PHY 305F – ELECTRONICS LABORATORY I
Fall Semester 2003

EXPERIMENT 8
TRANSISTORS AND TRANSISTOR AMPLIFIERS
Lab notebook is due at 1 PM in MP238 on December 8

INTRODUCTORY COMMENT:

Most active electronic devices are based on transistors as the fundamental amplifying component. However, in this era, very little electronic circuit design is done using isolated transistors. Rather, integrated devices, such as the op-amps that you have just studied, are the building blocks from which circuits are constructed. This lab on transistors is intended to help you develop some understanding of the characteristics of the fundamental amplifying units.

There are two types of transistors. Field-effect transistors (JFETs and MOSFETs) are high-input-impedance devices, while bipolar junction transistors (BJTs) are low-input-impedance devices. This lab deals with JFETs, which may be easier to conceptualize, and with BJTs.

LEARNING OBJECTIVES:

(1) To become familiar with the basic properties of JFETs, particularly as used in a simple amplifier application.

(2) To gain further practice in wiring devices into circuits and in measuring amplifier characteristics.

(3) To become familiar with the basic properties of BJTs used as a simple amplifier and as a constant current source.

REFERENCES:

A.J. Diefenderfer and B.E. Holton, Principles of Electronic Instrumentation, 3rd Edition, Chapter 8.

P. Horowitz and W. Hill, The Art of Electronics, 2nd Edition, Chapters 2 and 3.

R.E. Simpson, Introductory Electronics for Scientists and Engineers, 2nd Edition, Chapters 5 and 6.

L.R. Fortney, Principles of Electronics, Analogue and Digital, Chapter 6.

G. Rizzoni, Principles and Applications of Electrical Engineering, 3rd Edition, Chapters 9 and 10.

<u>WHAT TO DO:</u>

NOTE: Use the same FET (2N3819 general purpose n-channel FET) for all parts 1, 2, and 3.

(1) Using the circuit in the figure below with a 2N3819 JFET, plot $(I_D)^{1/2}$ vs. V_{GS} by varying the value of the source bias resistor R. (R could be one of the larger 10 kΩ "pots" or a resistance box.) Before proceeding on with the experiment, deduce from your graph the best fit values of V_P and I_{DSS} in the equation:

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 .$$

Note that V_P (the pinch-off voltage) and I_{DSS} (the drain to source current when the gate is shorted to the source) are constants of the particular JFET that you are using. V_P is negative for n-channel JFETs.
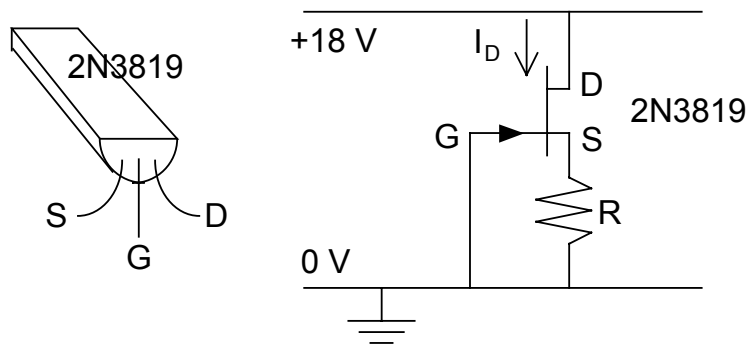

(2) Using the circuit in the figure below, with the same 2N3819 JFET, adjust R_S to make the drain current $I_D = 0.5$ mA. Measure the gain of the circuit at 10 kHz and find the maximum undistorted output voltage. Verify that the gain of the circuit approximately agrees with the formula:

$$A = -g_m R_L \quad \text{where} \quad g_m = 2\frac{\sqrt{I_D I_{DSS}}}{|V_P|} .$$

Note that V_P and I_{DSS} are constant characteristics of your particular device, while I_D is your own imposed operating current.
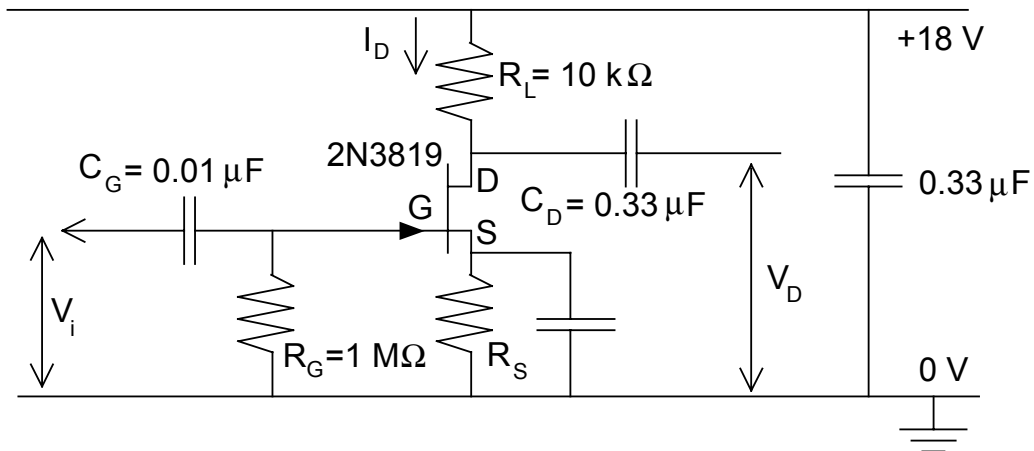
(3) Repeat the measurement of part (2), but with the source bypass capacitor, C_S removed from the circuit. Is the gain equal to the ratio R_L/R_S? Negative feedback is operating in this case. Explain how.

