National Polytechnic Institute
Superior School of Computer Sciences

Analog Electronics.

Practice 2 - Rectifiers.

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Contents

1 Objective:

- Analyze the operation of the different rectifiers with diodes.
- Analyze the behavior of different integration filter rectifiers.
- Interpret the obtained values and compare them with the theoretical values.

2 Introduction:

The diode analysis will now be expanded to include time-varying functions such as the sinusoidal waveform and the square wave. There is no question that the degree of difficulty will increase, but once a few fundamental maneuvers are understood, the analysis will be fairly direct and follow a common thread.

2.1 Half-Wave Rectification:

Over one full cycle, defined by the period $\boldsymbol{T}$ of Figure 2.1.0, the average value (the algebraic sum of the areas above and below the axis) is zero. The circuit of Figure 2.1.0, called a ***half-wave rectifier***, will generate a waveform V_o that will have an average value of particular, use in the ac-to-dc conversion process. When employed in the rectification process, a diode is typically referred to as a rectifier. Its power and current ratings are typically much higher than those of diodes employed in other applications, such as computers and communication systems.

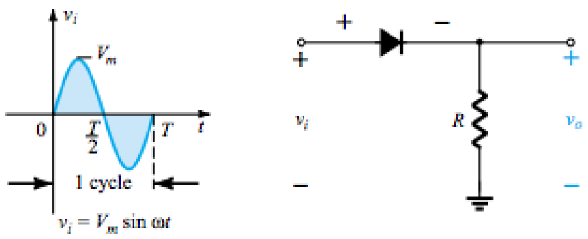

Figure 2.1.0: Half-Wave Rectifier.

During the interval $\boldsymbol{t} = 0 \rightarrow \frac{T}{2}$ in Figure 2.1.0 the polarity of the applied voltage V_i is such as to establish "pressure" in the direction indicated and turn on the diode with the polarity appearing above the diode. Substituting the short-circuit equivalence for the ideal diode will result in the equivalent circuit of Figure 2.1.1, where it is fairly obvious that the output signal is an exact replica of the applied signal. The two terminals defining the output voltage are connected directly to the applied signal via the short-circuit equivalence of the diode.

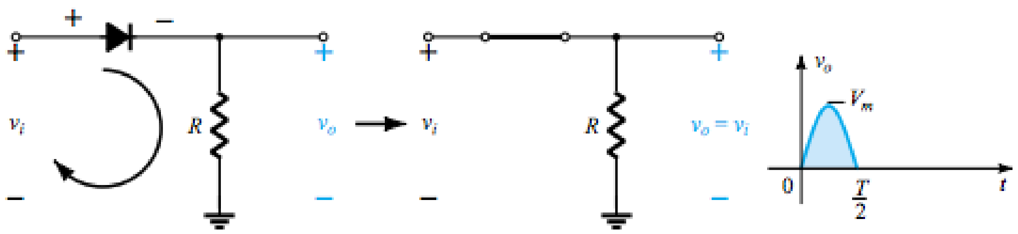

Figure 2.1.1: Conduction Region ($0 \rightarrow \frac{T}{2}$).

For the period $\frac{T}{2} \rightarrow T$, the polarity of the input V_i is as shown in Figure 2.1.2 and the resulting polarity across the ideal diode produces an off state with an open-circuit equivalent. The result is the absence of a path for charge to flow and $V_o = \boldsymbol{iR} = \boldsymbol{(0)R} = 0$ V for the period $\frac{T}{2} \rightarrow T$. The input V_i and the output V_o were sketched together in Figure 2.1.3 for comparison purposes. The output signal V_o now has a net positive area above the axis over a full period and an average value determined by:

$$V_{dc} = 0.318 V_m \tag{1}$$

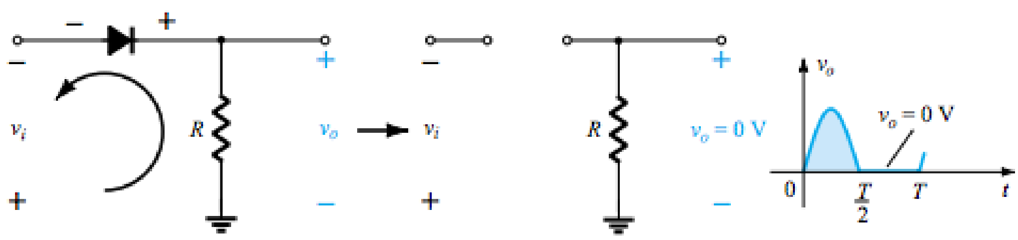

Figure 2.1.2: Non-conduction region ($\frac{T}{2} \rightarrow T$).

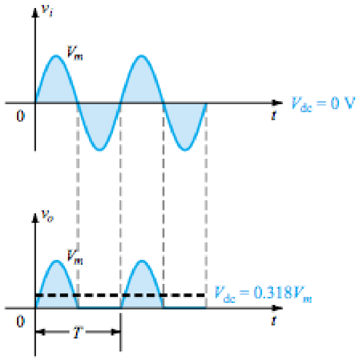

Figure 2.1.3: Half-wave rectified signal.

The process of removing one-half the input signal to establish a dc level is aptly called ***half-wave rectification.***

2.2 Full-Wave Rectification:

2.2.1 Bridge Network:

The dc level obtained from a sinusoidal input can be improved 100% using a process called ***full-wave rectification.*** The most familiar network for performing such a function appears in Figure 2.2.1.0 with its four diodes in a bridge configuration. During the period t = 0 to $\frac{T}{2}$ the polarity of the input is as shown in Figure 2.2.1.1.The resulting polarities across the ideal diodes are also shown in Figure 2.2.1.1 to reveal that D_2 and D_3 are conducting while D_1 and D_4 are in the off state. The net result is the configuration of Figure 2.2.1.2, with its indicated current and polarity across $\boldsymbol{R}$. Since the diodes are ideal the load voltage is $V_o = V_i$, as shown in the same figure.

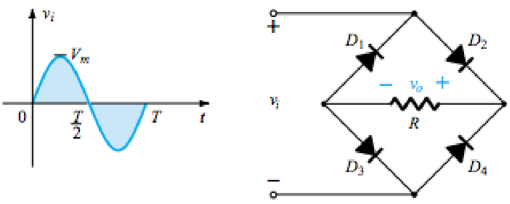

Figure 2.2.1.0: Full-wave bridge rectifier.

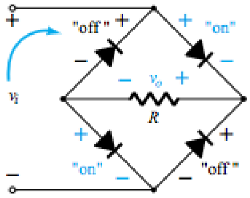

Figure 2.2.1.1: Network of Figure 2.2.1.0 for the period $0 \rightarrow \frac{T}{2}$ of the input voltage V_i.

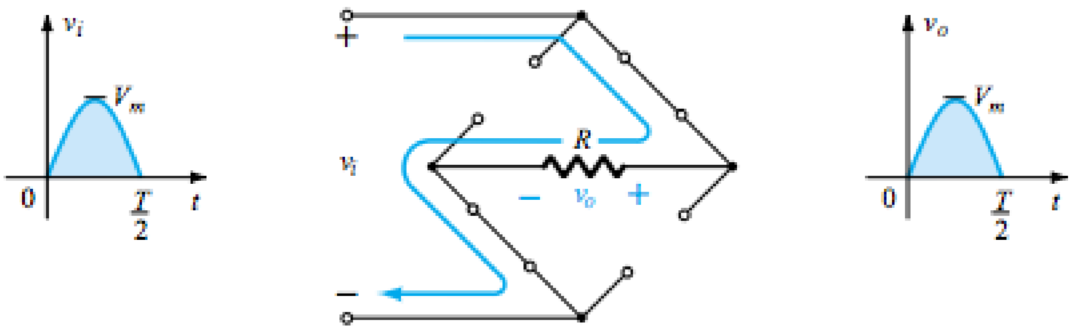

Figure 2.2.1.2: Conduction path for the positive region of V_i.

For the negative region of the input the conducting diodes are D_1 and D_4, resulting in the configuration of Figure 2.2.1.3. The important result is that the polarity across the load resistor $\boldsymbol{R}$ is the same as in Figure 2.2.1.1, establishing a second positive pulse, as shown in Figure 2.2.1.3. Over one full cycle the input and output voltages will appear as shown in Figure 2.2.1.4.

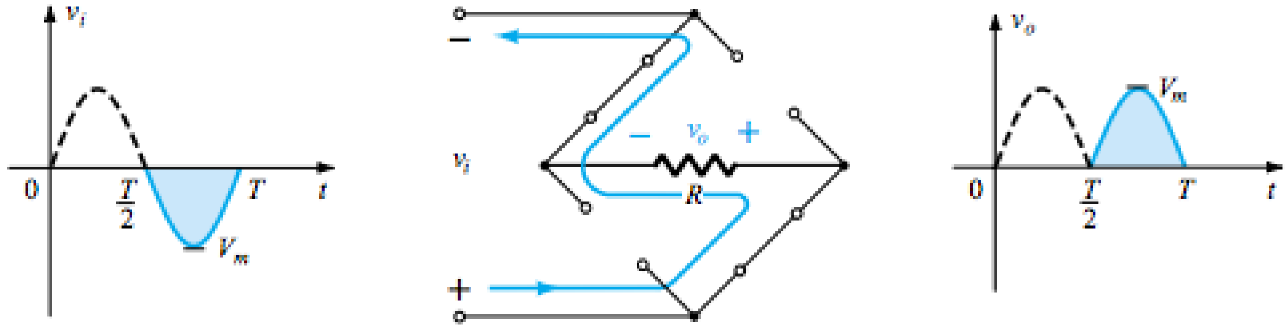

Figure 2.2.1.3: Conduction path for the negative region of V_i.

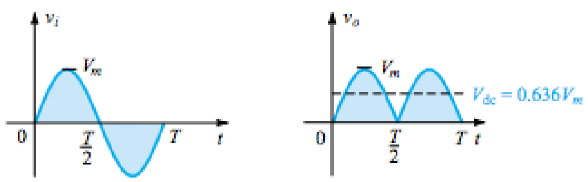

Figure 2.2.1.4: Input and output waveforms for a full-wave rectifier.

