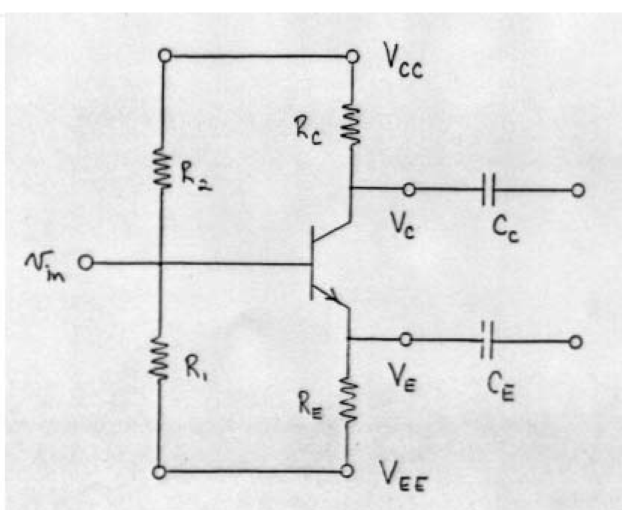
EXPERIMENT 10: SINGLE-TRANSISTOR AMPLIFIERS 5/9/06

In this experiment we will measure the characteristics of common emitter and common collector amplifiers. We will use the 2N3904 npn transistor.

I. THE COMMON EMITTER AMPLIFIER

The common emitter amplifier has a moderate gain as well as moderate input and output impedances. The circuit we will use is shown below. In this circuit resistors R_1 and R_2 are used to set the base to the desired DC operating voltage. Often in circuits of this kind, one uses an input capacitor to decouple the DC voltage level of v_{in} from the base. In the present circuit what we do instead is adjust V_B to match the DC level of the source, thus making the capacitor unnecessary. The output of the amplifier is taken from the collector through capacitor Cc, so that v_{out} has a DC level of zero.

The resistor R_E provides negative feedback in the following way. If the base voltage V_B is raised, I_B and I_E both increase. As more current flows through R_E, the emitter voltage also rises (since $V_E = V_{EE} + I_E R_E$). This prevents V_{BE} from changing by very much, which in turn means that the changes in I_E will not be too large. If one chooses a small value for R_E the gain of the amplifier will be large, but the amplified signal will be distorted and sensitive to changes in temperature.



Before you come to lab, you should complete the homework problems (problems 8.7 and 8.8 in Sprott) that involve designing and calculating the properties of a common emitter amplifier. .

1. The circuit we will use is mounted on a pre-wired circuit board. Sketch the circuit in your lab notebook, labeling the values of all components including the precision of all resistors used in the circuit. The value of C_C is not apparent from the markings on the capacitor and will be measured in step 5 below.

2. Use the transistor curve tracer to obtain the collector characteristics for your transistor and place a fully labeled printed copy in your lab notebook.

3. (a) Install the transistor in the circuit board. Connect the power supplies for V_{CC} and V_{EE} and then set V_{CC} = +20 V, and V_{EE} = –1.5 V. For now, the function generator (v_{in}) should not be connected. Using a DMM, adjust V_{EE} to get V_B to within 1 mV of zero. Then measure V_{EE}, V_C, and V_E (with the DMM) and calculate the quiescent (DC) value of I_C.

   (b) Draw the load line on your copy of the transistor characteristics, and mark the DC operating point. Determine I_B at the operating point (from the plot) and find β.

   (c) Calculate r_{tr}, r_{in}, R_{in}, R_{out}, G, and the values of V_C at cutoff ($I_C = 0$) and at saturation ($V_{CE} = 0.3$ V).

4. (a) Set up the function generator to produce sine waves with frequency f = 10 kHz. Install a 4.7 Ω resistor across the terminals of the function generator and connect it between the base and ground. Adjust the amplitude of v_{in} to obtain an AC voltage of 2 V (RMS) at the collector (use a DMM). Make a sketch of v_{in} and the voltage at the collector (remember that the collector voltage has both AC and DC parts).

   (b) Use a DMM to measure v_{in} and v_{out} and calculate the open circuit (noload) gain, G_0. Compare your result with the calculated value of G.

