EE230: Lab 4
Schmitt Trigger, Astable Multivibrator and Monostable Multivibrator

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1 Overview of the experiment

1.1 Aim of the experiment

To understand the design and workings of the Schmitt Trigger, Astable Multivibrator and Monostable Multivibrator by simulating their models in NGSpice and observing their outputs.

1.2 Methods

We first implemented the netlist circuits for Schmitt Trigger, Astable Multivibrator and Monostable Multivibrator by simulating these models in NGSpice. Next we observed their output voltages for various inputs by performing transient and DC analysis.
We observed various parameters for these models (such as higher and lower threshold voltages, values of R and C) and how these parameters affect the working of the models.

2 Design

2.1 Schmitt Trigger

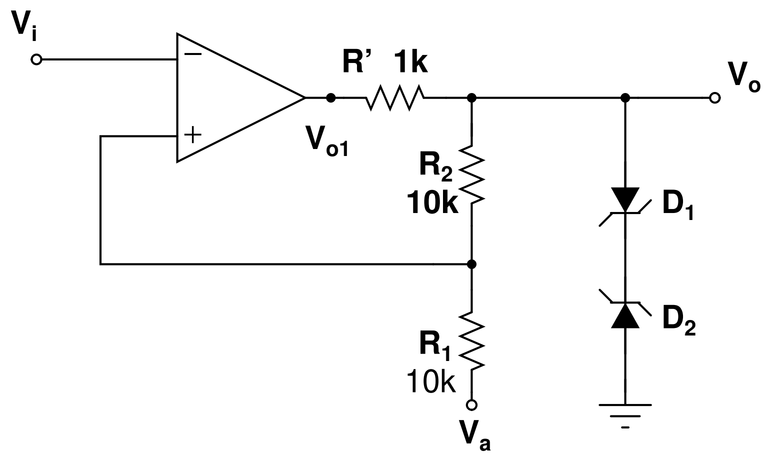

Figure 1: Schmitt Trigger

The Schmitt Trigger consists of an op-amp with a positive feedback loop. The input voltage V_i is applied to the inverting terminal. Three resistances R', R_1 and R_2 are connected as shown in the figure 1 above. The diodes are connected at the output to maintain a constant output voltage.

2.2 Astable Multivibrator

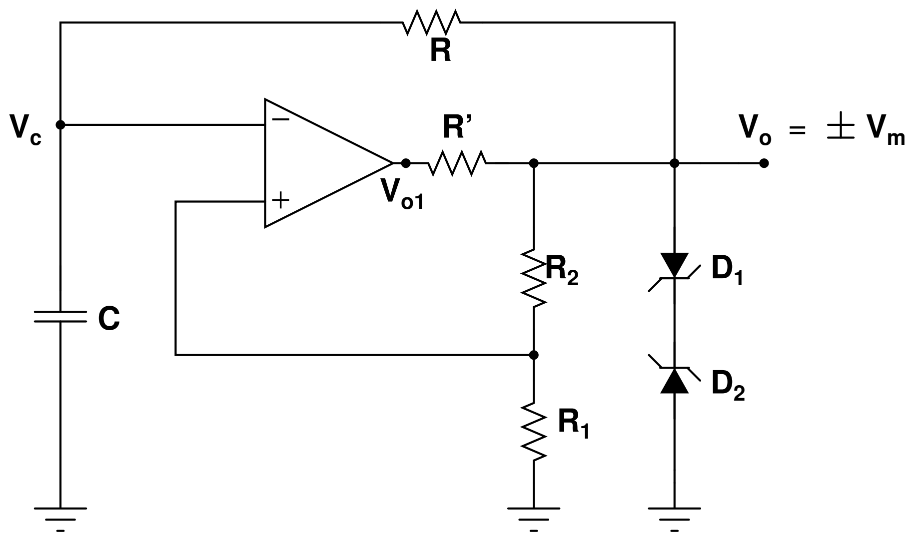

Figure 2: Astable Multivibrator

The Astable Multivibrator consists of the Schmitt Trigger as a part of its circuit. Additionally, a capacitor C and a resistor R are connected to the inverting input of the op-amp as shown in the figure 2 above.