Since the area above the axis for one full cycle is now twice that obtained for a half-wave system, the dc level has also been doubled:

$$V_{dc} = 0.636V_m \tag{2}$$

2.2.2 Center-Tapped Transformer:

A second popular full-wave rectifier appears in Figure 2.2.2.0 with only two diodes but requiring a center-tapped (CT) transformer to establish the input signal across each section of the secondary of the transformer. During the positive portion of V_i applied to the primary of the transformer, the network will appear as shown in Figure 2.2.2.1. D_1 assumes the short-circuit equivalent and D_1 the open-circuit equivalent, as determined by the secondary voltages and the resulting current directions. The output voltage appears as shown in Figure 2.2.2.1.

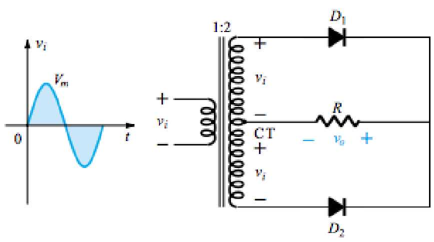

Figure 2.2.2.0: Center-tapped transformer full-wave rectifier.

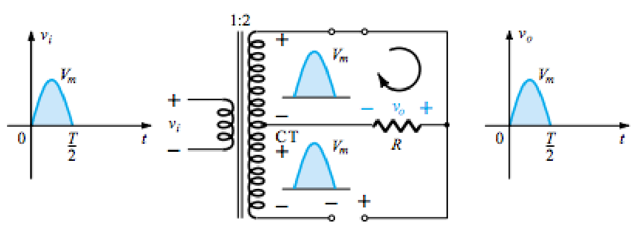

Figure 2.2.2.1: Network conditions for the positive region of V_i.

During the negative portion of the input the network appears as shown in Figure 2.2.2.2, reversing the roles of the diodes but maintaining the same polarity for the voltage across the load resistor $\boldsymbol{R}$. The net effect is the same output as that appearing in Figure 2.2.1.4 with the same dc levels.

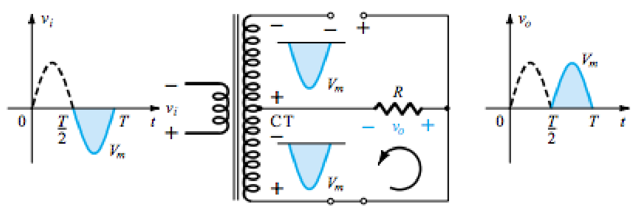

Figure 2.2.2.2: Network conditions for the negative region of V_i.

3 Development:

We are going to analyze several circuits, with different resistors and capacitors, to visualize how the ***half-wave*** and ***full-wave*** rectification looks in physical circuits and with the help of an oscilloscope we are going to capture the form of the output signal after being rectified. Theoretically, this signal must be CC.

3.1 Transformer:

After rectified the signal, we assembly the circuit of the Figure 3.1.0, the transformer to be used it's of ***12V_{rms} to 1A*** this means that in the ***secondary winding*** the voltage will be approximately of 12V_{rms}. The ***primary winding*** will be connected to the outlet plug and the voltage that will be driving will be approximately of 117V_{rms}.

We are going to be switching between two resistors: One of 100Ω at 10W and the other one of 22Ω at 25W. For each resistor, the voltage will be measured, and the result its going to be registered in the table bellow.

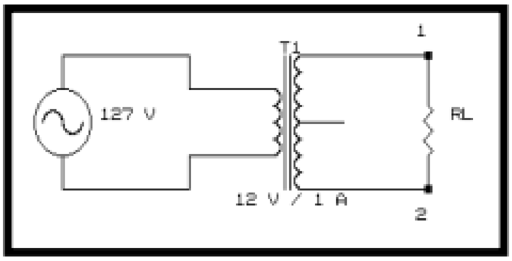

Figure 3.1.0: Transformer circuit.

R_L	V_{rms}
100Ω	13.2V_{rms}
22Ω	12.1V_{rms}

Table 1: Measured values of Figure 3.1.0.

3.2 Half-Wave Rectifier:

The ***half-wave rectifier***, "cancels" the negative voltage, and rectifies the A.C into C.C. But still, has a Voltage loss in the second semi-period as we have seen in Figure 2.1.2.

Using the 100Ω resistor as R_L and a 1N4003 diode, the circuit of the Figure 3.2.0 was assembled.

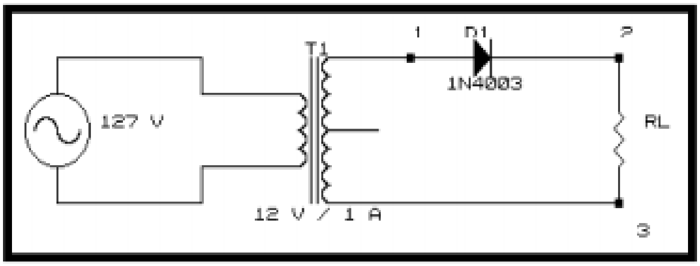

Figure 3.2.0: Half-wave rectifier circuit.

For measure the signal before being rectified, we put the positive terminal of the voltmeter in the terminal 1 of the Figure 3.2.0 and the negative terminal of the voltmeter in the terminal 3 of the Figure 3.2.0. We will call this voltage V_T (Transformer Voltage).

$$V_T = 13.3\ V_{rms} \tag{3}$$

Observation: To measure V_T the Voltmeter needs to be in the A.C option.

In the same terminals (1 and 3), of the Figure 3.2.0, the terminals of the oscilloscope were connected same as the voltmeter. Now, as can we see in Figure 3.2.1, the signal isn't being rectified yet. To visualize the rectified signal, the terminals of the oscilloscope were connected to the terminals 2 and 3 of the Figure 3.2.0. Now, as we can see in Figure 3.2.2 the signal is rectified from A.C to D.C. Now there's no negative voltage.

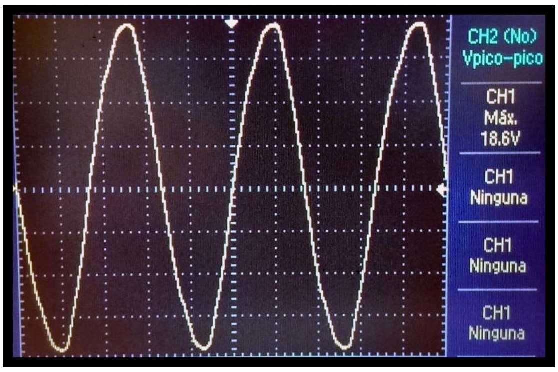

Figure 3.2.1: Transformer output signal.

$\frac{5V}{div}$ *and* $\frac{5mseg}{div}$.

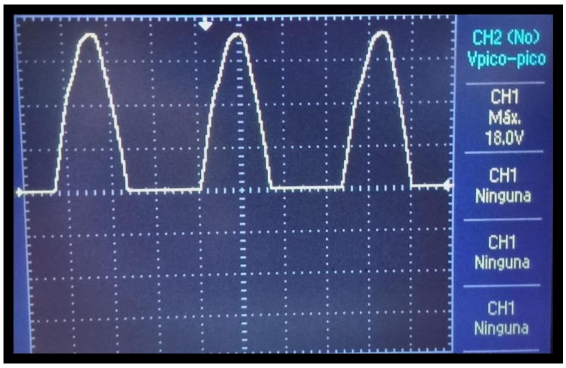

Figure 3.2.2: Half-wave rectified signal.

$\frac{5V}{div}$ *and* $\frac{5mseg}{div}$.

Observation: In the oscilloscope we are only using the channel 1 in D.C option.

To measure the voltage in R_L, its necessary to connect the positive terminal of the voltmeter in the terminal 2 of the Figure 3.2.0 and the negative terminal of the voltmeter in the terminal 3 of the Figure 3.2.0. We will call this voltage V_0, also the resistor R_L will have a current, we will call it I_0 and with Ohm's Law we can find it.

$$V_0 = 5.6\ V_{rms} \tag{4}$$

Observation: To measure V_0 the Voltmeter needs to be in the D.C option.

Using Ohm's Law: $I = \frac{V}{R}$.

$$I_0 = \frac{5.6\ V_{rms}}{0.100\ \Omega} = 0.056\ A \tag{5}$$

- ***For V_p (Peak Voltage) of Figure 3.2.1:***

When the terminals of the oscilloscope are connected to the circuit and the signal it's displayed on screen as Figures 3.2.1 shows. We will put the oscilloscope in the option ***measures*** and search for the option ***Max Voltage***.

$$V_p = 18.6V \tag{6}$$

- ***Finally, $V_p - V_D$, where V_p it's the peak voltage in Figure 3.2.1 and V_D it's the diode Voltage:***

$$V_p - V_D = 18.6V - 0.7V = 17.9V \tag{7}$$

3.3 Half-Wave Rectifier With Filter:

Using basically the same circuit of the Figure 3.2.0, we are going to connect in parallel to the R_L ***resistor*** a ***electrolytic capacitor***, this device will act like a filter. The voltage coming out from rectifiers is not smooth and a filter rectifier circuit is used to smoothen it for more stable constant DC voltage. We are going to be exchanging between two different capacitors, one of $470\mu F$ and another of $2200\mu F$.

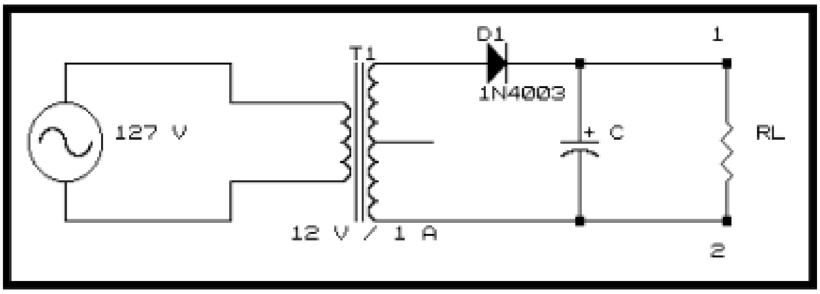

Figure 3.3.0: Half-wave rectifier circuit with filter.

Once the circuit it's armed using the 100Ω *resistor as* R_L we will measure with the voltmeter the ***Voltage*** and ***Current*** in this component. According to the Figure 3.3.0, we will connect the Positive terminal of the voltmeter in the terminal 1 of Figure 3.3.0 and the Negative terminal of the voltmeter in the terminal 2 of Figure 3.3.0, we will call this voltage V_0 for the current I_0 we can use ***Ohm's Law***:

Using Ohm's Law: $I_0 = \frac{V_0}{R_L}$.

Capacitor	V_0	I_0
$470\mu F$	14.6 V	0.146 A
$2200\mu F$	15.06 V	0.150 A

Table 2: Measured values of Figure 3.3.0.

