KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
DEPARTMENT OF ELECTRICAL ENGINEERING
Electronic Circuits I - EE203

Experiment # 4
Rectifier Circuits

OBJECTIVE

To Build and understand the operation of an AC to DC power supply.

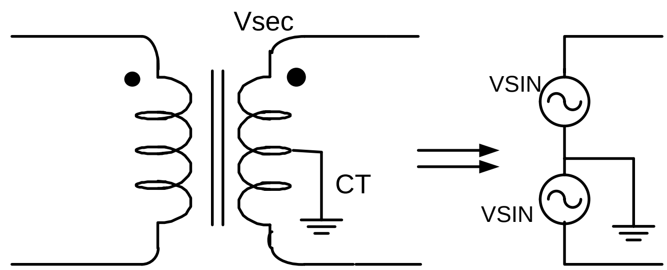
COMPONENTS REQUIRED

•	Rectifier Diodes	GE1N5059(2)
•	Zener Diodes	D1N750 (Vz =10V) (1)
•	Resistors	1KΩ, 2.2kKΩ
•	Capacitor	22µF, 100µF, 1000µF
•	Center-tap Transformer	12VAC (1)

PRELAB

For the regulated power supply circuit shown in Figure 6, assume regular diodes with 0.7V forward drop and a Zener diode with 0. 7V forward drop, Vz=10V at 20mA, I_{min}=5mA and r_z=10Ω. Use a 15V (peak), 60Hz sine wave at the transformer secondary and assume a maximum ripple level of 1V.

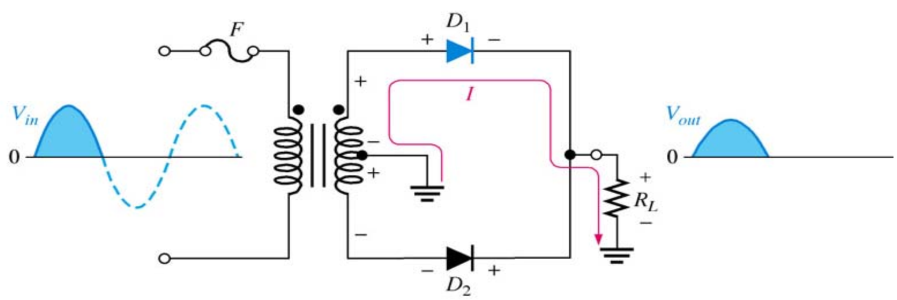
(a) Compute the unknown components needed to design 10V DC supply. Refer Figure 6. Hint: find R first, and then C assuming a discharge path through R and the Zener, $r_{z,}$ (Load R_L is disconnected). What is the ripple level for C=22µF? Sketch the rectified, filtered, and regulated outputs.
(b) Verify the experimental work with Pspice. Use two VSIN sources instead of center-tap transformer (as shown below). Note: rest of the circuit is same in experimental procedure, so follow experimental procedure to do Pspice work.



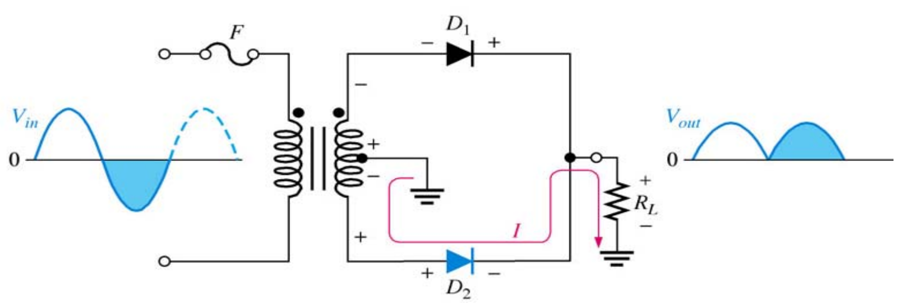
SUMMARY OF THEORY

The objective of the lab is to reacquaint you with the fundamentals of AC (alternating current) and DC (direct current) voltages as well as introduce you to the basics of AC to DC conversion through the use of diode rectifiers. In Figure 1, $\boldsymbol{R_L}$ simulates the load placed on the power supply, which can be a battery operated electronic device, a computer (though it would need a DC-DC step down converter), or any other circuit that requires a DC input.

