**Operational Amplifier as mono stable multi vibrator**

**Aim** :- To construct a monostable multivibrator using operational amplifier 741 and to determine the duration of the output pulse generated and to compare it with that of theoretical value.

**Apparatus** :- Operational amplifier (IC 741), C.R.O., two power supplies to the operational amplifier, four non-inductive fixed resistors ($R_1$, $R_2$, $R_4$, and $R_5$), one non-inductive variable resistor ($R_3$), two capacitors ($C_1$ and $C_2$), three diodes ($D_1$, $D_2$, and $D_3$) and connecting terminals.

**Formula** :- Duration of the output pulse generated or time duration of quasi-stable state

\[
T = 2.303 \times R_3 C_1 \log_{10} \left( \frac{R_1 + R_2}{R_1} \right) \text{ Sec}
\]

Where

- $R_1$ and $R_2$ = Fixed non-inductive resistances (Ω)
- $R_3$ = Variable non-inductive resistance (Ω)
- $C_1$ = Capacitance (μF)

and if $R_1 = R_2$

Then

\[
T = 0.693 R_3 C_1
\]
**Description** :- The above figure is the circuit of the monostable multi vibrator. A capacitor C₁ is connected to the inverting terminal (2) of the operational amplifier from the ground and a diode D₁ is connected in parallel to C₁ such that n of diode D₁ is grounded. Similarly, a series combination of a capacitor C₂ and another diode D₂ is connected to the non-inverting terminal (3) of the operational amplifier as shown in the figure. The junction of C₂ and D₂ is grounded through a resistor R₄. The input external triggering pulse is given to the capacitor C₂. The output terminal (6) of the amplifier is fed back to inverting and non-inverting terminals of operational amplifier through resistors R₃ and R₁ respectively. Here R₁ is fixed resistor and R₃ is variable resistor. For the fast recovery of the multivibrator, from the quasi-stable state, a series combination of a diode D₃ and a resistor R₅ is connected parallel to the resistor R₃. The non-inverting terminal (3) is also grounded through another resistor R₁ so as the combination of R₂ and R₁ acts as a potential divider for the feed back. The terminals (7) and (4) of the op. amp. are connected to +15 V and -15 V of the D.C. power supplies separately. To observe the output waveform, the output terminal (6) is connected to CRO Y- Plates phase terminal and the other terminal of CRO is grounded. Also observe that (R₅ < R₃) and (R₄ > R₃).

**Theory** :- Multivibrators are a group of regenerative circuits that are used extensively in timing applications. They are wave shaping circuits which give symmetric or asymmetric square output. They have two states either stable or quasi-stable depending on the type of the multivibrator.

There are three types of multivibrator. 1) **Astable** (free-running) 2) **Monostable** (one shot) and 3) **Bistable** (flip-flop).

All the three circuits operate by using positive feedback to drive the op-amp into saturation, therefore it is not the case that the two inputs of the op-amp can be assumed to be at the same potential.

**Astable Multivibrator**: It is a free running oscillator having two quasi-stable states. Thus there is oscillations between these two states and no external signals are required to produce the change in state. In this the two states are stable only for a limited time and the circuit switches between them with the output alternating between positive and negative saturation values.

**Monostable Multivibrator**: A **monostable multivibrator** (MMV) has one stable state and one quasi-stable state. The circuit remains in its stable state till an external triggering pulse causes a
transition to the quasi-stable state. The circuit comes back to its stable state after a time period $T$. Thus it generates a single output pulse in response to an input pulse and is referred to as a one-shot or single shot. An external trigger signal generated due to charging and discharging of the capacitor produces the transition to the original stable state. So, mono stable multi vibrator is one which generates a single pulse of specified duration in response to each external trigger signal.

**Bistable Multivibrator**: It maintains a given output voltage level unless an external trigger signal is applied. Application of an external trigger signal causes a change of state, and this output level is maintained indefinitely until a second trigger is applied. Thus it requires two external triggers before it returns to its initial state. So, it has two stable states.

Monostable multivibrator circuit illustrated in figure is obtained by modifying the astable multivibrator circuit by connecting a diode $D_1$ across capacitor $C_1$ so as to clamp $V_c$ at $V_D$ during positive excursion. The main component of this circuit is the 741, a general-purpose operational amplifier. This is a timing circuit that changes state once triggered, but returns to its original state after a certain time delay. It got its name from the fact that only one of its output states is stable.

