UNIVERSITY OF UTAH
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
ECE 2280

A. Rasmussen/A. Stolp
1/14

Lab #2 {100 pts} Diodes

OBJECTIVES:

- Understand the basic operation and characteristics of a diode.
- Understand basic circuits containing a diode.

PARTS LIST:

- □ (4) silicon diodes (ex. 1N4001, 1N4004, etc.)
- □ 10kΩ potentiometer, single turn (trim pot) (any size from 5kΩ to 100kΩ will do)
- □ A couple capacitors (low value, medium value, large value)
- □ At least:2 - 0.1μF, 0.01μF ceramic capacitors (values not critical)
- □ 2 - 100μF electrolytic or tantalum capacitors
- □ Resistors's (See Experiment 3 below)
- □ condenser microphone (may be available for check-out, otherwise purchase or use your own)
- □ 2N3904 and 2N3906 transistors
- □ speaker (may be available for check-out, purchase or you may use your own)
- □ some operational amplifier(s): LM741, TL084, LF353, or similar {LF353 has better performance than 741)

PRE-LAB: Read Experiments

BACKGROUND INFORMATION:

Discussion about use of diodes, half-wave rectifiers, and Multimeter Testing.

Use of diodes

Diodes are mostly used in practice for emitting light (as LEDs) or controlling voltages in various circuits. The best way to think about diodes is to first understand what happens with an ideal diode and then to extend that knowledge to the real-world applications.

An ideal diode has an infinite resistance when the voltage across it is less than its "threshold voltage" and zero resistance when the voltage is greater than the threshold. The threshold voltage is just a characteristic of each individual diode (i.e. every silicon diode should have about the same threshold voltage whereas an LED may have a different threshold voltage). This threshold voltage concept comes from the fact that a diode is just a pn junction; the threshold voltage is defined by the concentration of donors and acceptors in the junction (Don't feel bad if you haven't studied *pn* junctions before; it is not crucial for this lab).

Given the above assumptions, we conclude that the I-V graph for an ideal diode should look like:

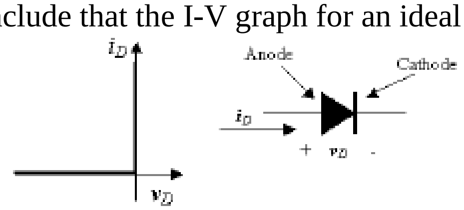


Fig. 2: Ideal Diode IV Curve and Schematic

In **Fig. 2**, the threshold voltage (i.e. the voltage when the slope of the line changes from 0 to ∞) is 0V. In the real-world the threshold voltage will be some positive voltage. For the diodes we will use in this lab, all threshold voltages will be positive (Zener diodes also have a low reverse threshold).

<u>Half-Wave Rectifier</u>

The half-wave rectifier is a circuit that allows only part of a sinusoidal input signal to pass. The circuit is simply the combination of a single diode in series with a resistor (see **Fig. 1**), where the resistor is acting as a load.

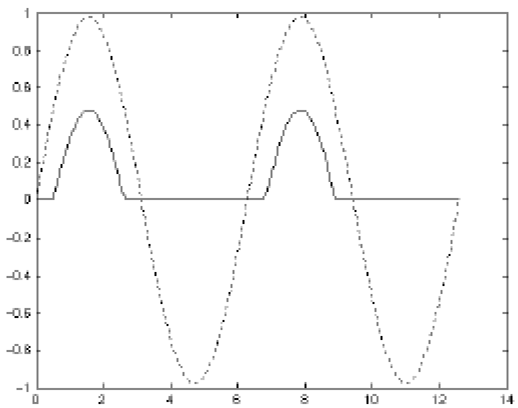


Fig. 3: Half-Wave Rectifier, Voltage vs Time

We see that the output voltage across the load is the input voltage minus the threshold voltage (this only holds when the input voltage is greater than the threshold voltage). Here, the threshold voltage is set to about 0.5 volts (can you see why?). We see that when the input voltage is not greater than the threshold voltage, we get zero voltage out. This makes sense if we look at **Fig. 2**.

Observations:

- We see that when the input voltage is less than the threshold voltage (and thus the voltage across the diode is less than the threshold voltage), we get zero current through the diode and the load (see **Fig. 2**).