The first section of the power supply, after the AC voltage source, is the transformer. It is responsible for converting the AC signal from a standard wall outlet down to a 12 VAC signal. Most DC power supplies maintain a voltage much less than 120 volts, so the transformer stage is necessary to get the AC source amplitude down to a more reasonable level.



(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.



(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

Figure 1

The second stage, consisting of the two diodes D1 to D2, is referred to as a full-wave rectifier. The diodes only allow current to flow in one direction (the direction of the arrow on their symbol. D1 work to allow only positive AC voltages to pass through the rectifier unaffected. On the other hand, D2 flip the sign of the negative AC voltages to make the whole output of the rectifier to be positive as shown in Figure 1. This converts the AC voltage (a sine wave) to an always-positive DC voltage (a flat signal).

Although the rectification stage makes the sine wave voltage to be positive, the rectifier's result is not as "flat" a DC value as we would like to have from a reliable voltage source, as you will measure in lab. The capacitor is included to help smooth out the ripples that result in the output from the rectification stage. Recall that the voltage across a capacitor cannot change instantaneously, but rather it requires a certain amount of time before it is fully charged. Large capacitance values help suppress the quickly changing voltage from the rectifier and result in a flatter DC value being supplied to the load. Typical power supply designs use relatively large capacitor values (greater than 1000 μF).

EXPERIMENTAL WORK

1. Connect the full-wave rectfier shown in Figure 2. Observe the voltage across the secondry.Why is it necessary to use two channels to view the entire secondary voltage?

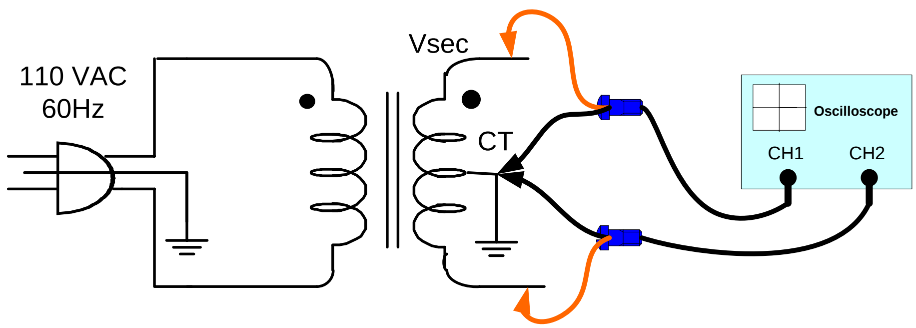


Figure 2

2. Connect the full wave rectifier circuit shown in Figure 3. Use R_L=2.2K. (Precaution: the ac line voltage must not be exposed; the transformer should be fused properly). Notice the polarity of diode. The line indicates the cathode side (the negative side). Connect the oscilloscope so that channel 1 is across the transformer secondary and channel 2 is across the output (load) resistor. The oscilloscope should be for "LINE Triggering" as the waveform to be viewed in this experiment is synchronized with the ac line voltage.