The small unwanted residual periodic variation of the direct current (DC) output of a power supply which has been derived from an alternating current (AC) source it's called ***Ripple***. To measure the ***ripple voltage*** ΔV it's necessary to connect the ***oscilloscope terminals*** in the terminals 1 and 2 of the Figure 3.3.0 in the option of AC.

- Using the $470\mu F$ capacitor:

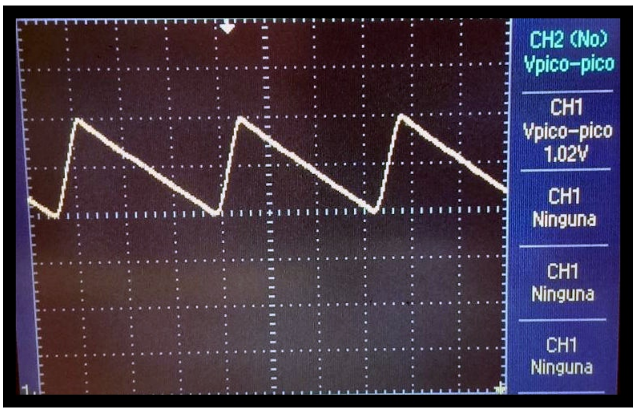

Figure 3.3.1: Half-wave with filter rectified signal.

$\frac{2V}{div}$ *and* $\frac{5mseg}{div}$.

- Using the $2200\mu F$ capacitor:

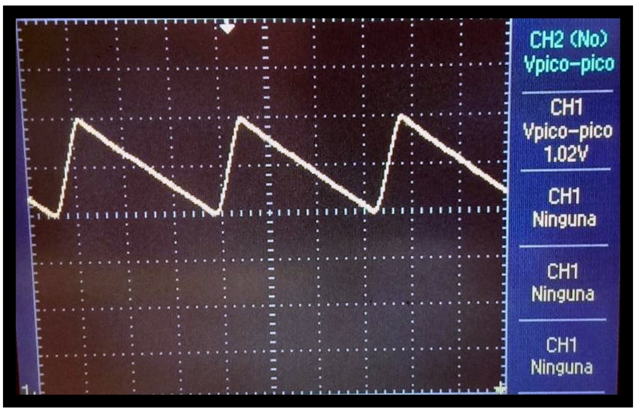

Figure 3.3.2: Half-wave with filter rectified signal.

$\frac{500mV}{div}$ *and* $\frac{5mseg}{div}$.

- ***For the ripple voltage (ΔV):***

When the terminals of the oscilloscope are connected to the circuit and the signal it's displayed on screen as Figures 3.3.1 and 3.3.2 shows. We will put the oscilloscope in the option of ***measures*** and the ***ripple*** voltage will be the ***peak-to-peak voltage (V_{pp})***.

Capacitor	ΔV
$470\mu F$	$4.48\ V$
$2200\mu F$	$1.02\ V$

Table 3: Ripple Voltage of Figure 3.3.0.

3.4 Full-Wave Center-Taped Rectifier:

The ***full-wave center-taped rectifier***, converts alternating current (AC), which periodically reverses direction, to direct current (DC). This type of rectifier, unlike the ***half-wave***, during the negative period, reverse the roles of the diodes but maintaining the same polarity for the voltage across the load resistor. As result we have no lost of voltage.

Using the 100Ω resistor as R_L and two 1N4003 diodes, the circuit of the Figure 3.4.0 was assembled.

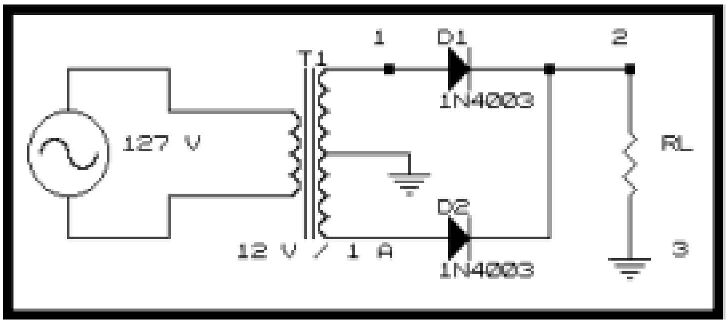

Figure 3.4.0: Full-wave center-taped rectifier.

For measure the signal before being rectified, we put the positive terminal of the voltmeter in the terminal 1 of the Figure 3.4.0 and the negative terminal of the voltmeter in the terminal 3 of the Figure 3.4.0. We will call this voltage V_T (Transformer Voltage).

$$V_T = 6.7\ V_{rms} \tag{8}$$

Observation: To measure V_T the Voltmeter needs to be in the A.C option.

In the same terminals (1 and 3), of the Figure 3.4.0, the terminals of the oscilloscope were connected same as the voltmeter. Now, as can we see in Figure 3.4.1, the signal isn't being rectified yet. To visualize the rectified signal, the terminals of the oscilloscope were connected to the terminals 2 and 3 of the Figure 3.4.0. Now, as we can see in Figure 3.4.2 the signal is rectified from A.C to D.C. Now there's no negative voltage.

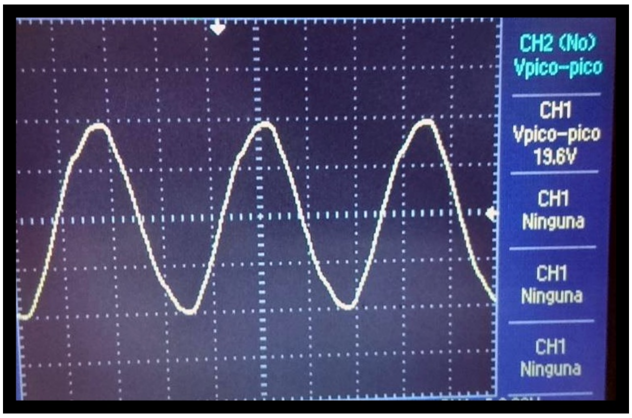

Figure 3.4.1: Transformer output signal.

$\frac{5V}{div}$ *and* $\frac{5mseg}{div}$.

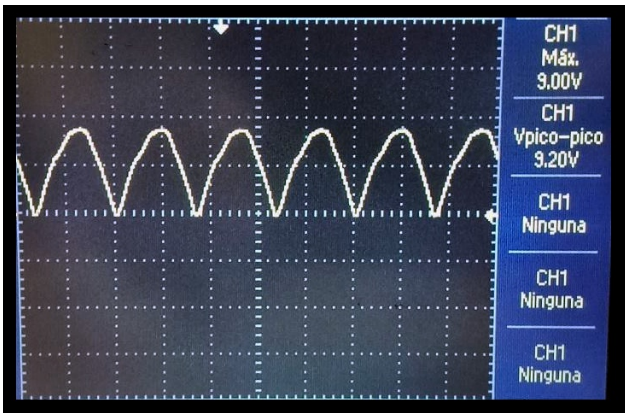

Figure 3.4.2: Full-wave rectified signal.

$\frac{5V}{div}$ *and* $\frac{5mseg}{div}$.

Observation: In the oscilloscope we are only using the channel 1 in D.C option.

To measure the voltage in R_L, its necessary to connect the positive terminal of the voltmeter in the terminal 2 of the Figure 3.4.0 and the negative terminal of the voltmeter in the terminal 3 of the Figure 3.4.0. We will call this voltage V_0, also the resistor R_L will have a current, we will call it I_0 and with Ohm's Law we can find it.

$$V_0 = 5.3\ V_{rms} \tag{9}$$

Observation: To measure V_0 the Voltmeter needs to be in the D.C option.

Using Ohm's Law: $I = \frac{V}{R}$.

$$I_0 = \frac{5.3\ V_{rms}}{0.100\ \Omega} = 0.053\ A \tag{10}$$

- ***For V_p (Peak Voltage) of Figure 3.4.1:***

When the terminals of the oscilloscope are connected to the circuit and the signal it's displayed on screen as Figures 3.4.1 shows. We will put the oscilloscope in the option ***measures*** and search for the option ***Max Voltage***.

$$V_p = 9.8V \tag{11}$$

- ***Finally, $V_p - V_D$, where V_p it's the peak voltage in Figure 3.2.1 and V_D it's the diode Voltage:***

$$V_p - V_D = 9.8V - 0.7V = 9.1V \tag{12}$$

3.5 Full-Wave Center-Taped Rectifier With Filter:

Using basically the same circuit of the Figure 3.4.0, we are going to connect in parallel to the R_L ***resistor*** a ***electrolytic capacitor***, this device will act like a filter. The voltage coming out from rectifiers is not smooth and a filter rectifier circuit is used to smoothen it for more stable constant DC voltage. We are going to be exchanging between two different capacitors, one of $470\mu F$ and another of $2200\mu F$.

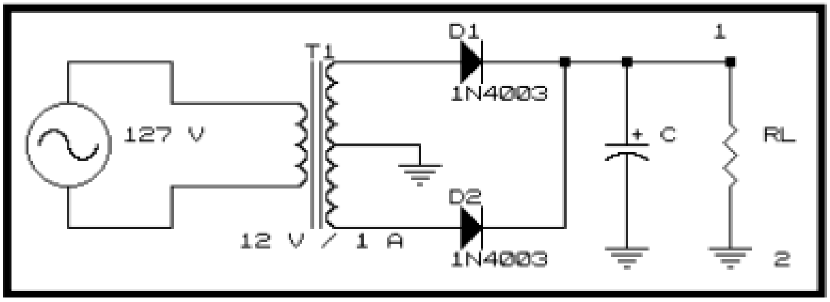

Figure 3.5.0: Full-wave rectifier circuit with filter.

Once the circuit it's armed using the 100Ω *resistor as* R_L we will measure with the voltmeter the ***Voltage*** and ***Current*** in this component. According to the Figure 3.5.0, we will connect the Positive terminal of the voltmeter in the terminal 1 of Figure 3.5.0 and the Negative terminal of the voltmeter in the terminal 2 of Figure 3.5.0, we will call this voltage V_0 for the current I_0 we can use ***Ohm's Law***:

Using Ohm's Law: $I_0 = \frac{V_0}{R_L}$.

Capacitor	V_0	I_0
$470\mu F$	$8.1\ V$	0.081 A
$2200\mu F$	$8.2\ V$	0.082 A

Table 4: Measured values of Figure 3.5.0.