(4) Using the circuit in the following figure with a 2N3904 BJT, measure the small signal gain at 10 kHz and verify that its value is $-g_m \times R_L$, where $g_m = 40 \times I_C$ (g_m in Ω^{-1}, I_C in Amperes).
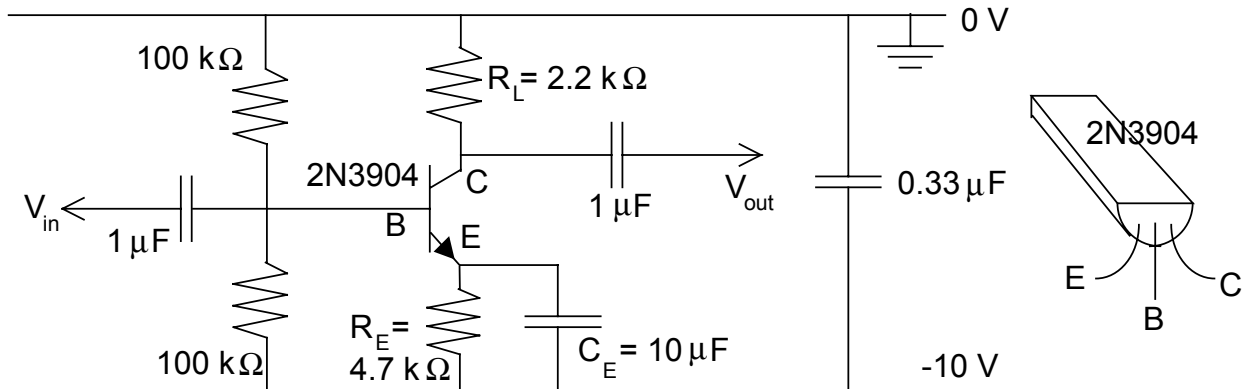
(5) Using the same 2N3904 BJT as in part (4), but modifying the circuit by removing the input capacitor and C_E, the emitter bypass capacitor (as shown in the circuit below), you may now consider this new circuit as a constant current source feeding the collector load resistor R_L. Test out the constancy of this source (or in other words, measure the circuit impedance). Do this measurement at DC (by observing the voltage across R_L as you vary R_L) and also do the measurement at 1 kHz by putting a voltage source in series with R_L and measuring the voltage drop across R_L using the differential voltage capability of your CRO.
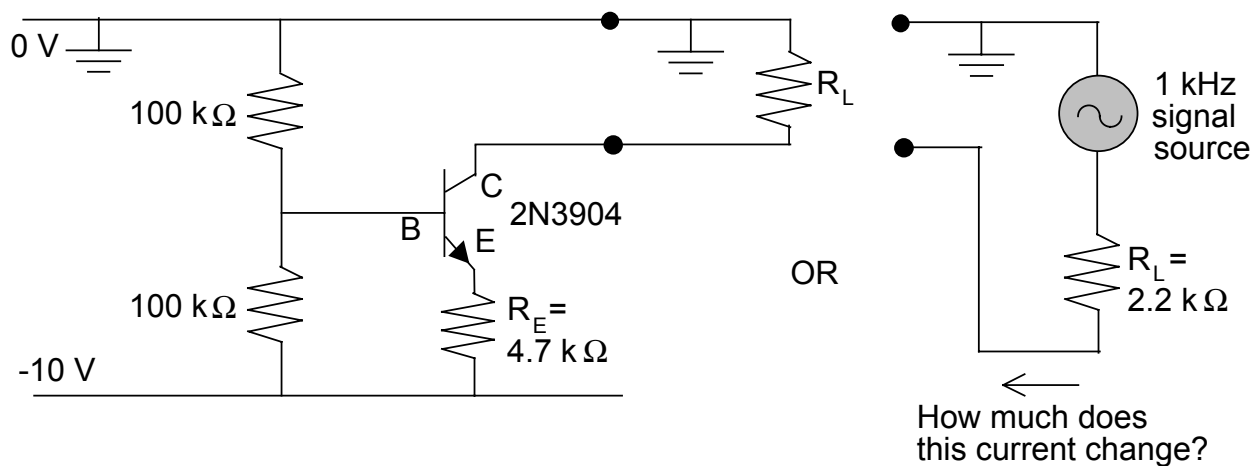
COMMENTS:

At each step in this experiment, be sure that you understand what you see and explain in your lab notebook how the circuits are operating. In your analysis, be sure that you understand and explain the roles of all the capacitors in the circuits.