# MAS.836
# LABORATORY TWO

**Introduction to Power Supplies and Operational Amplifiers:**
The purpose of this laboratory exercise is to familiarize yourself with the implementation of op-amp circuits. You will be given a kit of parts, and will be required to design, build, and test a number of amplifier configurations. You are welcome to use any design you choose, as longs as it meets the design goals, and uses the parts you are given. The exception to this rule, is that you may use as many resistors or capacitors as you wish. These resistors and capacitors will not come with your kit, and can be picked up, as you need them, from the laboratory area. You will also be able to get the solid-core, hook-up wire, which you will use to build your circuits, from the laboratory area.

Before beginning your lab, please check that your kit has all the parts you need, and please write your name on the bottom of the protoboard. Two things will be required of each laboratory assignment. First, you will need to turn in your functioning kit on your signed protoboard. Second, you will need to turn in a report detailing the design you chose, answering any questions given in the laboratory assignment, and plotting any performance criterion asked for in the laboratory assignment. Both of these things will be collected directly after class on the due date.

**Kit Parts List**

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| 1 | protoboard |
| 1 | power supply |
| 1 | power connector |
| 1 | 7805 voltage regulator |
| 2 | 100µF electrolytic capacitors |
| 2 | .1µF ceramic capacitors |
| 2 | LEDs |
| 1 | force sensitive resistor |
| 1 | piezo film vibratab |
| 1 | TLV2374 quad op-amp |
| 1 | metal electrode |

**Problem One:** Power supply construction

It is important to know how to create a constant voltage source. This is critical for two reasons. First, the electronic components you will be using (amplifiers and microcontrollers) are designed to run off of specific voltages. Higher or lower voltages than those specified will result in your circuit not working, or damage to the electronic devices. Secondly, the power supply voltage must be kept relatively constant (within approximately 50mV) to have a reference with which to compare your sensor readings. Your sensor output will necessarily be a function of your power supply voltage, so the tighter you can regulate your power supply the more accurate your sensor reading will be.

There are application specific voltage reference chips which can be used in cases where a greater degree of accuracy is required, but for most cases, using your power supply as your voltage reference is adequate.

Although there are many ways to create a constant voltage source, the easiest is to use a three terminal voltage regulator running off of a higher voltage source than what your circuit will run at. These devices have a number of important parameters to be aware of, but the main ones include: minimum headroom, maximum current draw, maximum input voltage, and maximum power dissipation. The headroom is the minimum amount of voltage above the regulated output voltage that must be applied for the regulator to operate. For example, if you have a 5V regulator with a minimum headroom of 3V, you must apply at least 8V to the regulator for it to function. The maximum current draw is the limit of the output current that the regulator can source before it stops working, usually due to overheating and melting. The maximum input voltage is the largest voltage which you can apply to the input pin before the voltage regulator stops working, usually do to junction breakdown within the device, which can result in the regulator exploding. finally, the maximum power dissipation is the total amount of power that the device can handle before it overheats. This value is calculated by multiplying the total voltage drop across the device by the current passing through the device (just as you would calculate the power consumption of any electronic component). For example, if we have a 5V regulator running off of 10V, and we are drawing 1A, the total power will be (10V - 5V) x 1A which equals 5W. It is important to note that the maximum power consumption and maximum current draw listed in the datasheet is under ideal heat dissipation conditions, and to achieve these in practice you will be required to use thermal paste and put a heatsink on the regulator. In most cases, if you are drawing less than 200mA from a regulator in a TO-220, package you will not need a heatsink.

The regulator you will be using for these laboratories will be the 7805, which is a three terminal voltage regulator. It follows an industry standard naming convention for linear voltage regulators. The first term 78 tells you that it is a positive voltage regulator, i.e. it produces a positive voltage. If the first term was 79 it would be a negative voltage regulator. The 05 represents the value of the output voltage, in this case 5V. Finally, in the space between the 78 and the 05 there is sometimes a letter (either M or L). This letter represents the nominal current capacity. If the center letter was an L it would have a nominal capacity of 100mA, if it were an M it would be 500mA, and no center letter (as is this case) would mean 1A. So, if you were to have a 79L12, you would have a -12V regulator capable of 100mA output currents. There are other three terminal regulators with different naming conventions, but this one is most common.

