Physics 76 Spring 1998
Basic Electronics

Purpose

The purpose of these experiments is to introduce elementary ideas of solid state circuit design and construction. Device characteristics will be used to determine proper circuit elements, the circuit will be assembled on a protoboard and then the properties of the finished circuit will be measured and compared with predictions.

References

1. James J. Brophy, Electronics for Scientists, Chap. 6 and 8
2. Millman & Halkias, Electronic Devices and Circuits, Chap. 9-12, 14, 17-1 & 17-2
3. Horowitz and Hill, The Art of Electronics Chap. 2-5
4. Fortney, Principles of Electronics Chap. 3, 6, 8

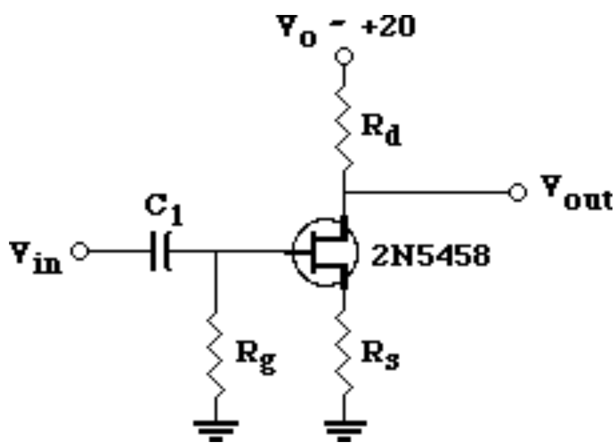
Preliminary Questions

1. Do the calculations for parts I A and II A below.
2. Define the FET small signal parameters, g_m and r_d , and give typical values.
3. Define the transistor hybrid parameters, h_{ie} , h_{re} , h_{fe} and h_{oe} , and give typical values.
4. Discuss each of the following briefly:
    a. operational amplifier
    b. virtual ground
    c. operational feedback
    d. voltage follower
    e. integrator
    f. differentiator

Experimental Work

I. FET Amplifiers

A. Using the characteristic curves for the 2N5458 n-channel depletion FET and a power supply voltage of 20 volts, find the appropriate drain and source resistors, R_D and R_S, to give a reasonable operating point for a common source amplifier (figure 1). (You may use load lines, transfer curves or any other method you wish.) Estimate g_m, the mutual transconductance, and r_d, the small signal drain resistance, at your chosen operating point.



Basic FET Amplifier (common source)
Figure 1

B. Build a common source amplifier on your protoboard. Use a gate resistor R_G 1 MΩ and input coupling capacitor $C_1 = .01\ \mu F$. Measure V_{DS} and V_{GS}.

C. Measure the following.

1. $A_v(f)$ for $10\ Hz < f < 100\ kHz$. Note phase of output with respect to input; and

2. Z_{in} and Z_{out} at $f = 1\ kHz$.

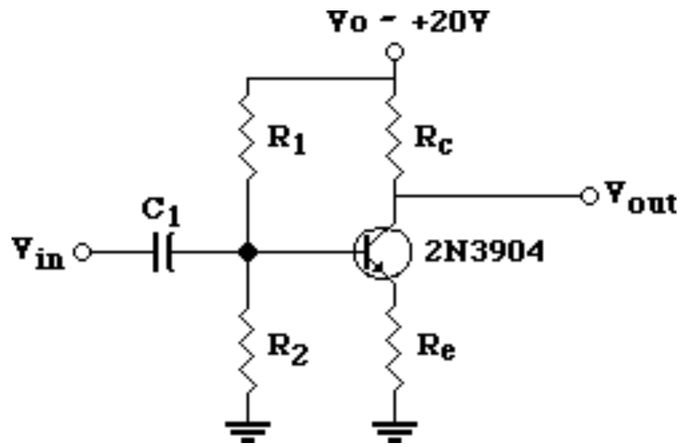
D. Compare the results of part I C with what you would predict from the results of I A. Try to explain discrepancies.

E. Bypass R_s with an appropriate capacitor and remeasure A_v at $f = 1\ kHz$. Explain.

F. Remove capacitor from part E and take output of amplifier from source terminal rather than drain. This is called the common drain configuration. Repeat I C and I D for this configuration.

II. Transistor Amplifiers

A. Using the characteristic curves for the 2N3904 npn silicon transistor calculate the appropriate values for the resistors R_1 , R_2 , R_C , R_E , in figure 2 to give a reasonable operating point. (See Brophy pp. 231-232) Calculate the DC current gain, H_{FE} and the small signal current gain, h_{fe} , for your chosen operating point.



