

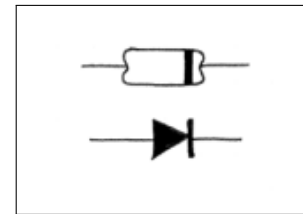
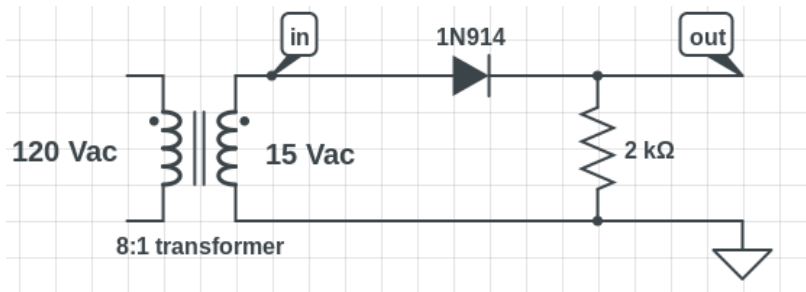
Physics 364, Fall 2014, Lab #6 **Name:** _____
(diode circuits)

Wednesday, September 17 (section 401); Thursday, September 18 (section 402)

Course materials and schedule are at positron.hep.upenn.edu/p364

Part 1
half-wave rectifier

Start Time: _____
(time estimate: 30 minutes)



Build a half-wave rectifier with a 15 V_{ac} (rms) transformer and a 1N914 diode, as shown above.¹ Notice that the stripe on the diode corresponds to the little bar on the diode's schematic symbol. Connect a 2 $k\Omega$ load and look at $V_{in}(t)$ and $V_{out}(t)$ on the scope.

1.1 Are the input and output waveforms what you expect? Do you expect $V_{out}(t)$ to be positive or negative? Can you see evidence of the 0.6 V “diode drop” in your $V_{out}(t)$ waveform? Why is the peak value of $V_{in}(t)$ so much larger than 15 V? What is the period of $V_{in}(t)$? What is the period for $V_{out}(t)$?

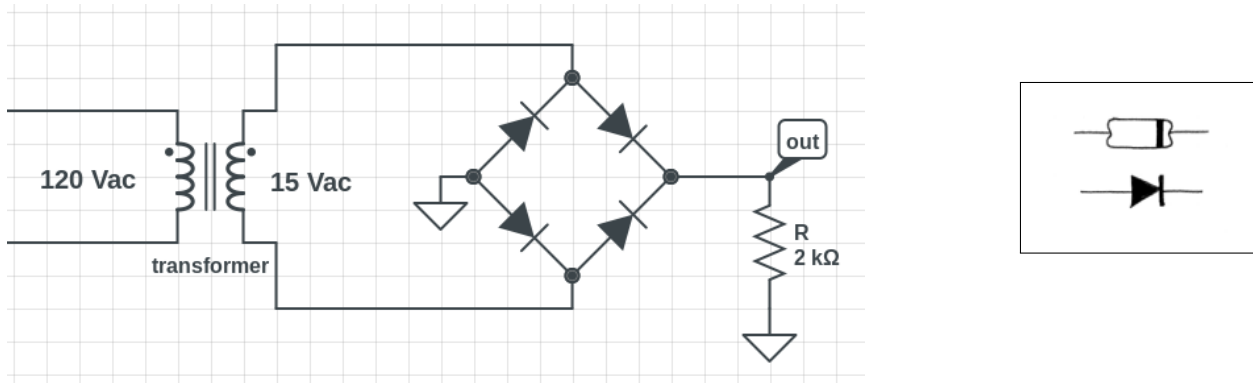
¹Most of today's lab is adapted from Tom Hayes's Lab 3.

1.2 Sketch the waveforms.

1.3 Connect a $1\text{ k}\Omega$ load resistor in parallel with the $2\text{ k}\Omega$ resistor, and observe whether or not the peak value of $V_{\text{out}}(t)$ is substantially changed by this loading. Does this change (or lack of change?) allow you to argue anything about the output resistance of this rectifier, e.g. to put a loose upper or lower bound on the rectifier's R_{out} ? (Since the rectifier circuit is often part of a power supply, so it should be able to supply a large current, its output resistance is important; by contrast, the output resistance of the diode clamp circuit that you saw in the reading is not so important.)