- We see that when the input voltage is greater than the threshold voltage, any current can pass through the diode.

For the Half-Wave Rectifier the diode acts as a switch (see the bullets below for the switching conditions).

Switching Behavior:

- Off Condition: input voltage $<$ threshold voltage. No current passes through the diode.
- On Condition: input voltage $\geq$ threshold voltage. Any current can pass through the diode.

For example, let’s make the input voltage of five volts and a threshold voltage that we look up to be 2 Volts (which is just the voltage across the diode). Then, we know that there are 3 V across the resistor. The diode is on and current is passing through the diode.

<u>Multimeter diode test</u>

Most multimeters won’t forward bias a diode in the regular ohmmeter setting. The ohmmeter just doesn’t put out enough voltage to overcome the diode’s forward voltage drop. Therefore, multimeters won’t show significant conductivity in either diode direction. Try it yourself and see. Set the bench multimeter to the ohmmeter setting. Measure the resistance of a diode in both directions. A little problematic isn’t it? You may find that your own body's conductivity is better than the diode's. Just hold the metal tips of the two meter probes in your two hands to see what I mean.

Most multimeters provide a special ohmmeter setting to measure diodes, usually marked with a small diode symbol. In this setting they use a high enough voltage to turn the diode on. Look for a diode symbol on your meter and set the meter to that position (It's a blue shift setting on the HP meter). Now the meter will test diodes.

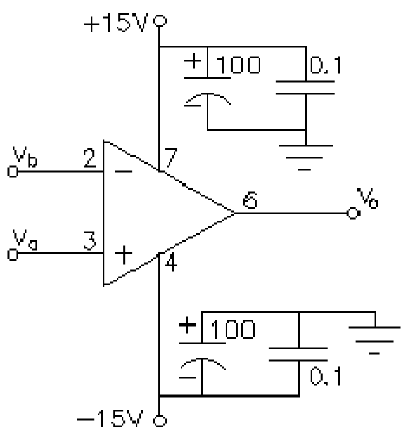
Most meters will show volts or mV (rather than Ω) when connected to the diode the right way. This indicates the forward drop across the diode at some low current and can be useful when comparing diodes. This test is also useful to see if the diode is not working correctly to see if the diode has been "blown".

MORE BACKGROUND INFORMATION:

Connecting power supplies, compensating a scope probe, potentiometers, and noise on the probes.

Power Supply Connections:

Whenever you connect power supplies to the operational amplifier, connect them as follows:



> **CAUTION**
> **It is very easy to leave the power supply set so that a small accidental touch of the round knob can suddenly change your supply voltage by as much as 10 V– that's not good for your circuit.**
>
> **To protect against this, don't leave the knob set to adjust the most significant digit, or simply hit the +6 V button and the knob will be set to adjust a voltage that we are not using.**

Note: The bypass capacitors attached from the power supply pin to ground. This protects your circuit from power supply noise and any noise or glitches that your power leads might pick up. Sometimes they will help keep the circuit from spuriously oscillating. If you look at commercially produced circuit boards, you will often see bypass caps by every IC. Your bypass capacitors should be right on your breadboard and as close to the IC as possible.

For each voltage from the supply, use a parallel combination of a fair size electrolytic or tantalum capacitor (100 µF shown here) and a smaller low-inductance ceramic disk or monolithic ceramic capacitor (0.1µF shown here). Pay close attention to the electrolytic polarities. They can blow up if you hook one up backwards. See the **Capacitors** box from **Lab #1**.

Scope Probes:

You might want to begin using the 10x scope probes rather than the BNC –to-clip cables(1x). It is your choice, just be aware of the following information:

The 10x refers to the fact that the input impedance to the scope is 10 times higher when using a 10x scope probe. When you hook the scope directly to your circuit, the circuit "sees" a load of 1 MΩ in parallel with about 13 pF. When using a 10x probe, the circuit will instead “see” a load of 10 MΩ in parallel with about 1.3 pF. This lessens the effect of the scope on the circuit, making your measurement more accurate. The price of this higher impedance is that the scope will only get one-tenth the signal that it would with a 1x probe. Be aware of these tradeoffs in scope performance to get the most accurate measurements from the scope.

