uses an inductor divider for feedback.

The **resonant frequency** is determined by the formula:

fr=12πLC

where:

- L = inductance (H)
- C = capacitance (F)

Problems with LC Oscillators:

- Frequency drift due to **temperature changes**.
- **Parasitic resistance** causes losses, reducing stability.

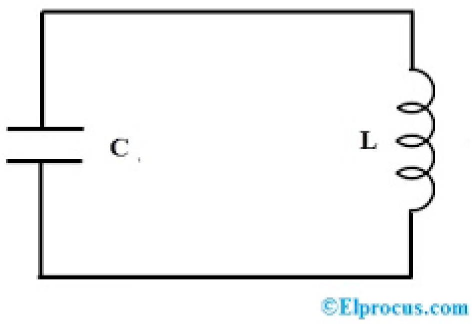

Fig17.2: LC Oscillator Circuit Diagram

Crystal Oscillators

Crystal oscillators use a **quartz crystal** to provide a **highly stable frequency reference**, commonly used in **microcontrollers, computers, and communication systems**.

- **Working Principle**:

- A quartz crystal exhibits **piezoelectric properties**, vibrating at a precise frequency when an electric field is applied.
- It acts as a resonant LC circuit but with extremely high **Q-factor** (quality factor), ensuring minimal frequency drift.

- **Advantages**:
  - **Highly accurate and stable**.
  - **Low power consumption**.

The frequency is given by the same resonant frequency formula:

fr=12πLC

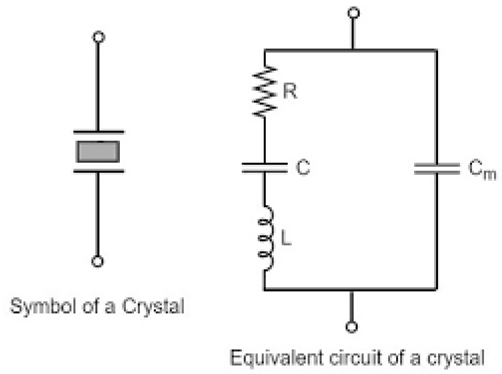

Fig17.3: Crystal Oscillator Circuit Diagram

Relaxation Oscillator & Rectangular Wave Generation

A **relaxation oscillator** generates **non-sinusoidal waveforms** such as **square, rectangular, or triangular waves**.

- **Working Cycle**:
  1. A capacitor **charges** through a resistor until it reaches a threshold.
  2. A switching device (like a transistor or **555 Timer**) quickly **discharges** the capacitor.
  3. The cycle repeats, producing a **rectangular waveform**.
- **Applications**:
  - Clock generators, LED flashers, function generators.

555 Timer IC – Working and Pin Configuration

The **555 Timer IC** is a versatile component used in oscillators, pulse generation, and time delays.

Pin Configuration

1. **GND (Pin 1)** – Ground.
2. **VCC (Pin 8)** – Power supply (4.5V to 15V).
3. **Trigger (Pin 2)** – Starts the timing cycle when voltage falls below 13VCC\frac{1}{3}V_{\text{CC}}.
4. **Output (Pin 3)** – Provides the pulse signal.
5. **Reset (Pin 4)** – Resets the timer when pulled low.
6. **Control Voltage (Pin 5)** – Adjusts threshold voltage (usually left unconnected).
7. **Discharge (Pin 7)** – Controls capacitor discharge in astable mode.
8. **Threshold (Pin 6)** – Ends the timing cycle when voltage exceeds

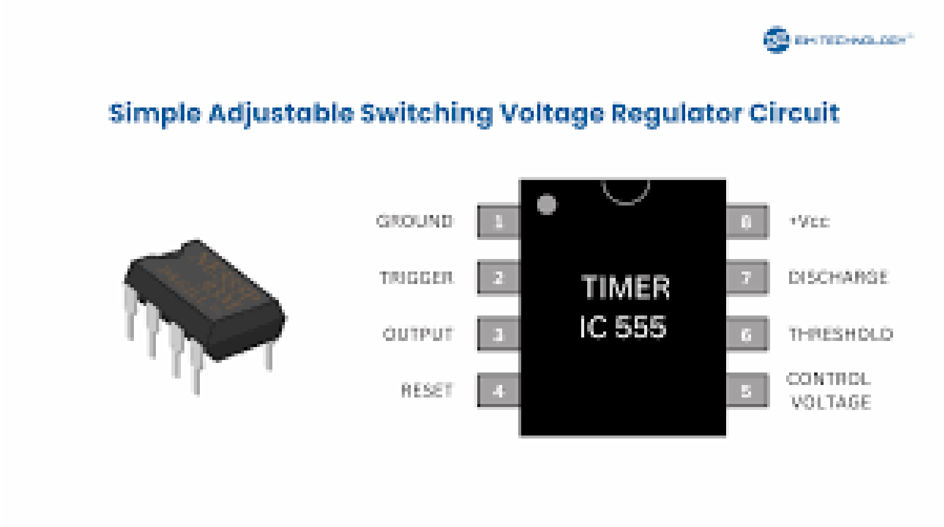

Fig17.4: 555 Timer IC Diagram

Modes of Operation

- **Astable Mode (Oscillator)** – Generates a continuous square wave.
- **Monostable Mode (One-Shot)** – Produces a single pulse.
- **Bistable Mode (Flip-Flop)** – Acts as a latch or switch.

The **frequency in astable mode** is given by:

$f=1.44(R1+2R2)C$

where:

- $R1,R2$= resistors (Ω)
- C = capacitor (F)

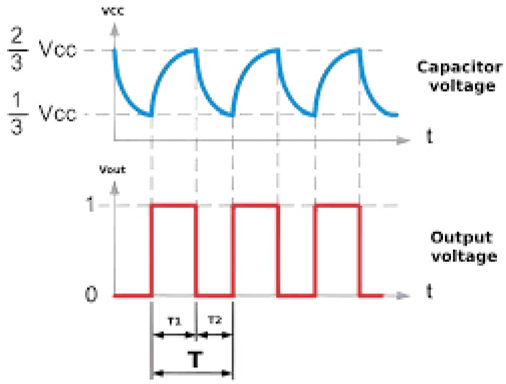

Fig17.5: Waveform in 555 Timer IC

Increasing Frequency Using LC Resonators

To increase the frequency of an oscillator:

- **Decrease Inductance (LL) or Capacitance (CC)** in LC circuits.
- Use **quartz crystals**, which provide **high-frequency stability**.
- Reduce **parasitic losses** with high-quality components.

Problems with High-Frequency Oscillators:

- **Parasitic capacitance** affects performance.
- **Skin effect** causes resistance increase at high frequencies.
- **Temperature variation** affects stability.

Using an Amplifier Transistor to Maintain Oscillations

To **sustain oscillations**, an amplifier circuit is required to compensate for **energy losses**. A **common transistor amplifier** in oscillators:

- **Provides gain** to compensate for losses in the LC circuit.
- **Maintains the feedback loop** to ensure oscillations continue.
- Works in **Class A or Class C mode**, depending on the application.

Example: In a **Colpitts Oscillator**, a **BJT or FET amplifier** amplifies the weak oscillations, ensuring a stable output.

Conclusion

- **Oscillators** are essential in electronics for generating continuous signals.
- **RC oscillators** are suitable for low-frequency applications, while **LC oscillators** are used for high-frequency applications.

- **Crystal oscillators** provide the best frequency stability, ideal for **precision circuits**.
- The **555 Timer IC** is a versatile component for waveform generation.
- **Amplifier circuits** are necessary to sustain oscillations in practical applications.

Would you like additional details on any specific type of oscillator?