BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Electrical and Computer Engineering Department

CIRCUITS AND ELECTRONICS LABORATORY– ENEE2103

Experiment No. 6 Prelab

Diode Characteristic and Applications

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Prelab instructions:

1. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).

2. Verify if Simulation Results match the expected results

Procedure and Discussion

Part 1: Diode characteristics

1.1 Normal diode:

Connect the Circuit of Fig 1, Switch on the power supply and adjust it from zero to 1 volt in 0.1V steps and in 0.5 steps from 1V to 3V.

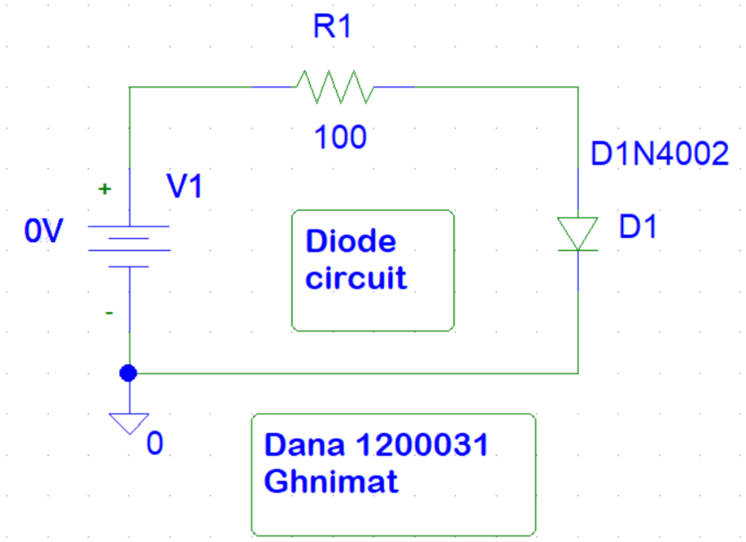

Figure 1 Diode Characteristic

Table 1 Diode Characteristic

SET	Measure	Calculate	
V_S	V_R	V_D	I_D
0	0	0	0
0.1	0.00001 V	0.09999 V	85nA
0.2	0.00007 V	0.19993 V	684nA
0.3	0.00048 V	0.29952 V	4.8µA
0.4	0.00323 V	0.39677 V	32µA
0.5	0.01726 V	0.48274 V	172µA
0.6	0.05646 V	0.54354 V	564µA
0.7	0.11844 V	0.58156 V	1.184mA
0.8	0.19328 V	0.60672 V	1.933mA
0.9	0.27514 V	0.62486 V	2.751mA
1.0	0.36116 V	0.63884 V	3.612mA
1.5	0.819 V	0.681 V	8.190mA
2	1.29532 V	0.70468 V	12.95mA
2.5	1.77888 V	0.72112 V	17.79mA
3	2.26629 V	0.73371 V	22.66mA

$V_R = Vs - Vd.$

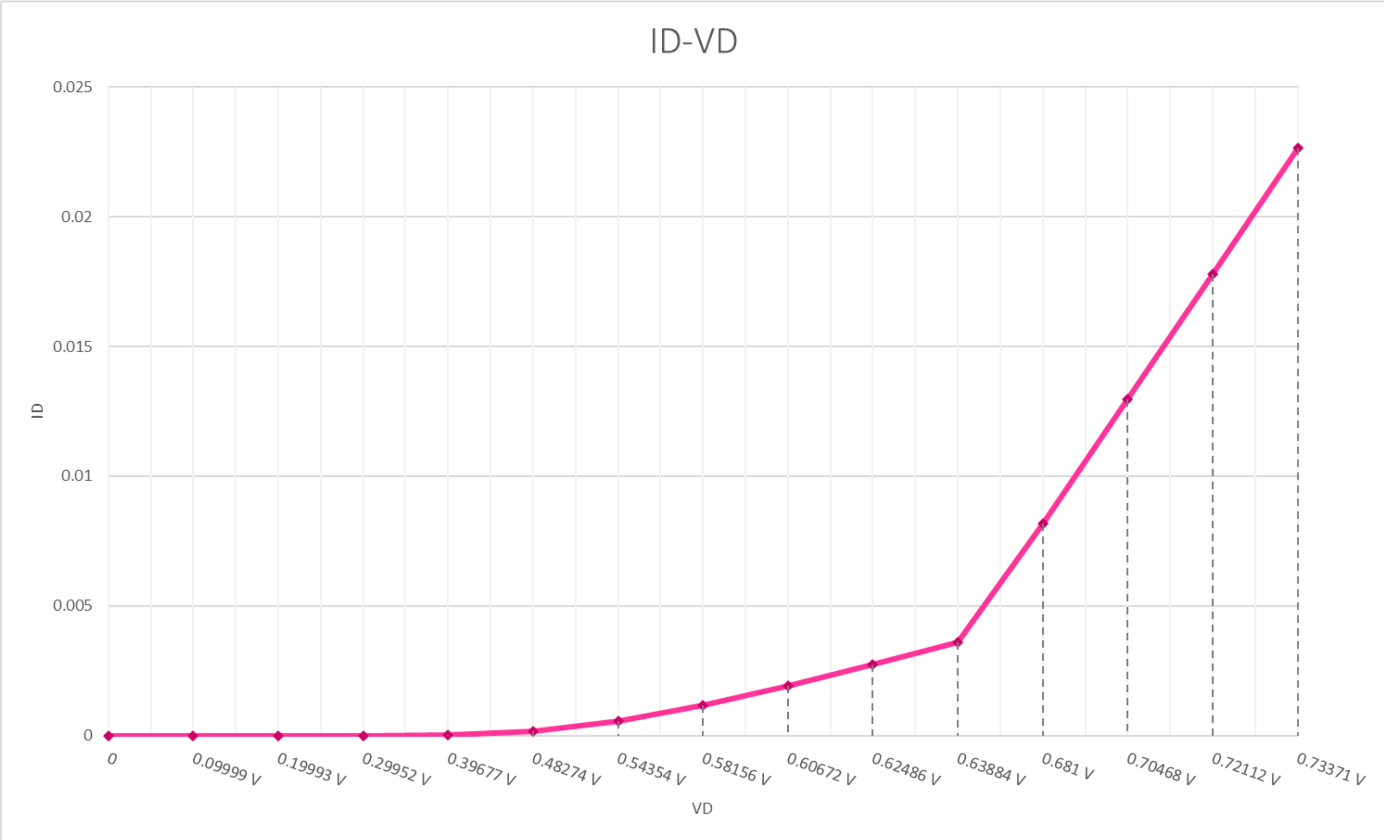

Figure 2 current - voltage diode graph

Noticing from the paragraph we noticed the change happened after 0.6Volt the current starts to pass throw the Diode (the current start slowly rises noticeably). And doesn't rise much after that point.

1.2 reverse diode:

After connecting the previous circuit and putting the diode on reverse:

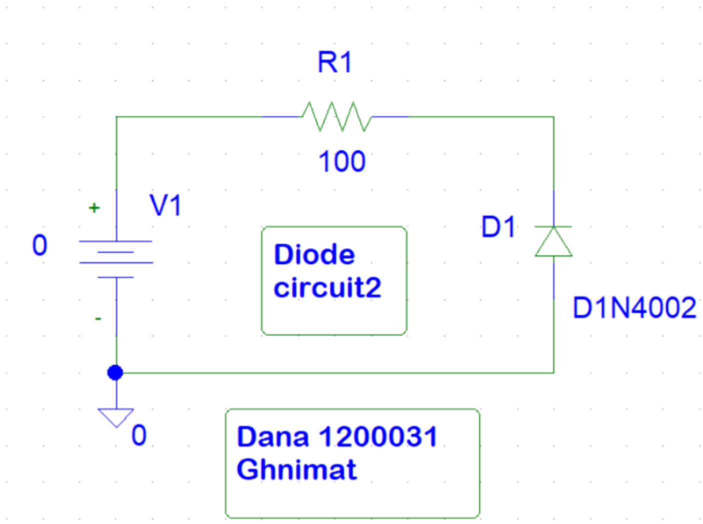

Figure 3 Reverse diode circuit

Table 2 Reverse diode Characteristics Table

SET	Measure	Calculate	
V_S	V_R	V_D	I_D
0	0 V	0	0
0.1	0 V	0.1 V	12nA
0.2	0 V	0.2 V	13nA
0.3	0 V	0.3 V	14nA
0.4	0 V	0.4 V	14nA
0.5	0 V	0.5 V	14nA
0.6	0 V	0.6 V	14nA
0.7	0 V	0.7 V	14nA
0.8	0 V	0.8 V	14nA
0.9	0 V	0.9 V	14nA
1.0	0 V	1 V	14nA
1.5	0 V	1.5 V	14nA
2	0 V	2 V	14nA
2.5	0 V	2.5 V	14nA
3	0 V	3 V	14nA

We noticed how the diode acted like an open circuit, and reversing the diode makes the voltage across the anode is greater than the voltage across the cathode. as $V_D = V_s$.