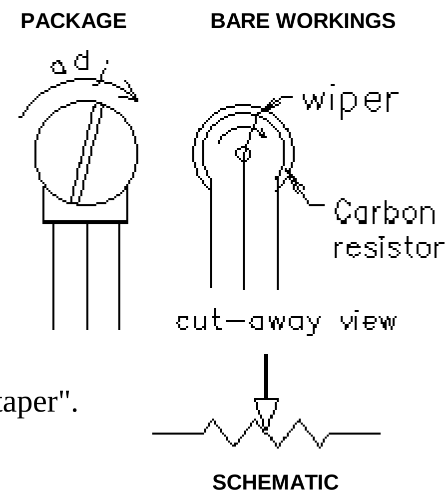
In this lab neither the input impedance nor the signal strength will be a problem, so the only reason to use the 10x probes is that they’re a little nicer to use. There is, however, one little “gotcha” with 10x probes. Notice that I said that the scope input capacitance was “about” 13 pF. Well, each scope is a little different and the scope probe will need to be adjusted or “compensated” each time it is used with a different scope. This is especially true in our lab, where the same probes are used with the Tektronics and HP scopes. The frequency response of an uncompensated probe can seriously mess-up your measurements. <u>You should always compensate a 10x probe before using it</u>.

<u>To compensate a probe:</u>

1) Connect the probe to the scope as normal.
2) Switch the probe to 10x if it has a switch.
3) Determine how to adjust your probe. Most probes have a small adjustment screw somewhere on the probe. Some probes adjust by twisting some part of the probe. (In rare cases the adjustment may be located at the scope end of the probe lead.)
4) Find a small metal contact near the scope screen marked with a square wave: “Probe Adjust”, “Cal”, or something similar. This is a square wave output provided by the scope specifically for probe adjustment. Connect the probe tip to this contact.
5) Adjust the scope controls to get a trace. You should see a good square wave if the probe is properly compensated.
6) If the leading edge of the square wave is distorted (rounded or peaked), adjust the probe for the best possible square wave (the most square).

<u>Potentiometers:</u>

An adjustable resistor is called a potentiometer. (The name comes from its old-time use in voltage measurements.) All potentiometers (pots) work in a similar manner: with a moveable slider or "wiper" that makes contact with a resistor somewhere between its two ends. A rotary potentiometer is shown here: in its package, as bare workings, and as a schematic symbol.



The resistance of a pot is the full resistance between the two outside terminals and is usually written on the part somewhere. Almost every time you turn a knob on a stereo, TV, or instrument in the lab, you are turning a potentiometer. The resistor in a potentiometer can have a linear or an audio "taper". Audio taper potentiometers are used as volume controls in audio circuits.

<u>Noise on the probes:</u>

Noise can be a problem with these scopes, especially with all the computers in close proximity. The noise will usually manifest itself as a high frequency fuzz that “rides” your signal waveform. If you’re having trouble with noise, see the following box:

<u>Noise Problems:</u>

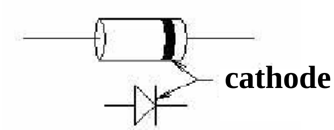
Turn the **BW lim**it “on” for each of the analog channels (**A1** and **A2**). This limits the bandwidth of the scope somewhat, cleans up the signal, and won’t seriously affect our measurements.

Also, trigger the scope off v_o rather than v_i and do whatever is needed to make the signal stable (**Reject HF**, **Noise Rej**ect, etc. under **Mode / Coupling**).

EXPERIMENT 1 Half Wave Rectifier: (20 pts)

IMPORTANT: *Do not exceed the power rating for the diode you are using.*

Procedure:



1. (20 pts) Rectifier Testing

(1a) (3 pts) Select a diode and test it using the multimeter to verify it should operate correctly(use the diode setting).

(1b) (2 pts) Build the circuit in Fig. 4 using a 10k potentiometer.