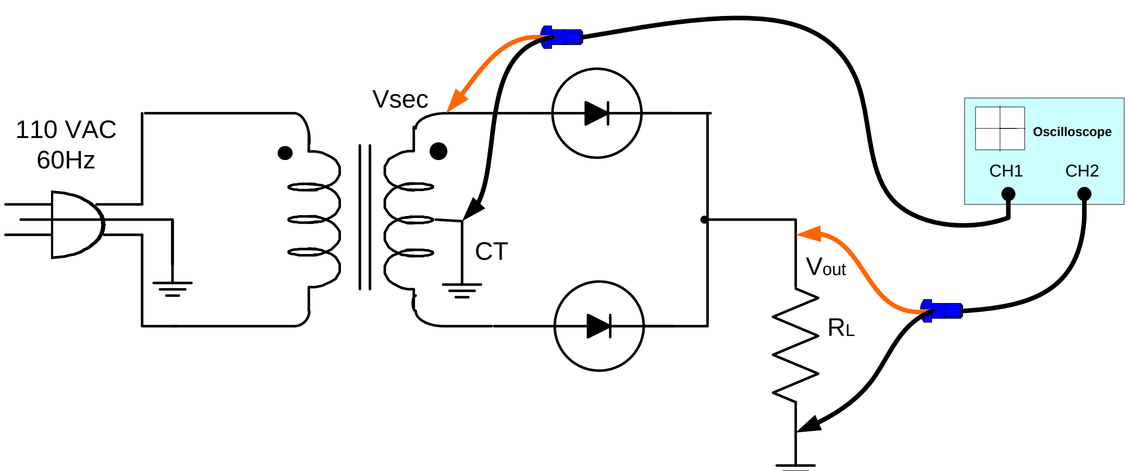


Figure 3

3. View the V_{sec} of the transformer and the output voltage (V_{out}), waveform for this circuit and sketch them . Label voltage and time on your sketch. Calculate frequency Check the rms voltage using Digital multimeter (DMM).

4. Comment on the waveform voltage frequency before and after the diodes.

5. Using an RMS voltmeter measure the voltage drop across the diodes; and comment on the diode peak inverse voltage (PIV).

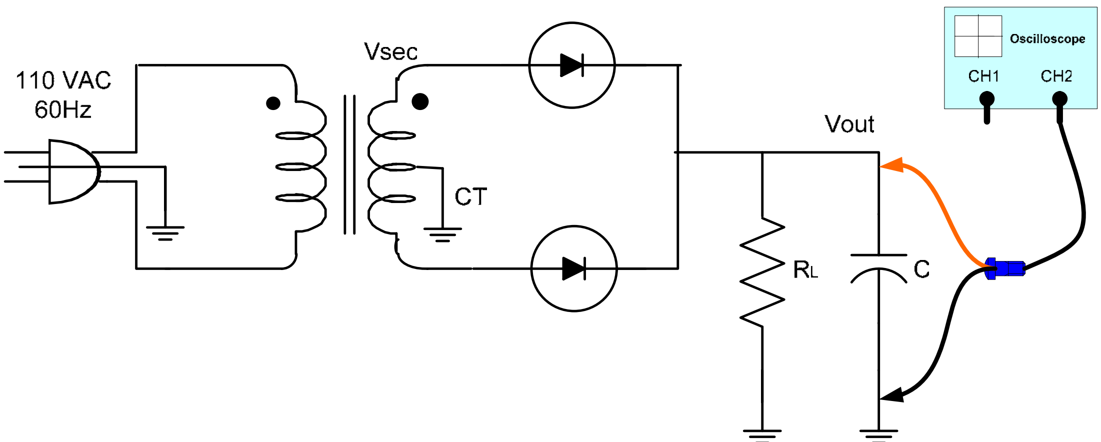


Figure 4

6. Though the output of the circuits is a DC current, but its amplitude fluctuates, i.e., it does not change direction but amplitude changes as shown in Figure 5. In order to smooth the rectified output voltage, a filter is needed. An electric filter is a Capacitor-Resistor circuit that stores voltage when the rectified DC voltage is high and discharges the stored voltage when the rectified DC is low. Now, the power supply filter is examined.

   Connect a 22 μF filter capacitor in parallel with the load resistor (R_L). Check the polarity of the capacitor- the negative side goes towards ground (the long lead of capacitor is positive). Measure the dc load voltage, V_{out} (DC), and peak to peak ripple voltage, $V_{r(pp)}$, in the output as show in Figure 5. To measure the ripple voltages, switch the oscilloscope to AC coupling. This slows you to magnify the small ac ripple voltage without including the much larger dc level. Measure the ripple frequency at which the waveform repeats.

