Laboratory Project 1b: Electromyogram Circuit

***Abstract*-You will add a differential amplifier circuit to your pre-amp circuits to create an electromyogram circuit. After designing, constructing, and testing the circuit, you will connect electrodes to your biceps muscle and measure the small voltages generated by the activity of neurons terminating on muscle fibers. By recording these signals on an oscilloscope, you will create electromyograms that you will analyze to determine the rate of neural activity associated with lifting various weights.**

I. Preparation

For Lab 1b, which will last about three weeks, you will need the additional parts listed in Table I, (in addition to the parts from Lab 1a). You may purchase these parts from the stockroom next to the lab or purchase them elsewhere.

TABLE I
PARTS LIST FOR LAB 1B

Item	Qnty	Description
1	4	Resistors (values determined during lab)
2	1	LF353 Operational Amplifier
3	1	10 Ω Resistor
4	1	1 kΩ Resistor
5	1	1 MΩ Resistor
6	1	1 0.1 µF Capacitor
7	3	Electrodes

II. Learning Objectives

1) Learn about voltage dividers and understand why pre-amps increase current drive of weak signals from electrodes.
2) Learn how to derive equations for op-amp circuits, such as pre-amps and differential amplifier, using Kirchhoff's and Ohm's laws.
3) Understand how to design a differential amplifier to meet practical constraints
4) Determine the relationship between neuromotor activity and force applied by a muscle

III. Introduction

In Lab 1a you built pre-amp circuits that output the same voltage as an input signal but with a higher current-drive capability. The intent is to eventually place electrodes on your biceps muscle and connect them to these pre-amps. In Lab 1b, you will add a differential amplifier to the pre-amps to complete an electromyogram (EMG) circuit that measures the tiny voltages produced by the biceps muscle and picked up by the electrodes.

EMG studies are useful for assessing the health of the neuromuscular system, since certain diseases, such as multiple sclerosis, slow down or even suppress normal nerve and muscle firing. In addition, several research groups have recently studied the possibility of using EMG signals to control artificial limbs for patients who have lost an extremity; the EMG signal would be obtained from a surviving portion of the limb and would represent the patient's central nervous system's desire to move the limb in a certain direction with a certain force.

IV. Design Project Overview

You will complete design and construction of an EMG circuit that receives input from two neighboring electrodes placed on the biceps of the upper arm plus a reference electrode placed on the elbow. The power in the signals picked up by the electrodes is minute. A differential amplifier is useful for amplifying the small signals. In particular, the differential amplifier magnifies the difference between the electrodes, which is equivalent to magnifying the voltage drop across the muscle.

Attaching the electrodes directly to a differential amplifier, however, would draw too much current from the electrodes, causing their voltage to drop to almost zero. Consequently, we use the pre-amps, constructed in Lab 1a, to create higher-power signals. The pre-amps can output higher current at the same voltage as the electrodes while drawing virtually zero current. The outputs of the pre-amps can then drive a differential amplifier.

Fig. 1 shows a block diagram of the electromyogram circuit with the pre-amps and differential amplifier that you will build in this lab. You will connect the output voltage, v_3, to an oscilloscope to record an EMG.

