

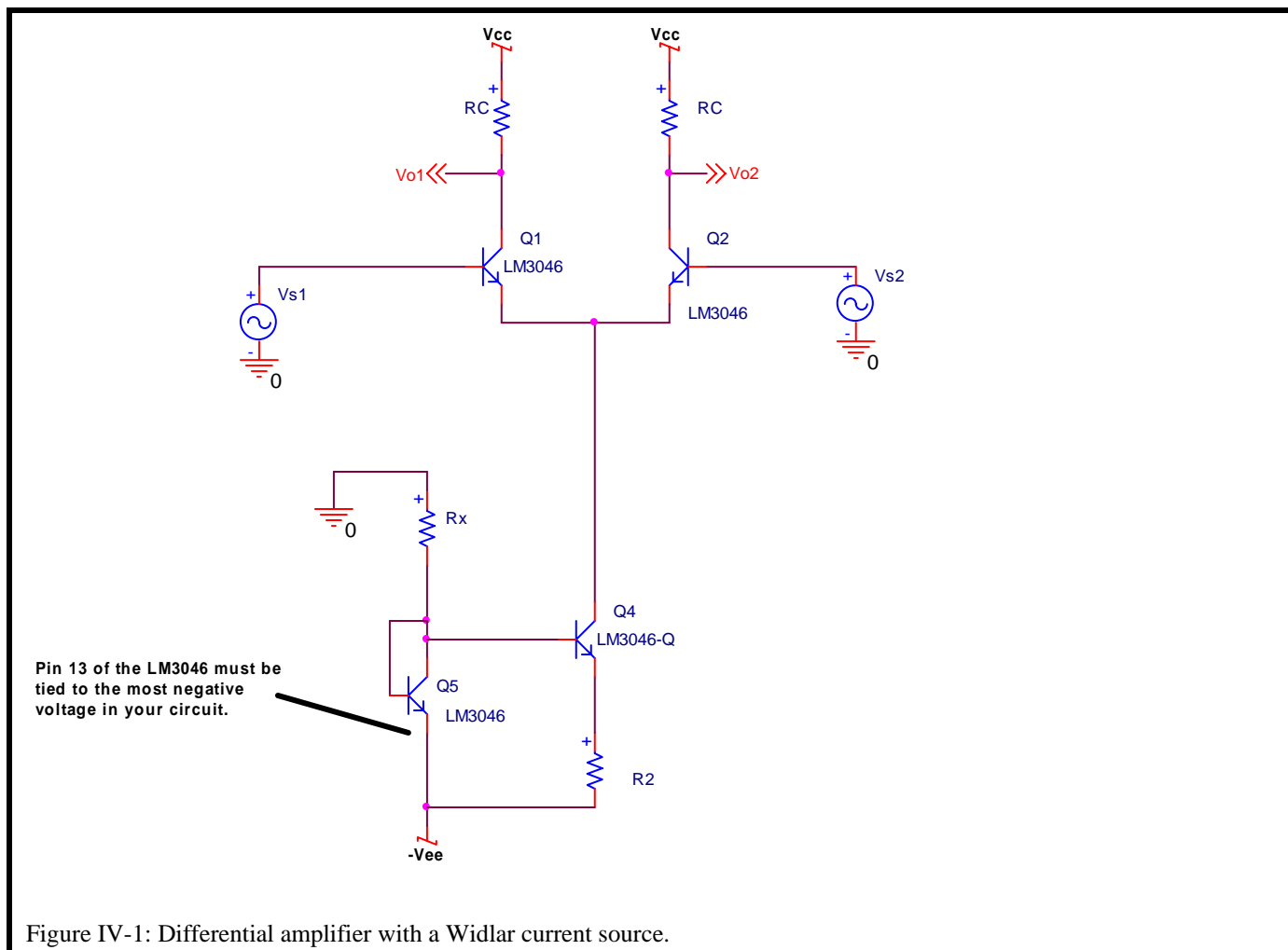
ECE 351 Lab IV

Operation of a Differential Amplifier

In this lab we will construct and test the differential amplifier shown in Figure IV-1.

