Laboratory 6.1 **Single Transistor Circuits**

Name **Section**

PURPOSE

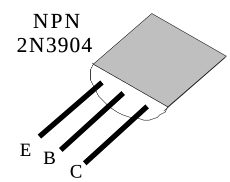
1. Construct a common emitter transistor amplifier and measure its characteristics.
2. Construct a common collector transistor amplifier and measure its characteristics.

COMMENT

Part of the purpose of this lab is to measure some of the small signal parameters for a specific transistor. Remember that these parameters are generally functions of the collector current I_C; a measurement at one I_C is not valid at another. Also remember that when making these measurements you must observe the "small signal" requirement that $|i_C| << I_C$ if the linear analysis methods are to work. Practically, this means that when making measurements your AC output signals should have amplitudes substantially less than 1 volt.

The frequencies used in this lab are such that the impedance of the various capacitors is very small compared to other resistive impedances in the circuit. This means that there are no phase shifts associated with these capacitors and the complex voltage and current expressions are not needed.

SPECIAL EQUIPMENT



One NPN bipolar transistor with characteristics similar to the 2N3904 is required. This transistor has a very high current gain of approximately 300. If you do not have 5 or 10 MΩ resistors available for R_B, you may need to use an R_{B2} base resistor as shown in figure 6.11c in your text.

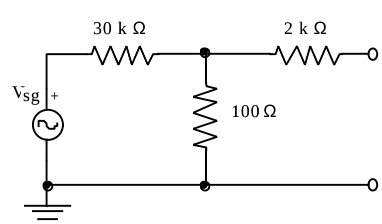
A. Common Emitter Amplifier

This transistor configuration produces both a current gain and a voltage gain. For that reason we need to modify the signal generator to produce a smaller signal for input to the common emitter amplifier.

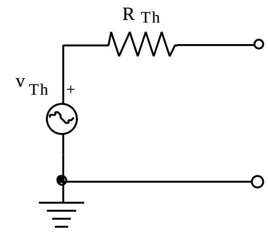
1. Preliminary design work

Do the work in Section 1 before lab.

a. Your first job in lab will be to modify your signal source to conform to the following circuit. The normal 600 Ω output impedance of the signal generator is insignificant compared to the 30 kΩ resistor and can be ignored.



b. Your modified signal source can be represented by the Thevenin equivalent circuit at the right. Determine the value of R_{Th} that applies to the previous circuit. Your answer need only be good to 10%; after all the actual resistors you are using are probably not known to any better accuracy.



R_{Th} =

c. On your breadboard, find a place where you can measure a signal that is nearly the same as v_{Th}, even after the output is connected to a load. Label this signal v_m on the circuit of Section 1a.

d. The amplitude of this measured voltage v_m v_{Th} will still vary slightly with the load, but it is easy to calculate an upper limit by considering the case where the output is shorted. Calculate the ratio [v_m(open)-v_m(short)]/v_m(open).

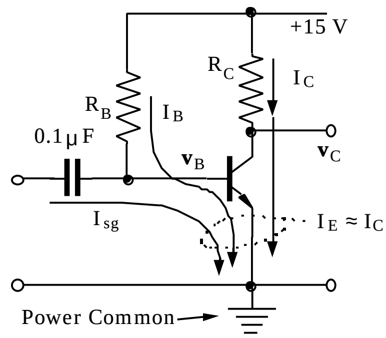
2. Modify signal generator

Build the signal generator modification on your breadboard and connect the A channel scope probe to measure v_m. Display a 1 kHz sine wave output and verify that v_m behaves as you predicted.

3. Preliminary design work

Complete the work in Section 3 before you come to lab.

a. Complete the following schematic by adding the equivalent circuit for the signal source.



b. Make the assumption that h_{FE} = 300 and determine the resistance values on the following circuit that will establish a DC operating point of V_C = 10 V with I_C = 1 mA.

R_C =

R_B =

c. If your actual V_C turns out to be less than 10 V, which resistor should you change to meet the V_C and I_C design goals and should it be larger or smaller than your first estimate?

4. Build and test the CE amplifier.

You will be using the +15 V power supply in this lab, so be sure this voltage and its return are connected to the long strips on the side of your breadboard. Turn the power off during all construction!

If you are using a new transistor with straight leads, don't bend the leads! Spread them only enough to fit into adjacent pins of the breadboard.

a. Build this amplifier and record the actual operating point

V_C = implies I_C =

b. From this result, determine the actual h_{FE} of your transistor

h_{FE} =

and then adjust one of the resistors to get within 20% of the target operating point. Be sure that I_C is still 1 mA. Explain what you had to do.

5. Measure AC parameters.

Be sure you satisfy the small signal requirements!

a. Apply an appropriate 1000 Hz signal and measure the AC voltage gain.

v_C/v_{Th} =

This answer should reflect the correct phase relationship between the input and output signals.

b. Scan the frequency spectrum from 10 Hz to 200 kHz and note the approximate location of any corner frequencies that you find.

c. Use the method outlined in the introduction of this manual to measure the output impedance of this amplifier. A 0.01 μF capacitor is about right; a too-small value will not produce a corner lower than the Miller effect corner, and a too-large value will confuse the high-pass and low-pass corners. Briefly explain your method, record your directly measured values, and show your calculation.

R_{out}=

d. Remove the capacitor and increase the amplitude of the input signal until the output distorts significantly from a sine wave. Make the 30 kΩ resistor smaller if necessary. Sketch the distorted output.

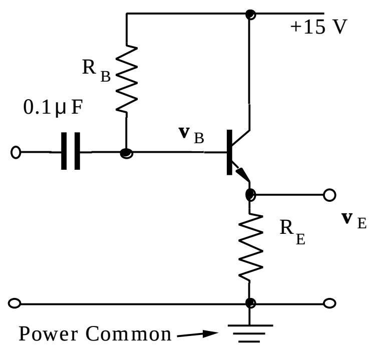
B. Common Collector Amplifier

This portion of the lab deals with the common collector (emitter follower) amplifier. Since this circuit produces no voltage gain, you will need to remove the resistor network used with the signal generator in part A. Replace it with a single resistor to make the total output impedance of the generator 10,600 Ω.

1. Preliminary design work

Do the work in Section 1 before you come to lab.

a. Add the Thevenin equivalent of this newly modified signal generator to the following sketch.



b. Assuming h_{FE} = 300, choose the resistors so that the operating point of this CC amplifier will be at V_E = 5 V and I_C = 10 mA.

R_B =

R_E =

c. At a sufficiently high frequency that $\mathbf{Z}_C$ can be neglected, write an expression for the output impedance of this amplifier, then evaluate it under the assumption that h_{fe} = 300, and h_{ie} = 5000 Ω.

Equation R_{out} =

Result R_{out} =

2. Build and test the CC amplifier.

a. Using the same transistor as in the CE circuit, build the CC amplifier then turn on the power supply and measure its DC operating voltage V_E.

V_E =

b. Again estimate the actual h_{FE}.

h_{FE} =

c. By calculation and/or trial-and-error find a value of R_B that will produce the desired operating point.

$R_B =$

d. Your new value of h_{FE} should be significantly different from the one found with the CE circuit. Explain why that should be the case.

e. Apply a 1000 Hz signal to the this amplifier and measure the AC voltage gain

$v_E/v_{Th} =$

f. With a 0.1 μF capacitor as a load, measure the output impedance of this circuit. Show your raw measurements and calculations.

$R_{out} =$

g. Use this answer to estimate the AC parameter h_{fe}. Show your equations and work.

$h_{fe} =$