2.3 Monostable Multivibrator

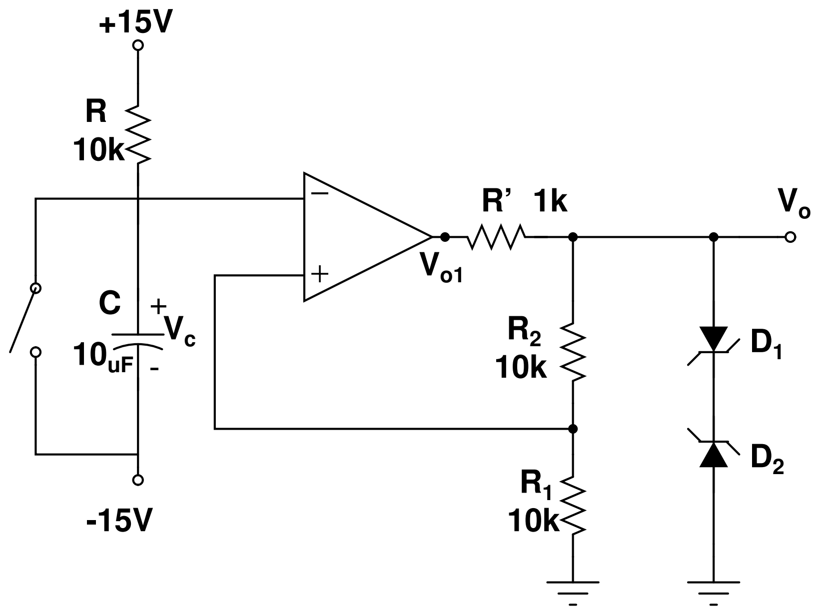

Figure 3: Monostable Multivibrator

The Monostable Multivibrator also works on the principle of the Schmitt Trigger. A capacitor C is connected at the inverting terminal of the op-amp. Two diodes D_1 and D_2 are connected at the output to maintain a constant voltage.

3 Simulation results

3.1 Code snippet

3.1.1 Schmitt Trigger

```
Schmitt trigger
.include ua741.txt
.include zener_B.txt
vin 1 0 0
v1 6 0 15
v2 7 0 -15
r1 3 4 1k
r2 4 2 10k
r3 2 0 10k
x1 2 1 6 7 3 ua741
x2 4 5 DI_1N4734A
x3 0 5 DI_1N4734A
.control
dc vin -6 6 0.1
dc vin 6 -6 -0.1
plot dc1.v(4) dc2.v(4)
.endc
.end
```

3.1.2 Astable Multivibrator

Case 1: Without resistor R' and diodes D_1 and D_2

```
Astable Multivibrator
.include ua741.txt
v1 5 0 15
v2 6 0 -15
r0 2 3 50k
r1 1 0 30k
r2 3 1 35k
c1 2 0 0.01u
x1 1 2 5 6 3 ua741
.tran 0.001ms 10ms
```

```
.control
run
plot v(2) v(3)
.endc
.end
```

Case 2: With resistor R' and diodes D_1 and D_2

```
Astable Multivibrator with Diodes and resistor
.include ua741.txt
.include zener_B.txt
v1 6 0 15
v2 7 0 -15
r0 2 4 50k
r1 1 0 30k
r2 4 1 35k
r3 3 4 1k
c1 2 0 0.01u
x1 1 2 6 7 3 ua741
x2 4 5 DI_1N4734A x3 0 5 DI_1N4734A
.tran 0.001ms 10ms
.control
run
plot v(2) v(4)
.endc
.end
```

