Multivibrators: A Comprehensive Study on MUltivibrator.

Introduction to Multivibrators

A multivibrator is a fundamental electronic circuit that generates non-sinusoidal waveforms, primarily square or rectangular pulses. Often referred to as relaxation oscillators or function generators, these circuits are characterized by having two main states and employing regenerative (positive) feedback to rapidly switch between them. This regenerative feedback ensures that once a transition begins, it quickly completes, driving the circuit firmly into one of its stable or quasi-stable states.

Invented by Henri Abraham and Eugene Bloch in 1920, multivibrators were initially built using vacuum tubes. Today, they are ubiquitous in modern electronics, serving as essential building blocks for generating timing signals, clock pulses, and as core components in digital logic circuits and memory elements. Their ability to produce precise pulses makes them indispensable in a wide array of applications, from simple LED flashers to complex microprocessors.

Types of Multivibrators

Multivibrators are broadly classified into three main types based on the stability of their states and how they transition between them: Astable, Monostable, and Bistable.
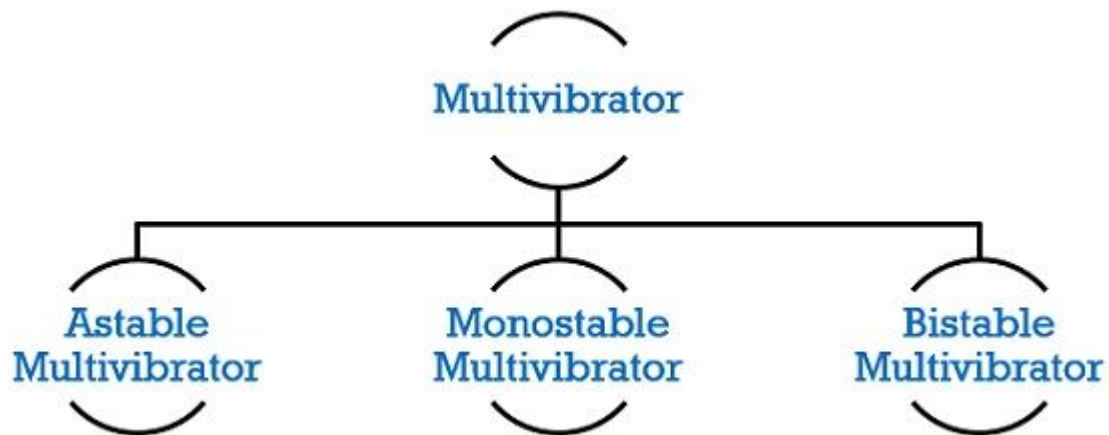
a) Astable Multivibrator (Free Running Multivibrator)

The astable multivibrator is aptly named because it has no stable states. It continuously oscillates between two quasi-stable (temporarily stable) states, generating a repetitive square wave or pulse train output without the need for any external triggering. It is essentially a self-exciting oscillator.

Operation Principle:

The most common implementation uses two cross-coupled active devices, such as BJTs or inverters, along with RC (resistor-capacitor) networks. Consider a basic BJT-based astable multivibrator:

1. When power is applied, due to slight imbalances, one transistor (e.g., Q1) turns ON faster, driving its collector voltage low.

2. This low voltage is coupled through a capacitor (C1) to the base of the other transistor (Q2), forcing Q2 OFF.

3. With Q2 OFF, its collector voltage rises to VCC. This high voltage is coupled through another capacitor (C2) to the base of Q1, reinforcing Q1's ON state (positive feedback).

4. As Q1 remains ON and Q2 OFF, capacitor C1 starts charging, eventually causing the base voltage of Q2 to rise.

5. When Q2's base voltage reaches the turn-on threshold, Q2 rapidly switches ON, causing its collector voltage to drop.

6. This falling voltage is coupled back to the base of Q1 through C2, driving Q1 OFF.

7. The cycle repeats with Q1 OFF and Q2 ON, and capacitor C2 charges until Q1's base voltage rises, causing Q1 to turn back ON.

Circuit Diagram of BJT Astable Multivibrator
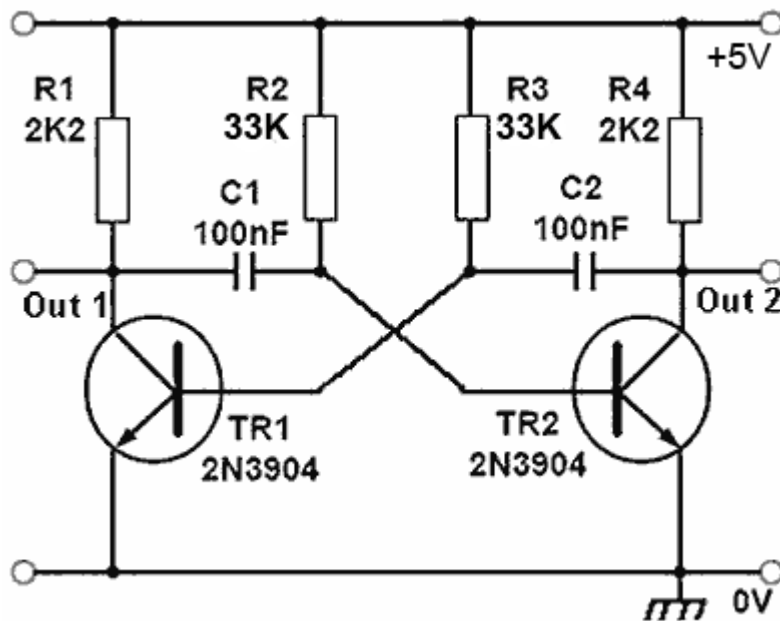
Timing Analysis:

The duration of each state (ON and OFF periods) is determined by the RC time constants.

