Lab 05 – Common Emitter

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ELE404 – Electronics I
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Introduction:

Using the 2N3904 NPN BJT, we will test a common-emitter (CE) amplifier and investigate a bipolar-junction transistor (BJT) in active mode in this lab. Additionally, we will learn how to measure the input and output resistances of an amplifier, which is a crucial ability for practicing electronics.

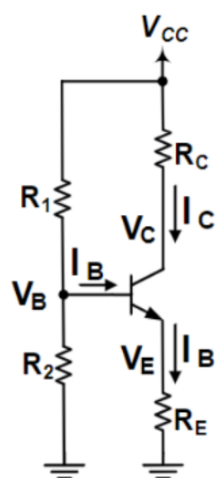
Objective:

Gaining expertise with the 2N3904 NPN BJT and improving our knowledge of amplifier input and output resistances are the goals of this lab for our team. By concentrating on testing a Common-Emitter (CE) amplifier and biasing the BJT in its active state, we hope to build vital technical skills that are necessary for any student studying electronics. Additionally, we will learn how to accurately measure the input and output resistances of an amplifier by using experimental assessment procedures. We also want to investigate how the load resistance affects the output voltage of the amplifier. In addition to helping us better understand amplifier performance, this useful information will be a great starting point for more complex electronic research.

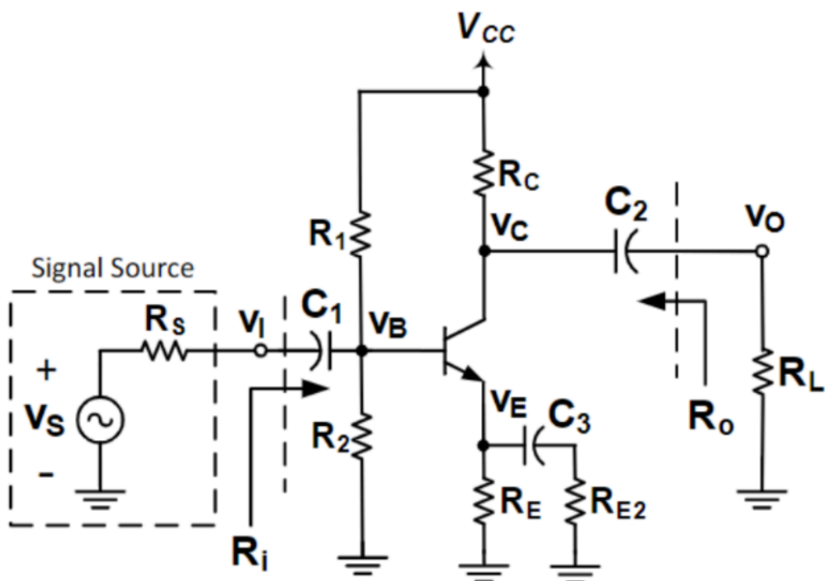
Circuit Under Test:

We examine a simple circuit layout in the first section of the experiment, which consists of a transistor and two resistors at the emitter and collector positions. A voltage divider is also included at the base of this configuration. Our job, which is powered by a DC source, is to measure the DC voltage across the transistor's emitter, base, and collector terminals and use the voltages to determine the currents (Ic, Ie, and Ib). The following is the schematic that shows this circuit:

The circuit configuration stays the same in the following stage of our experiment, but the voltage divider resistor values are increased tenfold, which affects how the circuit shapes waves.



By adding more components, we transform the original circuit into an amplifier in the experiment's second section. Using a series capacitor, we connect a load resistor to the collector terminal. Additionally, we use a series capacitor as our input to supply a signal source to the voltage divider at the base. Lastly, we connect a second resistor, RE2, in parallel with RE (in series with a capacitor). Our goal at this point is to measure the input and output voltage's decibel (dB) and root mean square (RMS) values while tracking any changes that occur when the load resistance is connected and unplugged. This section of the experiment's circuit is displayed below:



We built the circuit from step P4 in the last phases of our experiment, adding a test resistor and our amplifier. First, we took note of the input voltage and the voltage across the test resistor's RMS values. Then, since the same resistor was used for both purposes, we made sure that our measurements were consistent by swapping out the load resistor for the test resistor and measuring the RMS output voltage with and without the load. Finally, we adjusted the circuit to measure vt and vi values precisely by connecting a Rt,in resistor in series with the amplifier's input and the signal generator's output.

Experimental Results:

We began this lab by building the first circuit using a transistor and two resistors, Re and Rc, at the emitter and collector positions. Additionally, the circuit featured a voltage divider at the base made up of

R1 and R2. In order to determine the currents across the base, collector, and emitter of this circuit, we had to use the multimeter to determine the voltages VB, VC, and VE. After that, we added two resistors (RL and Rs) and three capacitors (two 10 µF and one 100 µF) to turn this circuit into a common-emitter amplifier. With the oscilloscope (E2), we could visualize this circuit graphically and get the Vi, Vo, and Av values in dB and rms. The values of Vi, Vo, and Av in db and rms were then determined by removing RL to see our values when RL = ∞. In order to determine Vt and Vi, we next connected the input terminal of the amplifier and the output terminal of the signal generator using a test resistor. Next, we substituted a test resistance for RL and noted the amplifier's no-load and loaded rms output voltages.