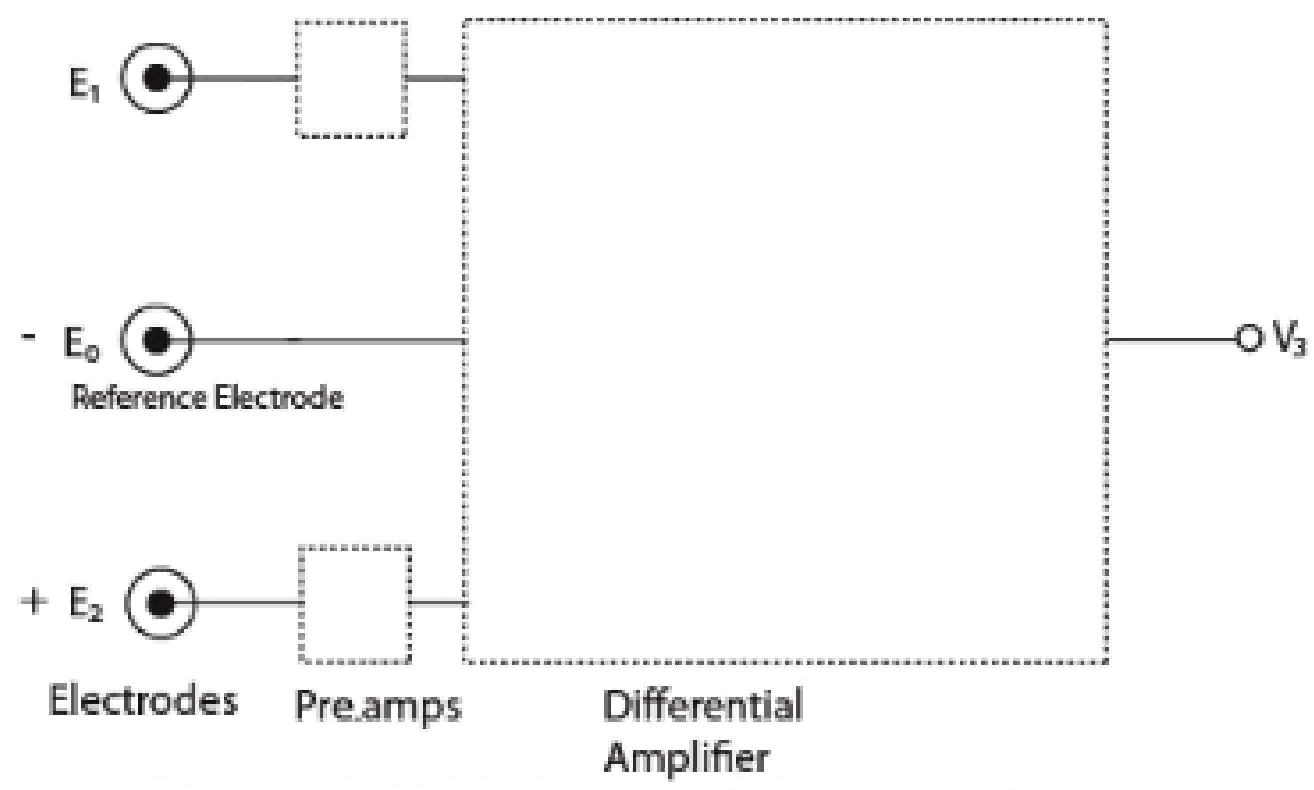


Figure 1. Block diagram of electromyogram circuit.

V. Demonstrating the need for Pre-amps

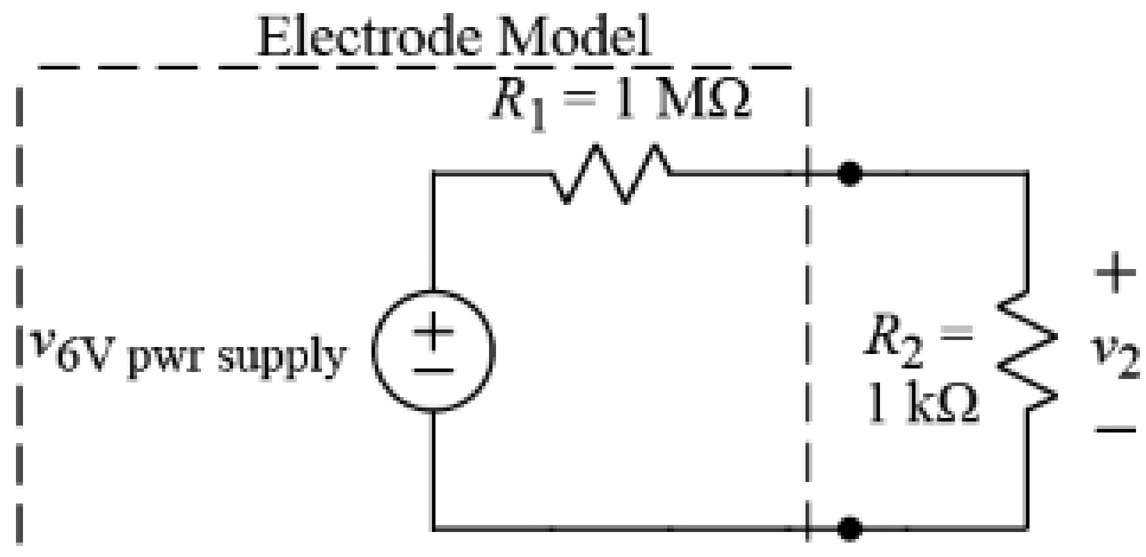
A. Rationale

In this part of the lab, you will demonstrate that using the electrodes to directly drive the differential amplifier would result in signals too small to be accurately measured. This scenario is similar to considering what would happen if we tried to use a 12V camera battery instead a car battery to start a car—the smaller battery would be unable to supply enough current to the starter motor, and output voltage of the small battery would drop to almost 0 V.