The reason these devices are called three terminal voltage regulators is because they only have three electrical terminals: one for input voltage, one for ground, and one for output voltage. This makes them very easy to use, you merely connect your power input to the input pin, your circuit power supply to the output pin, and the ground pin to the ground of both your input power supply and the circuit power supply. It is important to place capacitors at both the input and output of these regulators to keep the power supply voltage from oscillating too much. For this reason, the kit comes with two 100µF electrolytic capacitors; one for the input pin and one for the output pin. The kit also comes with two .1µF ceramic capacitors, one to be placed at the output pin of the voltage regulator, and the other to be placed as close as possible to your op-amp. The electrolytic capacitors are of a relatively large value, and will help supply extra current when your circuit's current draw varies quickly, keeping the regulator's current draw from varying too quickly and making the output voltage unstable. The ceramic capacitors are of a relatively smaller value and will minimize high frequency pickup on your power supply lines.

**Note:** electrolytic capacitors are polarized, i.e. they have one terminal which must be kept positive with respect to the other terminal. If you place an electrolytic capacitor in backwards (with its negative terminal to the positive supply rail) it will explode and spew very hot electrolyte on you. Please be careful to note which pin is negative and place that pin to ground. Also, electrolytic capacitors have a maximum working voltage, which must not be exceeded or the capacitor will explode. This value should be written on the side of the capacitor case. Before placing an electrolytic capacitor into a circuit, make sure that you will not exceed the maximum working voltage.

Please read the datasheet for the 7805 linked off of the class website to familiarize yourself with this device. Note which pins are the input, the output, and ground. Use the 7805 to build a regulated 5V source for your protoboard. Place the regulator near the power connector on your protoboard and place the two electrolytic capacitors as close as possible to the voltage regulator. Place one of the ceramic capacitors as close as possible to the output of the voltage regulator, and place the other near your op-amp. Finally, connect power and ground to the power rails of the protoboard.

**Questions:**
1. What is the minimum headroom of the 7805 at 500mA?
2. What is the maximum input voltage of the 7805?
3. What is the input voltage on your circuit board?
4. What is the maximum power consumption of the 7805 without a heatsink?
5. What is the maximum current your circuit can draw without overheating the 7805?

**Problem Two:** First-order bandpass amplifier construction

For all of your laboratory projects you will be using the TLV2374 quad op-amp. Please look over the datasheet for this op-amp, which is linked off of the class website. Note which pins are the input pins, which are the output, and which are the power supply pins.

Design and build a single pole passband amplifier for frequencies between 2kHz and 20kHz with a gain of -10 and an input impedance of 20kΩ. Please include the schematic of your circuit in your lab report. Also, produce a graph showing the absolute value of the amplifier gain versus frequency for frequencies from 1Hz to 1MHz with two data points per decade outside of the passband, and ten data points per decade within the passband. The plot should be on a lin-log graph with the x-axis logarithmic in frequency and the y-axis linear in decibels.

**Questions:**
1. How does your bandpass amplifier circuit's performance compare to the idealized version's 3dB points and roll off characteristics?
2. What might account for any differences found?

**Problem Three:** Second-order bandpass amplifier construction

Design and build an active, second order (-40dB/decade roll-off in the stopbands), butterworth filter with the exact same gain and passband characteristics as your amplifier from the previous exercise. Please leave your previous amplifier built on your protoboard, and use another section of the TLV2374 for this exercise. You may have to use multiple amplifiers for this design, but you can not use more than three, as you only have a quad op-amp package, and one amplifier has already been used. Again, include a schematic of your design, and produce a graph showing the absolute value of the amplifier gain versus frequency for frequencies from 1Hz to 1MHz with two data points per decade outside of the passband, and ten data points per decade within the passband.

**Questions:**
1. How does this passband amplifier compare with the previous one in terms of its 3dB points, roll off characteristics, and amplitude response in the passband?
2. What are the relative advantages and disadvantages of each amplifier configuration?