Part 2
full-wave bridge rectifier

Start Time: _____
(time estimate: 60 minutes)



2.1 Now build a “full-wave bridge rectifier” circuit, as shown above. Be careful about the diode polarities. Look at, **and sketch**, the output waveform. (But **don’t** try to look at $V_{in}(t)$ — the 15 V_{ac} signal from the transformer — at the same time. This would require connecting one “ground” lead of the scope to one side of the transformer’s 15 V_{ac} coil. What unwanted outcome would that cause? If you do want to look at $V_{in}(t)$, use math mode to subtract the signals from two separate scope probes.)

2.2 Does your $V_{\text{out}}(t)$ waveform make sense to you? What is its period? (It should be different from the period of the half-wave rectifier. Why?)

What is the peak value of $V_{\text{out}}(t)$? (It should be about a “diode drop” smaller than the peak you saw with the half-wave rectifier, which itself was about one “diode drop” below $V_{\text{in}}(t)$. Why?)

2.3 Look at the region of the output waveform that is near zero volts. Why are there flat regions? Measure their duration, and use your knowledge of the diode’s I - V curve to explain them. (Very optional: If you really want to test your theory, you could try rebuilding your bridge rectifier using four red LEDs, and see whether the flat regions become wider or narrower.) Don’t spend more than a couple of minutes here.

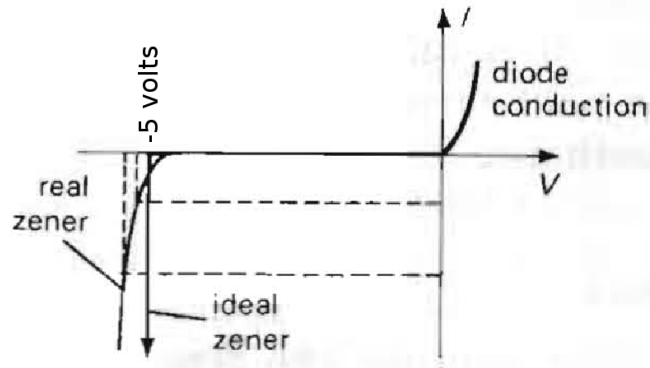
Don’t be too alarmed if you find yourself burning out diodes with this circuit. If this does happen to you, you will probably find that diodes in this circuit usually fail in pairs.

Part 3
turning rectifier into power supply

Start Time: _____
(time estimate: 30 minutes)

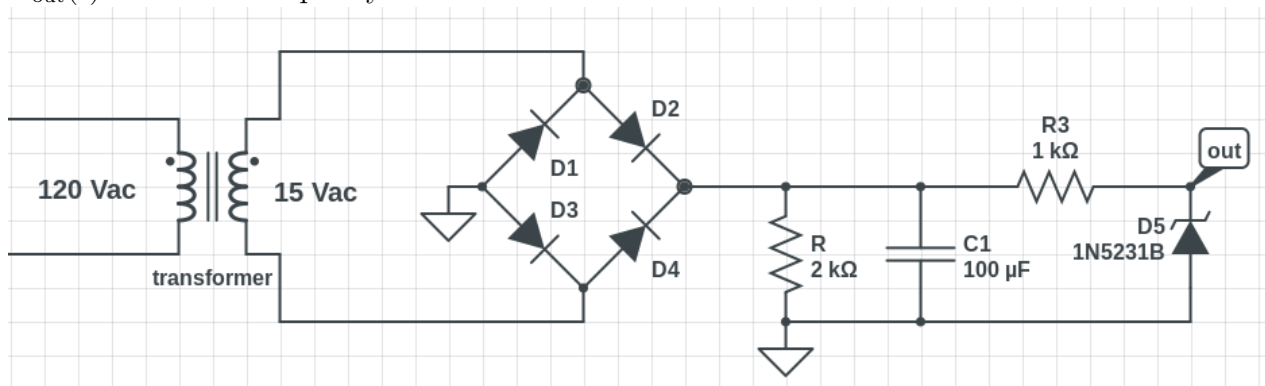
3.1 Keep your bridge rectifier together! Now connect a $10\ \mu\text{F}$ filter capacitor across the output of your bridge rectifier. Does the shape of the output make sense to you? Estimate roughly what the “ripple” amplitude should be, then measure it and compare.