Part 2: Rectification:

I. Half - Wave rectification:

I.1 Normal diode:

After we disconnected the resistance R5 from the circuit, R4 = R1= Rx=1kΩ R6=4.7kΩ and made the voltage source equal 5V, $10V_{p\text{-}p}$.

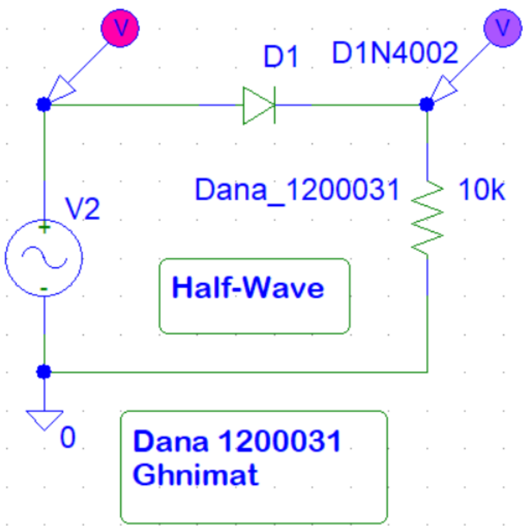

Figure 4 Half-wave rectifier circuit forward diode

As the frequency = 200 Hz, each wave needs 1/200 seconds which is equal to 5ms, so 25ms for 5 cycles to display.

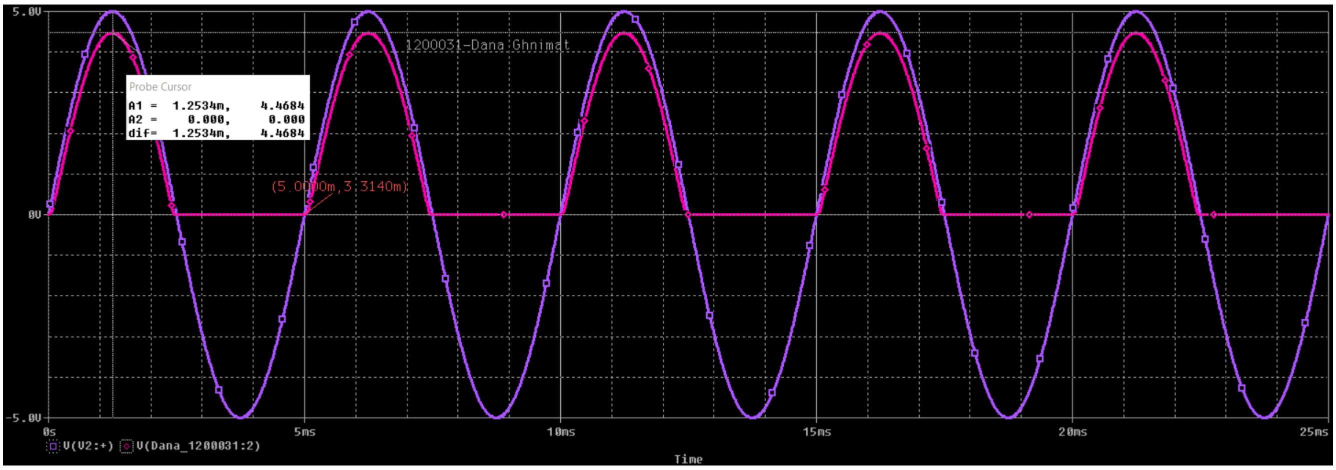

Figure 5 Half-wave rectifier graph forward diode

From figure 5, we noticed that the peak is 4.4684V, and Period T is 5ms, which match our calculations of 1/200 seconds.

V_{pk} = 4.4684V $T_{(sec)}$ = 5 ms. DC value = V_{pk}/π = 1.4223V.

From figure 6, we noticed that the DC Value is equal to 1.4095 which is close to the value we got theoretically.

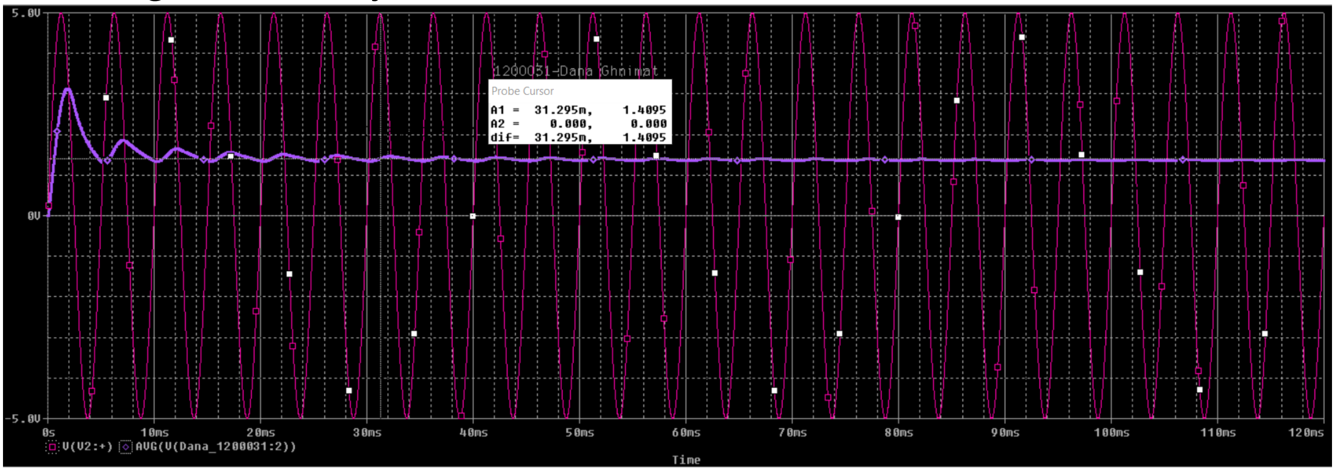

Figure 6 Half-wave rectifier graph DC value

I.2 Reverse Diode:

Reversing the diode:

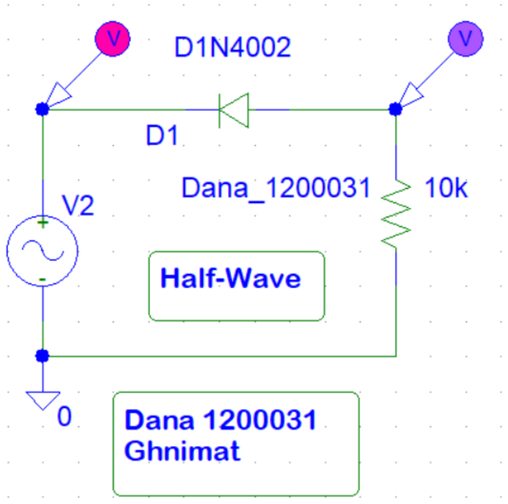

Figure 7 Half-wave rectifier circuit reverse diode

By reversing the diode in Half-wave rectifier circuit, we noticed that it gives us the values from 0 to negative 4.4684, which is the opposite of the original diode position, as shown in figure 7.