IV.A. Devices

You must use the LM3046 transistor array for this lab. **The LM3046 has one requirement when wiring up your circuit. Pin number 13 must be tied to the most negative voltage in your circuit.**



This requirement forces you to tie the emitter of Q5 in the LM3046 package to the negative supply as shown in Figure IV-1. **If you do not connect pin 13 to the most negative voltage in the circuit, you will burn out your LM3046 chip.**

A model for the LM3046 is available in OrCAD PSpice. The part named LM3046 is a pair of transistors wired as a differential pair. The part named LM3046-Q is a single transistor. Both use the same PSpice model.

IV.B. Prelab Calculations

IV.B.1. Bias Calculations

Bias the differential amplifier such that $I_{C1}=I_{C2}\cong 25\ \mu\text{A}$ and $V_{CE1}=V_{CE2}\cong 7\ \text{V}$. Calculate the minimum and maximum values of V_{C1} , V_{C2} , and V_E for the bias of Q_1 and Q_2 and record the values in Table IV-1. You must include tolerance for all resistors and tolerance in V_{BE} for the transistors.

IV.B.2. Gain Calculations

Now that the bias is complete we can calculate the gain of the circuit. Since we only have one signal generator, the circuit of Figure IV-5 will be used in lab to measure the gain. Since we do not know the equivalent resistance of the current source, R_{EE} , we can not calculate the common mode gain. However, for academic harassment we will assume that $R_{EE} \cong 5\ \text{M}\Omega$. Calculate the maximum and minimum differential and common mode gains of your circuit and enter the values in Table IV-1. Calculate the gains v_{o1}/v_{s1} and v_{o2}/v_{s1} for the circuit of Figure IV-5 and enter them in Table IV-1. Note that this input contains both common mode and differential mode inputs:

$$v_{dm} = \frac{v_{s1} - v_{s2}}{2} = \frac{v_{s1}}{2}$$

$$v_{cm} = \frac{v_{s1} + v_{s2}}{2} = \frac{v_{s1}}{2}$$

IV.B.3. PSpice Simulations

Use PSpice to measure the following quantities of your differential amplifier circuit:

1. Bias voltages.
2. Differential mode gain versus frequency.
3. Common mode gain versus frequency.
4. Maximum peak-to-peak output voltage swing.

The common mode gain can be simulated using the circuit of Figure IV-2. The differential mode gain can be simulated using the circuit of Figure IV-3. v_{dm1} and v_{dm2} are AC sources with the same magnitude. Note that they are 180° out of phase.