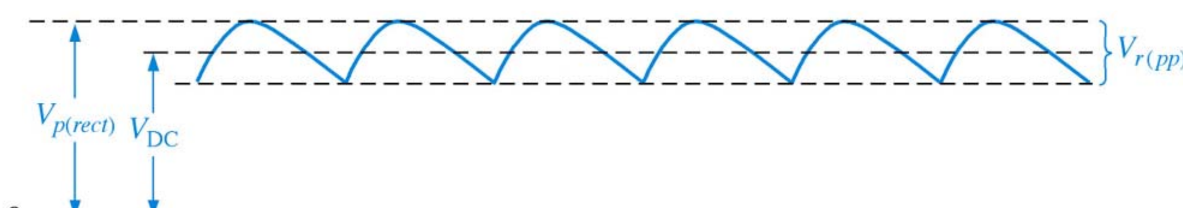


Figure 5

7. Connect (a) 100µF (b) 1000µF, sketch ripple and calculate ripple factor. What happens to ripple as you increase the value of capacitance from 100µF to 1000µF? (Note: Larger the value of capacitance, the smaller the ripple and more effective the filtering)

8. Investigate the effect of the load resistor on the ripple voltage by connecting a 1K resister. The filter capacitor is not shown but should be place in parallel also. Measure the ripple voltage. What can you conclude about the effect of additional load current on the ripple voltage?

9. The output still contains ripples what do you suggest.

10. Connect the complete circuit as shown in Figure by adding the available Zener diode. Use the designed values (from prelab) for R and C and a load resistor R_L=2.2kΩ. Sketch and label the observed output.

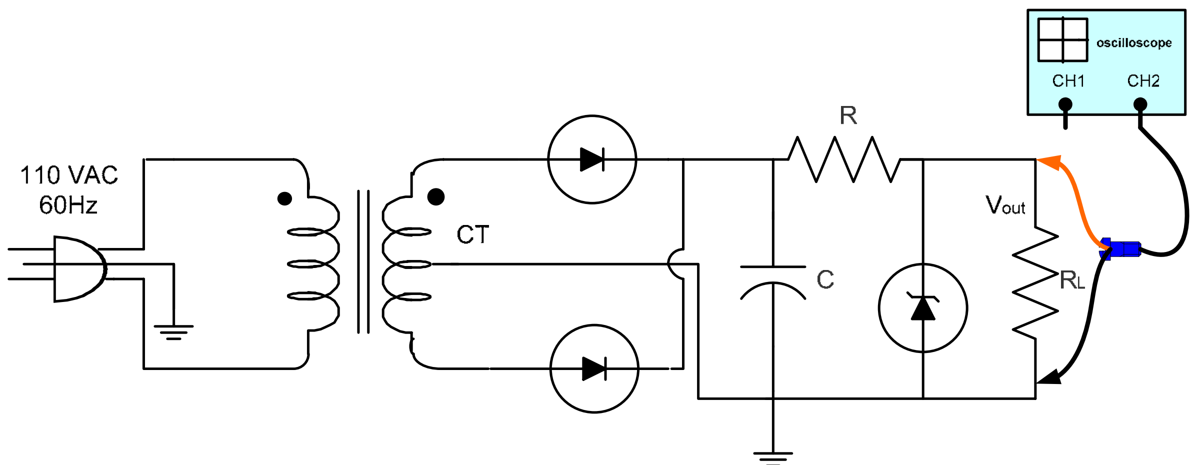


Figure 6

11. Connect a smaller R_L (e.g. 1kΩ) and notice the effect on the output. Compared to part (7), what function did the Zener diode perform? What is the effect of the load on DC output?

DATA SHEET

The amount and type of information found on data sheets for zener diodes varies from one type of diode to the next. The data sheet for some zeners contains more information than for others. Figure 7 gives an example of the type of information that you have studied that can be found on a typical data sheet but does not represent the complete data sheet.

Electrical characteristics

The Electrical characteristics are listed in tabular form in Figure 7, with zener type numbers in first column. This feature is common to most device data sheet.