E2)

Table E1. Measured terminal voltages and currents of the BJT in the circuit of **Figure 1**.

$V_B\ [V]$	$V_C[V]$	$V_E[V]$	$I_B[mA]$	$I_C[mA]$	$I_E\ [mA]$
5.0968V	0.5204	4.4792	1.94×10^{-3}	0.291	0.293

Table E2(a). Input and output ac voltages and gain of the CE amplifier, with $R_L = 10\ k\Omega$.

$V_i\ [Vrms]$	$V_O[Vrms]$	$A_v[V/V]$	$V_I[dB]$	$V_O[dB]$	$A_v\ [dB]$
0.27102	1.294	4.774	16.263	29.844	13.581

Table E2(b). Input and output ac voltages and gain of the CE amplifier, with $R_L = \infty$.

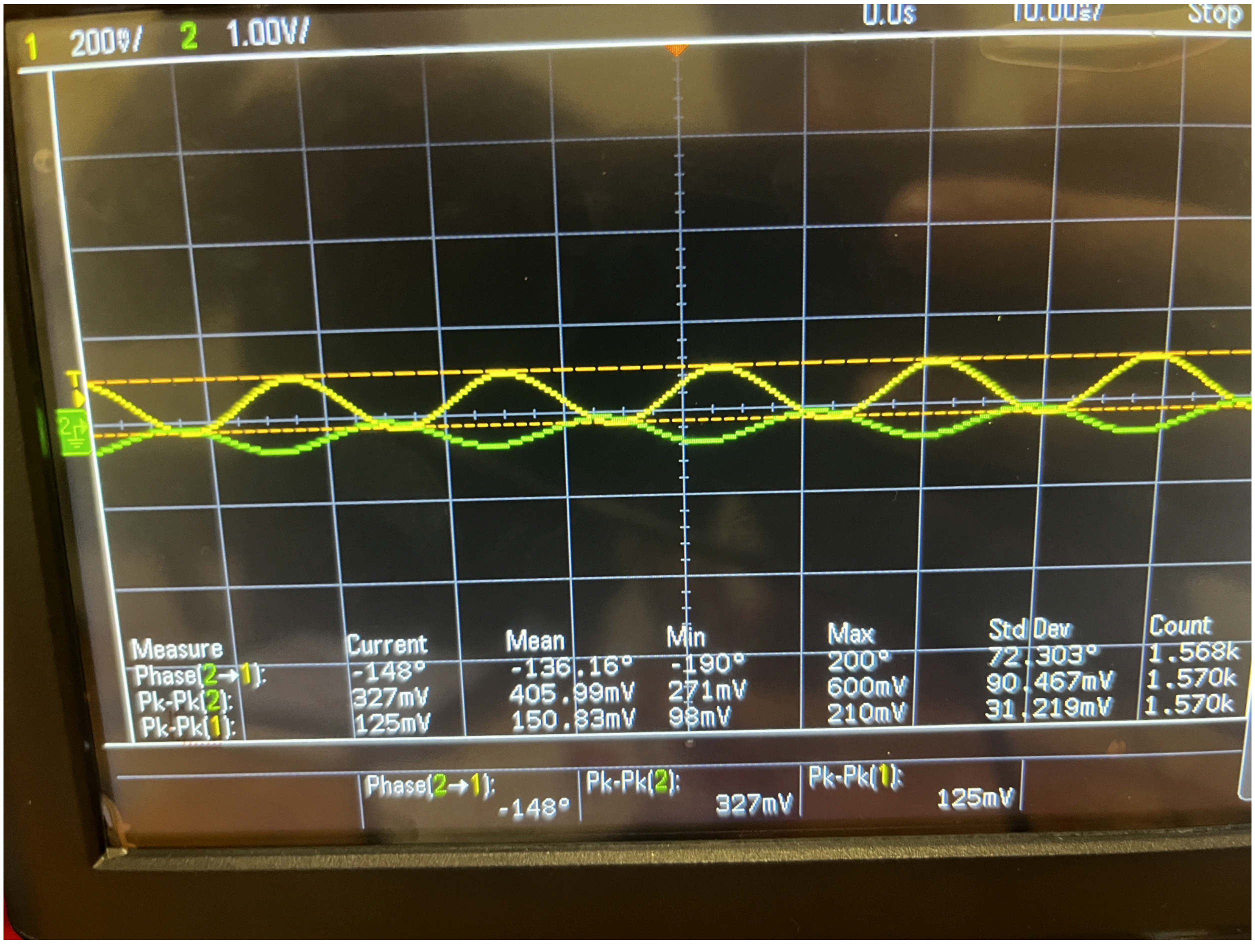
$V_i\ [Vrms]$	$V_O[Vrms]$	$A_{vo}[V/V]$	$V_I[dB]$	$V_O[dB]$	$A_{vo}\ [dB]$
0.27103	3.1575	11.6	16.263	37.589	21.326

Table E3. Parameters of the CE amplifier for determining its input resistance.

