**NOTE:** The “text” mentioned below refers to the Sedra/Smith, 5th edition.

Fig. 7.12 shows a differential amplifier built by bipolar transistors. The discussion and calculation of this typical circuit can be found in section 7.3. The two bipolar transistors are supposed to be identical in their current-voltage characteristics. Therefore, the output taken from the difference of $v_{C1}$ and $v_{C2}$ should be responsive to the difference of the input signals. That is, the gain of the differential pair amplifier is defined to be $(v_{C1} - v_{C2})$ divided by $(v_{B1} - v_{B2})$.

The differential amplifier is used as the first stage of an operational amplifier.

The constant dc current source at the emitter side can be implemented by a current mirror.

The larger the load resistance $R_C$, the higher the voltage gain. [The differential gain is derived to be $-g_m R_C$, see equation (7.93).] This fact brings out the idea of using a constant dc current source as the load. By definition, a dc constant current source has large effective ac impedance. So, while the dc current source can output a constant dc current that is consistent with what the differential amplifier needs, the large ac impedance can much increase the voltage gain. Such circuit using a constant current source as the load is called “active load,” see section 7.5.5. An example of differential amplifier using active load is shown in Fig. 7.32 below.
A. Pre-laboratory work
1. Design a differential pair amplifier using bipolar transistors. You determine whether you would use npn or pnp types. Either one is fine. The required specifications:
   a. The dc constant current source is a current mirror;
   b. Active load;
   c. The amplitude of the resulting differential voltage gain is at least 10.
2. PSPICE simulate the circuit you want to build in the laboratory. Calculate the voltages and currents everywhere.
3. Do PSPICE simulation:
   a. Simulate the bipolar transistor’s I-V curve first to determine the proper operating point, that is, determine the dc current amplitude passing through the emitter;
   b. Based on this dc current passing through each transistor, design your current mirror and the active load (which is also a current mirror passing through the same amount of dc current);
4. After using a current mirror at the emitter side, now consider the load. For design#1 using resistors as the load:
   a. Determine (that is, design) the resistor values --- there is a range of values that fit;
   b. Draw your circuit diagram;
   c. Simulate the differential voltage gain, and, finally,
   d. Calculate the bandwidth of this amplifier.
5. For design#2 using active load:
   a. Draw your circuit diagram;
   b. Simulate the differential voltage gain, and, finally,
   c. Calculate the bandwidth of this amplifier.

B. What to do in the laboratory
1. Wire up your circuits with resistors as the load.
2. Measure the **differential mode gain**. Verify that the phase of the amplifier is 180 degrees out of phase relative to the input. Keep the input voltage amplitude small. (Much less than 26mV. A small voltage of 1mV is preferred. This can be accomplished by a voltage divider.)

3. Measure the **common mode gain**. Keep the input voltage amplitude small. (Much less than 26mV. A small voltage of 1mV is preferred. This can be accomplished by a voltage divider.)

4. With the differential gain mode, measure the **frequency response**. Vary the input frequency from low (below 1kHz) to high (more than 1MHz), until the gain drops to one half of its value at the “mid-band” frequencies. Record the gain versus frequency, as well as the output phase versus frequency.

5. Use “active load” in a differential pair amplifier. Measure again the differential mode gain, common mode gain, and the frequency response.

C. Post-laboratory report questions, in addition to your report on data and your additional observation

1. Present data.
2. Discussion of yours.
3. What is the typical application of a differential pair amplifier? The answer is in the textbook.