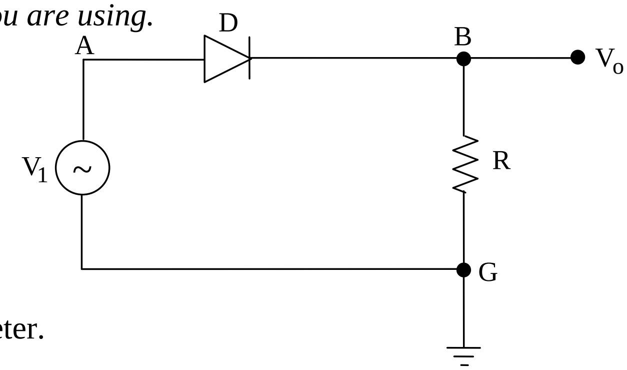
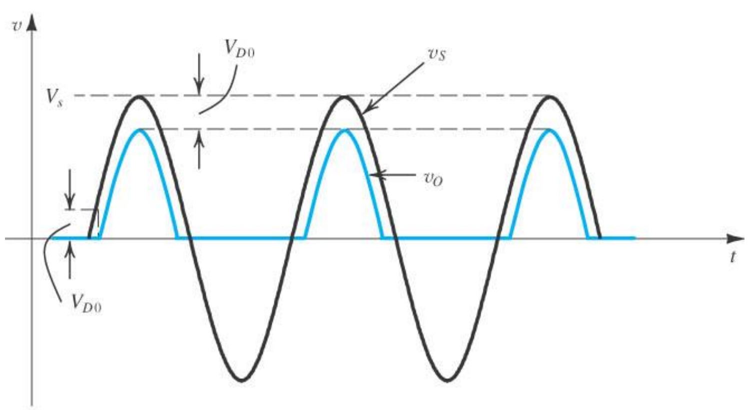


Fig. 4 Basic Rectifier Circuit

(1c) (12 pts) Apply a 100Hz sine wave with 5V peak as the input.

- Using the oscilloscope, measure the signals at nodes A and B.
- Compare the voltage values at A and B with Fig. 3.25(d) from the textbook noted below.
- Estimate the diode voltage drop at the peak of the output, V_{DO} (or $V_{D,on}$), and compare it to the datasheet for the diode.
- Adjust the potentiometer turned all the way to one side and observe the signals at nodes A and B.
- Adjust the potentiometer all the way to the other side and observe the signals at nodes A and B.
- What effect does the R have?

(1d) (3 pts) Switch the generator to a square-wave output. Notice the direct effect of the diode drop.



(d)

Fig. 3.25(d) { ***Sedra and Smith, Microelectronic Circuits, 5th edition*** **}**

EXPERIMENT 2 Diode Bridge(Full Wave): (30 pts)

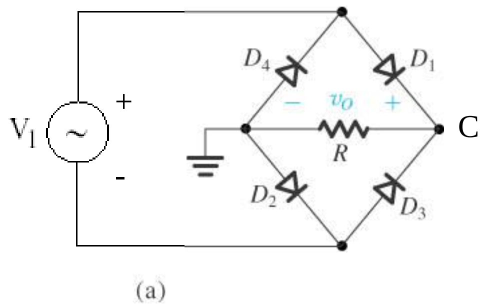


Fig. 5 Diode Bridge Rectifier

(2a) (5 pts) Expand Fig. 4 into the diode bridge shown in Fig. 5 on your breadboard. (Add D2-D4 diodes)

(2b) (5 pts) Apply a 100Hz sine wave with 5V peak as the input.

- Using the oscilloscope, measure the signal at node C.
- Compare the measurement with Fig. 3.27(b) from the textbook noted below.

(2c) (10 pts)

- Adjust the potentiometer all the way to one side and observe the signal at node C.
- Adjust the potentiometer all the way to the other side and observe the signal at node C.
- What effect does the R have? Sketch appropriate graphs if necessary.

(2d) (10 pts)

- Place a capacitor with a small value in **<u>parallel</u>** with the resistor, R. Observe signal at node C.
- Replace the capacitor first with a medium value and then with a large value for C. Observe the signals at node C.
- Explain in detail how the capacitor works in the circuit. (You can refer to Sec. 3.5.1 of your book)