The small unwanted residual periodic variation of the direct current (DC) output of a power supply which has been derived from an alternating current (AC) source it's called ***Ripple***. To measure the ***ripple voltage*** $\Delta \boldsymbol{V}$ it's necessary to connect the ***oscilloscope terminals*** in the terminals 1 and 2 of the Figure 3.5.0 in the option of AC.

- Using the $470\mu F$ capacitor:

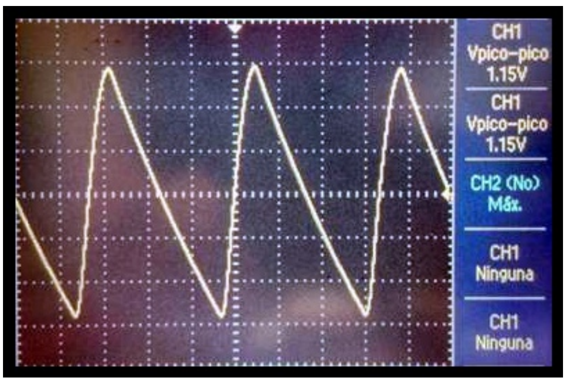

Figure 3.5.1: Full-wave with filter rectified signal.

$\frac{200mV}{div}$ *and* $\frac{2.50mseg}{div}$.

- Using the $2200\mu F$ capacitor:

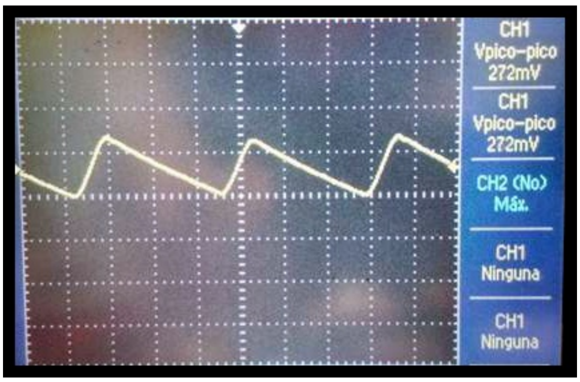

Figure 3.5.2: Full-wave with filter rectified signal.

$\frac{200mV}{div}$ *and* $\frac{2.50mseg}{div}$.

- ***For the ripple voltage (ΔV):***

When the terminals of the oscilloscope are connected to the circuit and the signal it's displayed on screen as Figures 3.5.1 and 3.5.2 shows. We will put the oscilloscope in the option of ***measures*** and the ***ripple*** voltage will be the ***peak-to-peak voltage (V_{pp})***.

Capacitor	ΔV
$470\mu F$	1.15 V
$2200\mu F$	272 mV

Table 5: Ripple Voltage of Figure 3.5.0.

3.6 Full-Wave Bridge-Network Rectifier:

The ***full-wave bridge-network rectifier***, converts alternating current (AC), which periodically reverses direction, to direct current (DC). This type of rectifier, unlike the ***half-wave***, during the negative period, reverse the roles of the diodes but maintaining the same polarity for the voltage across the load resistor. Unlike the ***center-taped rectifier*** that use one diode per semi-period, this network uses two diodes per semi-period. As result we have no lost of voltage.

Using the 100Ω resistor as R_L and four 1N4003 diodes, the circuit of the Figure 3.6.0 was assembled.

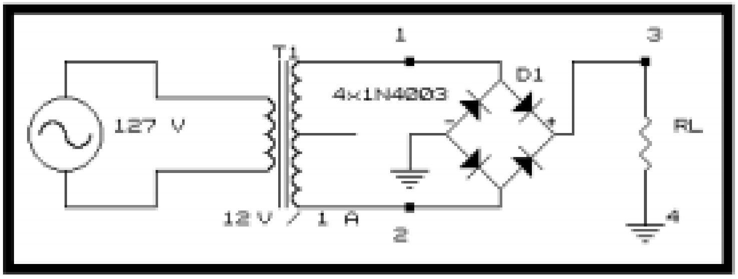

Figure 3.6.0: Full-wave bridge-network rectifier.

For measure the signal before being rectified, we put the positive terminal of the voltmeter in the terminal 1 of the Figure 3.6.0 and the negative terminal of the voltmeter in the terminal 3 of the Figure 3.6.0. We will call this voltage V_T (Transformer Voltage).

$$V_T = 13.35\ V_{rms} \tag{13}$$

Observation: To measure V_T the Voltmeter needs to be in the A.C option.

In the same terminals (1 and 3), of the Figure 3.6.0, the terminals of the oscilloscope were connected same as the voltmeter. Now, as can we see in Figure 3.6.1, the signal isn't being rectified yet. To visualize the rectified signal, the terminals of the oscilloscope were connected to the terminals 2 and 3 of the Figure 3.6.0. Now, as we can see in Figure 3.6.2 the signal is rectified from A.C to D.C. Now there's no negative voltage.

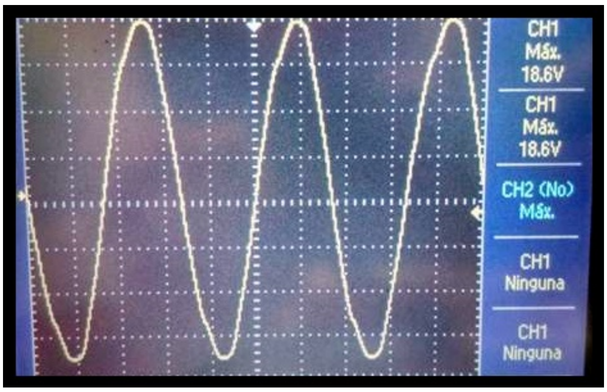

Figure 3.6.1: Transformer output signal.

$\frac{5V}{div}$ *and* $\frac{5mseg}{div}$.

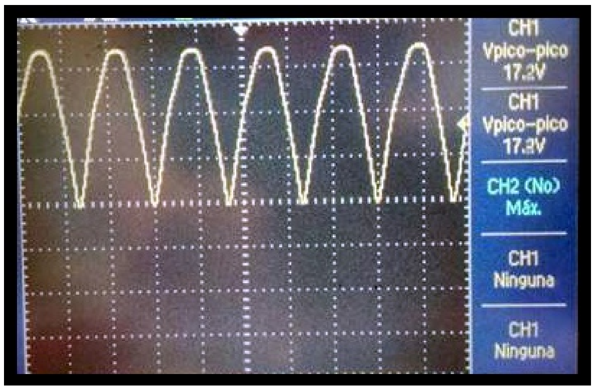

Figure 3.6.2: Full-wave rectified signal.

$\frac{5V}{div}$ *and* $\frac{5mseg}{div}$.

Observation: In the oscilloscope we are only using the channel 1 in D.C option.

To measure the voltage in R_L, its necessary to connect the positive terminal of the voltmeter in the terminal 2 of the Figure 3.6.0 and the negative terminal of the voltmeter in the terminal 3 of the Figure 3.6.0. We will call this voltage V_0, also the resistor R_L will have a current, we will call it I_0 and with Ohm's Law we can find it.

$$V_0 = 10.4\ V_{rms} \tag{14}$$

Observation: To measure V_0 the Voltmeter needs to be in the D.C option.

Using Ohm's Law: $I = \frac{V_0}{R_L}$.

$$I_0 = \frac{10.4\ V_{rms}}{0.100\ \Omega} = 0.104\ A \tag{15}$$

- ***For V_p (Peak Voltage) of Figure 3.6.1:***

When the terminals of the oscilloscope are connected to the circuit and the signal it's displayed on screen as Figures 3.6.1 shows. We will put the oscilloscope in the option ***measures*** and search for the option ***Max Voltage***.

$$V_p = 18.6V \tag{16}$$

- ***Finally, $V_p - V_D$, where V_p it's the peak voltage in Figure 3.6.1 and V_D it's the diode Voltage:***

$$V_p - (2)V_D = 18.6V - (2)(0.7V) = 17.2V \tag{17}$$

3.7 Full-Wave Bridge-Network Rectifier With Filter:

Using basically the same circuit of the Figure 3.6.0, we are going to connect in parallel to the R_L ***resistor*** a ***electrolytic capacitor***, this device will act like a filter. The voltage coming out from rectifiers is not smooth and a filter rectifier circuit is used to smoothen it for more stable constant DC voltage. We are going to be exchanging between two different capacitors, one of $470\mu F$ and another of $2200\mu F$.

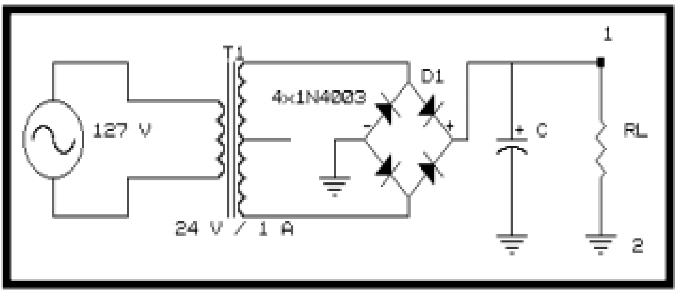

Figure 3.7.0: Full-wave rectifier circuit with filter.

Once the circuit it's armed using the 100Ω *resistor as* R_L we will measure with the voltmeter the ***Voltage*** and ***Current*** in this component. According to the Figure 3.7.0, we will connect the Positive terminal of the voltmeter in the terminal 1 of Figure 3.7.0 and the Negative terminal of the voltmeter in the terminal 2 of Figure 3.7.0, we will call this voltage V_0 for the current I_0 we can use ***Ohm's Law***:

Using Ohm's Law: $I_0 = \frac{V_0}{R_L}$.

Capacitor	V_0	I_0
$470\mu F$	15.5 V	0.155 A
$2200\mu F$	15.6 V	0.155 A

Table 6: Measured values of Figure 3.7.0.

The small unwanted residual periodic variation of the direct current (DC) output of a power supply which has been derived from an alternating current (AC) source it's called ***Ripple***. To measure the ***ripple voltage*** ΔV it's necessary to connect the ***oscilloscope terminals*** in the terminals 1 and 2 of the Figure 3.7.0 in the option of AC.