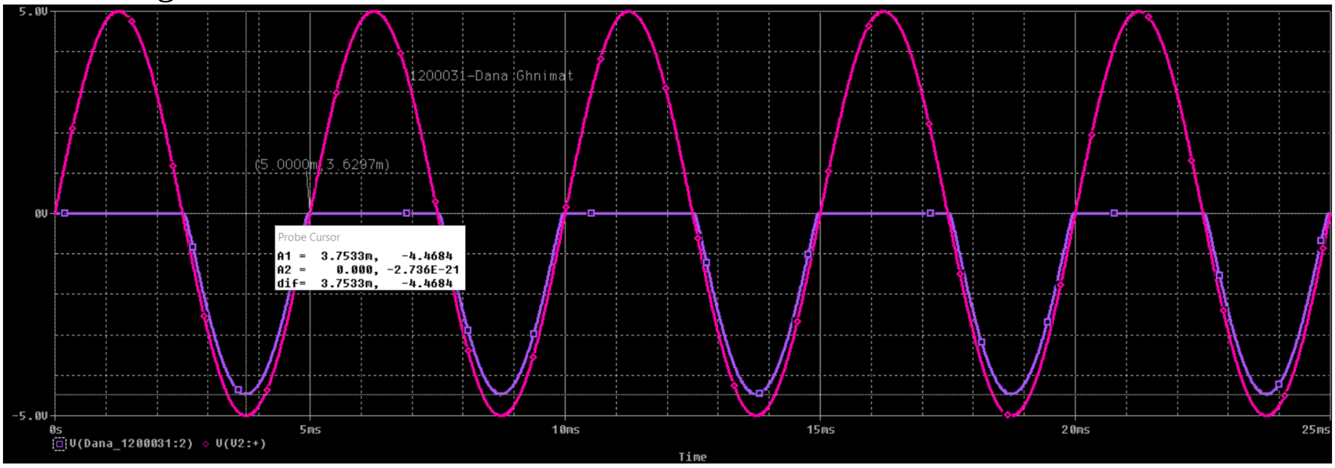

Figure 8 Half-wave rectifier graph reverse diode

As shown in Figure 5. When Vin < 0, Vout = 0. Otherwise Vout ≈ Vin, because the voltage drops across the Diode.

From the figure 5 we can notice that the difference between Vin and Vout at 1.253ms equals | 5 - 4.4684V | = 0.5316 V, the value remains the same when we also reverse the diode, but at different time which is at 3.6297ms.

I.3 Half wave rectifier with capacitor:

2.2µF Capacitor:

Half wave rectifier circuit with a capacitor as the following:

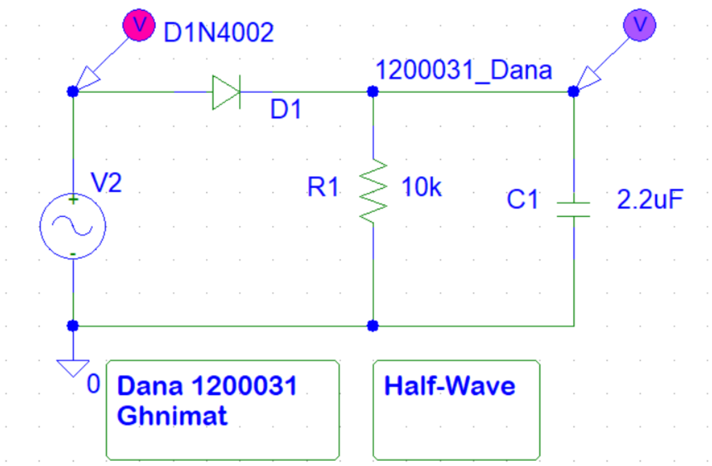

Figure 9 Half-wave rectifier circuit with capacitor

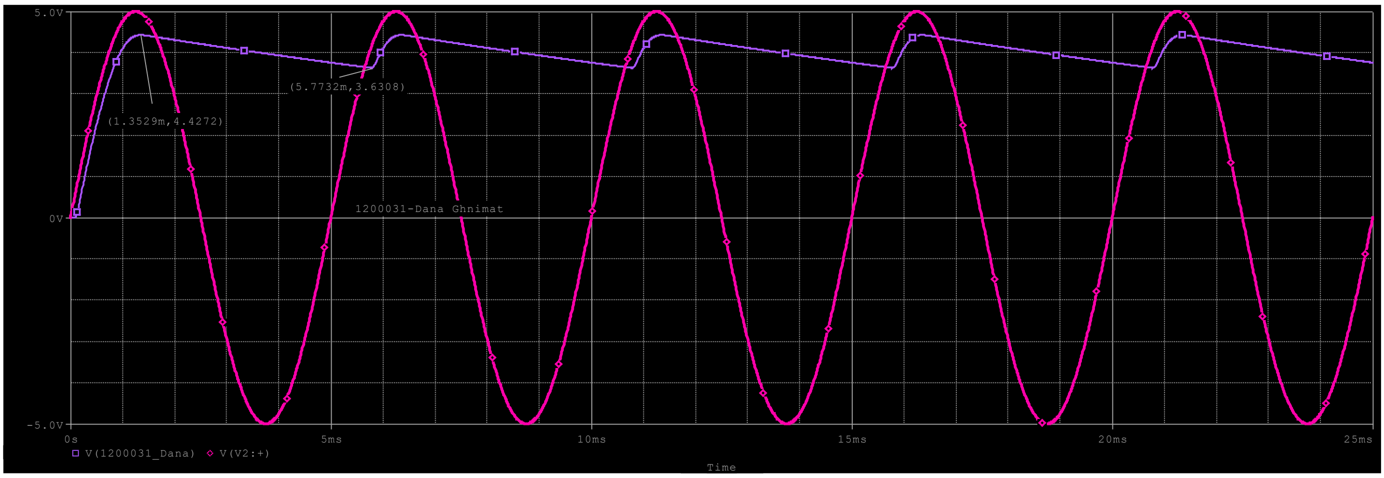

Figure 10 Half-wave rectifier figure with 2.2µF capacitor

From figure 10, we noticed that $V_{out,\,min} = 3.6208V$ and $V_{out,\,max} = 4.4272V$.

$$V_{p\text{-}p} = V_{Max} - V_{Min}$$
$$= 4.4272 - 3.6308$$
$$= 0.7964\ V$$

$$V_{RMS} = \frac{Vpp}{2\sqrt{3}}$$
$$= \frac{0.7964}{2\sqrt{3}}$$
$$= 0.2299\ V$$

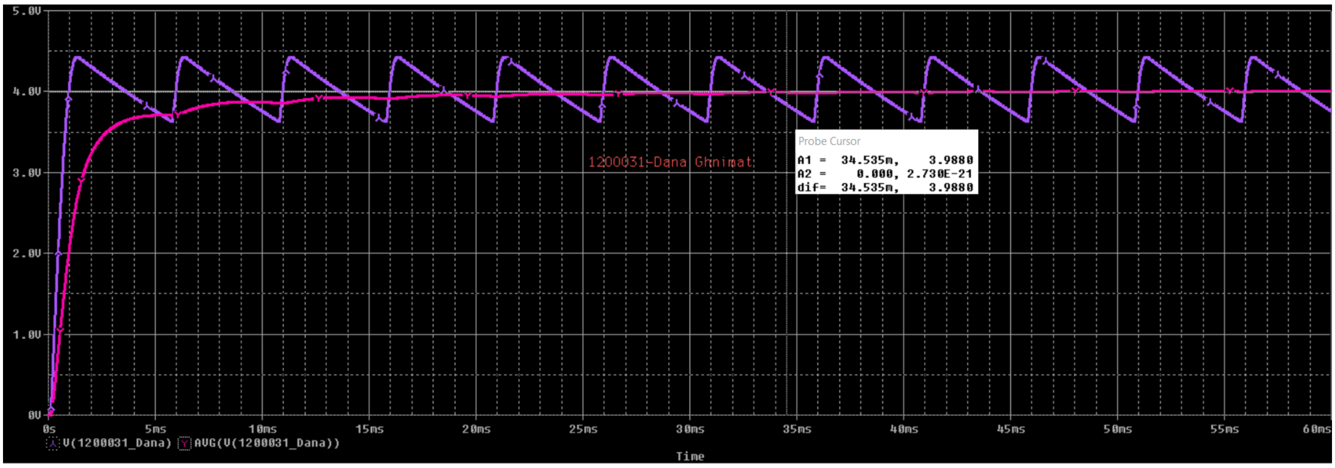

Figure 11 Mean Value of the Output Voltage of 2.2μF Capacitor

As shown in Figure 11, the Mean value nearly equals 3.9880V, then:

$$\textit{Ripple factor} = \frac{\textit{RMS (ripple of output voltage)}}{\textit{Average value of the output signal}} \times 100\%$$
$$= \frac{0.2299}{3.9880} \times 100\%$$
$$= 5.7647\ \%$$

Adding 47μF Capacitor:

Building the previous circuit of the rectifier but replacing the Capacitor with 47μF capacitor:

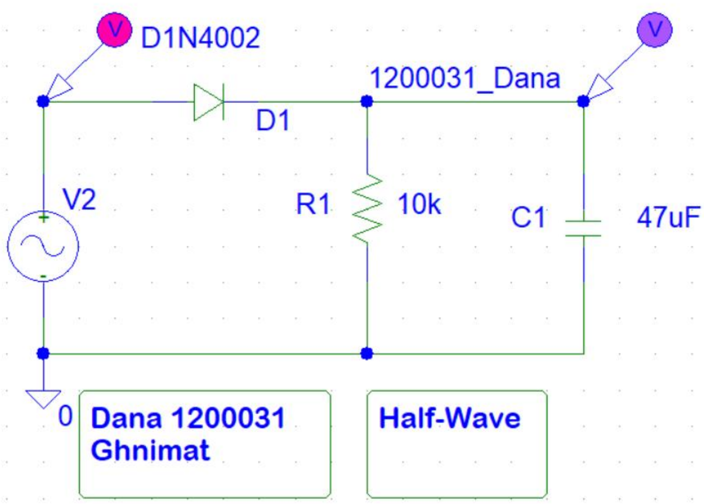

Figure 12 Half-wave rectifier Circuit with 47μF capacitor

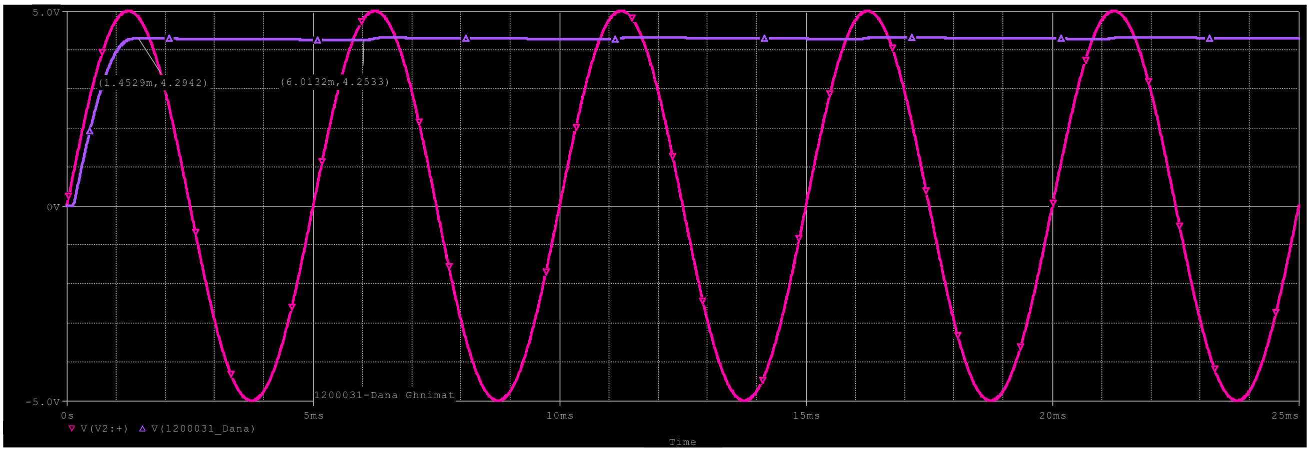

Figure 13 Half-wave rectifier figure with 47µF capacitor

There is almost no ripple compared to the previous circuit (when C = 2.2µF).

that's because the capacitor plays an important role in reducing the ripple of the output voltage. As the capacitor smooths out the DC pulsing output of the rectifier.

As figure 13 shows how the $V_{out,\, min} = 4.2533V$ and $V_{out,\, max} = 4.2942V$.

$$V_{p\text{-}p} = V_{Max} - V_{Min} = 4.2942 - 4.2533 = 0.0409V$$

$$V_{RMS} = \frac{Vpp}{2\sqrt{3}} = \frac{0.0409}{2\sqrt{3}} = 0.0118\ V$$

To measure the mean value, which is 4.2744V.

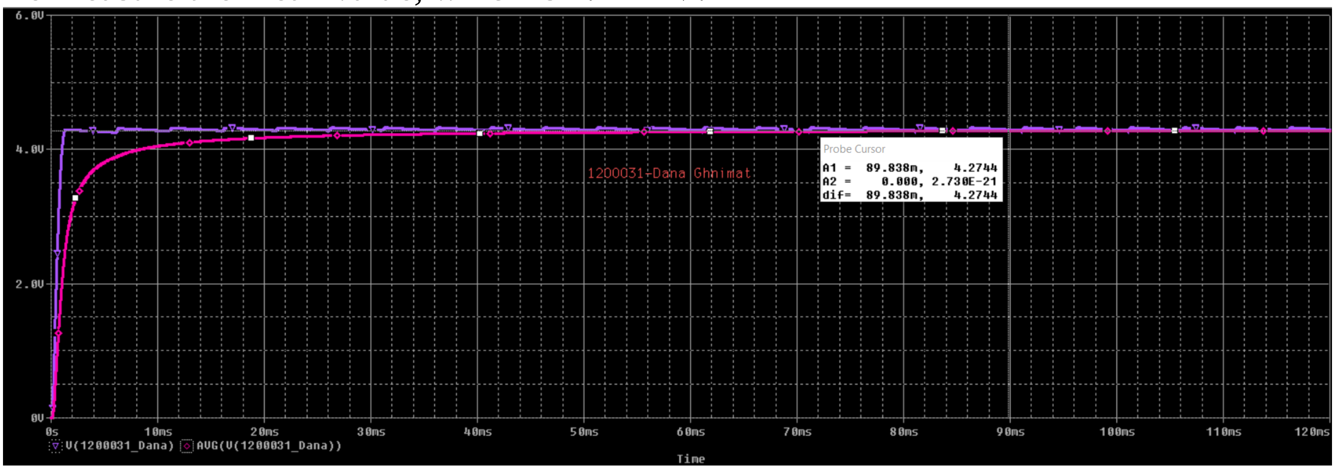

Figure 14 Mean Value of the Output Voltage (Vout) with C = 47uF

$$\textit{Ripple factor} = \frac{RMS\ (\textit{ripple of output voltage})}{\textit{Average value of the output signal}} \times 100\%$$
$$= \frac{0.0118}{4.2744} \times 100\%$$
$$= 0.2760\ \%$$

We conclude that the higher the value of the capacitor, the less the ripple factor. Meaning the capacitors play an important role in reducing output voltage ripple.

II. Full - Wave rectification:

II.1 Without Capacitor:

Figure 15 shows Bridge full-wave rectifier using 2:1 Transformer and 20Vp-p, 2KHz AC Power Supply.

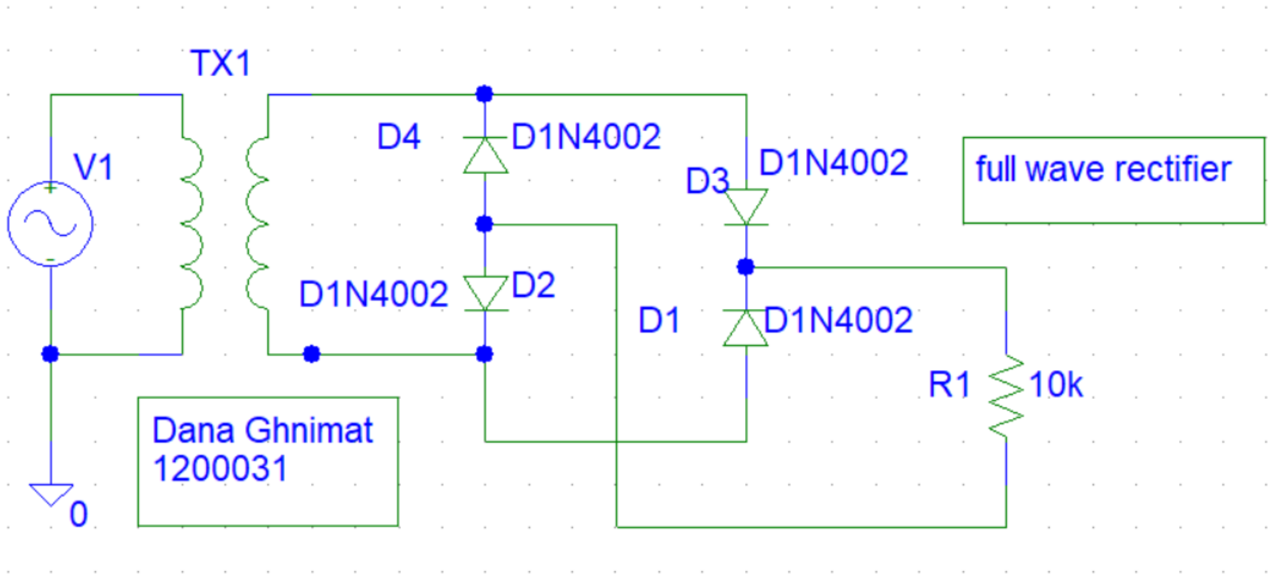

Figure 15 Bridge full-wave rectifier Circuit with Transformer

Then we can transform to 10Vp-p, 2KHz AC Power Supply.

