Use your bench power supply to provide V_{CC} = 10 V. Use an emitter resistor R_E ~ 500 Ω. From your previous measurements of the 2N5210, you know that a reasonable operating current is I_{CE} = 2 mA, which gives V_E ~ 1 V. Since V_{BE} ~ 0.6 V, you will want V_B ~ 1.6 V. Choose R_1 and R_2 to set this base bias, as shown in the figure below. A possible choice for these resistors is R_1 = 1.6 KΩ and R_2 = 8.4 KΩ.

In order to allow a usefully large voltage swing on the output, you would like to have the steady-state drop across the transistor to be several volts. For maximal signal output, one would choose V_{CE} ~ 0.6 V_{CC} = 6 V. Or, you could choose V_{CE} to correspond to your previously found "operating" point. Choose your value of R_C accordingly.

Measure each resistor that you select for the circuit to make certain that you have close to the desired value. Then assemble the circuit and use the DVM to check the voltages, V_{CE}, V_E and V_B.

Using the ideal small signal transistor model (see section 6.2.4, Fortney), calculate the gain expected from the circuit with the values of resistors you have used. The gain can be calculated as follows:

$$v_B = v_E = (i_B + i_C) R_E = i_B (1 + h_{fe}) R_E$$

$$i_B = \frac{v_E}{(1+h_{fe}) R_E}$$

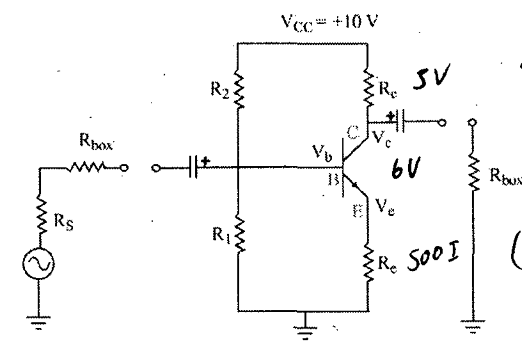
$$v_C = -i_C R_C = -h_{fe} i_B R_C$$

$$\frac{v_C}{v_E} = -\frac{h_{fe}}{(1+h_{fe})} \frac{R_C}{R_E}$$

Measure the gain by applying a 10 KHz sine wave (0.01 – 0.1 V peak-to-peak) to the input, and monitor both input and output on the oscilloscope.

Vary the frequency 1 Hz < f < 1 MHz, and establish the frequency limitations (if any) of the amplifier.

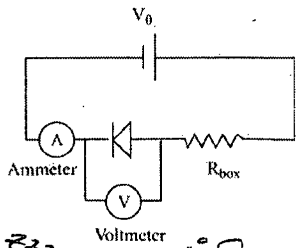
Determine the range of signal amplitudes over which the response is linear by increasing the input voltage until the output voltage is distorted. You will find this can be done very effectively by superimposing the two signals on the oscilloscope with their relative gains adjusted so as to produce exactly the same trace. At large amplitudes, the peaks of the signal will be "clipped." Look at the collector voltage with the oscilloscope on 1 V DC. What is the lowest voltage the collector swings to? How does this compare to two diode drops for V_{CE}?

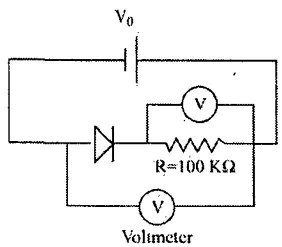


The Common Source JFET Amplifier

We want to now use a JFET to make a common source amplifier similar to the bipolar transistor above. Perform the following steps to first establish the operating point and then find the amplifier characteristics.

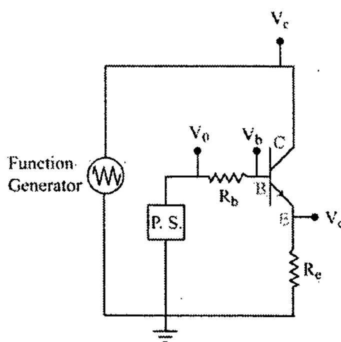
- Use one side of your bench supply to give V_{DD} = 15 V. Use the other side of your bench supply to control -2 V < V_G < 0 V.
- Measure and plot I_{DS} vs V_G, with R_D = 1 KΩ. Compare with Fortney, Fig. 6.25b.
- Determine the drain-to-source current I_{DSS} which flows when V_{GS} = 0 ("shorted").
- Determine the (negative) gate voltage at which I_{DS} = 0. Forney calls this "V_0". Manufacturers call it "V_{GS} (off)".
- Compare your measurements of I_{DSS} and V_{GS} (off) to the spec sheet for the 2N5484.
- Set up a self-biased operating point with I_{DS} ~ 1 mA, as shown above. Here, V_G = 0 due to the 1 MΩ resistor, since I_G < 1 nA. The (positive) source voltage is established as V_S = $I_{DS}R_S$, making V_{GS} = -V_S ~ -0.5 V. Check these voltages with the DMM.
- Set up the amplifier circuit with R_D = 5 KΩ.
- Measure the voltage gain A_0 at f = 10 KHz.
- What value of g_m does your measured gain correspond to? Compare this gm to the spec sheet's $|y_{fs}|$.