- Using the $470\mu F$ capacitor:
- Using the $2200\mu F$ capacitor:

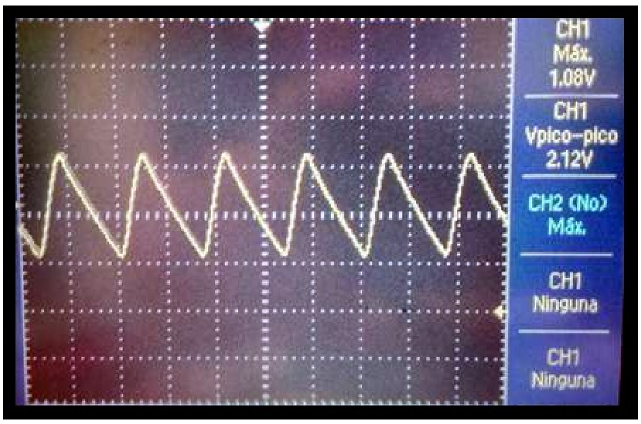

Figure 3.7.1: Full-wave with filter rectified signal.

$\frac{1V}{div}$ *and* $\frac{5mseg}{div}$.

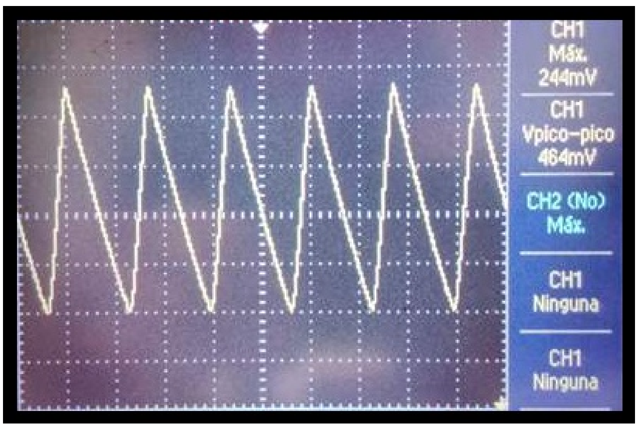

Figure 3.7.2: Full-wave with filter rectified signal.

$\frac{100mV}{div}$ *and* $\frac{5mseg}{div}$.

- ***For the ripple voltage (ΔV):***

When the terminals of the oscilloscope are connected to the circuit and the signal it's displayed on screen as Figures 3.7.1 and 3.7.2 shows. We will put the oscilloscope in the option of ***measures*** and the ***ripple*** voltage will be the ***peak-to-peak voltage (V_{pp})***.

Capacitor	ΔV
$470\mu F$	2.20 V
$2200\mu F$	464 mV

Table 7: Ripple Voltage of Figure 3.7.0.

4 Simulations:

For each one of the circuits previously showed, a corresponding simulation was made, we capture the output voltage of the transformer V_T, the Voltage in the R_L resistor V_0 with and without filters and finally, the signal that corresponded to each circuit. Also all this information will be displayed in a table with the simulated circuit and his PSpice signal.

4.1 Transformer:

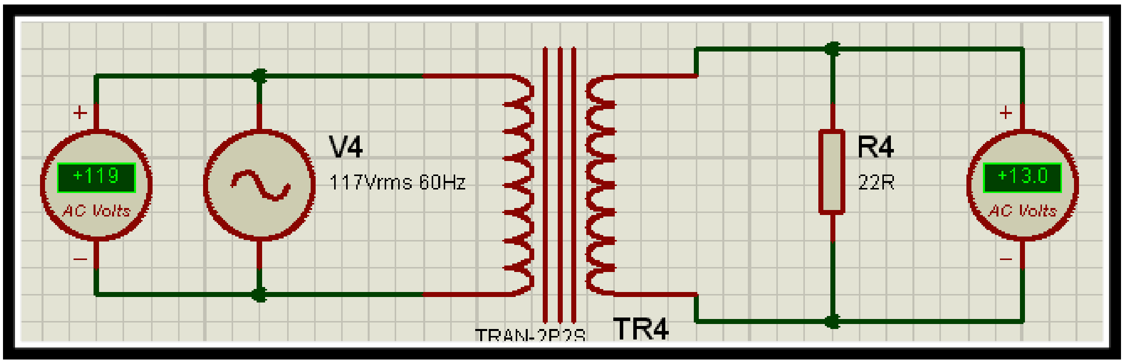

Figure 4.1.0: Transformer with 22 Ω resistor.

Resistor	V_{rms}
22 Ω	13.0 V

Table 8: Measured values of Figure 4.1.0.

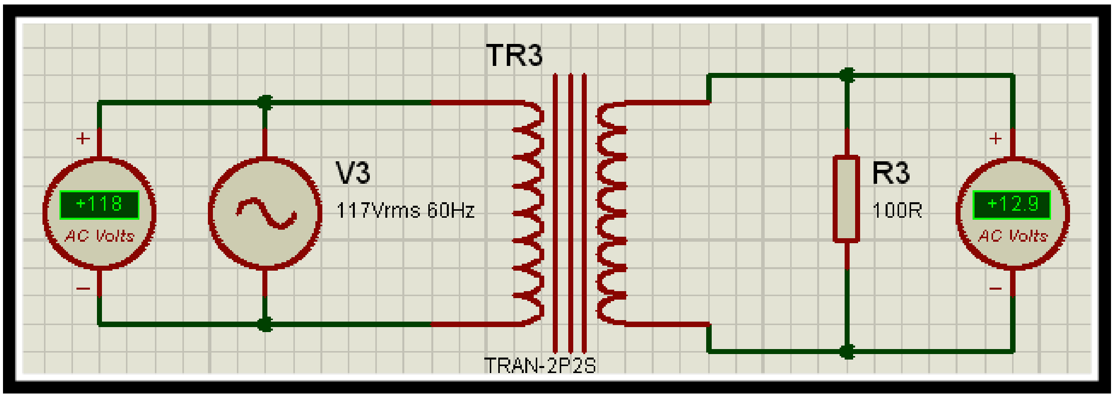

Figure 4.1.1: Transformer with 100 Ω resistor.

Resistor	V_{rms}
100 Ω	12.9 V

Table 9: Measured values of Figure 4.1.1.

4.2 Half-Wave Rectifier:

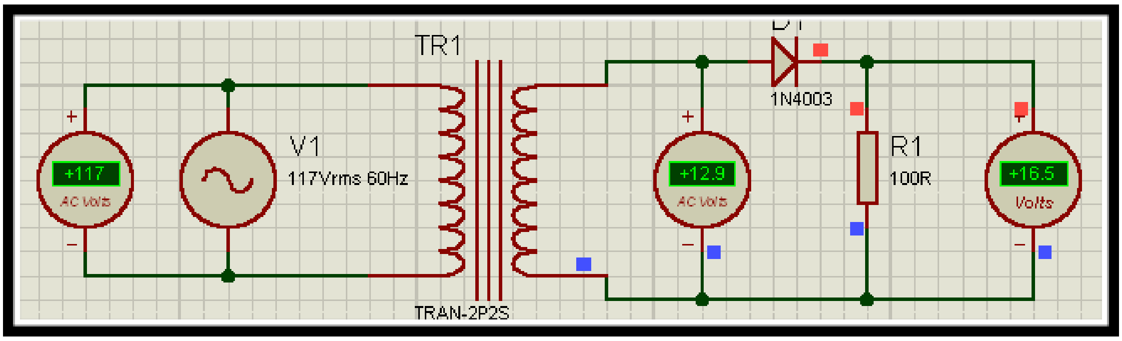

Figure 4.2.0: Half-wave rectifier.

Resistor R_L	V_T	V_0
100 Ω	12.9 V	16.5 V

Table 10: Measured values of Figure 4.2.0.

4.3 Half-Wave Rectifier With Filter:

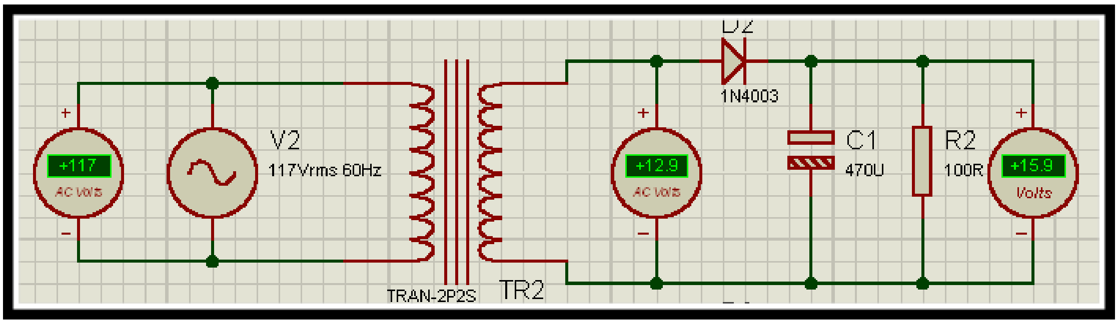

Figure 4.3.0: Half-wave rectifier with 470 μF capacitor.

Capacitor	V_T	V_0
470 μF	12.9 V	15.9 V

Table 11: Measured values of Figure 4.3.0.

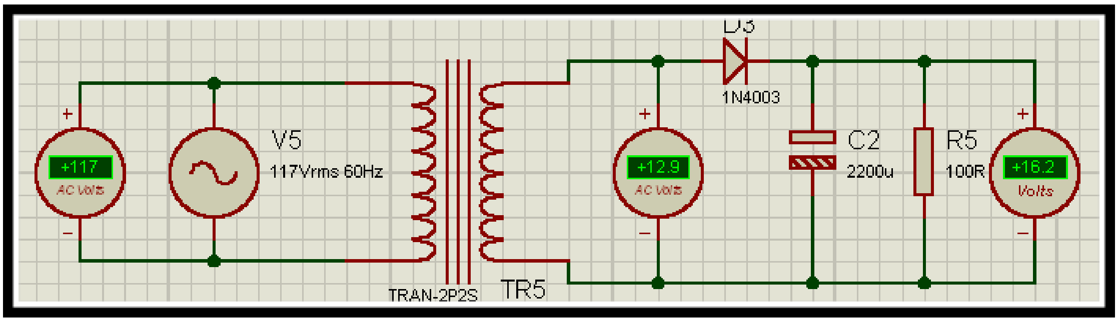

Figure 4.3.1: Half-wave rectifier with 2200 μF capacitor.

Capacitor	V_T	V_0
2200 μF	12.9 V	16.2 V

Table 12: Measured values of Figure 4.3.1.