3.1.3 Monostable Multivibrator

```
Monostable multivibrator
.include ua741.txt
.include zener_B.txt
.SUBCKT button_sw 1 2
S1 1 2 c 0 b_sw1
* Initial value, pulsed value, delay time, rise time, fall time, pulse width *
V1 c 0 pulse(0 10 0.10 0.02 0.02 0.05 100)
.model b_sw1 sw vt=1 vh=0.2 ron=1 roff=1000MEG
.ENDS button_sw
```

```
v1 3 0 15
v2 4 0 -15
v3 5 0 15
v4 6 0 -15
r1 2 3 10k
r2 7 8 1k
r3 8 1 10k
r4 1 0 10k
c1 4 2 10u
x1 1 2 5 6 7 ua741
x2 8 9 DI_1N4734A
x3 0 9 DI_1N4734A
x4 4 2 button_sw
.tran 0.01ms 5s
.control
run
plot v(2) v(8) v(7) v(1)
.endc
.end
```

3.2 Simulation results

3.2.1 Schmitt Trigger

Case 1 : $V_a = 0$

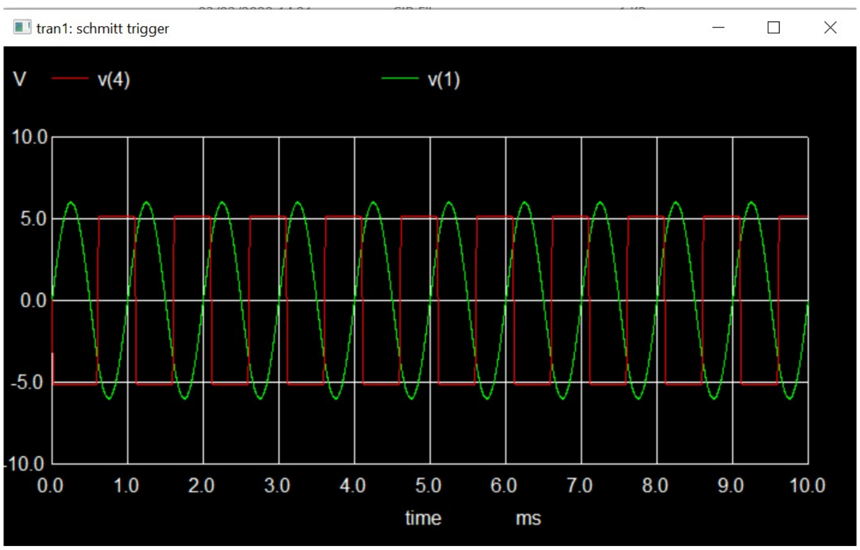

Figure 4: Schmitt Trigger : Vout vs Vin

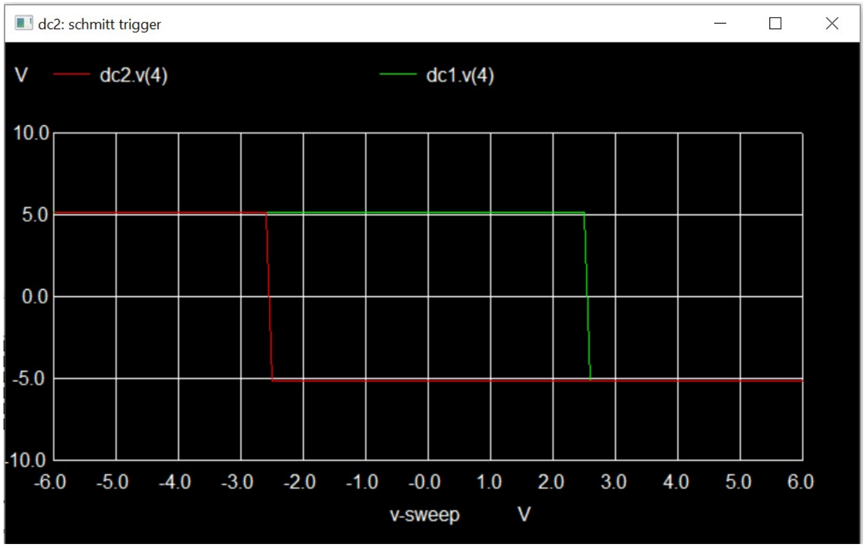

Figure 5: Schmitt Trigger : Vout vs Vin

3.2.2 Theoretical Analysis

Threshold voltages : V_{TH} and V_{TL}
The higher threshold voltages is given by :

