



Experiment No. 3.

Diodes and Bridge Rectifiers

By: Prof. Gabriel M. Rebeiz
The University of Michigan
EECS Dept.
Ann Arbor, Michigan

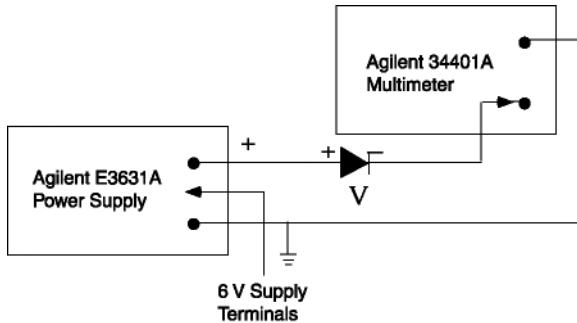
Purpose

To learn about diodes and to use a diode bridge to build a 14V full-wave rectifying DC power supply.

- Read this experiment and answer the pre-lab questions.

1.0 Diode Test Circuit:

1. Set the Agilent E3631A power supply to give a maximum current of 0.6A for the +6V supply. This is important so as not to burn the diode while testing it.
2. Connect the MUR 105 silicon rectifier diode as follows:



3. Measure the diode current for $V = 0.3, 0.4, 0.5, 0.7, 0.8, 0.9, 1.0, 1.2$ and 1.3 up to a diode current of 0.5A.

Determine the diode voltage for $I_d = 1\text{mA}, 10\text{ mA}$ and 100 mA .

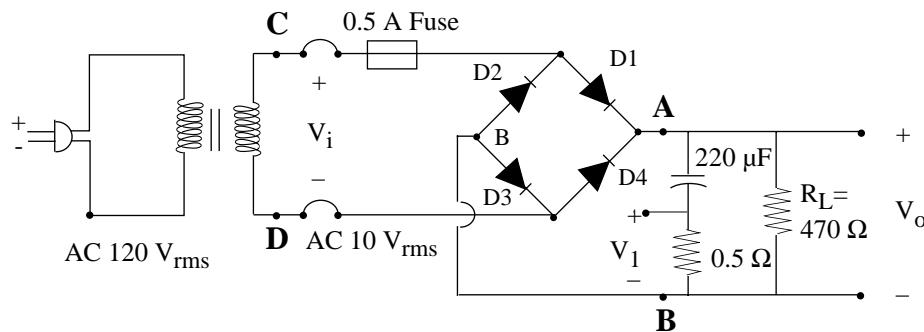
2.0 Full-wave Bridge Rectifier with a Single Output:

1.
 - Measure R_L and the $0.5\ \Omega$ resistor accurately using the multimeter.
 - Measure C using the capacitance meter in the lab.
2. Connect the full-wave bridge rectifier as shown below and make sure that the diode polarity and the capacitor polarity are correct. There is a small ($0.5\ \Omega$) resistor in series with the $220\ \mu\text{F}$ capacitor. This resistor is needed so as to measure the current in the $220\ \mu\text{F}$ capacitor ($I_C = V_C/R$).



TURN OFF THE POWER SUPPLY AND THE MULTIMETER. DISCONNECT ALL CABLES FROM THESE UNITS AND RETURN THE CABLES TO THEIR ORIGINAL PLACE. THIS IS VERY IMPORTANT SO AS NOT TO HAVE GROUND LOOPS AND BURN THE FUSE! YOU WILL NOT USE THESE UNITS AGAIN.

ALSO, ALWAYS OPERATE WITH A SINGLE COAX TO BANANA-PLUG OSCILLOSCOPE CABLE!



After you have checked the circuit, connect the transformer to the 120 V AC wall outlet. If there is a short-circuit, the fuse will blow and $V_i = 0$!

- a. Draw the circuit in your lab notebook.
- b. Measure $V_{i\text{ppk}}$ and $V_{i\text{rms}}$ using the scope. At this time, connect the oscilloscope ground to point D. It should be 10-11 V_{rms} .
- c. Measure the spectrum of V_i in dB (f_0 , $3f_0$ and $5f_0$). You will notice that the waveform is not perfectly sinusoidal due to the cheapie wall transformer. The magnetic case is saturating at high voltages and distorting the transformer output signal (V_i)!

BE CAREFUL WHEN YOU ARE DOING VOLTAGE MEASUREMENTS ACROSS THE DIODE BRIDGE ACROSS R_L , ETC. MAKE SURE THAT THE SCOPE GROUND IS NOW CONNECTED TO NODE B!

3. Remove the capacitor and measure V_o . Make sure that you have a full-wave rectified voltage. (Do not worry if you see a distorted sinewave.) Measure $V_{o\text{pk}}$ and determine the diode voltage drop (per diode).
4. a. Connect the capacitor to the circuit and measure $V_{o\text{pk}}$, $V_{o\text{av}}$ and V_R (the ripple voltage) and compare with your pre-lab calculations. Plot V_o .
 - Measure the frequency of the output voltage ripple.
 - From the output voltage waveform, measure the charging and discharging time of the capacitor.
 - From the output voltage waveform, measure the slope ($\Delta V/\Delta T$) of the discharge portion at the center of the linear portion. As discussed in class, this results in the discharge capacitor current ($I = C \Delta V/\Delta T$) which is equal to the load current.
- b. Measure V_o in the frequency domain and write the fundamental harmonics in dB (120, 240, 360 and 480 Hz).