4.4 Full-Wave Center-Taped Rectifier:

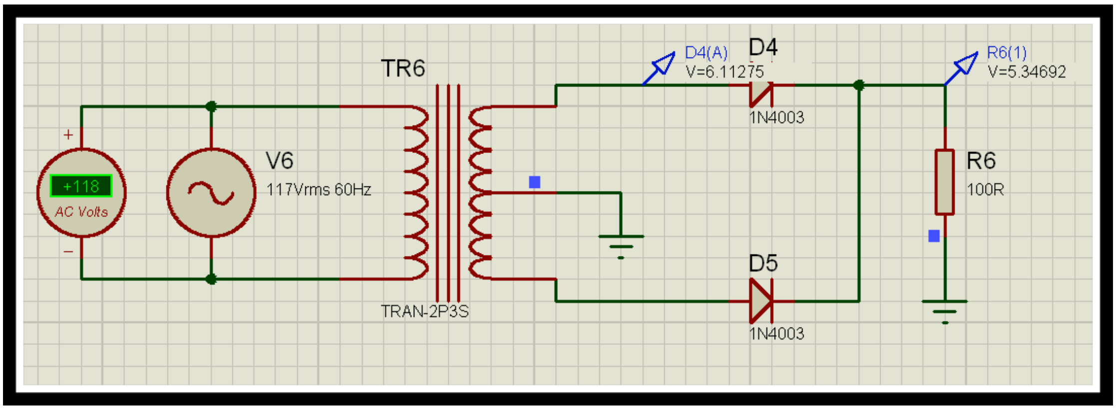

Figure 4.4.0: Full-wave center-taped rectifier.

Resistor R_L	V_T	V_0
100 Ω	6.11 V	5.34 V

Table 13: Measured values of Figure 4.4.0.

4.5 Full-Wave Center-Taped Rectifier With Filter::

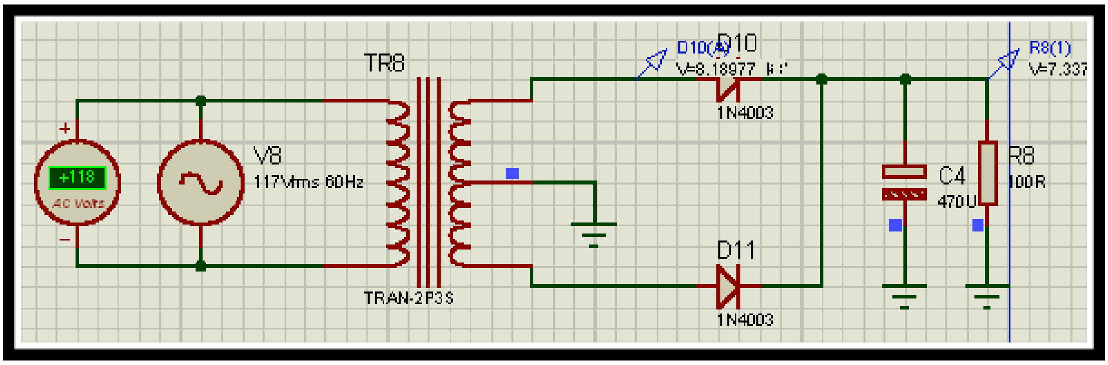

Figure 4.5.0: Full-wave center-taped rectifier with 470 μF capacitor.

Capacitor	V_T	V_0
470 μF	8.1 V	7.3 V

Table 14: Measured values of Figure 4.5.0.

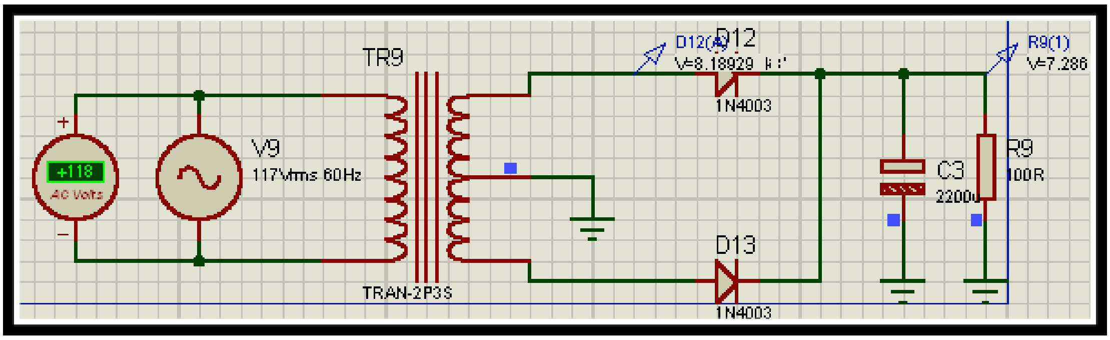

Figure 4.5.1: Full-wave center-taped rectifier with 2200 μF capacitor.

Capacitor	V_T	V_0
2200 μF	8.1 V	7.2 V

Table 15: Measured values of Figure 4.5.1.

4.6 Full-Wave Bridge-Network Rectifier:

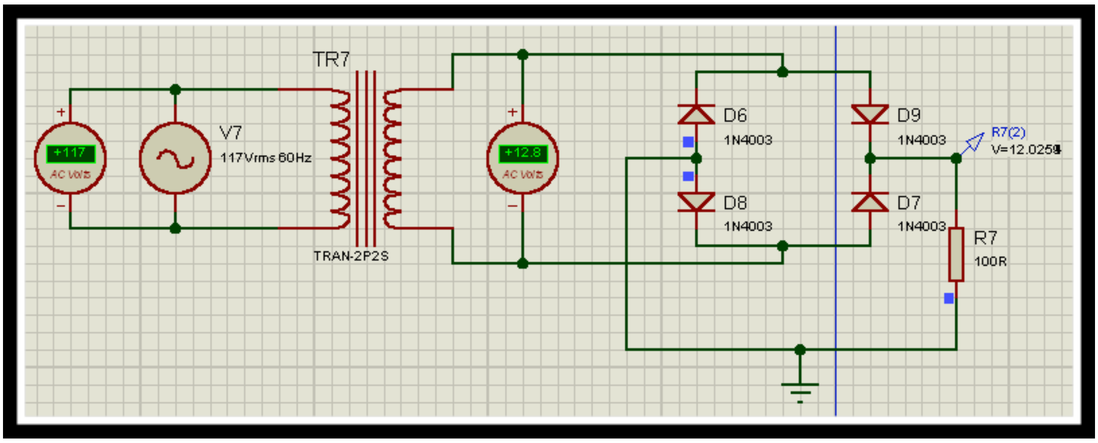

Figure 4.6.0: Full-wave bridge-network rectifier.

Resistor R_L	V_T	V_0
100 Ω	12.8 V	12.02 V

Table 16: Measured values of Figure 4.6.0.

4.7 Full-Wave Bridge-Network Rectifier With Filter::

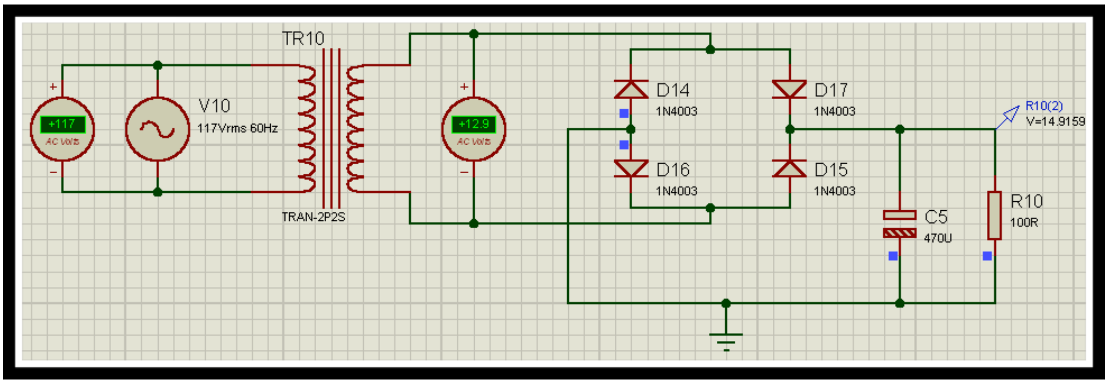

Figure 4.7.0: Full-wave bridge-network rectifier with 470 μF capacitor.

Capacitor	V_T	V_0
470 μF	12.9 V	14.91 V

Table 17: Measured values of Figure 4.7.0.

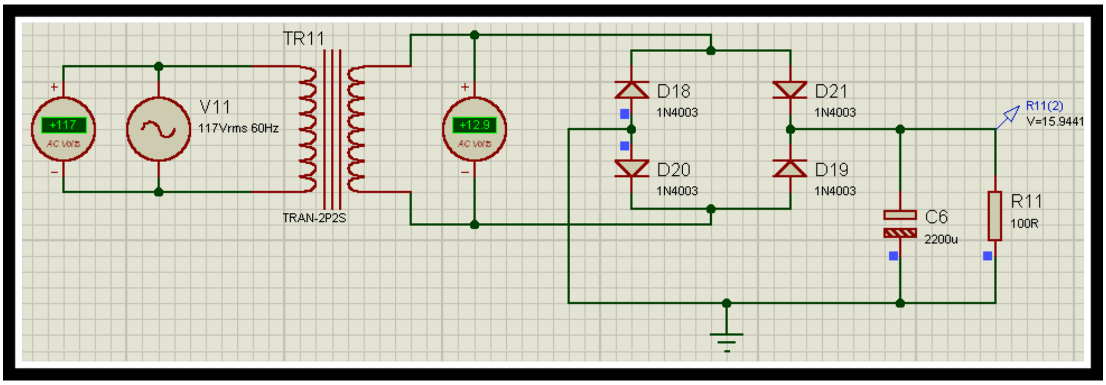

Figure 4.7.1: Full-wave bridge-network rectifier with 2200 μF capacitor.

Capacitor	V_T	V_0
2200 μF	12.9 V	15.94 V

Table 18: Measured values of Figure 4.7.1.

5 Theoretical Analysis:

For each one of the circuits showed in the section ***Development***, a corresponding Theoretic Analysis was made, calculating the Voltage and Current in the resistor R_L, as well the Peak-Voltage V_p and if it's required, the Ripple-Voltage (ΔV).

5.1 Transformer:

Calculate the Voltage (V_0) in R_L given the following resistors:

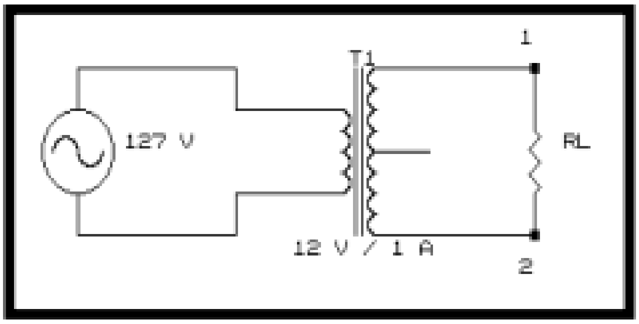

Figure 5.1.0: Transformer.