For a symmetrical BJT astable multivibrator where R1 = R4 = R and C1= C2 = C:

A. Time period of one state: T1 = 0.693×R2 × C1 (for Q1 OFF)

B. Time period of the other state: T2 = 0.693 × R3 × C2 (for Q2 OFF)

C. Total period: T = T1 + T2 = 0.693 × (R2C1 + R3C2)

D. If symmetrical (R2 = R3 = RB, C1 = C2 = C): T = 1.386 × RB × C

E. Frequency: f=1/T

555 Timer as Astable Multivibrator:

The 555 timer is a popular IC for creating astable multivibrators due to its simplicity and reliability.

Operation: The capacitor charges through RA and RB and discharges through RB and an internal transistor. The internal comparators and flip-flop control the charging/discharging cycle, producing a continuous square wave.

Timing:

Thigh = 0.693 × (RA+RB) × C

Tlow = 0.693 × RB × C

T = Thigh+ TLOW = 0.693 × (RA+2RB)×C

Frequency: f = 1/T

Duty Cycle: D=(THIGH/T)×100%

Applications:

1. **Clock Generators:** Providing timing signals for digital circuits and microcontrollers.

2. **Pulse Generators**: Creating series of pulses for various triggering purposes.

3. **LED Flashers/Blinkers:** Simple timing for visual indicators.

4. **Tone Generators:** Producing audio frequencies in alarms and musical instruments.

5. **Modulation:** Used in pulse-width modulation (PWM) applications.

b) Monostable Multivibrator (One-Shot Multivibrator)

A monostable multivibrator has one stable state and one quasi-stable (unstable) state. It remains indefinitely in its stable state until triggered by an external pulse. Upon receiving a suitable trigger, it transitions to the quasi-stable state for a predetermined duration, after which it automatically returns to its stable state, generating a single output pulse.

Operation Principle:

In its stable state, one transistor (e.g., Q1) is ON (saturated) and the other (Q2) is OFF. A capacitor connected between the collector of Q1 and the base of Q2 is discharged.

1. A trigger pulse (usually a negative pulse) momentarily turns OFF Q1.

2. As Q1 turns OFF, its collector voltage rises, which is coupled through the capacitor to the base of Q2, quickly turning Q2 ON. This is the quasi-stable state.

3. The capacitor now begins to charge.

4. As the capacitor charges, the base voltage of Q1 gradually rises.

5. When Q1's base voltage reaches its turn-on threshold, Q1 switches back ON, which in turn switches Q2 OFF through the cross-coupling.

6. The circuit returns to its original stable state. The duration Q2 was ON (the pulse width) is determined by the RC time constant of the charging capacitor.

Timing Analysis:

The pulse width (duration, Tpulse) is precisely controlled by the values of the resistor and capacitor.

For a BJT-based monostable multivibrator: Tpulse ≈ 0.693×R×C

For a 555 timer in monostable mode: Tpulse = 1.1×R×C

Applications:

1. **Pulse Stretching/Widening**: Converting short input pulses into longer, defined output pulses.

2. **Timing Circuits:** Generating fixed-duration time delays.

3. **Switch Debouncing:** Eliminating unwanted multiple pulses from mechanical switches.

4. **Frequency Division:** Dividing a higher frequency input into a lower frequency output.

5. **Missing Pulse Detection:** Detecting when a periodic pulse is absent.

c) Bistable Multivibrator (Flip-Flop / Latch)

The bistable multivibrator, also known as a flip-flop or latch, has two stable states. It can remain indefinitely in either of these two

states (HIGH or LOW, or SET/RESET) until an external trigger pulse causes it to switch to the other state. Unlike astable and monostable types, it does not have any timing components (capacitors) that cause it to automatically change states or return to a default state.

Operation Principle:

A bistable multivibrator is essentially a two-stage amplifier with strong positive feedback that latches into one of two states. Consider a basic BJT-based bistable multivibrator (also known as a toggle flip-flop or T-type flip-flop):

1.The circuit has two stable states: either Q1 is ON and Q2 is OFF, or Q1 is OFF and Q2 is ON.

2. If Q1 is ON (saturated), its collector voltage is low. This low voltage keeps Q2 OFF.

3. If Q2 is OFF, its collector voltage is high. This high voltage is coupled to the base of Q1, keeping Q1 ON. This is one stable state.