Basic Transistor Amplifier (common emitter)

Figure 2

B. Build a common emitter amplifier using C_1 = 2.2 μF. Why must it be so large? Measure V_{CE} and V_{BE}.

C. Repeat I C and I D. (You may assume h_{ie} ~ 5 kΩ and h_{re} and h_{oe} are negligible.)

D. Bypass R_E with appropriate capacitor and measure A_v and Z_{in} at f = 1 kHz . Calculate h_{ie} .

E. Remove bypass capacitor from part II D and move output to the emitter terminal. This is the common collector or emitter follower configuration. Repeat I C and I D.

III. Operational Amplifiers - The OP AMP used in this lab is the µA741 integrated circuit (IC). It's equivalent circuit and open loop gain (A) characteristics are shown in figure 3a and 3b. R_{in} is typically 5 MΩ and R_{out} is typically 75 Ω. The package we are using is called a 8-lead minidip (Dual In-line Plastic); the lead connections are shown in figure 4. The µA741 requires both + 15 V and - 15 V supply voltages. This can be obtained from your HP power supply as shown in figure 5a. The offset null terminals are to be connected as shown in figure 5b.

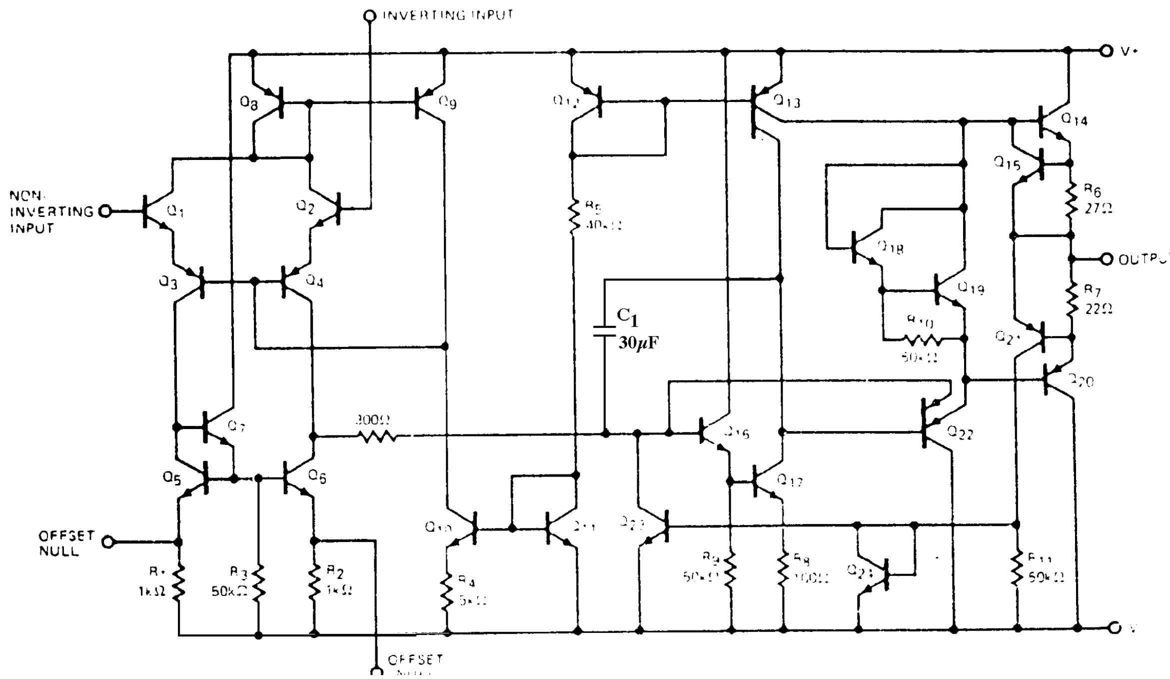


Figure 3a

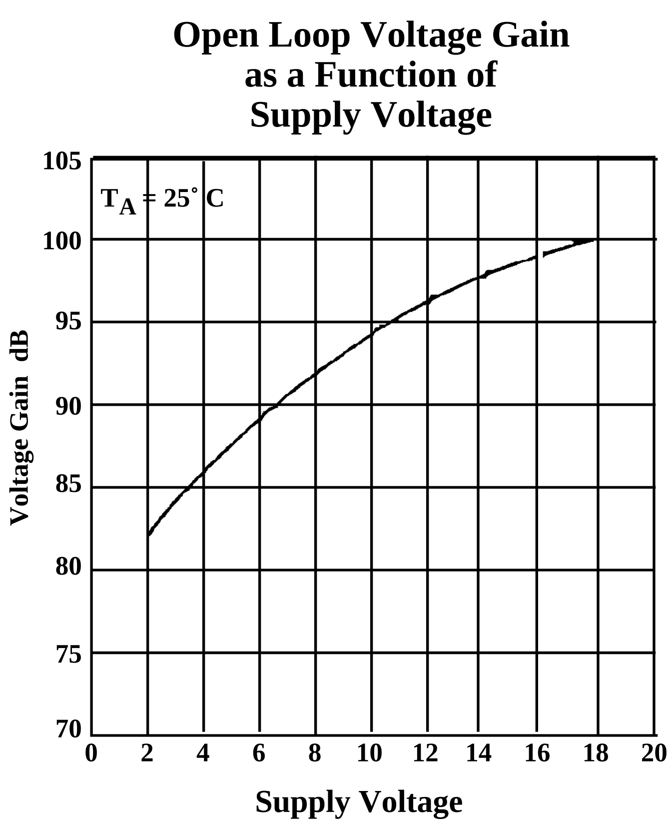


Figure 3b

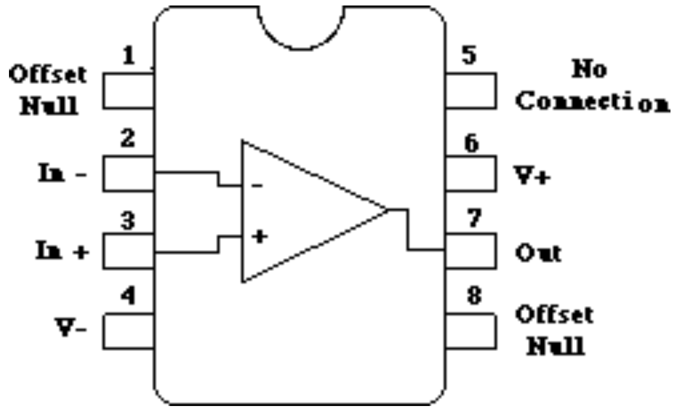
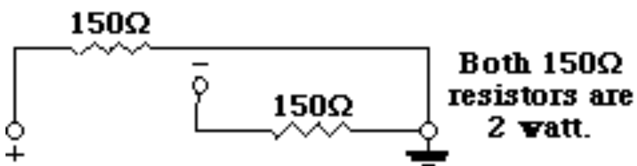
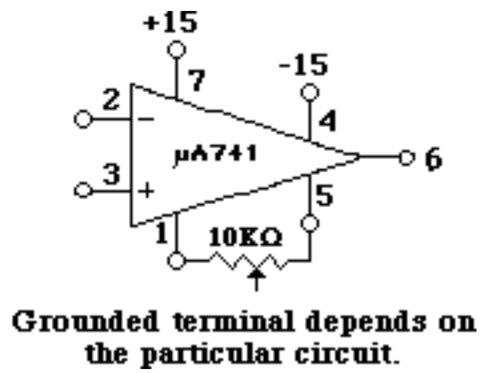


Figure 4



5a

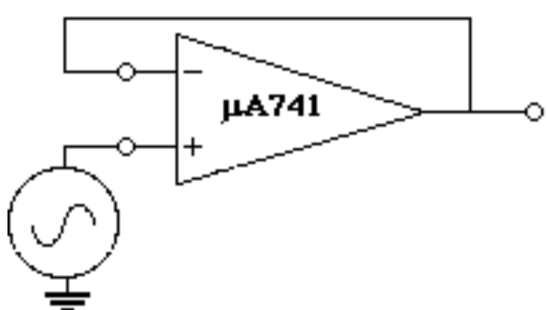


5b

Figure 5

A. Voltage Follower

1. Build a voltage follower shown below. Calculate Z_{in}^{op} and Z_{out}^{op} at f = 1 kHz.



$$Z_{in}^{op} = AR_{in}$$

$$Z_{out}^{op} = \frac{R_{out}}{A}$$

$$A_f^{op} = 1$$

Figure 6

2. With the input shorted set the offset null pot so that the DC output level is as near zer as possible. You should not have to adjust this again.

3. Measure the voltage gain, A_f^{op} , for 10 Hz < f < 100 kHz . Note relative phase of input and output.

B. Inverting Amplifier (Non inverting input is to be grounded for parts B - E of this lab)

1. The basic inverting amplifier circuit is shown in below. Build an inverting amplifier with a voltage gain (A_f^{op}) of ~ 10 and an input impedance (Z_f^{op}) of ~ 1000 Ω .