For: $R_L = 100\Omega$ and $R_L = 22\Omega$.

- ***Where the voltage at the output of the transformer is:***

  (i) $\boldsymbol{V_T = 12\ V}$

Solution:

- ***For*** $R_L = 100\Omega$***:***

  (i) Using Ohm's Law: $V = (\ I\ )(\ R\ )$.

$$V_0 = (100\Omega)(I_0) \tag{18}$$

- ***For*** I_0***:***

$$I_0 = \frac{12V}{100\Omega} = 0.12A \tag{19}$$

- ***Substituting (19) in (18):***

$$\begin{align} V_0 &= (100\Omega)(0.12A) \tag{20} \\ &= 12V \tag{21} \end{align}$$

- ***For*** $R_L = 22\Omega$***:***

  (i) Using Ohm's Law: $V = (I)(R)$***.***

$$V_0 = (22\Omega)(I_0) \tag{22}$$

- ***For*** I_0***:***

$$I_0 = \frac{12V}{22\Omega} = 0.54A \tag{23}$$

- ***Substituting (23) in (22):***

$$\begin{aligned} V_0 &= (22\Omega)(0.54A) && (24)\\ &= 11.8V && (25) \end{aligned}$$

5.2 Half-Wave Rectifier:

Calculate the Voltage in R_L (V_0), the current in R_L (I_0), the Peak-Voltage (V_p) at the output of the Transformer V_T and V_p - V_D:

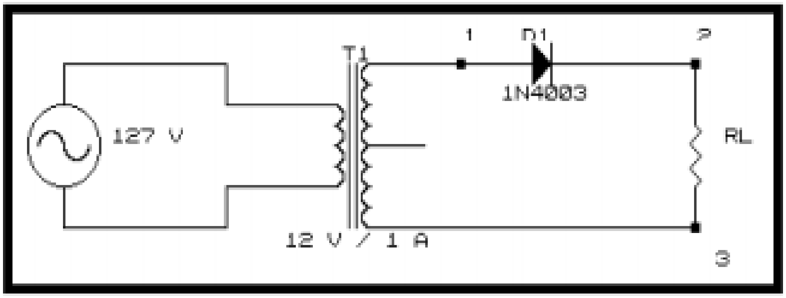

Figure 5.2.0: Half-wave rectifier.

Where:

(i) R_L = ***100*** Ω

(ii) V_D = ***0.7 V***

(iii) V_T = ***12 V***

Solution:

- ***For peak voltage at the transformer output:***

  (i) ***Where:*** $V_p = (\sqrt{2})(V_{rms})$.

$$V_p = (\sqrt{2})(V_T) = (\sqrt{2})(12V) = 16.97V. \tag{26}$$

- ***For*** V_0***:***

  (i) ***Where:*** $V_{DC} = \frac{(\sqrt{2})(V_{rms})}{\pi}$.

$$V_0 = \frac{(\sqrt{2})(V_T)}{\pi} = \frac{(\sqrt{2})(12V)}{\pi} = 5.40V. \tag{27}$$

- ***For*** I_0***:***

  (i) ***Using Ohm's Law:*** $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{5.4V}{100\Omega} = 0.054A. \tag{28}$$

- ***Finally*** V_p - V_D***:***

$$V_p - V_D = 16.97V - 0.7V = 16.27V \tag{29}$$

5.3 Half-Wave Rectifier With Filter:

Calculate the Voltage in R_L (V_0), the current in R_L (I_0), the Peak-Voltage (V_p) at the output of the Transformer V_T, the Ripple-Voltage (ΔV) and V_p - V_D:

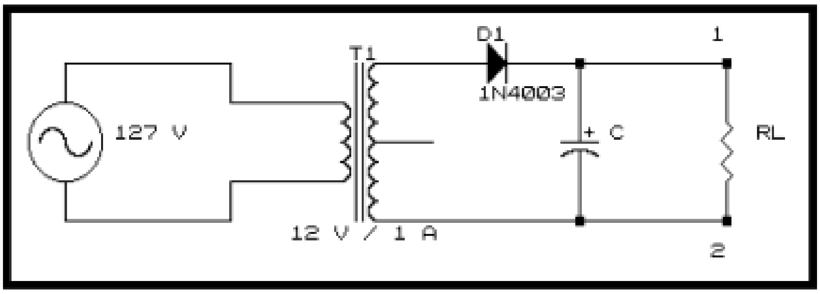

Figure 5.3.0: Half-wave rectifier with filter.

Where:

(i) R_L *= 100* Ω

(ii) V_D *= 0.7 V*

(iii) V_T *= 12 V*

(iv) f = 120Hz

Solution:

- ***For peak voltage at the transformer output:***

  (i) ***Where:*** $V_p = (\sqrt{2})(V_{rms})$.

$$V_p = (\sqrt{2})(V_T) = (\sqrt{2})(12V) = 16.97V. \tag{30}$$

- ***Finally*** V_p *-* V_D*:*

$$V_p - V_D = 16.97V - 0.7V = 16.27V \tag{31}$$

- ***Using*** *470*μF ***capacitor:***

  (i) ***Where Ripple-Voltage:*** $\Delta V = (\frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]})[\ V_p - V_D\ ]:$

$$\Delta V = (\frac{1}{[\ 2(\ 60Hz\ )(\ 100\Omega\ )(\ 470\mu F\ )\ ]})[\ 16.27V\ ] = 2.88V \tag{32}$$

- ***For*** V_0*:*

  (i) ***Where*** $V_0 = [1 - \frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]}][\ V_p - V_D\ ]$

$$V_0 = [1 - \frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 470\mu F\ )\ ]}][\ 16.27V\ ] = 13.38V \tag{33}$$

- ***For*** I_0*:*

  (i) ***Using Ohm's Law:*** $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{13.38V}{100\Omega} = 0.133A. \tag{34}$$

- ***Using 2200μF capacitor:***

  (i) Where Ripple-Voltage: $\Delta V = (\frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]})[\ V_p - V_D\ ]:$

$$\Delta V = (\frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 2200\mu F\ )\ ]})[\ 16.27V\ ] = 616mV \tag{35}$$

- ***For V_0:***

  (i) Where $V_0 = [1 - \frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]}][\ V_p - V_D\ ]$

$$V_0 = [1 - \frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 2200\mu F\ )\ ]}][\ 16.27V\ ] = 15.65V \tag{36}$$

- ***For I_0:***

  (i) Using Ohm's Law: $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{15.65V}{100\Omega} = 0.156A. \tag{37}$$

5.4 Full-Wave Center-Taped Rectifier:

Calculate the Voltage in R_L (V_0), the current in R_L (I_0), the Peak-Voltage (V_p) at the output of the Transformer V_T and V_p - V_D:

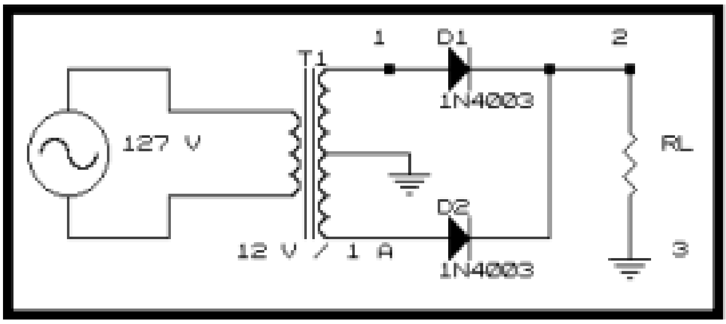

Figure 5.4.0: Full-wave center-taped rectifier.

Where:

(i) R_L = ***100*** Ω

(ii) V_D = ***0.7 V***

(iii) V_T = ***12 V***

Solution:

- ***For peak voltage at the transformer output:***

  (i) ***Where:*** $V_p = \frac{(\sqrt{2})(V_{rms})}{2}$.

$$V_p = \frac{(\sqrt{2})(V_T)}{2} = \frac{(\sqrt{2})(12V)}{2} = 8.4V. \tag{38}$$

- ***For*** V_0***:***

  (i) ***Where:*** $V_{DC} = (2)\frac{(\sqrt{2})(V_{rms})}{2\pi}$.

$$V_0 = (2)\frac{(\sqrt{2})(V_T)}{2\pi} = \frac{(2)(\sqrt{2})(12V)}{2\pi} = 5.4V. \tag{39}$$

- ***For*** I_0***:***

  (i) ***Using Ohm's Law:*** $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{5.4V}{100\Omega} = 0.054A. \tag{40}$$

- ***Finally*** V_p - V_D***:***

$$V_p - V_D = 8.4V - 0.7V = 7.7V \tag{41}$$

5.5 Full-Wave Center-taped Rectifier With Filter:

Calculate the Voltage in R_L (V_0), the current in R_L (I_0), the Peak-Voltage (V_p) at the output of the Transformer V_T, the Ripple-Voltage (ΔV) and V_p - V_D:

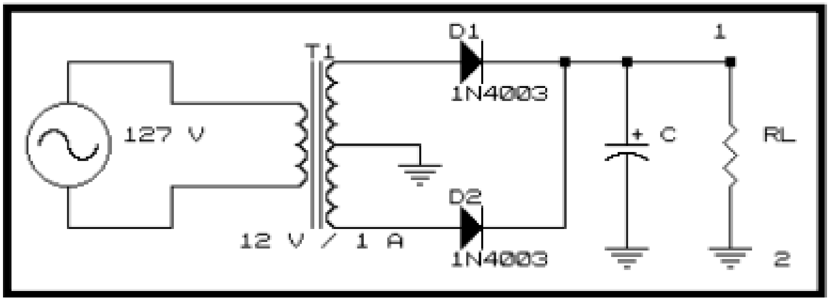

Figure 5.5.0: Full-wave center-taped rectifier with filter.