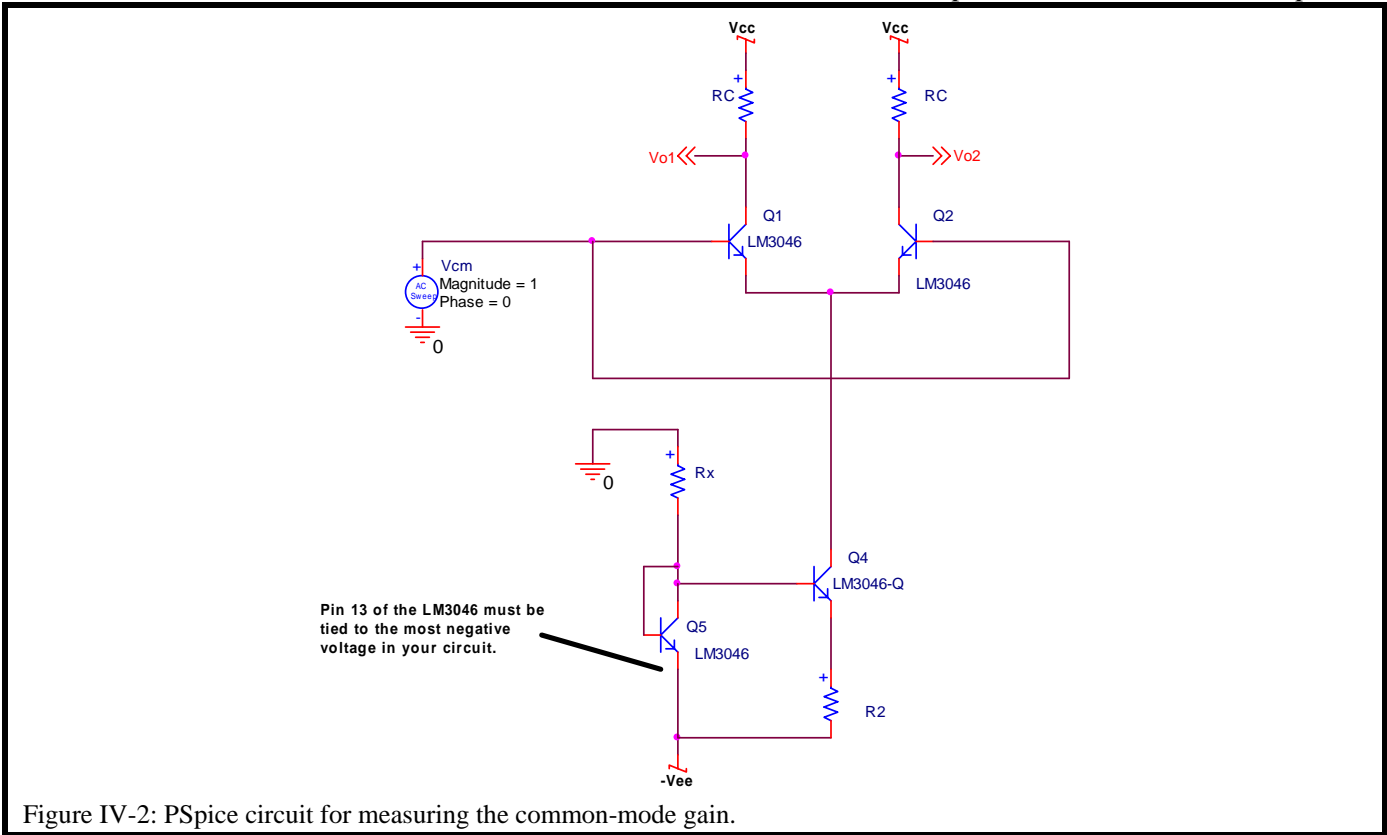


Figure IV-2: PSpice circuit for measuring the common-mode gain.

