6.2. AC Rectifier

Overview

The AC Rectifier converts the sinusoidal wall input at 120V\textsubscript{RMS} into DC with 52V on the positive side and -52V on the negative side. The DC output from the Rectifier still has a periodic ripple with maximum peak-to-peak amplitude of 5V when the load is drawing 1A of current.

![AC Rectifier Block Diagram](image)

6.2.1. AC Rectifier Interface Definition

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Description</th>
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</table>
| AC Input   | Input            | Frequency: 60Hz  
Voltage: 120VAC  
Maximum Current: 1 Amp |
| V+         | Internal Power Output | Nominal Voltage: 52VDC  
Max current: 1A  
Max Ripple Voltage: 5V\textsubscript{pp} |
| V-         | Internal Power Output | Nominal Voltage: -52VDC  
Max current: 1A  
Max Ripple Voltage: 5V\textsubscript{pp} |
| LED        | Indicator        | ON if power supply is on  
OFF if power supply is on |

6.2.2. AC Rectifier Schematic and Theory of Operation
Explanation of the AC Rectifier Circuit

1. The input to the transformer is a 120V$_{\text{RMS}}$, 60Hz sinusoidal AC coming from the wall outlet. The two input wires are connected to the primary side of the transformer.

2. The transformer contains two coils of wire that interact through a ferromagnetic core to step down the voltage from a 120V$_{\text{RMS}}$, 60Hz sinusoidal on the primary side to a 24V$_{\text{RMS}}$ AC of the same frequency on the secondary side. This voltage ratio is determined proportionally by the turn ratio of the transformer.

3. The center tapped transformer splits the 24V$_{\text{RMS}}$ into two sinusoids that each have half of the total voltage, or 12V$_{\text{RMS}}$, when measured from the center tap line.

4. The 4-diode full wave rectifier network allows only the positive cycle of the sinusoidal to go through the filter capacitor and the load. The current from the negative half of the sinusoidal will also go through the same path (from V+ to V-). Therefore the V+ node in the schematic would see a full-rectified sinusoidal with a frequency of 120Hz.

5. The center tap wire, or the center ground line, is placed between the two capacitors as shown in the schematic so that if one were to measure the V- node referenced from this ground wire, he or she would find the RMS voltage to be -12V.

6. The increasing half of the full-rectified voltage on node V+ will start charging up the filter capacitors. After the full rectified voltage reaches its peak, the capacitor will start to discharge through the load. The cycle continues until the capacitor is fully charged, for which the output voltage on node V+ and V- have a periodic ripple waveform from constant charging and discharging of the capacitor.

7. The ripple voltage on the output is determined by the following equation:

$$V_{\text{ripple}} = \frac{I_{\text{LOAD}}\Delta t}{C} \approx \frac{I_{\text{LOAD}}}{2f \cdot C} = \frac{V_{\text{PEAK}}}{2f(R_{\text{LOAD}} C)}$$

This equation makes perfect sense because higher load resistance will result in a lower load current, and the ripple voltage will be smaller. On the other hand, if we increase the filter capacitance, the time constant of the
capacitors will be longer, and the rate of discharge will slow down. The result will be similar to that of increasing load resistance, a smaller ripple voltage. A low-pass filter. The higher fundamental frequencies until only the DC component is left.

8. Base on the ripple voltage equation, we would obtain a ripple voltage of about:

\[
V_{\text{Ripple}} = \frac{I_{\text{LOAD}}}{2f \cdot C} = \frac{900 \text{mA}}{2(60)(15000 \mu F)} = 0.5V
\]

Therefore, the theoretical ripple voltage should be 0.5V based on a load current of 900mA. We set 0.75 as an upper bond for uncertainties in the capacitors.

Additional Considerations

- The indicator LED is connected from the V+ node to the ground in series with a 1kΩ resistor. Because the maximum current the LED can withstand is 25mA and the maximum voltage on the V+ is 18V, the required resistance is at least 720Ω. Therefore, a 1kΩ resistor in this case would suffice.

- There will be source resistance in the wall outlet and in the transformer output. These resistances are modeled in the schematic as Rs1 and Rs2. We estimated these resistances to be small compared to the load, or around 1Ω. Because these resistances form an approximate voltage divider with the load, a value would significantly reduce the voltage available across the load.

- The 1N4004 diodes are designed to operate best under an ambient temperature of 80ºC, so that the average rectified forward current is 1A. This forward current will be severely impaired (<0.4A) if the ambient temperature exceeds 120ºC.