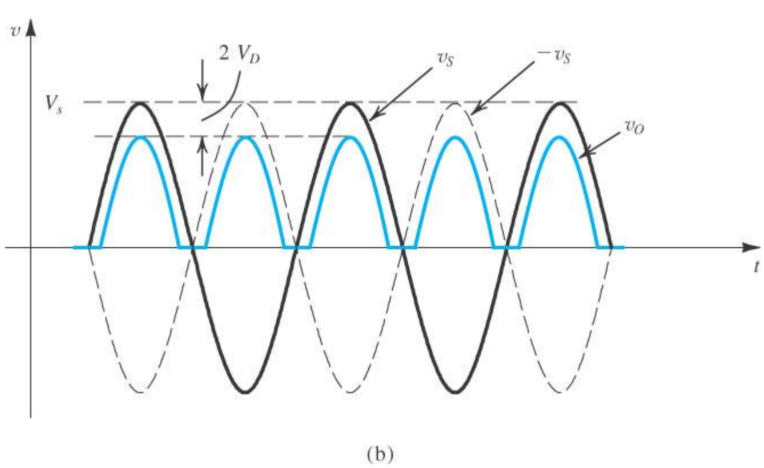
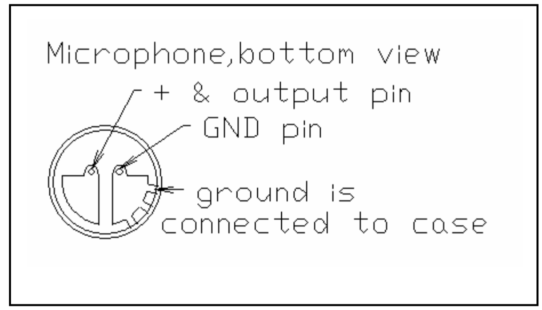


Fig. 3.27(d) { ***Sedra and Smith, Microelectronic Circuits, 5th edition*** **}**

<u>NOTE:</u> ***This concept is half of your first design project. This creates one side of your rail voltage.***

EXPERIMENT 3: (50 points)
Procedure: (DO NOT DISCONNECT THIS CIRCUIT AFTER EXPERIMENT)