- *Zener voltage***:** For each zener type number, the nominal zener voltage, V_Z, for a specified value of zener test current, I_{ZT}, is listed in the second column. The nominal value of V_Z can vary depending on the tolerance. For example, the 1N750 has nominal V_Z of 4.7 V. For 10% tolerance, this value can range from 4.23 V to 5.17 V.

FAIRCHILD
SEMICONDUCTOR™

Discrete POWER & Signal Technologies

1N746A - 1N759A Series Half Watt Zeners

Absolute Maximum Ratings*

TA = 25°C unless otherwise noted

Parameter	Value	Units
Storage Temperature Range	-65 to +200	°C
Maximum Junction Operating Temperature	+ 175	°C
Lead Temperature (1/16" from case for 10 seconds)	+ 230	°C
Total Device Dissipation Derate above 25°C	500 3.33	mW mW/°C

*These ratings are limiting values above which the serviceability of the diode may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 200 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Tolerance: A = 5%

DO-35

Electrical Characteristics

TA = 25°C unless otherwise noted

Device	V_Z (V)	Z_Z (Ω) @	I_{ZT} (mA)	I_{R1} (μA) @	V_R (V)	I_{R2} (μA) @	V_R T_A=150°C (V)	T_C (%/°C)	I_{ZM}* (mA)
1N746A	3.3	28	20	10	1.0	30	1.0	- 0.070	110
1N747A	3.6	24	20	10	1.0	30	1.0	- 0.065	100
1N748A	3.9	23	20	10	1.0	30	1.0	- 0.060	95
1N749A	4.3	22	20	2.0	1.0	30	1.0	+/- 0.055	85
1N750A	4.7	19	20	2.0	1.0	30	1.0	+/- 0.030	75
1N751A	5.1	17	20	1.0	1.0	20	1.0	+/- 0.030	70
1N752A	5.6	11	20	1.0	1.0	20	1.0	+ 0.038	65
1N753A	6.2	7.0	20	0.1	1.0	20	1.0	+ 0.045	60
1N754A	6.8	5.0	20	0.1	1.0	20	1.0	+ 0.050	55
1N755A	7.5	6.0	20	0.1	1.0	20	1.0	+ 0.058	50
1N756A	8.2	8.0	20	0.1	1.0	20	1.0	+ 0.062	45
1N757A	9.1	10	20	0.1	1.0	20	1.0	+ 0.068	40
1N758A	10	17	20	0.1	1.0	20	1.0	+ 0.075	35
1N759A	12	30	20	0.1	1.0	20	1.0	+ 0.077	38

*IZM (Maximum Zener Current Rating) Values shown are based on the JEDEC rating of 400 milliwatts. Where the actual zener voltage (VZ) is known at the operating point, the maximum zener current may be increased and is limited by the derating curve.

Figure 7

- *Zener impedence:* Z_Z is the value of dynamic impedence in ohms measured at the test current. The values of Z_Z for each zener type are listed in the 3rd column. The term dynamic means that it is measured as an ac quantity; that is, the change in voltage for a specified change in current ($Z_Z = \Delta V_Z \,/\, \Delta I_Z$). You cannot get Z_Z using V_Z and I_{ZT}, which are dc values.
- *Zener test current:* The value of zener current, I_{ZT}, in mA at which the nominal zener voltage is specified is listed in the 4th column.

- *Reverse leakage current:* The values of leakage current are listed in the 5^{th} and 7^{th} column for different temperature and Reverse voltage (V_R). The leakage current is current through reverse-biased zener diode for values of reverse voltage less than the value at the knee of the characteristics curve. Notice that the values are extremely small as was the case for rectifier diodes.

- *Maximum zener current:* The maximum dc current, I_{ZM}, is listed in 10^{th} column. The value of I_{ZM} is specified based on the power rating, the zener voltag at I_{ZM}, and the zener voltage tolerance. An approximate value for I_{ZM} can be calculated using the macimum power dissipitaion, $P_{D(max)}$ and V_Z at I_{ZM} as follows:

$$I_{ZM} = P_{D(max)} / V$$