Under steady-state condition, this circuit will remain in its stable state with the output $V_{out} = +V_{out}$ and the capacitor $C_1$, is clamped at the voltage $V_D$ (on-voltage of diode, $D_1$, i.e. $V_D = 0.7 \text{ V}$). The voltage $V_D$ must be less than $(\beta V_{out})$ for $V_{in} < 0$. The circuit can be switched to the other state by applying a negative pulse with amplitude greater than $(\beta V_{out} - V_D)$ to the non-inverting (+) input terminal.

When a trigger pulse with amplitude greater than $(\beta V_{out} - V_D)$ is applied, $V_{in}$ goes positive causing a transition in the state of the circuit to $-V_{out}$. The capacitor $C_1$ now charges exponentially with a time constant $\tau = R_3C_1$ toward $-V_{out}$ (diode $D_1$ being reverse-biased). When capacitor voltage $V_c$ becomes more negative than $(- \beta V_{out})$, $V_{in}$ becomes negative and, therefore, output swings back to $+V_{out}$ (steady-state output). The capacitor now charges towards $+V_{out}$ till $V_c$ attain $V_D$ and capacitor $C_1$ becomes clamped at $V_D$.

The width of the trigger pulse $T_p$ is much smaller than the duration of the output pulse $T$ generated i.e. $T_p \ll T$. For reliable operation the circuit should not be triggered again before $T$. 
During the quasi-stable state, the capacitor voltage is given as

\[ V_c = -V_{\text{out}} + (V_{\text{out}} + V_D) e^{-t/\tau} \]

At instant \( t = T \) and \( V_c = -\beta V_{\text{out}} \)

Where \( \beta = \left( \frac{R_2}{R_1+R_2} \right) = \text{Feed back factor} \)

So

\[ -\beta V_{\text{out}} = -V_{\text{out}} + (V_{\text{out}} + V_D) e^{-T/\tau} \]

Where Time constant \( \tau = R_3C_1 \)

or

\[ V_{\text{out}} (1-\beta) = V_{\text{out}} (1 + \frac{V_D}{V_{\text{out}}}) e^{-T/\tau} \]

In general \( V_D \ll V_{\text{out}} \)

So

\[ (1-\beta) = e^{-T/\tau} \]

\[ \frac{T}{\tau} = \log_e \left( \frac{1}{1-\beta} \right) \]

\[ T = R_3C_1 \log_e \left( \frac{1}{1-\beta} \right) \]

\[ \therefore \tau = R_3C_1 \]

\[ T = R_3C_1 \log_e \left( \frac{R_1+R_2}{R_1} \right) \]

and if \( R_1 = R_2 \)

Then

\[ \beta = \frac{1}{2} \]

Or

\[ T = R_3C_1 \log_e 2 = R_3C_1 \times 2.303 \times \log_{10} 2 \]

\[ T = 0.693 R_3 C_1 \]

**Procedure** :- Connect the circuit as shown in the figure. Take the \( R_1 = R_2 = 1\, \text{K}\Omega, \ C_1 = C_2 = 0.1\, \mu\text{F and } R_3 = 10\, \text{K}\Omega \) (variable resistance) or any convenient values. Apply the DC power supplies to the terminals (7) and (4) of the operational amplifier. Keep the \( R_3 \) value at a convenient value. Set the voltage sensitivity band switch of the Y- plate and time base band switch of C.R.O. to the convenient positions such that at least two or more complete square wave forms are observed on the screen of CRO. The length of –ve value or –\( V_{\text{out}} \) is the duration of the quasi-stable state. Now measure the horizontal length (l) of the quasi-stable state. Also note the
time base value (m) of the X-plates of the CRO in the table. From this calculate the time duration of the quasi-stable state. This is the experimental value. Similarly the theoretical value can also be calculated by substituting the values of $R_3$, $R_1$, $R_2$ and $C_1$ in the above given equation.

Now the experiment is repeated for different values of $R_3$ by increasing its value in equal steps (Multiples of 100 $\Omega$).

**Precautions** :- 1. Check the continuity of the connecting terminals before connecting them.
2. Keep the band switches of the C.R.O. such that steady wave form is observed on the screen.
3. Observe the output square wave on the screen of CRO and measure the horizontal length accurately.

**Results** :- It is found that the observed duration and calculated duration are equal.

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Table

<table>
<thead>
<tr>
<th>S.No.</th>
<th>$C_1$ ($\mu$F)</th>
<th>$R_3$ ($\Omega$)</th>
<th>Theoretical time duration</th>
<th>Experimental time duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T = R_3C_1 \log_e \left( \frac{R_1+R_2}{R_1} \right)$ (Sec)</td>
<td>Horizontal length (l) (Div)</td>
</tr>
</tbody>
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