$$V_{TH} = V_o \frac{R_1}{R_1 + R_2} + V_a \frac{R_2}{R_1 + R_2} \tag{1}$$

The lower threshold voltages is given by :

$$V_{TL} = -V_o \frac{R_1}{R_1 + R_2} + V_a \frac{R_2}{R_1 + R_2} \tag{2}$$

By substituting the values of V_o, R_1 and R_2, we get the the values of V_{TL} and V_{TH} as follows:

$$V_{TL} = -2.5V \tag{3}$$

$$V_{TH} = +2.5V \tag{4}$$

Case 2 : $V_a = +3\mathbf{V}$

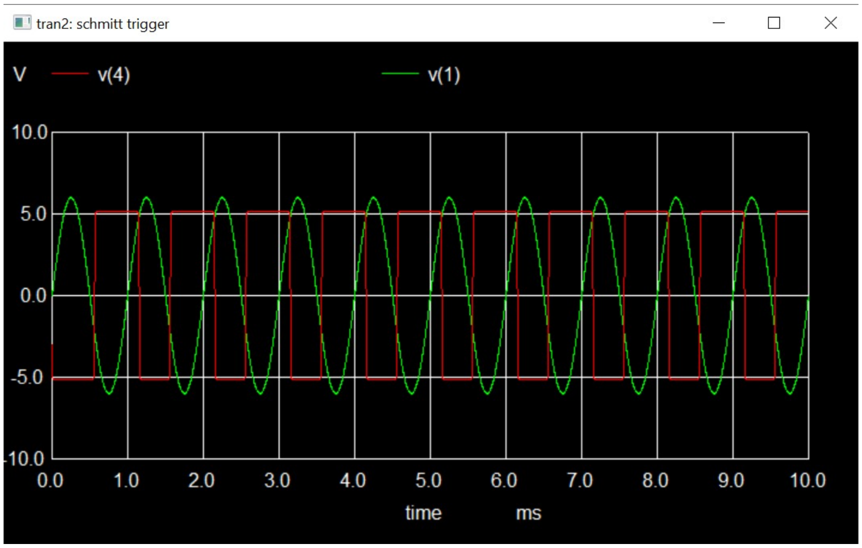

Figure 6: Schmitt Trigger : Vout vs Vin with Va = +3V

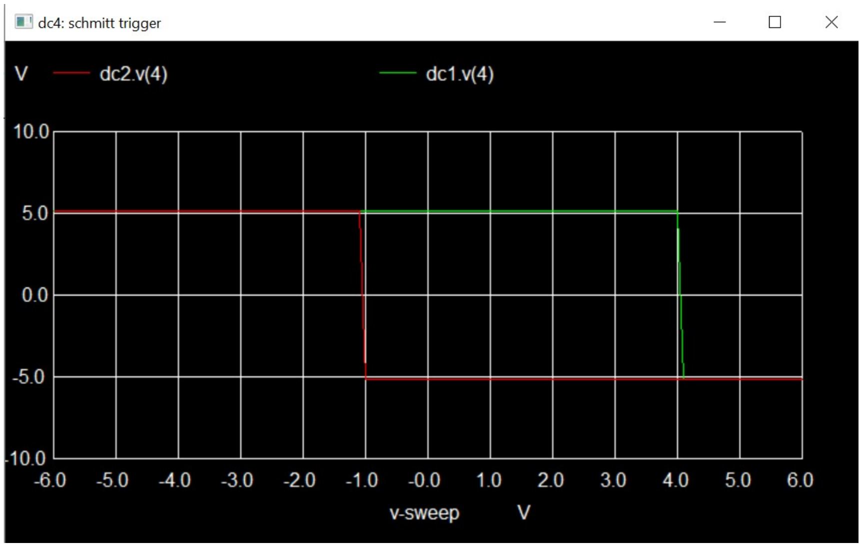

Figure 7: Schmitt Trigger : Vout vs Vin

By substituting the values of V_o, R_1 and R_2, we get the the values of V_{TL} and V_{TH} as follows:

$$V_{TL} = -1.0V \tag{5}$$

$$V_{TH} = +4.0V \tag{6}$$

Case 3 : $V_a = -3$**V**

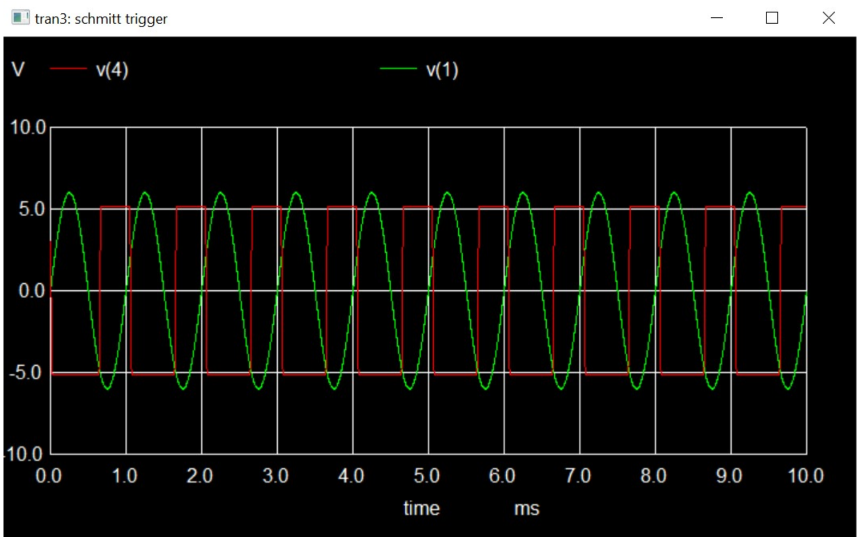

Figure 8: Schmitt Trigger : Vout vs Vin with Va = +3V

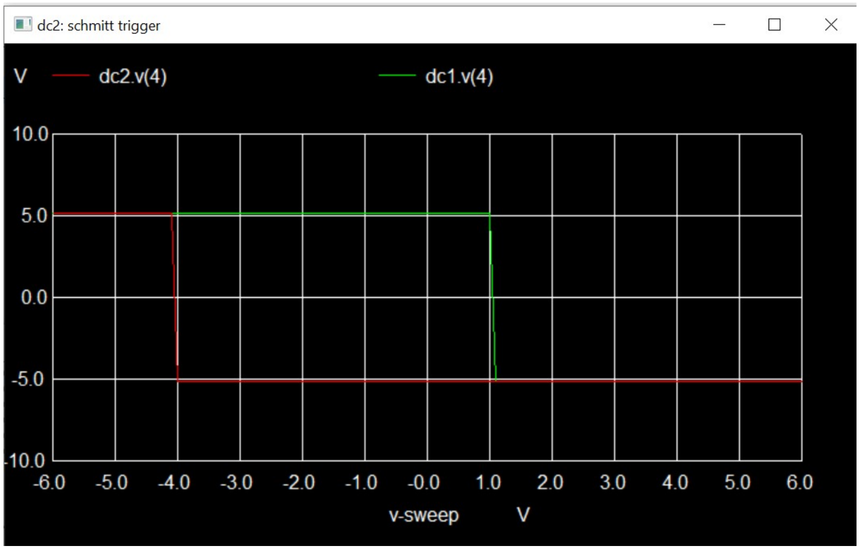

Figure 9: Schmitt Trigger : Vout vs Vin

By substituting the values of V_o, R_1 and R_2, we get the the values of V_{TL} and V_{TH} as follows:

$$V_{TL} = -4.0V \tag{7}$$

$$V_{TH} = +1.0V \tag{8}$$

3.2.3 Astable Multivibrator

Case 1 : Without diodes D1,D2 and resistor R'