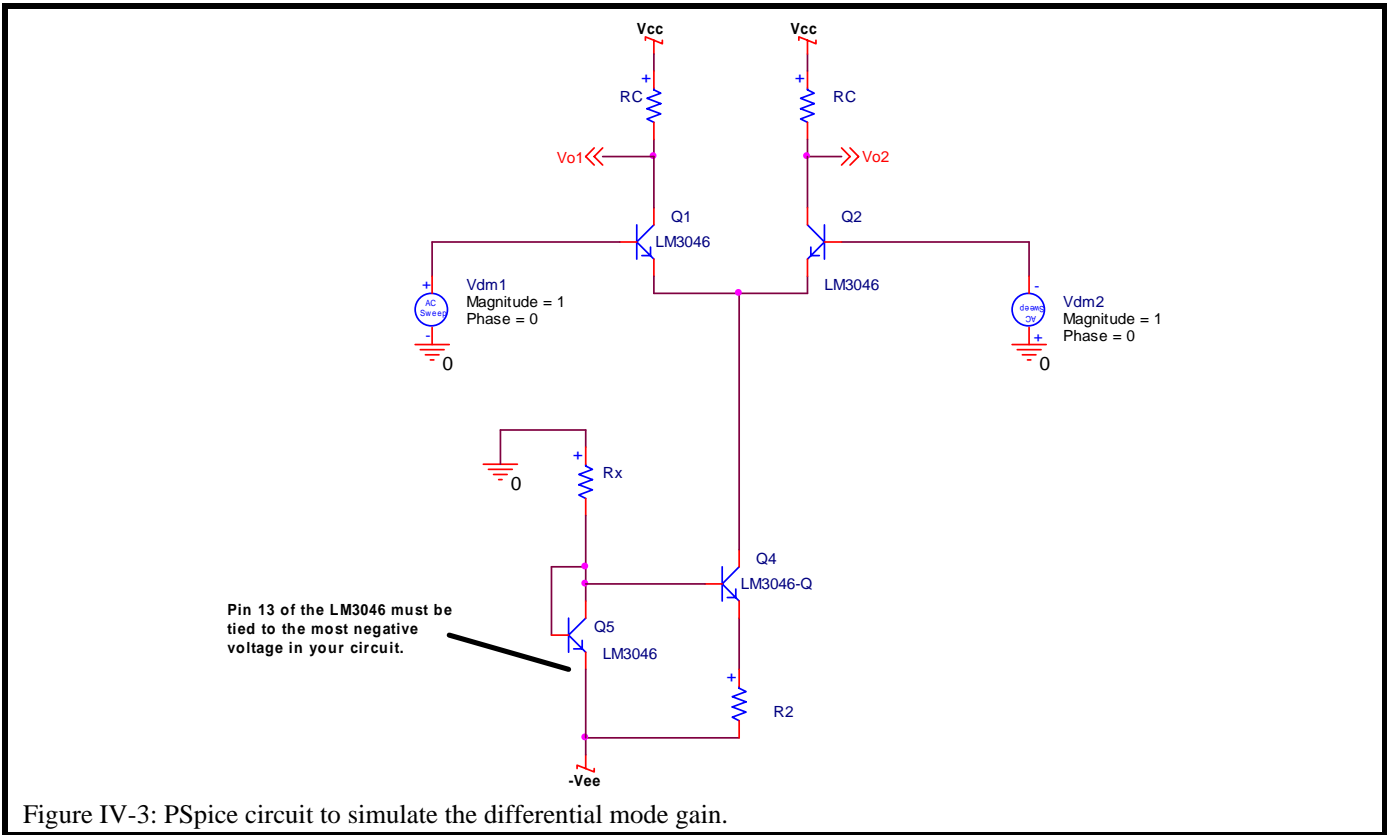
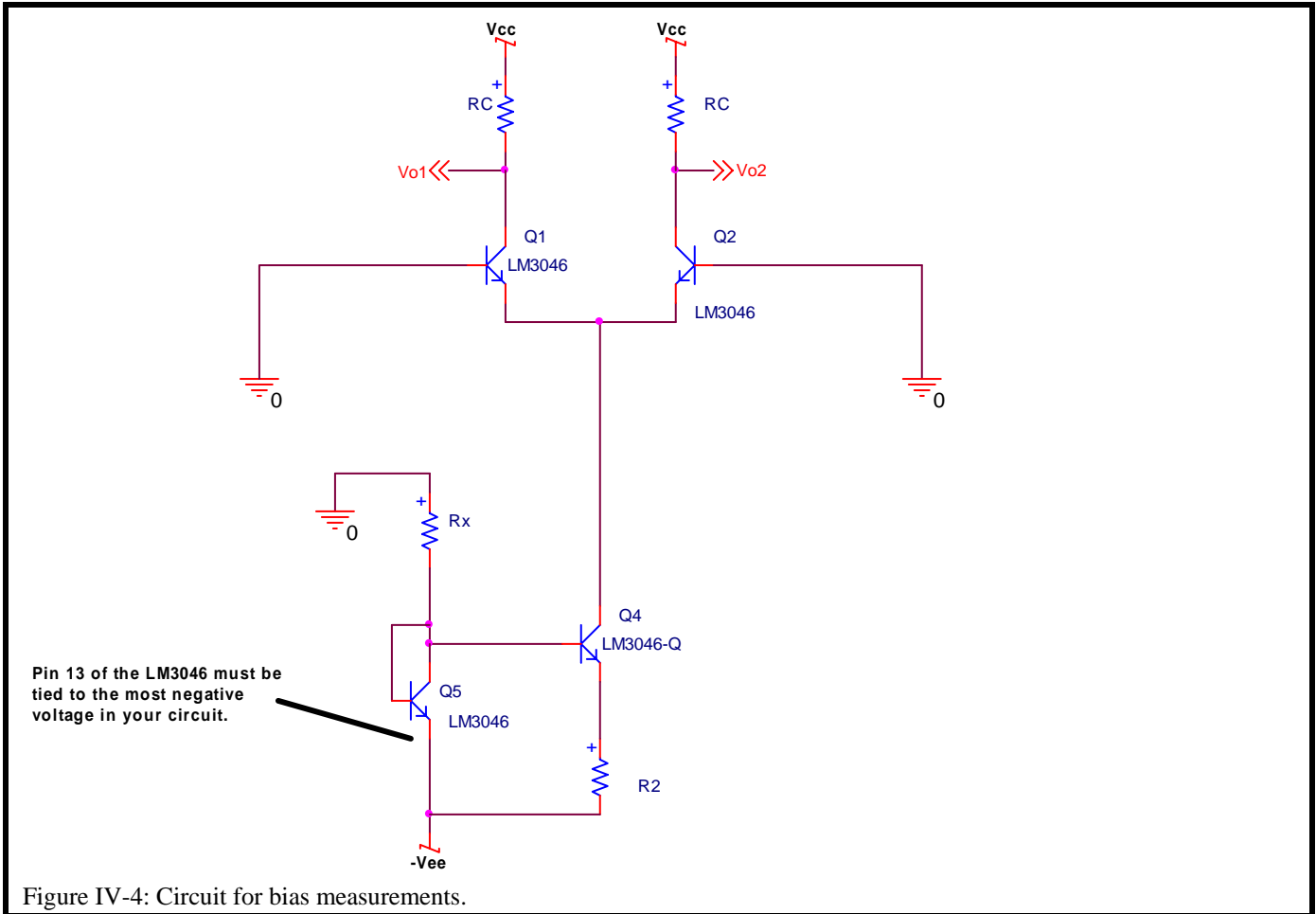


