

BASIC ELECTRONICS - RECTIFICATION AND FILTERING

PURPOSE

Suppose that you wanted to build a simple DC electronic power supply, which operated off of an AC input (*e.g.*, something you might plug into a standard outlet). In this lab, you'll build a series of circuits, each of which will come closer to that goal. That is, the first circuit you build will convert an AC input into an output that always pushes charge in *one* direction, but it won't produce an output that is *constant*. On the other hand, the final circuit should produce a reasonably constant output, with only small remnants of the variations associated with the AC input.

PROCEDURE

REASONABLE ***CAUTION*** SHOULD BE EXERCISED WHEN BUILDING ***OR CHANGING*** THE CIRCUITS OF THIS EXPERIMENT.
IT IS RECOMMENDED THAT THE CIRCUITS BE **DISCONNECTED FROM LINE VOLTAGE** WHILE CHANGES ARE MADE.
IT IS FURTHER SUGGESTED THAT **NO PART OF YOUR BODY COME IN CONTACT** WITH BARE TERMINALS.

I. The Transformer: Converting high voltage to low voltage

To isolate your circuit board from all others, use a transformer. This sort of set-up also allows you to work with voltages that are considerably less than line voltage (*i.e.*, the wall socket). If the “primary” side of your transformer is connected to a line voltage of 115 VAC (“VAC” means “volts, AC”), the “secondary” voltage is roughly 6 VAC. We shall use the “Universal Transformer” which has variable settings for output voltage.

Connect your transformer to line voltage and use Channel A of the oscilloscope to measure the frequency and peak-to-peak voltage out of the secondary.

FREQUENCY of secondary: _____ (Scope)
Peak-To-Peak Voltage of secondary: _____ (Scope)
PEAK Voltage: _____.

We remark here that transformers are available to convert just about any primary voltage (0-50,000 volts or more) to any secondary (or *multiple* secondary) voltages (0-50,000 volts or more). From your measurement calculate the rms voltage, recalling that for a *simple sine wave* signal:

$$V_{\text{rms}} = \frac{V_{\text{peak}}}{\sqrt{2}} = 0.707V_{\text{peak}}$$

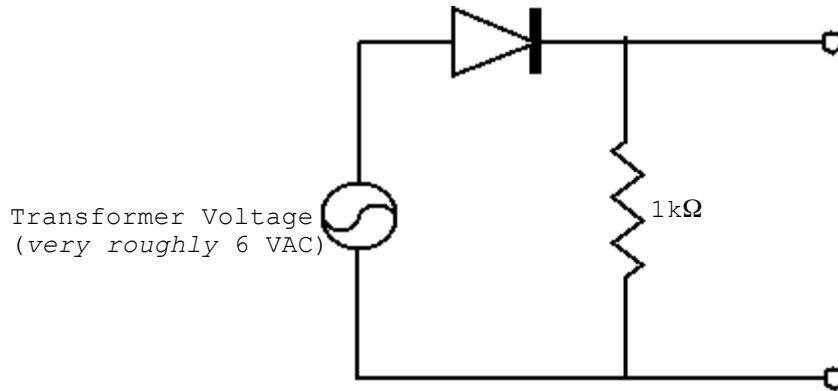
CALCULATED, from peak voltage: _____ Volts (RMS)

MEASUREMENT reported by DMM (on ac scale): _____ Volts (RMS)

Based upon your measurement, do you believe that this particular hand-held DMM is sold as one which measures “true RMS” or not? (Some models are advertised as “true RMS” meters, others are explicitly *not* “true RMS” meters.)

II. Rectification, “Half Wave:” conversion of AC to DC

You can use a *diode* to convert the AC voltage of the secondary into a DC voltage (albeit not a steady one). A diode is a device designed to pass current in only one direction; thus it will conduct current during only one half of the voltage cycle. Connect the following circuit observing the proper diode connections (by convention, the triangle points in the direction of allowed current flow while the bar indicates the input that is “barred” from accepting current input). Use a $1\text{k}\Omega$ resistor for the output load, as shown below.