5. On the scope, measure the voltage (V_1) across the 0.5Ω resistor. This measurement results in the charging and discharging capacitor current ($I = V_1/R$, $R = 0.5 \Omega$). Again, the discharge capacitor current is equal to the load current.
 - Draw accurately the current waveform ($I = V_1/R$) on your lab notebook and label the peak positive (charging) current and its duration, the average negative (discharge) current and its duration (the average discharge current is found at the center of the linear portion of V_1). Label the charging and discharging periods of the capacitor.

3.0 Half-Wave Power Supply With a Single Output:

Assume that one of the diodes blew up and became an open circuit (D2 for example). The circuit becomes a half-wave rectifier.

- Take D2 out of the circuit now. Draw the circuit in your lab notebook.
- Repeat parts 3, 4 and 5 of section #2.



Experiment No. 3.

Diodes and Bridge Rectifiers

Pre-Lab Assignment

1. For the full-wave bridge rectifier with $C = 220 \mu F$, $R_L = 470 \Omega$ and $V_i = 10 \text{ Vrms}$:
 - a. Calculate the ripple frequency, V_{pk} , V_R , I_L , $I_{D(av)}$ and $I_{D(pk)}$.
 - b. Calculate the time in msec (per period) that the diode(s) is turned on.
 - c. Plot the current in the $220 \mu F$ capacitor for one period.
2. Repeat (1) but for a full-wave bridge rectifier when one of the diodes is blown. This is equivalent to a half-wave rectifier but with two diodes in series. Therefore, in this special case, you should take into account the voltage drop of two diodes and $V_{opk} = V_{ipk} - 2 V_D$ in the half-wave rectifier equations.
3. Regulators are essential for low output ripple voltages and this problem will show why! For the full-wave rectifier with $R_L = 470 \Omega$,
 - a. Choose C to result in $V_R = 100 \text{ mV}$ and $V_R = 10 \text{ mV}$.
 - b. Calculate $I_{D(av)}$ and $I_{D(pk)}$ in each case.
 - c. Calculate the time in msec or μsec (per period) that the diode(s) is turned on.

You will find that in order to get a low ripple voltage from a bridge rectifier, the time each diode is "on" is very short and the peak diode current is extremely large! This is why most bridge rectifiers have a ripple voltage around $\pm 10\%$ and are followed by linear regulators.

4. Calculate the efficiencies of the multiple output linear regulators of Fig. 3a and 3b if each output is delivering the same current I (the answer is independent of I).
5. Assume that the Agilent E3631A power supply with a variable output from 0–25 V does not have a controlled-tap transformer, and $V = 26 \text{ V}$ (fixed) after the bridge rectifier/low-pass filter.
 - a. Calculate the efficiencies of the linear regulator when the output voltage is set at 2 V, then at 25 V, and delivers 1 A to a load in both cases.
 - b. What is the power consumed by the linear regulator in each case?
 - c. Repeat a and b above with a controlled tap transformer (take a 1 V drop across the regulator).

Experiment No. 3.

Diodes and Bridge Rectifiers

Lab Report Assignment

1. Report all your measured values in the full-wave bridge rectifier $C = 220 \mu F$, $R_L = 470 \Omega$ (voltages and capacitor current times, input voltage, component values, etc.) and compare with calculations done using your measured V_{rms} (or V_{ppk}), and assuming an ideal diode model ($V_D = 0.7$ V). Put the measured data and calculations in table form. Comment on the discrepancies, especially for the peak current in the capacitor.
2. Report all your measured values in the half-wave bridge rectifier $C = 220 \mu F$, $R_L = 470 \Omega$ (voltages and capacitor current). Put the measured data and calculations in table form. Compare with calculations and comment on the discrepancies.
3. The load current can be obtained in three separate methods:
 - Using $V_O(\text{av})/R_L = I_L(\text{av})$
 - Using the slope of the discharge portion of V_O ($I = C \Delta V/\Delta T$).
 - Using V_1/R in the middle of discharge period of the capacitor.

Using your measurements and the exact values of R_L , C and the 0.5Ω resistor, determine $I_L(\text{av})$ using the above methods and comment on any discrepancies. You will find that the "slope" method is the least accurate. Why?

4. A high performance regulated power supply for audio systems with the following outputs is needed:

Power Supply #1:

$+5$ V ($I_{\text{max}} = 500$ mA): Microprocessor Circuitry

± 12 V ($I_{\text{max}} = 1$ A): Analog Small-Signal Audio Circuitry

Power Supply #2:

± 24 V ($I_{\text{max}} = 6$ A): Output Audio Power Amplifier to drive the speakers

- a. First of all, ideally how much audio power can this system give into an 8Ω speaker without clipping? The #2 supply can deliver a ± 24 V max. and ± 6 A current max. Therefore, the output of the power amplifier can go to ± 24 V (assume no voltage drop in the output amplifier).
- b. Design the power supplies (#1 and #2) for high efficiency. You can use a multiple-tap transformer and several rectifiers/regulators. Choose appropriate capacitors for each supply. The unregulated output of each rectifier should have a $\pm 15\%$ (or 30% total) ripple voltage at peak current load.
- c. Assume that the voltage drop is 0.5 V across the 5 V linear regulator and 1 V across each of the 12 V and 24 V linear regulators. Calculate the overall regulator efficiency.