$R_{t,in}\ [k\Omega]$	$V_t[Vrms]$	$V_i[Vrms]$	$R_i[k\Omega]$
2710Ω	0.27127	0.13444V	26.52

Table E4. Parameters of the CE amplifier for determining its output resistance.

$R_{t,out}\ [k\Omega]$ (i.e., the load)	$V_O[Vrms]$ without load (i.e., $A_{vo}v_i$)	$V_o[Vrms]$ with load	$R_o[k\Omega]$
15 kΩ	3.157	1.5785	14.876



Conclusion & Remark:

C1

Table C1. Calculated and measured (DC) voltages in the transistor circuit of **Figure 1**.

	$V_B[V]$	$V_C[V]$	$V_E[V]$
Calculated values (from Table P1)	5.11 V	10.5675 V	4.38 V
Measured values (from Table E1)	5.0968 V	10.5204 V	4.4792 V
Percent error, $e\%$	0.256 %	0.448 %	1.991 %

All three percent errors are under 2%, showing that this part of the experiment was conducted well to obtain these results.

C2

Table C2. Calculated and measured ac parameters for the CE amplifier of **Figure 2**.

	$A_v[V/V]$	$A_{vo}[V/V]$	$R_i[k\Omega]$	$R_o[k\Omega]$
Calculated Values (from Table P2)	5.011195991 V	12.528 V	30.627 kΩ	15 kΩ
Measured Values (from Tables E2, E3, and E4)	4.774 V	11.6 V	26.52 kΩ	14.876 kΩ
Percent Error, $e\%$	4.96 %	8 %	15.49 %	0.83 %

Revised Prelab A_{vo} and A_v $(R_E \| R_{E2})$ not $(R_E + R_{E2})$

$$A_{vo} = -\frac{g_m R_C}{1 + g_m R_E} = \frac{(0.0116)(15k\Omega)}{1 + (0.0116)(15k\Omega \| 1.2k\Omega)} = 12.528$$

$$A_v = -\frac{g_m (R_C \| R_L)}{1 + g_m R_E} = \frac{(0.0116)(15k\Omega \| 10k\Omega)}{1 + (0.0116)(15k\Omega \| 1.2k\Omega)} = 5.011195991$$

All the percent errors are under 16% which indicates that this part of the experiment was conducted fairly well with some discrepancies. These discrepancies could be due to sensitivity of the capacitors, component defects, or from the prelab calculations.

C3

C3:

from Figure F4:

$$i_i = \frac{V_t - V_i}{R_{t,in}} = \frac{0.27127 - 0.13444}{27k\Omega} = 5.068 \times 10^{-6}\ A$$

$$i_o = \frac{V_o}{R_{t,out}} = \frac{1.5785}{15k\Omega} = 1.052 \times 10^{-4}\ A$$

$V_o \leftarrow$ with load

$$A_i = \frac{i_o}{i_i} = \frac{1.052 \times 10^{-4}\ A}{5.068 \times 10^{-6}\ A} = 20.76$$

$$A_p = A_v A_i = (5.011195991)(20.76) = 104.03$$

C4

The effect of resistance R_{E2} of the CE amplifier on:

The voltage gain
The voltage gain can be described by the following equation:

$$A_V = \frac{-g_m (R_C \| R_L)}{1 + g_m (R_E \| R_{E_2})}$$

In the equation we see RE2 in the denominator. Therefore when RE2 increases, voltage gain decreases and when RE2 decreases, voltage gain increases.

The input resistance
The input resistance can be described by the following equation:

$$R_{in} = R_{th} \| (r_e + R_e \| R_{E_2})(\beta + 1)$$

In the equation we see that when RE2 increases, input resistance increases and when RE2 decreases, input resistance decreases.

The output resistance
The output resistance can be described by the following equation:

$$R_O = R_C \| R_L$$

We can see that the equation for Ro doesn't contain RE2, so Ro is not affected by RE2

The maximum magnitude of v_i before the output voltage exhibits distortions

When considering the maximum magnitude of vi, we know it is connected to the vs value. Therefore when vi reaches its maximum value before the output voltage is distorted, we can see vi is independent of the RE2 value. So the maximum magnitude of vi is not affected by RE2.

Remark

We finished the experiment in this lab and learned a lot about the common-emitter amplifier. In order to successfully develop our Common-Emitter amplifier and comprehend its use, we investigated the Bipolar-Junction Transistor's operation in its active state. Additionally, we witnessed personally the experimental assessment of this amplifier's input and output resistances. All things considered, this lab was a very instructive experience that improved our comprehension of these important electrical ideas.