By dividing the old Vp-p on steps of transformer, $V_{p\text{-}p,\ new}$ = 20 Vp-p /2 = 10V.

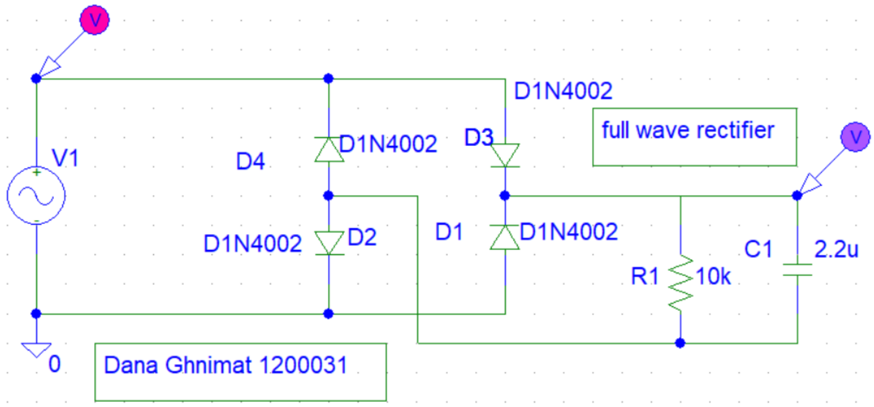

Figure 16 Bridge full-wave rectifier Circuit without Transformer

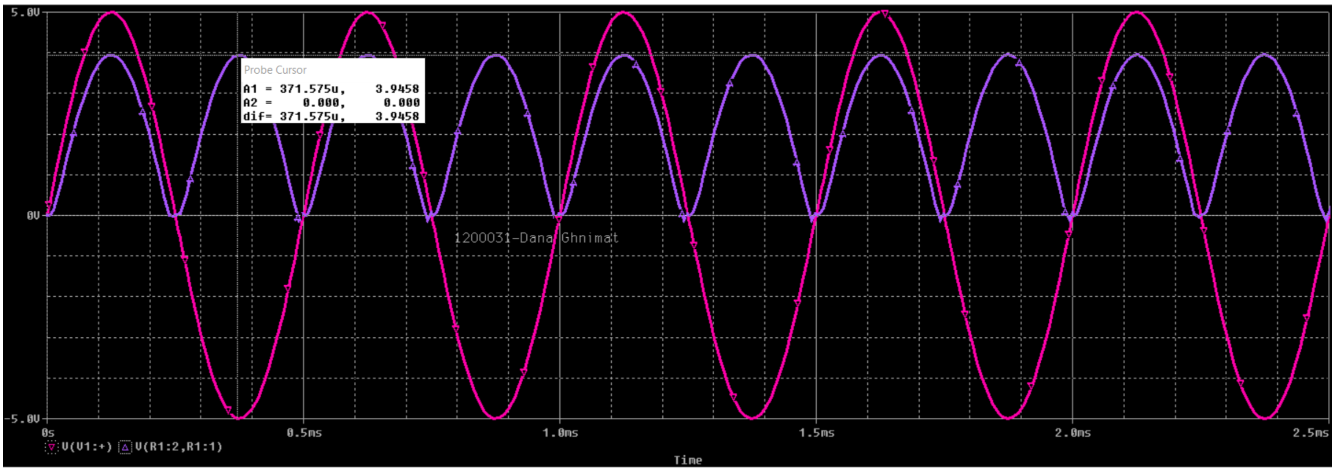

Figure 17 Bridge full-wave rectifier figure without Transformer

Waveform of the full wave Rectifier figure 17 shows that the $V_{out, Max}$ = 3. 9458V.Also, the Period equals 0.5ms in the simulation, and theoretically by:

Period T(sec) = 1/t (Hz)

= 1/2k

= 0.5m sec.

the output DC value of the full wave Rectifier. $V_{out, DC}$ = 2.2400V

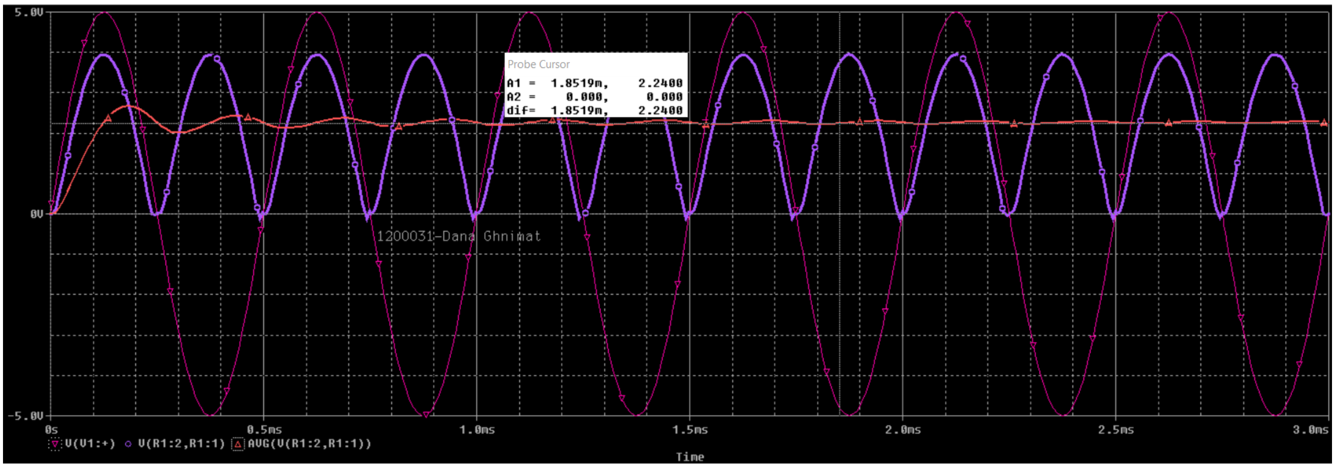

Figure 18 Bridge full-wave rectifier figure DC value

II.2 With Capacitor:

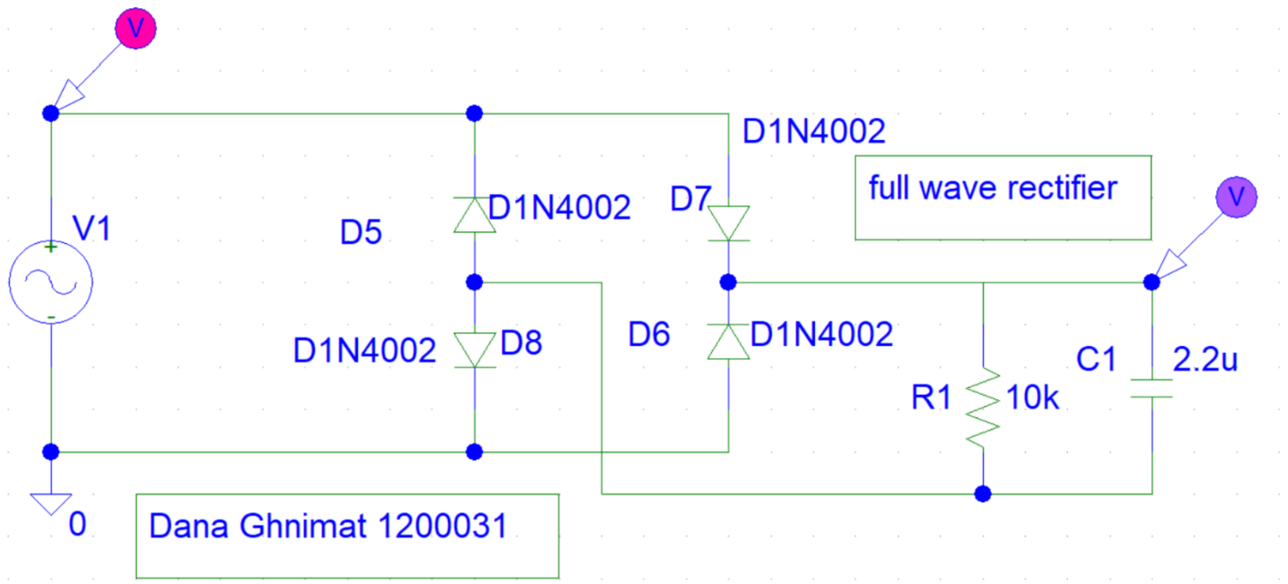

Figure 19 Full Wave Rectifier with C=2.2uF

Simulation:

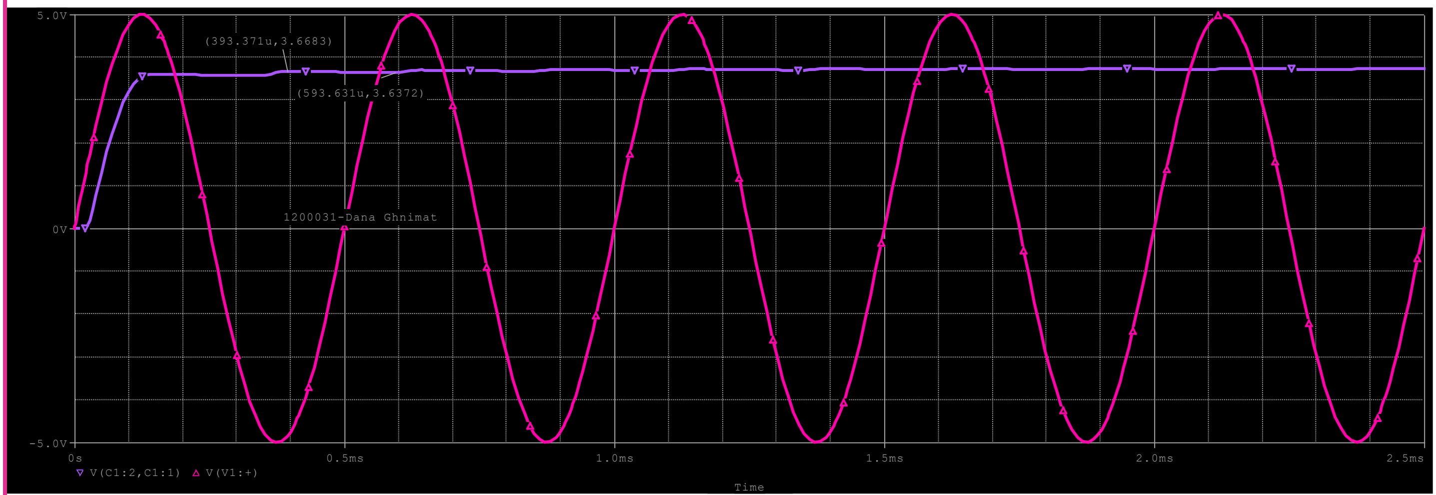

Figure 20 Full Wave Rectifier with Capacitor Waveform

As shown in Figure 20, $V_{out,\ Min}$ = 3. 6372V, while $V_{out,\ Max}$ = 3. 6683V, then

$$\mathbf{\mathit{Vp\text{-}p} = VMax - VMin}$$
$$\mathbf{= 3.6683 - 3.6372}$$
$$\mathbf{= 0.0311V}$$

$$VRMS = \mathit{Vp\text{-}p} / 2\sqrt{3}$$
$$= 0.0311/ 2\sqrt{3}$$
$$= 0.0089V$$

Then we find the Mean value in simulation:

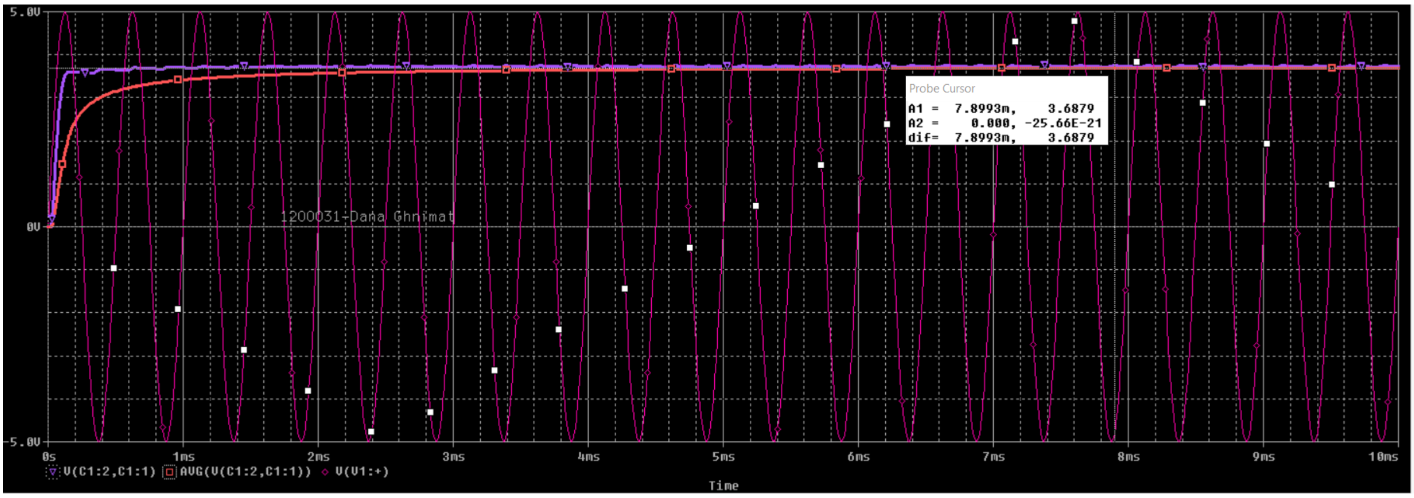

Figure 21 DC Value of Vout

the Mean value nearly equals 3.6879V, then

$$\text{Ripple factor} = \frac{RMS\ (\text{ripple of output voltage})}{\text{Average value of the output signal}} \times 100\%$$
$$= \frac{0.0089}{3.6879} \times 100\%$$
$$= 0.2413\ \%$$

In short, a full-wave rectifier is a type of rectifier that converts two halves of each cycle of an alternating current (AC) signal into a pulsed direct current (DC) signal, as it uses multiple diodes (4 diodes) to rectify.

Full-wave rectifiers are more efficient and provide smoother and more stable DC output than half-wave rectifiers.

The ripple amplitude, which is the change in the DC output voltage, is increases with respect to decrease in the product of the frequency (output) and the capacitance of the filter capacitor (C).

$$f_{ripple} = 2 \text{ x } f_{input}$$

$$Vr \propto \frac{1}{C\ x\ f_{input}}$$

To achieve the same ripple amplitude at a lower frequency, we would typically need a larger capacitor. (increase C when we decrease f, to maintain balance).