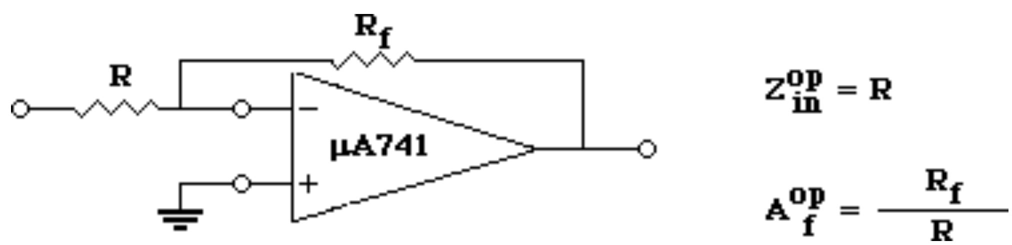


Figure 7

2. Measure the gain for 10 Hz < f < 100 kHz . Explain qualitatively any deviations from ideal OP AMP behavior. Measure Z_f^{op} at f = 1 kHz .

3. Build an amplifier with Z_{in}^{op} ~ 1000 Ω and A_f^{op} ~ 100 . Repeat III B 2.

C. Tuned Amplifier

1. Using the 10 mH inductor provided build a tuned amplifier with a maximum gain at frequency l kHz < f < 10 kHz and Z_{in}^{op} ~ 1000 Ω .

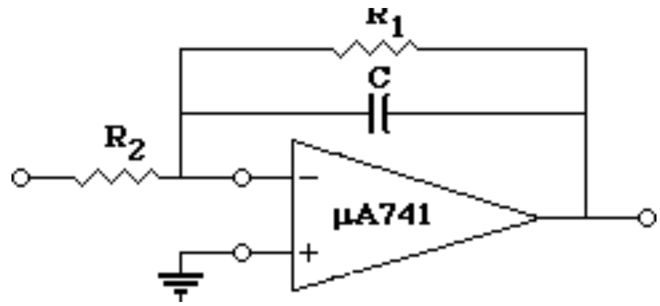
2. Measure the gain as a function of frequency. Using this data calculate the impedance of the resonant circuit at resonance.

D. Integrator

1. Build the integrator shown in figure 8. Use $R_1 \geq 1$ MΩ, C < 1 µF, and make Z_{in}^{op} > 1 kΩ . What is the purpose of R_1?

2. For a sinusoidal input measure A_f^{op} for 10 Hz < f < 10 kHz and compare with theory.

3. For a square wave input repeat IV D 2. Explain the output waveform, both the shape and amplitude.



Figur 8

E. Differentiator

1. Build the differentiator shown in figure 9. Use R_1 ~ 200-300 Ω , C < 1 µF and R_2 < 1 MΩ . The purpose of R_1 is to limit the high frequency gain; explain how it does this.

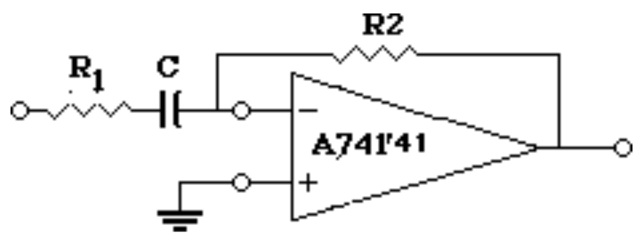


Figure 9

2. Repeat IV D 2.

3. Repeat IV D 3. Short R_1 and note the difference - explain.

Appendix I – Resistor Codes for Fixed Composition Resistors

A common type of resistor used in electrical circuits is made from a carbon composition in the form of a small solid cylinder with a wire lead attached to each end. The nominal resistance value is specified by a color code that is shown in figure 8.

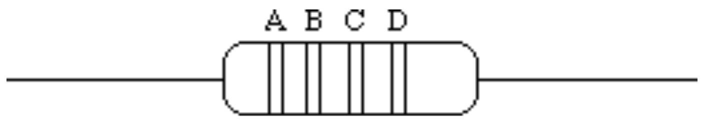


Figure 8

The first three bands give the resistance in ohms in the form $R = AB \times 10^C$, where A,B, and C are integers between 0 and 9. The first band is A, the second B and the third C. The color code for the integer is

0 - black	5 - green
1 - brown	6 - blue
2 - red	7 - violet
3 - orange	8 - gray
4 - yellow	9 - white

The fourth band specifies the tolerance, i.e. the allowed deviation from the nominal value, according to

5 % - gold
10 % - silver
20 % - (no band)

For example, suppose band A is red, band B is violet and C is yellow. The value of the resistance would then be 27×10^4 ohms (270K or 270,000 ohms). Obviously, this type of resistor is intended for applications where high presision is not important (a common case).