Figure IV-3: PSpice circuit to simulate the differential mode gain.

IV.C. Laboratory Procedure

IV.C.1. D.C. Bias Voltage Measurement

Wire up the differential amplifier and current source as shown in Figure IV-4. For this circuit, v_{s1} and v_{s2} are zero. Measure all D.C. node voltages and make sure they are within the maximum and minimum limits found in your calculations. If they are not within the limits, check your circuit for wiring errors. Do not proceed if your bias voltages are not correct; if the bias does not work nothing else will.



IV.C.2. Differential Amplifier Measurement

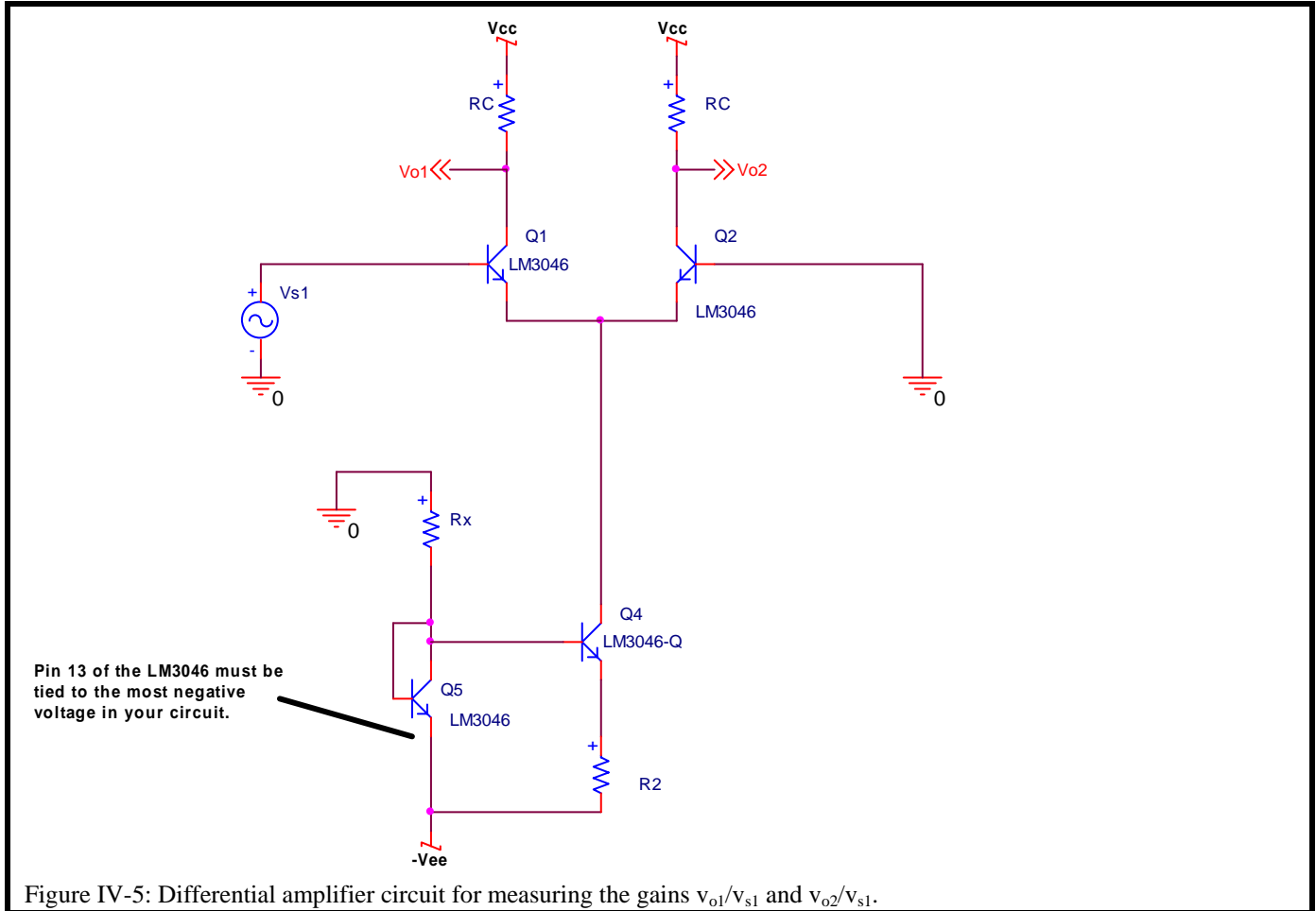
Connect the differential amplifier as shown in Figure IV-5. For this input