Part3: Other applications:

I. clipping:

Connected a Clipping Circuit with a Variable Power Supply control to zero and AC Power Supply with 6 Vpp and 200Hz

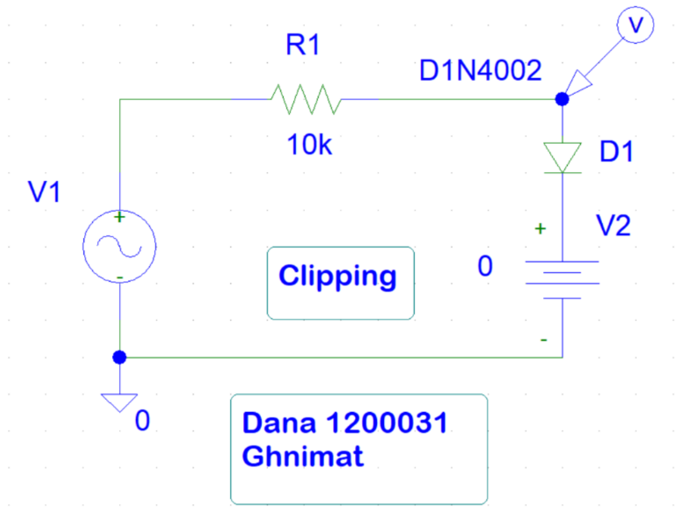

Figure 22 Clipping Circuit

Parameters of simulation:

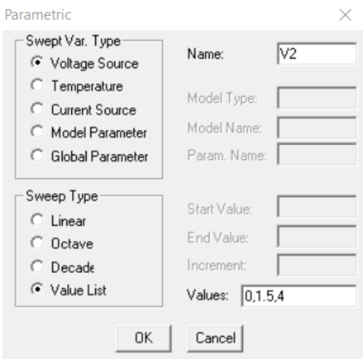

Figure 23 Parameters of clipping

Simulation:

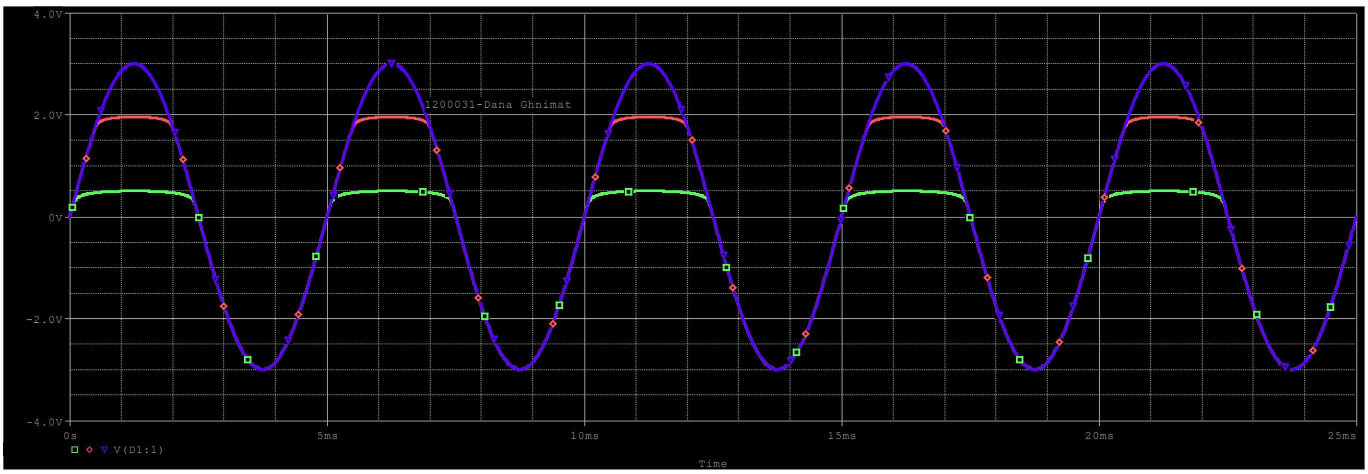

Figure 24 Clipping waveform figure

This diode clipping of the input signal produces an output waveform that looks like a flat version of the input as the output voltage never exceeds a certain level to protect the circuit from high voltage.

We saw in the signal diode Part 1 that when a diode is forward biased, it allows current to pass through itself, thereby establishing a voltage. When the diode is reverse biased, no current passes through it and the voltage across it is not affected, which is the basic operation of the diode cutoff circuit.

To produce diode clipping circuits for voltage waveforms at different levels, a bias voltage, V_{BIAS} is added in series with the diode to produce a combination clipper.

The voltage across the series combination must be greater than V_{BIAS} + 0.7V before the diode becomes sufficiently forward biased to conduct.

For example, if the V_{BIAS} level is set V volts, then the sinusoidal voltage at the diode's anode terminal must be greater than **V + 0.7** volts for it to become forward biased. Any anode voltage levels above this bias point are clipped off., Hence why when we put 4 Volts in V_{BIAS} it didn't show up.[1]

Whereas if the DC voltage (V_{BIAS}) is 1.5V then the positive peaks of the output waveform will be clipped at 2.2V (1.5V + 0.7V) < 3 V, since the diode conducts when the signal from the input exceeds the sum of the DC voltage and the forward voltage of the diode drop (0.7 Volts).

The relationship between clipping level and DC voltage is a Positive Bias Diode:
clipping level = DC voltage + diode forward voltage
which determines the characteristics of the clipped output waveform.

II. Clamping

Connected Clamping Circuit with a Variable Power Supply control to zero and AC Power Supply with 6 Vpp and 200Hz.

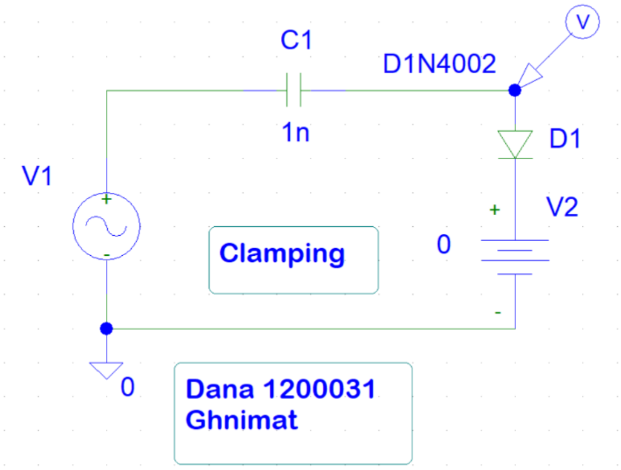

Figure 25 Clamping Circuit

Parameters:

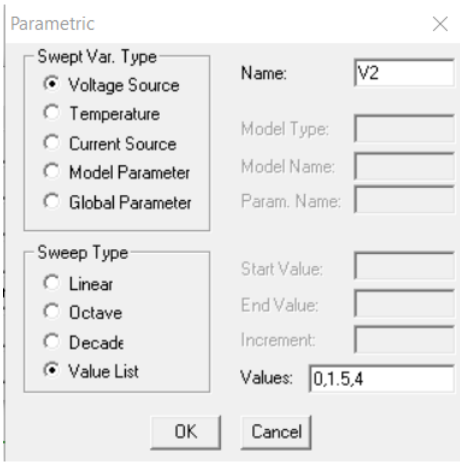

Figure 26 Clamping parameters

Simulation:

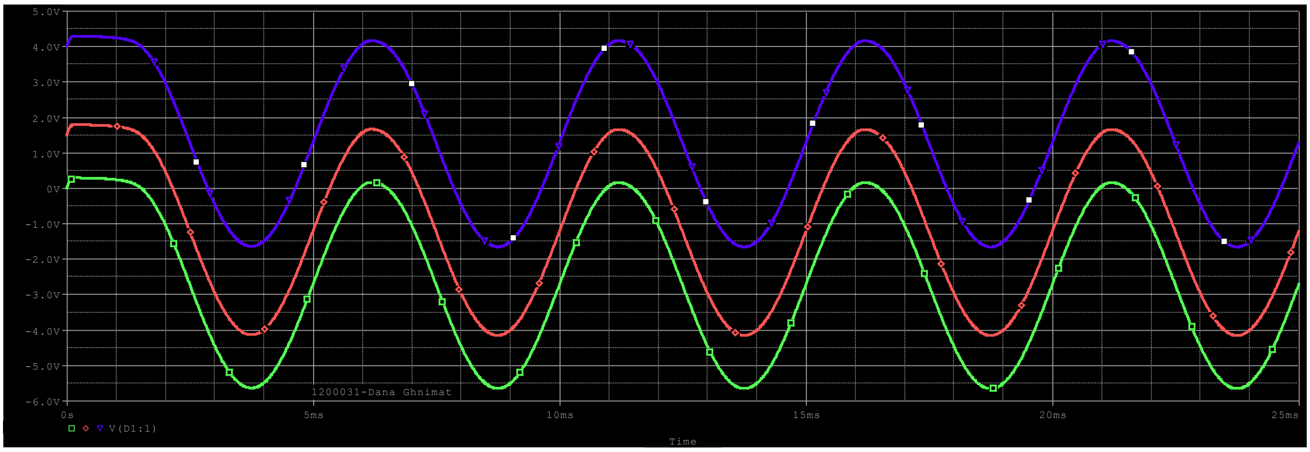

Figure 27 Clamping Waveform figure

This circuit reference to Negative clamper with positive V_{Bias},

Clamper circuits are constructed in a similar manner as that of clipper circuits. However, clamper includes an extra charging element that is the capacitor in its circuitry. The combination of diode and capacitor in the clamper circuit is used to maintain different dc level at the output of the clamper.