3.2 Now try a $100\ \mu\text{F}$ capacitor instead. Is the ripple reduced by roughly the factor that you would expect? Make a rough sketch of the output waveform.



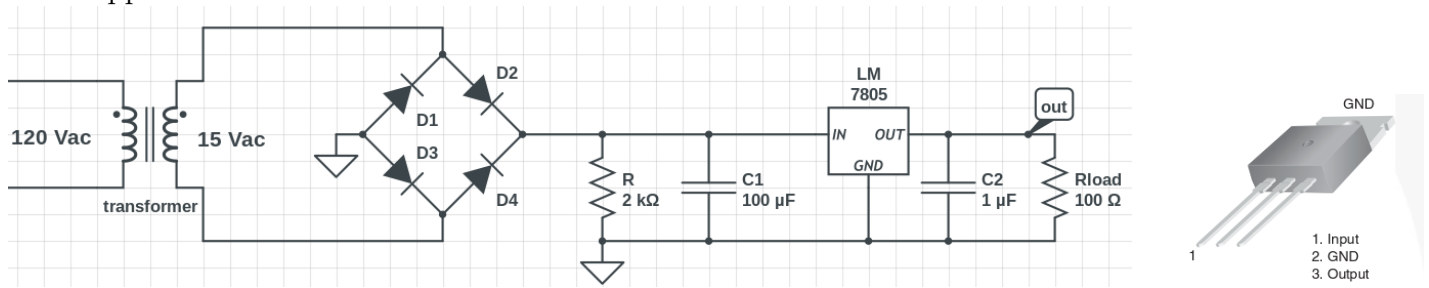
3.3 One classic technique for regulating the output voltage of a power supply, so that $V_{\text{out}}(t)$ is as flat as possible, is to use a Zener diode, whose I -vs- V curve is shown above. When you apply a reverse voltage to a normal diode, it remains non-conducting until you reach the “breakdown” voltage, which is $\mathcal{O}(100 \text{ V})$. A Zener diode, by contrast, is designed to break down at a much lower voltage (and it is not damaged by doing so).

The 1N5231B Zener diodes in our lab have a 5 V breakdown voltage. Its orientation in the circuit seems counter-intuitive until you look carefully at the I - V curve. The $1 \text{ k}\Omega$ resistor is needed to limit the power dissipated in the Zener diode. Give this a try and quickly sketch $V_{\text{out}}(t)$. It should be pretty flat at around 5.1 V.



3.4 In real-life circuits, one often uses a three-terminal device called a “voltage regulator” to turn a somewhat wiggly unregulated power supply into a high-quality voltage source, as described in Eggleston’s §3.2.6. The internal mechanism of these devices uses several transistors, which we will study later in the semester. We put this here today because it fits in with power supplies.

The very common LM7805 regulator² that we’ll use today turns a variable input voltage $7\text{ V} < V_{\text{in}} < 35\text{ V}$ into a reliable $V_{\text{out}} = 5\text{ V}$, with an output current rated up to 1 A, and a typical Thevenin resistance $R_{\text{out}} = 0.015\ \Omega$. Our situation, $V_{\text{in}} \approx 20\text{ V}$, is not ideal ($V_{\text{in}} \approx 8\text{ V}$ would be better), as a linear regulator has the property that the current drawn from the input voltage source approximately equals the current supplied to the downstream load. So the power dissipated in the regulator itself is $(V_{\text{in}} - V_{\text{out}})I_{\text{out}}$, which in our case is about $3\times$ as large as the power dissipated in the load itself. Our using a larger-than-needed V_{in} is wasting power and generating unwanted heat, which we would try to avoid in a real application.



Remove the Zener diode and the $1\text{ k}\Omega$ series resistor from your previous circuit, and add the LM7805 regulator, the bypass capacitor, and the $100\ \Omega$ load resistor. The purpose of the resistor is just to draw a current from the regulator: in real life some useful device in need of power (like your iPhone) would sit where R_{load} sits. The purpose of the “bypass” capacitor is to filter out any small wiggles in V_{out} , which often are caused by rapid changes in the current required by the load (maybe your iPhone receives a call).