   (c) Measure R_{in} and R_{out}, and compare your results with the calculate values. To measure $R_{in,}$ put a resistor R between the function generator and the base and adjust R until V_B (or v_{out}) drops by a factor of 2 (see Lab #1, step 5). To measure R_{out} use the procedure of Lab #3, step 2(c), with the resistor on the output side of C_C.

(if you were to connect the resistor on the collector side of C_C you would change the DC operating point of the amplifier)

5. (a) Connect a load resistor R_L = 3000 Ω between the output and ground. Using a DMM, measure and tabulate vin and v_{out} as a function of frequency for 20 Hz ≤ f ≤ 50 kHz (3 points/decade is sufficient except near the corner frequency). Plot the gain as a function of f on log-log paper.

   (b) The falloff in the gain at low frequencies is caused by the non-zero impedance of the output capacitor. From your graph determine the breakpoint frequency (i.e. the frequency at which G has dropped off by a factor of $\sqrt{2}$ compared to the high-frequency limit). At this frequency, the voltage across C_C is equal in magnitude to the voltage across the output resistors; i.e.,

$$|Z_C| = R_L + R_{out}.$$

   Use this formula together with your measured breakpoint frequency to determine C_C.

6. Remove R_L, set the function generator to f = 10 kHz, and increase v_{in} to drive v_C to both cutoff and saturation (you may need to remove the 4.7 Ω resistor for this step). Sketch the collector voltage and determine V_C(off) and V_C(sat). Compare your measured and calculated values.

7. In this step we will observe the behavior of the amplifier in the “grounded-emitter” configuration. Rather than grounding the emitter directly, the idea is to “bypass” R_E by connecting the capacitor C_E to ground. This keeps the DC operating point of the amplifier unchanged, while grounding the emitter as far as AC voltages are concerned. In other words, the emitter voltage will now be constant, which means that there is no longer any negative feedback.

   (a) Connect C_E to ground and adjust the amplitude of vin to obtain vout = 5 V peak-to-peak (you will need to put the 4.7 Ω resistor, back in). Use a DMM to measure the magnitude of v_{in} and v_{out}, and determine the open-circuit gain. For grounded-emitter operation the gain is given by $G = R_C/r_{tr}$. Use the measured value of G to determine the transresistance and compare your result with the expected value

$$r_{tr} = V_{kT}/I_E\,.$$

   (b) Switch the function generator to triangle waves and increase v_{out} to 8 V peak-to-peak. Make a sketch of the collector voltage, $v_C(t)$, including both the DC and AC parts. On the same graph, indicate the quiescent value of v_C (i.e. the value obtained with vin = 0). Can you explain why v_C looks the way it does?

   (c) Measure the input impedance. Compare your result with the expected value of R_{in} calculated with the measured value of r_{tr}.

II. THE COMMON COLLECTOR AMPLIFIER

The common collector amplifier has a gain of approximately 1, a moderate input impedance, and a very low output impedance. We will use the same circuit as above, with the output taken from the emitter.

1. Set the function generator frequency to f = 10 kHz. Adjust the amplitude of v_{in} to obtain an RMS emitter voltage of approximately 0.25 V. Sketch v_{in} and v_E, remembering to include both the AC and DC parts. Measure the gain (use a DMM) and compare your result with calculated value (use the measured value of r_{tr} in the calculation).

2. The final step is to measure the output impedance of the amplifier. Use the following procedure. First, remove the 4.7 Ω resistor and then put a 100 kΩ resistor in series with the function generator. Using a DMM, check that V_B is zero to within 1 mV, and if not, adjust V_{EE} to zero V_B. Next adjust the amplitude of v_{in} to obtain v_E = 0.1 V (RMS). Connect a load resistor R_L between the output side of C_E and ground, and then adjust R_L to obtain $v_{out} = v_B/2$ (here v_{out} is the voltage across R_L). At this point $R_L = R_{out}$. Note that as you adjust R_L, both v_{out} and v_B change. As a result, you need to measure both v_{out} and v_B as you adjust R_L.