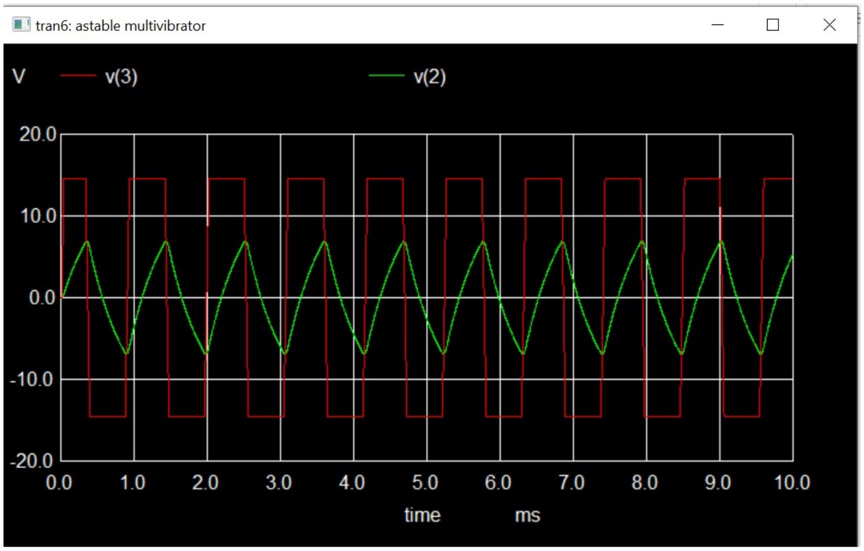

Figure 10: Astable Multivibrator : Vc and Vout

Here we can observe that the amplitude of the output waveform is +15V, -15V.

Observe that the time period of the output waveform is T = 0.8ms.
The frequency of the waveform is given by $\frac{1}{T}$.

$$\therefore f = \frac{1}{T} = 1.25kHz \tag{9}$$

Case 2 : With diodes D1,D2 and resistor R'

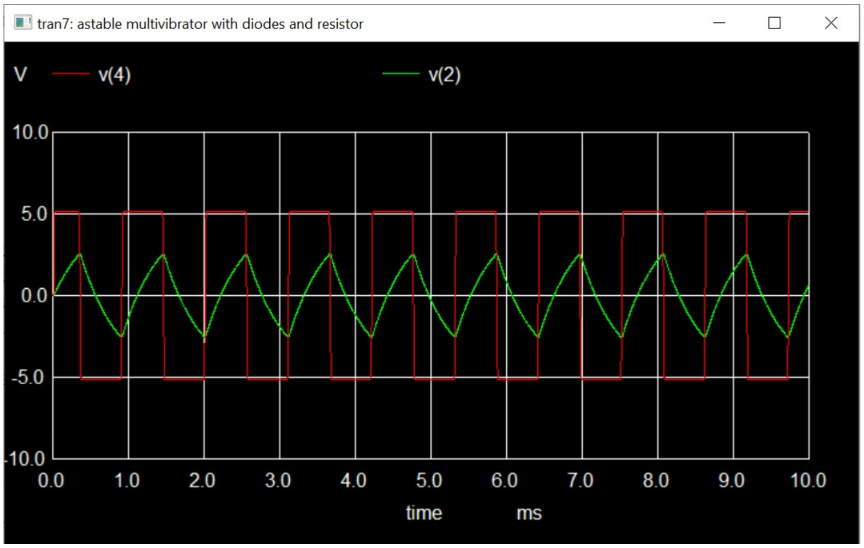

Figure 11: Astable Multivibrator : Vc and Vout

Here we can observe that the amplitude of the output waveform is +5V, -5V. This occurs because the diodes are connected at the output as shown in the figure 2 in the section 2.2

Observing the voltages at V_{o1} and V_o :