Wire this up and see if V_{out} appears to be a nice, flat 5 V . As a check that the regulator’s output resistance is very small, try adding a second $100\ \Omega$ resistor in parallel with the first: you should see no measurable change in V_{out} , indicating that $R_{\text{out}} \ll 50\ \Omega$.

²Datasheet at www.mouser.com/ds/2/149/LM7805-189995.pdf

Part 4

Start Time: _____

CircuitLab

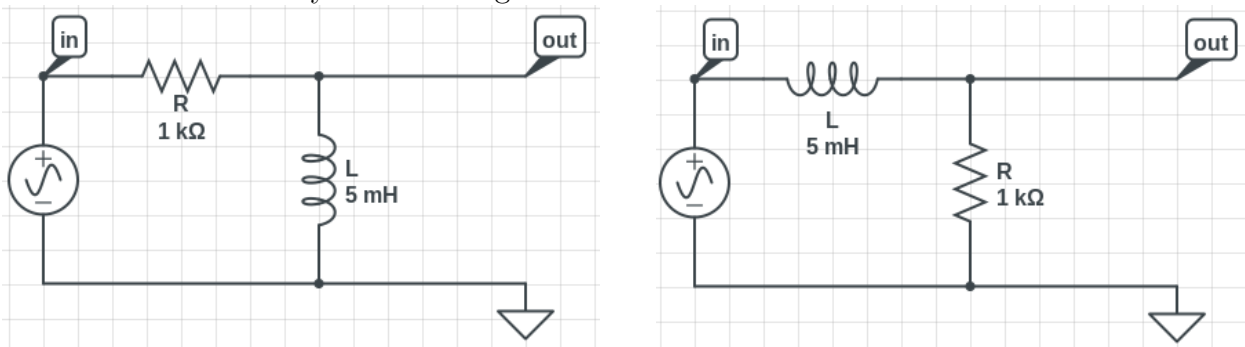
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Three options: do either 4.1 or 4.2 or 4.3, whichever you find most interesting. Skip this if you run out of time today, or if you already tried out CircuitLab in class earlier this week.

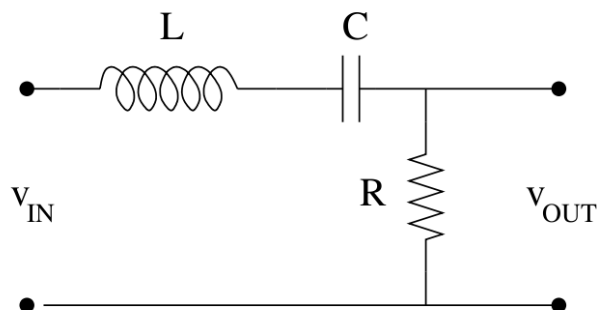
Using either your own computer or one of the lab's notebook computers, point your web browser at www.circuitlab.com and sign up for a free student account using your upenn.edu email address. The engineering school has a university-wide site license through 3/2015. CircuitLab lets you draw and simulate a wide range of electronic circuits, without the hassle of installing any software on your own computer. We aim to use it often in this course. Real-life circuit designers always simulate their circuit designs before building them, to be sure that they understand how the circuit they want to build is *supposed* to work. You will probably want our help getting started. If you have no preference, do 4.2.

4.1 Option 1: Repeat the key parts of Part 2 (RLC filter) of Lab 5 in the CircuitLab simulator.

4.2 Option 2: In CircuitLab, study the following two filters, along the lines of the RC filters in Lab 4. The time constant is now $\tau = L/R$ instead of $\tau = 1/RC$, so $f_{3dB} = \frac{R}{2\pi L}$. Which one should be the LPF / “integrator,” and which one should be the HPF / “differentiator?” (What happens to Z_L as $f \rightarrow 0$? What about $f \rightarrow \infty$?) Build and study the circuits in CircuitLab to confirm your reasoning.



4.3 Option 3: In CircuitLab, study the series version (shown below) of the resonant RLC circuit, using the same component values as in Part 2 of Lab 5 ($R = 100 \text{ k}\Omega$, $L = 10 \text{ mH}$, $C = 10 \text{ nF}$).



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