DO NOT TURN THE POWER ON before making some calculations to check that the load resistor has a power rating sufficient to handle the voltage that will be applied to it:

Based upon your *previous measurements*, what will be the maximum voltage out of the diode (and therefore across the resistor)?

$$V_{\text{peak}} \text{ (approx.) } \underline{\hspace{2cm}} \text{ volts}$$

When the voltage is that value, what current will flow in the $1\text{ k}\Omega$ resistor?

$$I = \underline{\hspace{2cm}} \text{ (calculated)}$$

Since $\text{Power} = IV$ in DC circuits, the power dissipated by the resistor will be

$$P = \underline{\hspace{1cm}} \text{ Watts (calculated)}$$

The resistor is *rated* to dissipate $\frac{1}{4}$ Watt. Is this resistor's power rating sufficient? .

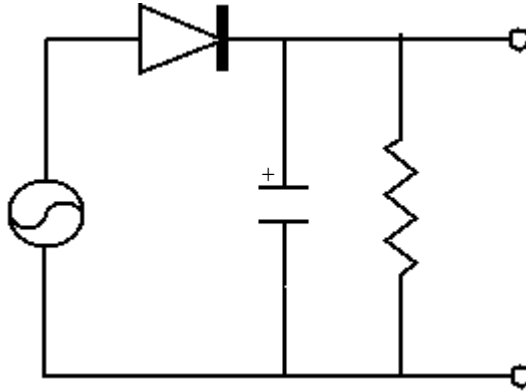
Now apply power and, with the **Channel B** of the scope, measure the peak voltage across R :

$$V_{\text{peak}} = \underline{\hspace{1cm}} \text{ (Scope)}$$

Sketch the waveform in your lab notebook; it should be what we will call a “half rectified” wave.

III. Filtering: smoothing out the signal

Since the current that you have produced now flows in only one direction it is called DC, but – as you can see – it is a fairly *bumpy* DC. More often than not applications call for very *steady* DC voltages. You can smooth out the bumps by adding a 100 μF capacitor as shown.



Observe the polarity of the capacitor!

On the first half of the cycle, current flows through the resistor and also charges the capacitor to peak voltage. On the second half cycle, when the diode does not conduct, the capacitor discharges through R in the manner of an RC discharge, and thus current is maintained for a longer period.

Sketch what you observe in your lab notebook. (Label your axes and indicates the location of zero voltage.)

CAUTION: A capacitor can remain charged for a significant period after the power is turned off if the *path available for discharge has low conductance* (*i.e.*, if the time constant, RC , is large).

Calculate the capacitor discharge time $\tau = RC =$ _____ seconds.

If you switch the scope from “DC Coupling” to “AC Coupling”, you can further amplify the signal (*i.e.*, you can amplify the signal without simultaneously amplifying any DC component of that signal). This trick of “removing the background” will allow you to examine small variations in a DC signal (“ripple”) without saturating the amplifier. However, remember to switch back to “DC Coupling” whenever you begin to examine a new circuit; moreover, if you then view the complete signal on a scale that also includes zero, you will clearly observe the progress made with each new circuit in this lab.

For your current circuit, what is the peak-to-peak ripple? _____ Volts.

Add a *second* 100 μF capacitor (note polarity) in parallel with the first and compare results with preceding ones.

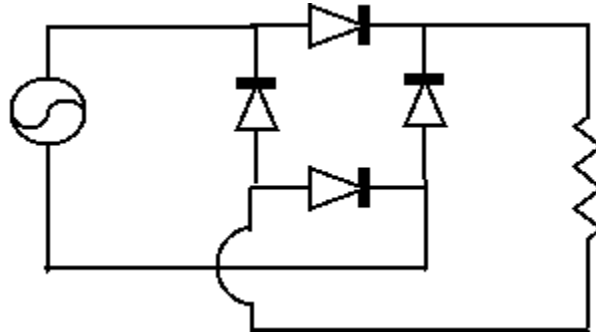
For this latest circuit, what is the peak-to-peak ripple? _____ Volts.

You should be aware that the choice of the 1 $\text{k}\Omega$ load resistor was completely arbitrary. The load could have had any resistance, provided the power requirements were met and you don't blow the diode by passing excessive current through it.

IV. “Full-wave” Rectification and Filtering

Why should we use only one-half of the AC cycle? Why not put the entire cycle to use by adding more diodes to the circuit?

That is, have a set of diodes that *alternate* conduction:



Have this circuit checked by your instructor
before turning power on!!!!

Once approved, turn on the circuit and sketch the waveform observed using DC coupling (so that you can include the location of zero Volts in your plot).

$$V_{\text{peak}} = \underline{\hspace{2cm}}.$$

Next, filter this fully rectified current by adding one 100 μF capacitor in parallel with R . Measure the ripple voltage with the scope and with a hand-held voltmeter. Also measure the frequency of the peak-to-peak ripple voltage.