$$v_{dm} = \frac{v_{s1} - v_{s2}}{2} = \frac{v_{s1}}{2}$$

$$v_{cm} = \frac{v_{s1} + v_{s2}}{2} = \frac{v_{s1}}{2}$$

Note that this signal has both common mode and differential mode components. The output of this circuit is a combination of the common mode and differential mode inputs. Make the following measurements.

1. You may need to use a 100 to 1 voltage divider to make the input voltage small enough. Display v_{o1} and v_{o2} on the scope. Show that they are the same magnitude but 180° out of phase. Record this scope display.
2. Measure the maximum peak-to-peak output swing of v_{o1} and v_{o2} . Record this scope display.



3. Measure the gains v_{o1}/v_{s1} and v_{o2}/v_{s1} for frequencies from 100 Hz to 2 MHz. Does your measured plot agree with PSpice? Make a Bode plot of the measured values of v_{o1}/v_{s1} and v_{o2}/v_{s1} versus frequency. Record the data in Table IV-2. Remember that a Bode plot graphs $20\text{Log}_{10}[v_{o1}/v_{s1}]$ versus frequency. Create your Bode plots using MATLAB. The code segment below can be used to generate the plot:

```

Freq=[1, 10, 100, 1000]; % This is the frequency coordinate of the measured data.
Gain=[100, 100, 100, 90]; % This is the gain coordinate of the measured data.
Gain_dB=20*log10(Gain);
semilogx(Freq, Gain_dB);
grid on;
ylabel('Gain(dB)');
xlabel('Frequency (Hz)');
title('Bode Magnitude plot of V_O/V_{IN}');
    
```

Wire up the differential amplifier as shown in Figure IV-2. **You do not need to use a 100 to 1 voltage divider for this circuit.** This circuit has only common mode input. Measure the common mode gains v_{o1}/v_{cm} and v_{o2}/v_{cm} for frequencies from 100 Hz to 2 MHz. Since the common-mode gain is less than 1, you will need to use a large input because the output is smaller than the input. Fill in the data in Table IV-3. Why does the common mode gain increase with frequency? Compare your measured plot to PSpice. Make a Bode plot of the measured values of common mode gain versus frequency. Create your bode plots using MATLAB.

When you have measured both the common mode gain and differential mode gain you can calculate a value of R_{EE} from the gains. Derive an expression for R_{EE} in terms of the gains and calculate R_{EE} .

Table IV-1: Data for Lab IV				
	Calculated Maximum	Calculated Minimum	PSpice	Measured
I_{C1}				
I_{C2}				
V_{C1}				
V_{C2}				
V_E				
Peak-Peak Swing				
A_{DM1}				
A_{DM2}				
A_{CM1}				
A_{CM2}				
v_{o1}/v_{s1}				
v_{o2}/v_{s1}				