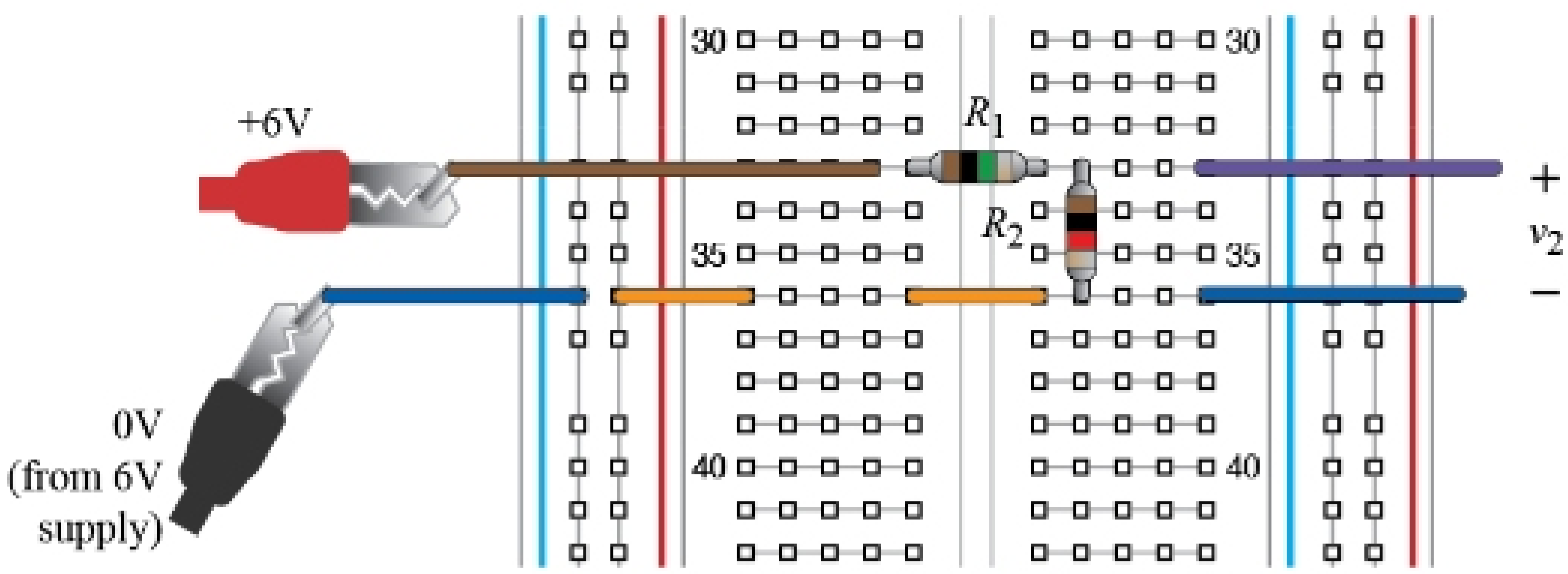
B. Procedure

Using the lower half of your breadboard (to avoid the already constructed pre-amp circuit), construct the voltage-divider circuit shown in Fig. 2. This circuit models the electrode driving a differential amplifier without a pre-amp. The 1 MΩ resistor simulates the resistance between the muscle fibers and the electrodes, including the skin, which has high resistance. The 1 kΩ resistor simulates the input of the differential amplifier.

In place of the electrode, use the 6V power supply in the same power supply used to power the pre-amps. (The 6V power supply is the third of three voltage sources in the power supply. To see its value it, press the 6V button on the front of the power supply. Use the gray knob to adjust its value. The 6V outputs are the two leftmost banana plugs on the front panel of the power supply.) Use long wires coming off the breadboard and banana-to-alligator clips to connect to the 6V power supply. Adjust the 6V power supply to the values shown in Table II and use the multimeter probes to measure the voltage drop across R_2. (Use the DCV button on the multimeter so the meter is reading voltage.) Record the measured voltage drop across R_2 in the second column of Table II. When you have completed the second column of Table II, use the voltage-divider formula from class to fill in the third column of Table II. Be sure to record what you are doing, including the voltage-divider formula, in your notebook.



(a)



(b)

Figure 2. Circuit model of an electrode driving differential amplifier: (a) schematic, (b) breadboard layout.

TABLE II-A
MODEL OF ELECTRODE DRIVING DIFFERENTIAL AMPLIFIER

Power Supply Voltage	R_2 Voltage
0 V	
2 V	
4 V	
6 V	

Repeat the above process using the circuit shown in Fig. 3 and Table III. In this circuit, the 6V power supply and the 10 Ω resistor simulate the output of the pre-amp. As before, R_2 simulates the input of the differential amplifier.

When you have filled out Tables II and III, determine which circuit gives an output that is closer to the value of the input voltage from the 6V power supply. Comment in your lab notebook on the results and explain why the pre-amps are needed in the EMG circuit. Note that,