Where:

(i) R_L *= 100* Ω

(ii) V_D *= 0.7 V*

(iii) V_T *= 12 V*

(iv) f = 120Hz

Solution:

- ***For peak voltage at the transformer output:***

  (i) ***Where:*** $V_p = \frac{(\sqrt{2})(V_{rms})}{2}$.

$$V_p = \frac{(\sqrt{2})(V_T)}{2} = \frac{(\sqrt{2})(12V)}{2} = 8.4V. \quad (42)$$

- ***Finally*** V_p ***-*** V_D***:***

$$V_p - V_D = 8.4V - 0.7V = 7.7V \quad (43)$$

- ***Using*** $470\mu F$ ***capacitor:***

  (i) ***Where Ripple-Voltage:*** $\Delta V = (\frac{1}{[2(f)(R_L)(C)]})[V_p - V_D]:$

$$\Delta V = (\frac{1}{[2(60Hz)(100\Omega)(470\mu F)]})[7.7V] = 1.36V \quad (44)$$

- ***For*** V_0***:***

  (i) ***Where*** $V_0 = [1 - \frac{1}{[2(f)(R_L)(C)]}][V_p - V_D]$

$$V_0 = [1 - \frac{1}{[2(60Hz)(100\Omega)(470\mu F)]}][7.7V] = 6.33V \quad (45)$$

- ***For*** I_0***:***

  (i) ***Using Ohm's Law:*** $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{6.33V}{100\Omega} = 0.063A. \quad (46)$$

- ***Using 2200μF capacitor:***

  (i) Where Ripple-Voltage: $\Delta V = (\frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]})[\ V_p - V_D\ ]:$

$$\Delta V = (\frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 2200\mu F\ )\ ]})[\ 7.7V\ ] = 291mV \tag{47}$$

- ***For V_0:***

  (i) Where $V_0 = [1 - \frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]}][\ V_p - V_D\ ]$

$$V_0 = [1 - \frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 2200\mu F\ )\ ]}][\ 7.7V\ ] = 7.4V \tag{48}$$

- ***For I_0:***

  (i) Using Ohm's Law: $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{7.4V}{100\Omega} = 0.074A. \tag{49}$$

5.6 Full-Wave Bridge-Network Rectifier:

Calculate the Voltage in R_L (V_0), the current in R_L (I_0), the Peak-Voltage (V_p) at the output of the Transformer V_T and V_p - V_D:

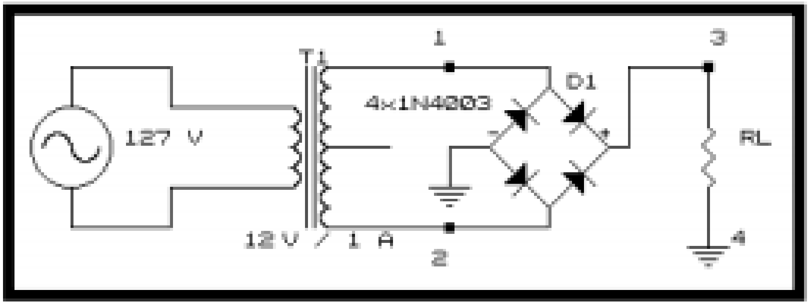

Figure 5.6.0: Full-wave bridge-network rectifier.

Where:

(i) R_L = ***100*** Ω

(ii) V_D = ***0.7 V***

(iii) V_T = ***12 V***

Solution:

- ***For peak voltage at the transformer output:***

  (i) ***Where:*** $V_p = (\sqrt{2})(V_{rms})$.

$$V_p = (\sqrt{2})(V_T) = (\sqrt{2})(12V) = 16.97V. \quad (50)$$

- ***For*** V_0***:***

  (i) ***Where:*** $V_{DC} = (2)\frac{(\sqrt{2})(V_{rms})}{\pi}$.

$$V_0 = (2)\frac{(\sqrt{2})(V_T)}{\pi} = \frac{(2)(\sqrt{2})(12V)}{\pi} = 10.08V. \quad (51)$$

- ***For*** I_0***:***

  (i) ***Using Ohm's Law:*** $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{10.08V}{100\Omega} = 0.10A. \quad (52)$$

- ***Finally*** V_p ***- (2)*** V_D***:***

$$V_p - (2)(V_D) = 16.97V - 1.4V = 15.57V \quad (53)$$

5.7 Full-Wave Bridge-Network Rectifier With Filter:

Calculate the Voltage in R_L (V_0), the current in R_L (I_0), the Peak-Voltage (V_p) at the output of the Transformer V_T, the Ripple-Voltage (ΔV) and V_p - V_D:

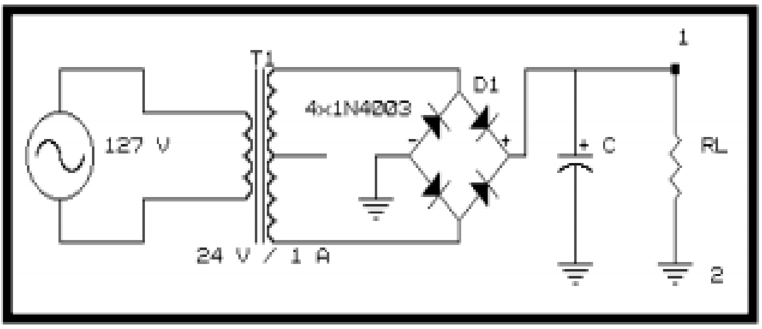

Figure 5.7.0: Full-wave bridge-network rectifier with filter.

Where:

(i) R_L *= 100* Ω

(ii) V_D *= 0.7 V*

(iii) V_T *= 12 V*

(iv) *f = 120Hz*

Solution:

- ***For peak voltage at the transformer output:***

  (i) ***Where:*** $V_p = (\sqrt{2})(V_{rms})$.

$$V_p = (\sqrt{2})(V_T) = (\sqrt{2})(12V) = 16.97V. \tag{54}$$

- ***For*** V_p ***- (2)*** V_D***:***

$$V_p - (2)(V_D) = 16.97V - 1.4V = 15.57V \tag{55}$$

- ***Using*** $470\mu F$ ***capacitor:***

  (i) ***Where Ripple-Voltage:*** $\Delta V = (\frac{1}{[2 (f)(R_L)(C)]})[V_p - (2)V_D]$:

$$\Delta V = (\frac{1}{[2 (60Hz)(100\Omega)(470\mu F)]})[15.57V] = 2.76V \tag{56}$$

- ***For*** V_0***:***

  (i) ***Where*** $V_0 = [1 - \frac{1}{[2 (f)(R_L)(C)]}][V_p - (2)V_D]$

$$V_0 = [1 - \frac{1}{[2 (60Hz)(100\Omega)(470\mu F)]}][15.57V] = 12.8V \tag{57}$$

- ***For*** I_0***:***

  (i) ***Using Ohm's Law:*** $I = \frac{V}{R}$.

$$I_0 = \frac{V_0}{R_L} = \frac{12.8V}{100\Omega} = 0.128A. \tag{58}$$

- ***Using 2200μF capacitor:***

  (i) Where Ripple-Voltage: $\Delta V = (\frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]})[\ V_p - (2)V_D\ ]:$

$$\Delta V = (\frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 2200\mu F\ )\ ]})[\ 15.57V\ ] = 580mV \tag{59}$$

- ***For V_0:***

  (i) Where $V_0 = [1 - \frac{1}{[\ 2\ (\ f\ )(\ R_L\ )(\ C\ )\ ]}][\ V_p - (2)V_D\ ]$

$$V_0 = [1 - \frac{1}{[\ 2\ (\ 60Hz\ )(\ 100\Omega\ )(\ 2200\mu F\ )\ ]}][\ 15.57V\ ] = 14.98V \tag{60}$$

- ***For I_0:***

  (i) Using Ohm's Law: $I\ = \frac{V}{R}$***.***

$$I_0 = \frac{V_0}{R_L} = \frac{14.98V}{100\Omega} = 0.149A. \tag{61}$$

6 Questionnaire:

- ***Mentions the importance of voltage rectifiers:*** We note that rectifiers are very important in all applications, since they can convert an AC signal into direct current, it also has uses like doubling, tripling or quadrupling voltage and these functions are used daily in many devices and electronic tools.

- ***Explains the difference between a half-wave rectifier and a full-wave rectifier:*** Half-wave rectifiers operate by passing half of the alternating current through one or more diodes, converting this half of the alternating current into direct electric current. Half-wave rectifiers are not very efficient because they only convert half of the alternating current into direct current. half-wave rectifiers are much less complicated and require only a diode for their operation.

- ***What is the difference of a full wave rectifier with central bypass and bridge type:*** The full-wave rectifier with central bypass uses both halves of the input sine wave; to obtain a unipolar output, reverses the negative semi cycles of the sinusoidal wave. In this application it is used in the central winding of the transformer in order to obtain two equal voltages in parallel with the two halves of the secondary winding. The bridge-type rectifier does not have variations in the output signal with respect to the rectifier with central bypass, the difference is that it does not use bypass but two more diodes. Its operation is that during the positive half-cycles of the input voltage the current is conducted through the diode1, the load and diode 2 (because it is positive). Meanwhile the diodes 3 and 4 are reverse biased.

- ***How to measure the output voltage of the rectifier?*** The output voltage of the rectifier can be measured with the oscilloscope by looking at the peak voltage (Vp) passing through the indicated or selected resistance the voltage is reduced according to the diodes that are by the passage of current flow

- ***How to measure the ripple voltage of the rectifier?*** Is called the ripple voltage to the difference between the maximum voltage and the minimum voltage of the output waveform of the DC voltage source of a rectifier that uses a capacitor. Basically the ripple voltage it's the peak-to-peak voltage, so, the easier way to measure it, it's with the oscilloscope, in the option ***measures*** in the section V_{pp}, the oscilloscope must be connected in the terminals of R_L (for this case).

7 Conclusions:

We discussed the purpose of a rectifier circuit as well as two specific types of rectifiers: the half-wave rectifier and the full-wave rectifier. Rectifiers are essential circuits for power supplies that convert an AC input voltage into a DC voltage supply that can be used to power electronic circuits. We saw that the half-wave rectifier utilizes alternate half-cycles of the input sine wave whereas the full-wave rectifier utilizes both positive and negative half-cycles. The rectifiers are the principle of the ***voltage sources***. With the capacitor we see that the signal it's more smoother, but we can get better results if we add after the capacitor a regulator to keep in our source a "constant" voltage, so that the ***ripple*** voltage always be fewer than 100mV.

Observation: *For some reason, in Proteus me and my team partner cannot run the oscilloscope. So the we cannot measure the simulated values for the* ***ripple voltage*** *or the* ***peak voltage*** *of the circuits. In case of being necessary, we can show to the professor our simulations to probe that the software don't run the it.*

8 Bibliographic References:

[1] BOYLESTAD, Robert L. "Electronic Devices and Circuit Theory". Edit. Prentice Hall. 2009.