4. To change the state, an external trigger pulse (e.g., at a "Set" input) momentarily forces Q2 ON.

5. As Q2 turns ON, its collector voltage drops, which is coupled to the base of Q1, forcing Q1 OFF.

6. With Q1 OFF, its collector voltage rises, reinforcing Q2's ON state (positive feedback). This becomes the new stable state.

7. Another trigger pulse (e.g., at a "Reset" input) would then flip the circuit back to its original state.

Bistable multivibrators are often implemented using logic gates (NAND or NOR gates) to form SR latches, D-flip-flops, JK-flip-flops, or T-flip-flops, which are fundamental in digital logic.

Applications:

1. **Memory Elements:** Storing one bit of binary data (0 or 1) in digital circuits.

2. **Counters**: Used to count the number of input pulses.

3. **Registers:** Storing data words.

4. **Frequency Dividers:** Dividing the frequency of a clock signal by two (in T-flip-flops).

5. **Data Latches:** Holding data at a specific moment.

  •

3. Key Components and Implementations

Multivibrators can be realized using various electronic components and integrated circuits:

1. **Discrete Components (BJTs/FETs)**: Traditional designs often use Bipolar Junction Transistors (BJTs) or Field-Effect Transistors (FETs) as the active switching elements. Resistors and capacitors form the timing networks and feedback paths. This approach provides a deep understanding of the fundamental principles but can be more complex for advanced designs.

2. **555 Timer IC:** The NE555 timer IC is a highly versatile and popular choice for building astable and monostable multivibrators. Its internal structure includes comparators, a flip-flop, a discharge transistor, and a voltage divider, making it simple to configure with minimal external components (typically just a few resistors and a capacitor). Its reliability and cost-effectiveness have made it a staple in electronics education and industry.

3. **Logic Gates:** For digital applications, bistable multivibrators are most commonly built using fundamental logic gates such as NAND, NOR, and NOT gates. Configurations like SR latches, D-flip-flops, JK-flip-flops, and T-flip-flops are standard building blocks in sequential logic circuits. Astable multivibrators can also be formed by connecting an odd number of NOT gates in a ring (ring oscillator).

4. **Operational Amplifiers (Op-Amps)**: Operational Amplifiers can be configured with positive feedback to create astable and monostable multivibrators, often referred to as Op-Amp relaxation oscillators. These designs can offer high precision and flexibility in controlling timing parameters, especially when combined with precision resistors and capacitors. Op-amps are particularly useful when stable, high-quality square waves are required.

Performance Parameters and Design Considerations

1. **Frequency Stability**: astable multivibrators, the stability of the output frequency is crucial. Factors like temperature

variations, power supply fluctuations, and component tolerances (especially resistor and capacitor values) can affect frequency stability. High-quality components and proper temperature compensation techniques are vital for precise applications.

2. **Pulse Width Control:** In monostable circuits, accurate control over the output pulse width is paramount. This requires precise values for the timing resistor and capacitor. In some applications, variable resistors (potentiometers) are used to adjust the pulse width dynamically.

3. **Rise and Fall Times**: The output waveform of a multivibrator is ideally a perfect square wave. However, in reality, the transitions between HIGH and LOW states are not instantaneous. They have finite rise times (time to go from 10% to 90% of final value) and fall times (time to go from 90% to 10% of final value) due to parasitic capacitances and the switching speeds of the active devices.

4. **Power Consumption:** Different multivibrator implementations have varying power consumption characteristics. Discrete component circuits might consume more power than IC-based solutions like the 555 timer, especially at higher frequencies. Power efficiency is a critical design consideration for battery-powered devices.

5. **Loading Effects**: The output of a multivibrator should drive its load without significant distortion or changes in its timing characteristics. Excessive loading can reduce the output voltage swing, increase rise/fall times, or even prevent oscillation. Proper impedance matching and buffer stages may be necessary.

6. **riggering Requirements:** For monostable and bistable multivibrators, the characteristics of the input trigger pulse are vital. This includes:

7. **Amplitude**: The trigger pulse must have sufficient amplitude to overcome the threshold voltage of the active devices.

8. **Duration**: The trigger pulse should be of a certain minimum duration to ensure proper triggering.

9. **Edge-Triggering**: Many digital flip-flops are edge-triggered (responding to either the rising or falling edge of the clock/trigger pulse), which is crucial for synchronous operations.

10. **Noise Immunity:** The circuit should be designed to avoid false triggering from noise. Schmitt triggers are often incorporated for this purpose.

o

Conclusion Significance

Multivibrators are foundational circuits in electronics, bridging the gap between analog and digital domains. Their inherent ability to generate pulses and manage discrete states makes them indispensable. From simple RC relaxation oscillators that create rhythmic blinks to the sophisticated flip-flops forming the memory and processing units of computers, multivibrators are everywhere. Understanding their classifications, operational principles, timing mechanisms, and practical implementation details is crucial for any higher institution student of electronics or electrical engineering. Their versatility and critical role in timing, control, and data storage underscore their continuing significance in the ever-evolving landscape of electronic design.