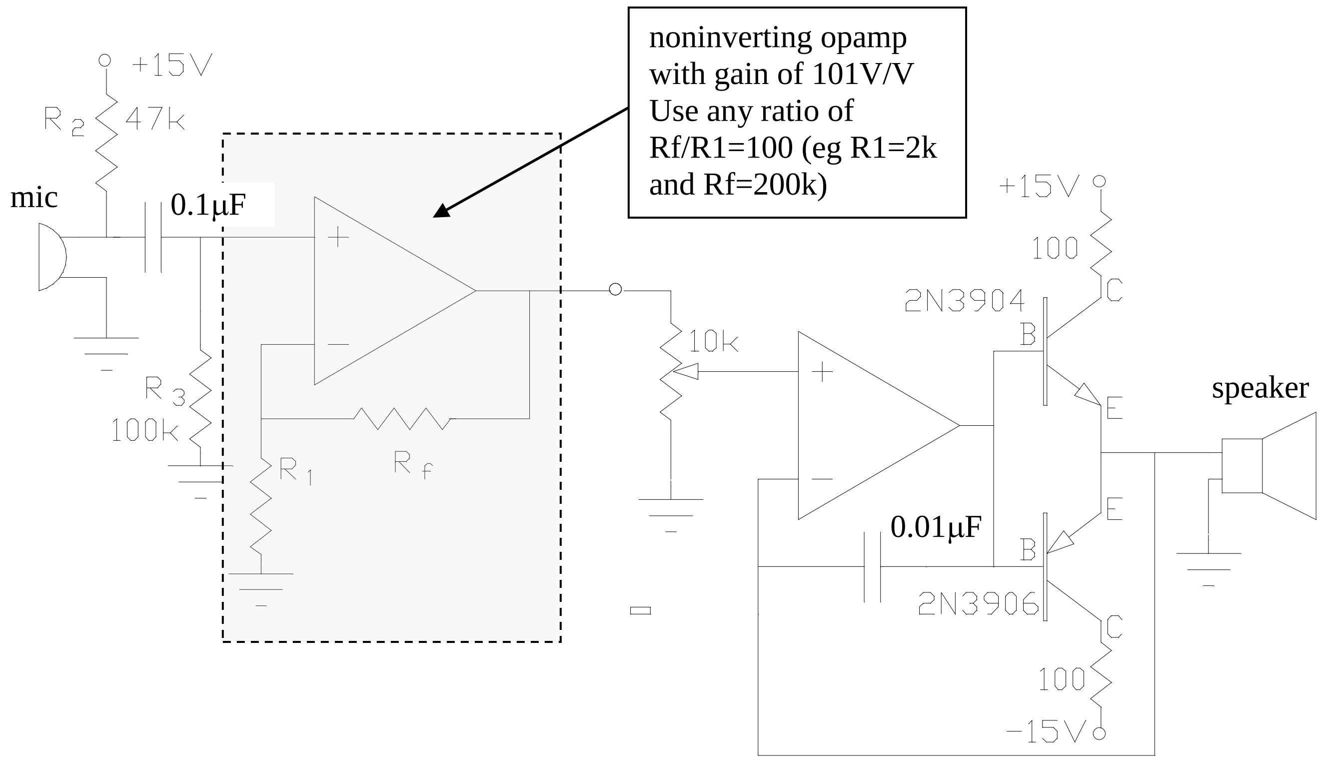


Figure 2. Microphone and Speaker circuit

1. (35 pts) Build and test the circuit in **Fig. 2**. You will receive all points once it is shown to be working.

IMPORTANT: *You can break the circuit into parts if it is not working by using the function generator in place of the microphone and testing that the first op amp is indeed amplifying the signal correctly. Note that the first amplifier is taking the input to it and multiplying it by 101. The function generator can also be connected as the input to the second op amp in place of the first op amp. Note that the voice range is from 300Hz to 3kHz. Once the function generator is connected at a set frequency (use as low an amplitude as possible) you should be able to hear a buzzing sound. The end result of the above circuit is that you should hear an amplification of your voice at the speaker when you speak into the microphone.*

Note: **Fig. 3** on the following page shows a possible breadboard layout.

Note: The 2N3904 and 2N3906 front is considered the flat part. With the flat part facing you, count from left to right 1,2,3. 1 is considered the Emitter (E), 2 the Base (B), and 3 the Collector (C). E, B, and C are shown on the schematic for each transistor. Verify your connections with your Lab TA before testing it.

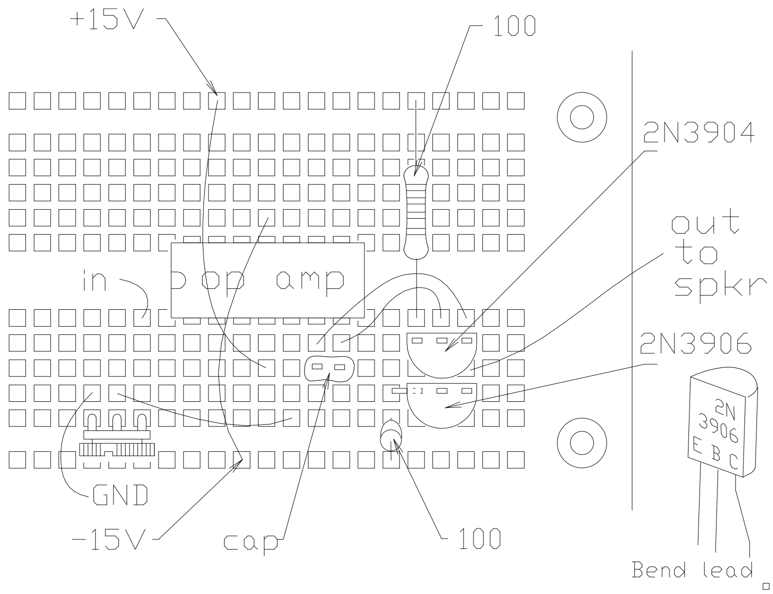


Fig. 3

2. (8 pts) The part shown between the output of the first op amp and the input to second op amp is a potentiometer, used as a volume control in this case.

- Describe in your notebook how the volume control works.

3. (7 pts) Determine how much maximum current is being pulled from both the positive power supply and negative. **You will use this information to design your power supply.**

__IMPORTANT:__ *You* ***WILL NEED*** *this information to build the power supply project (****PROJECT #1****). DO NOT DISCONNECT THIS CIRCUIT. YOU WILL USE IT FOR THE REST OF THE PROJECT'S.*