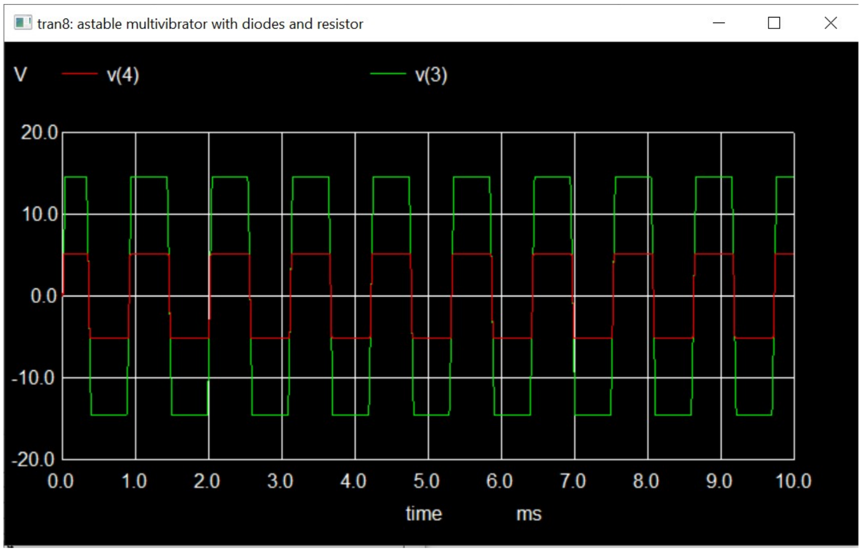

Figure 12: Astable Multivibrator : V_{o1} and V_o

Observe that the output voltage from the op-amp V_{o1} has amplitude 15V. However, because of the two diodes D_1 and D_2 connected at the output V_o as shown in the figure 2 in the section 2.2, the output voltage is maintained at +5V and -5V as can be seen from the figure 12 above.
We get the 5V since of the diodes is forward biased while the other is reversed biased.
Therefore the output votlage is $4.3 + 0.7 = 5$V
Analsying the frequency of the output voltage V_o :
From the plots shown in the figures 10, 11 and 12, observe that the time period of the output voltage remains constant at 0.8ms.
Therefore, the frequency of the output voltage also remains constant at 1.25khz.
Thus, we observe that the frequency of the output voltage **does not change**. The diode only help maintain the voltage and do not interfere with the frequency of the output voltage.

3.2.4 Monostable Multivibrator

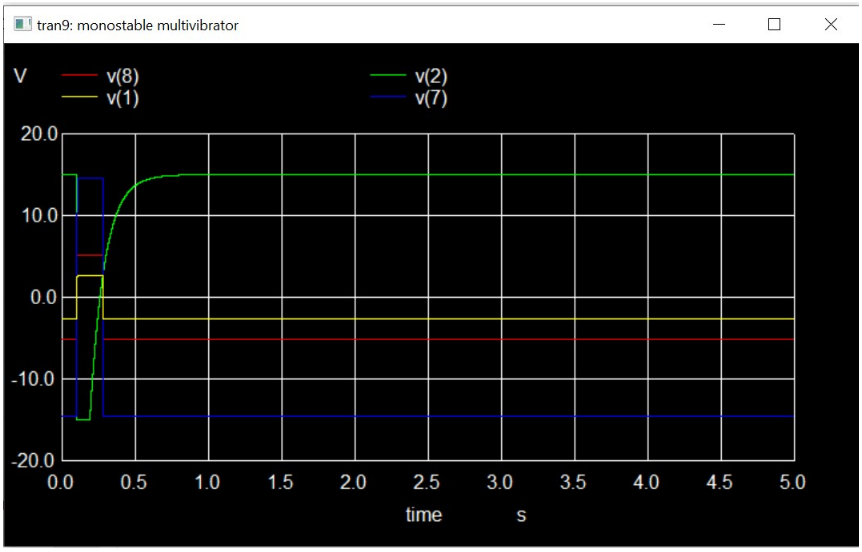

Figure 13: Monostable Multivibrator : Vout

The pulse starts at time t = 0.1s
And the pulse ends at time t = 0.275s.

We know that the time period (T) of a Monostable Multivibrator is given by the equation as follows :

$$T = RClog(\frac{V'}{V' - V_{TH}}) \tag{10}$$

Substituting the values for the parameters and solving for T, we get the time period as :

$$T = 18ms \tag{11}$$

From the plot above (Figure 13), we can analysed the plot and found the width of the output pulse to be 18ms.
Therefore, our theoretical analysis matches our simulation results.

Voltage at inverting terminal:
This is the voltage across the capacitor and can be observed in the figure

above (Figure 13, v(2)).
As soon as this reaches the threshold voltage, the output voltage drops to 0V as can be seen from the plot.