Transistor Characteristics

You will measure the I-V characteristics of a 2N5210 transistor, using the circuit shown below. The 2N5210 is an NPN device with the pins arranged as shown on the right in the figure below. The 2N5210 is a high-gain (h_{fe} in the hundreds), high-frequency transistor that may oscillate in your setup. If you get erratic data for this reason, try a small bypass capacitor (1000 pF) from collector to ground and/or base to ground.



A triangle ramp voltage of 0 → 10 V "powers" the circuit. Set the function generator to triangle, 0.2 x 1 Hz, and adjust the amplitude and offset to obtain a ramp $0 < V_{ramp}(t) < 10$ Volts (no negative voltages!). Note, once you have this ramp, *do not change* the amplitude or offset, or things may get confusing later.

Use your adjustable DC power supply to obtain $0 < V_0 < 30$ V. Connect V_0 through an $R_b = 1$ MΩ resistor to vary the Base-Emitter current. Since R_b is so large, R_E is small, and the transistor's $V_{BE} \sim 0.6$ V is almost constant, you can assume that $I_{BE} = (V_0 - 0.6) / R_b$.

For each setting of the base voltage, the collector voltage will be swept over most of its operating range by the triangle function. You will obtain plots of I_{CE} as a function of V_{CE} at fixed I_{BE} using your oscilloscope in the X-Y MODE. The current I_{CE} is given by the voltage across the small "shunt" resistor $R_e = 10\ \Omega$, as $I_{CE} = V_e/R_e$. Since the shunt resistance R_e is negligible, you can approximate $V_{CE} \sim V_C$.

Put the scope in XY mode, with Ch1 = 1 V/div DC and Ch2 = 20 mV/div DC, with no input cables connected. In XY mode, the Ch1 "Vertical" input (modified by the "Vertical" offset knob) gives the HORIZONTAL deflection of the scope spot, and the Ch2 vertical input gives the VERTICAL deflection. Adjust the Ch1 and Ch2 Vertical Offsets so that the spot is in the lower left corner of the xy grid of the oscilloscope.

Now connect the Ch1 scope input to measure the collector voltage, as Ch1 = V_C. The spot should then scan along the x-axis of the scope.

Now connect the Ch2 scope input to measure the collector current, as Ch2 = $V_e = I_{CE}R_e$. The scope will now trace out I_{CE} vs V_{CE} for the fixed I_{BE} determined by your power supply. The 0.2 Hz triangle ramp can be changed to ~100 Hz to make the display continuous. Turning on the 20 MHz BW filter will eliminate some noise on the trace.

Transcribe the scope display onto graph paper by hand, in pencil. Label and numerate the axes. For example, the y-axis label could be Ch2 = $V_e = I_{CE}$ x 10 Ω [20 mV/div] or I_{CE} [2 mA/div] or both. Draw the curve by transcribing three or four significant points (beginning, knee, end) and connecting them with a ruler.

Record I_{CE} vs V_{CE} for five or six different base currents in the range $0 < I_{CE} < 30$ mA. Label the curves.

Determine the forward current gain parameter h_{fe} and the output admittance h_{oe}. From your plots, determine an operating point near the center of the linear range of the transistor and estimate h_{FE} and h_{fe} in the neighborhood of this point. Use the slope of the I_{CE} vs V_{CE} curves to determine h_{oe}.

The NPN Common Emitter Amplifier

In this lab, you will need to use large valued electrolytic capacitors, which must be connected with the *correct DC polarity*. The negative lead is generally marked with a black band and a – sign; the other lead must *always* be more positive. If you are not sure, ask the TA for assistance.

The power line at V_{CC} is supposed to be an AC signal ground. To ensure this, you should filter the power line at the circuit with a capacitor to ground. For audio frequencies, this requires a large (>10 μF) electrolytic capacitor from V_{CC} to ground. This is not indicated on the circuit diagram, but you should use one of the 47 μF capacitors for this purpose.