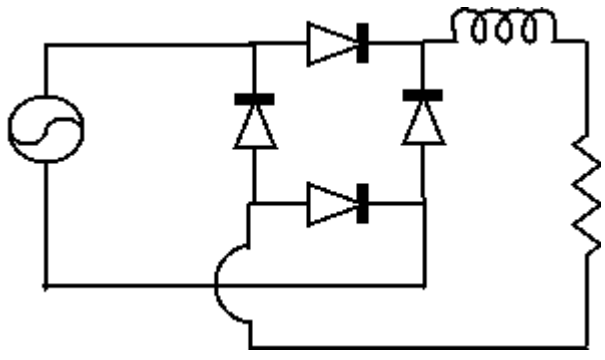
ripple voltage _____ (Scope)

ripple frequency _____ (Scope)

V_{ac} _____ (hand-held voltmeter)

V_{dc} _____ (hand-held voltmeter)

Instead of a capacitor, an inductor can also be used as a filter for the full-wave rectifier. Remove the capacitors from between A and B and construct this next circuit with a **10 Henry** inductor (a “honkin’ beast!”). The inductor shown below has been added to the output from your collection of four diodes (the resistor shown is the same load used previously, but the capacitor has been removed):



Sketch the DC-coupled waveform in your lab book.

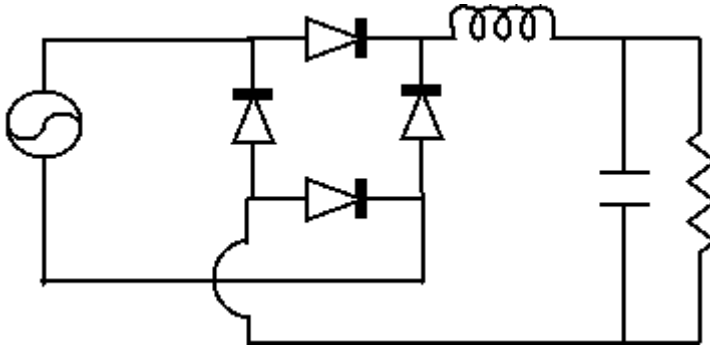
As the current through the inductor starts to drop off (on the half cycle of the full rectified wave), the magnetic field, B , around the inductor starts to collapse; this changing magnetic field produces an *emf* to oppose the changing current and the inductor tries to maintain the current. An inductor used this way is called a filter “choke” or choke filter, and by itself may not have a great effect.

Measure both the peak-to-peak ripple voltage and the DC voltage:

ripple voltage ____ (Scope)

V_{dc} _____ (voltmeter)

A better filter can be made with a *combination of C (100 μF) and L.*

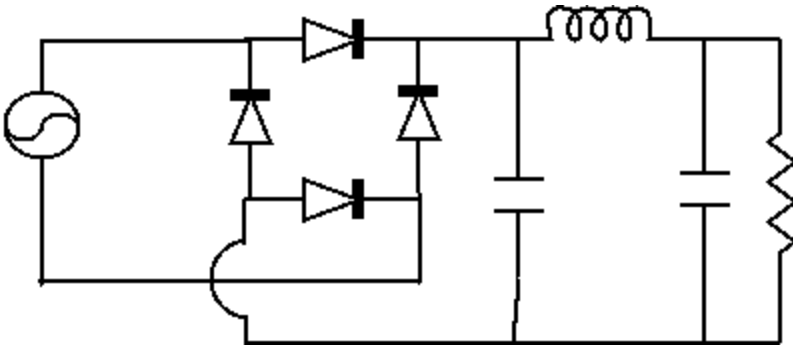


Sketch the DC-coupled waveform in your lab book.

Add back your 100 μF capacitor after the inductor, as shown above and measure-the voltages. This is called an “**L-section**” filter:

ripple voltage ____ (Scope)

V_{dc} _____ (voltmeter)



Sketch the DC-coupled waveform in your lab book.

Finally, add another 100 μF capacitor as shown below to make a “**Pi-section**” filter:

ripple voltage ____ (Scope)

V_{dc} _____ (voltmeter)

QUESTION

Why did the ripple frequency for the full wave rectified signal differ from 60 Hz?