The moment the positive half of the AC input is applied, the diode will go into forward-biased state resulting in no-load current at the output.

However, the signal is somewhat raised to a positive level due to the positively applied battery voltage. When positive half of the AC signal is applied, the diode is in the forward biased state due to ac supply but is reverse biased because of battery voltage. So, the diode conducts when ac supply surpasses battery voltage. The capacitor here is charged to the forward bias state of the diode.

When the negative half of the AC signal is applied, the diode will now be reverse biased state by cause of both the AC supply and battery voltage. This non-conducting state of the diode discharges the capacitor. Thus, the voltage across the capacitor appears at the output.

So, at the output the sum of the capacitor voltage and the input voltage will be obtained. at the output we have, $V_o = -V_b - V_m$, this results in a downward shift of the signal. [2]

Clamping Level = battery Voltage + AC Input Peak

III. Voltage multiplier circuits:

According to the old manual we have to connect Voltage multiplier circuit:

The circuit below contain a Voltages Multiplier Circuit with 10Vp-p and 500Hz AC Power Supply.

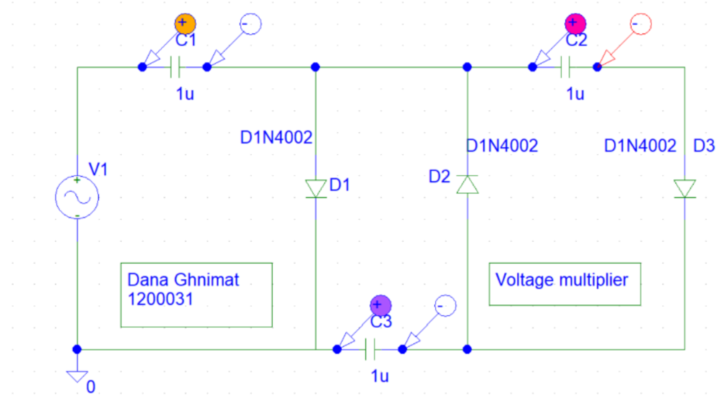

Figure 28 Voltages Multiplier Circuit

Simulation:

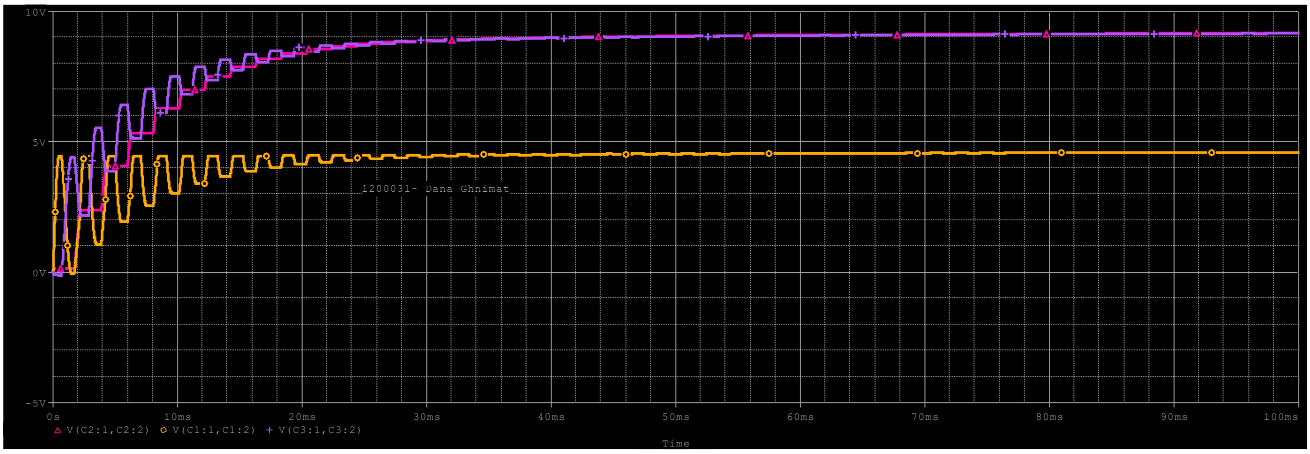

Figure 29 Voltages Multiplier Waveform

DC analysis:

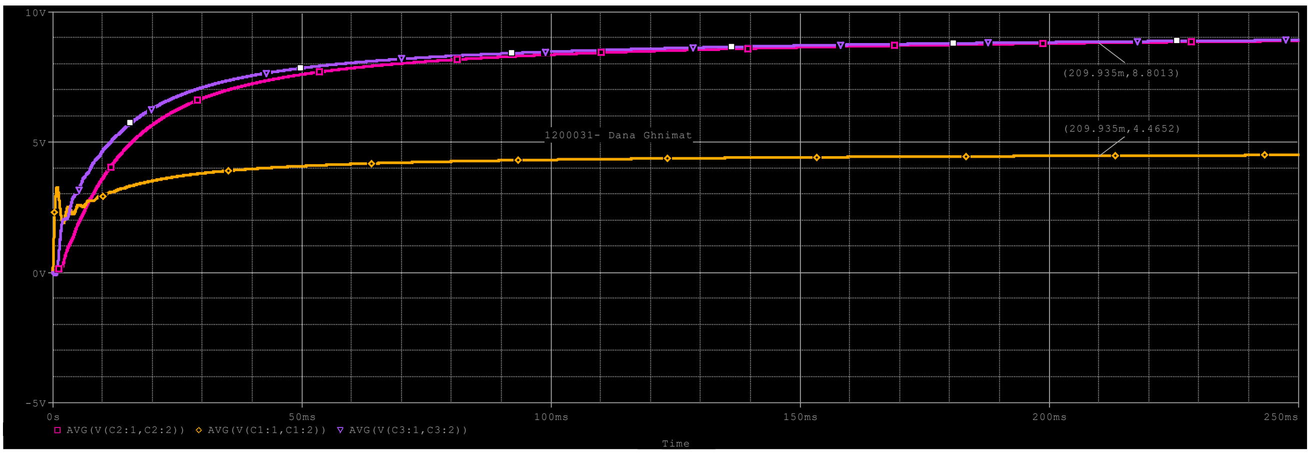

Figure 30 Voltages Multiplier Waveform DC analysis

Notice that the voltage across C2 and C3 are the same and equals 8.8013V. While the voltage across C1 is nearly the half of them and equals 4.4652V.

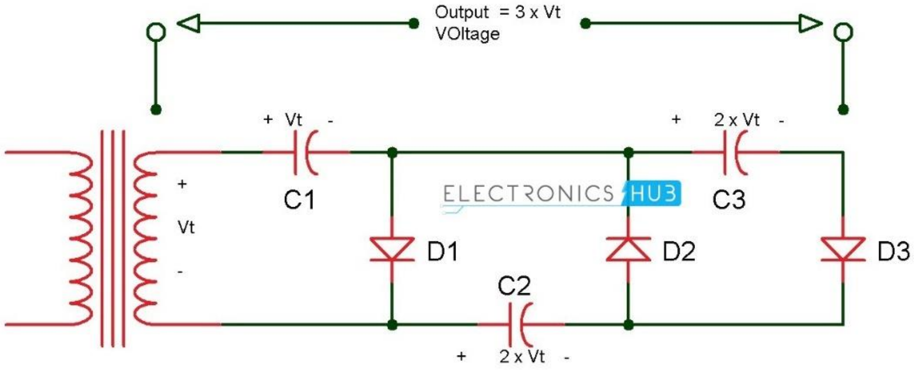

Figure 31 Voltage multiplier analysis

The PIV across each diode (D1, D2, D3) in a Voltage Tripler circuit is the sum of the peak voltage of the input AC and the voltages across the capacitors that after it in the circuit as the following: [3]

$$PIV_{D1} = V_{peak}$$
$$PIV_{D2} = V_{peak} + V_{peak} = 2 \times V_{peak}$$
$$PIV_{D3} = V_{peak} + 2 \times V_{peak} = 3 \times V_{peak}$$

References

[1]https://www.electronics-tutorials.ws/diode/diode-clipping-circuits.html (6:30Am 24-march)

[2] https://electronicscoach.com/clamper-circuits.html (6:50Am 24-march)

[3] https://www.electronicshub.org/voltage-doubler-voltage-tripler-circuits/ (7:00Pm 24-march)