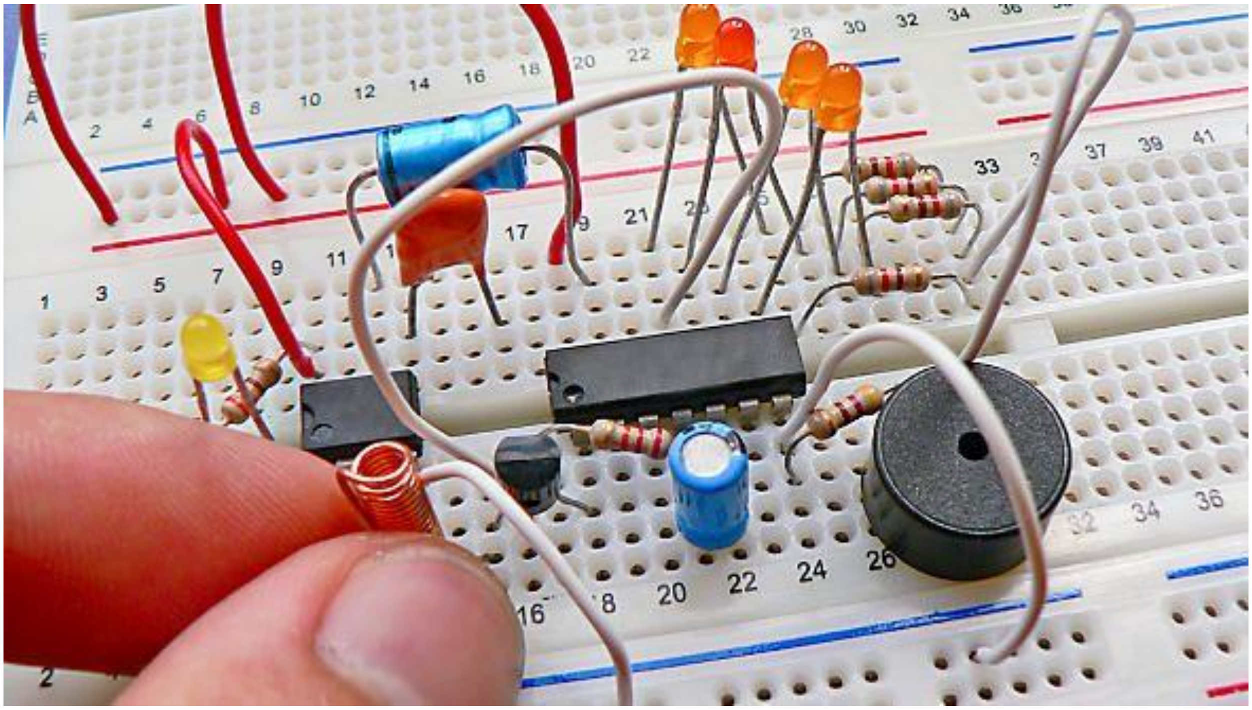
Lab 2: BJT and Amplifiers

EEE109 Electronic Circuits



In Lab 2, there are four sections, ***please read this material before the lab and perform the experiment following with the instructions step by step***.

Required Components and Technology

- **Platform: NI ELVIS III**
- **Components:**

Section 1:

- **2N3904 transistor**
- **33 kΩ resistor**
- **100 Ω resistor**
- **1 kΩ potentiometer on protoboard**

Section 2:

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Section 3:

- **560 Ω resistor**
- **1 kΩ resistor**
- **8.2 kΩ resistor**
- **18 kΩ resistor**
- **1 µF capacitor**
- **100 µF capacitor (Pay attention to the polarity)**
- **NPN 2N3904 transistor**

Section 4:

Only simulation

Section 1: Bipolar Junction Transistors

1.1 BJT Behavior

Instructions

From the Instruments tab of Measurements Live, open the following instruments:

- IV Analyzer

Note: For more information about accessing Measurements Live and launching instruments, visit http://www.ni.com/documentation/en/ni-elvis-iii/latest/getting-started/launching-soft-front-panels/.

Add the Transistor and Set up the IV Analyzer

Instructions

1. Place the transistor in the **Base**, **DUT+** and **DUT-** terminals in the NI ELVIS III, as indicated in the instrument's window.
2. Place the *Base* of the transistor in **BASE**.
3. Place the *Collector* of the transistor in **DUT+**.
4. Place the *Emitter* of the transistor in **DUT-**.

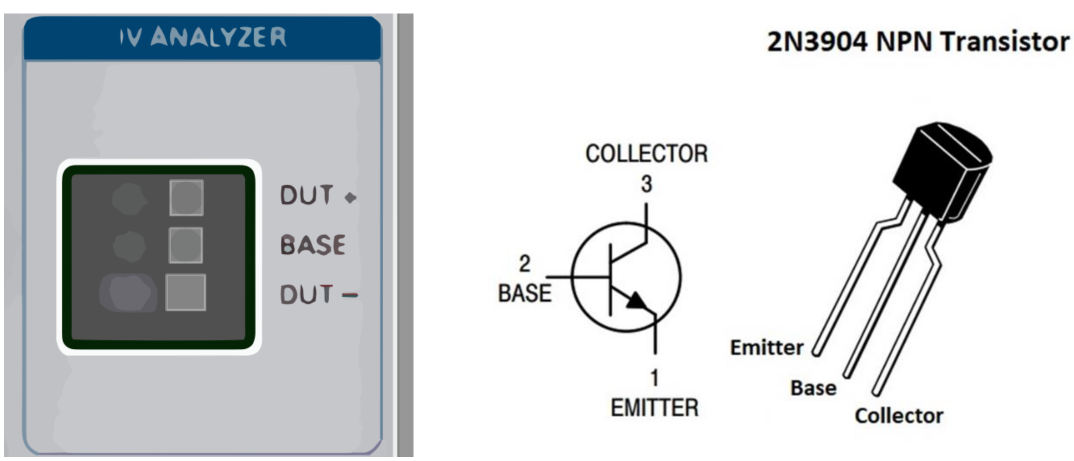

Figure 1-1 IV Analyzer and the diagram of 2N3904 transistor.

5. Set the IV Analyzer according to the settings in the table below:

Table 1-1 IV Analyzer Settings

Analyzer Mode	Transistor
Transistor Type	NPN
Collector resistance	Low (The first from left 左起第一格)
Collector Voltage Sweep	
V_c Start	0.00 V
V_c Step	0.10 V
V_c Stop	3.00 V
I_c Limit	30 mA
Base Current Sweep	
I_b Start	15.00 μA
I_b Step	11.00 μA
Number of Curves	5

6. The graph was generated by the IV Analyzer. Include it with your lab report.

1.2 BJT Measurements in the Active Region

Instructions

Note: You will now obtain curves for the active region manually using the power supply and Multimeter.

1. Use the NI ELVIS III to set up the following circuit:

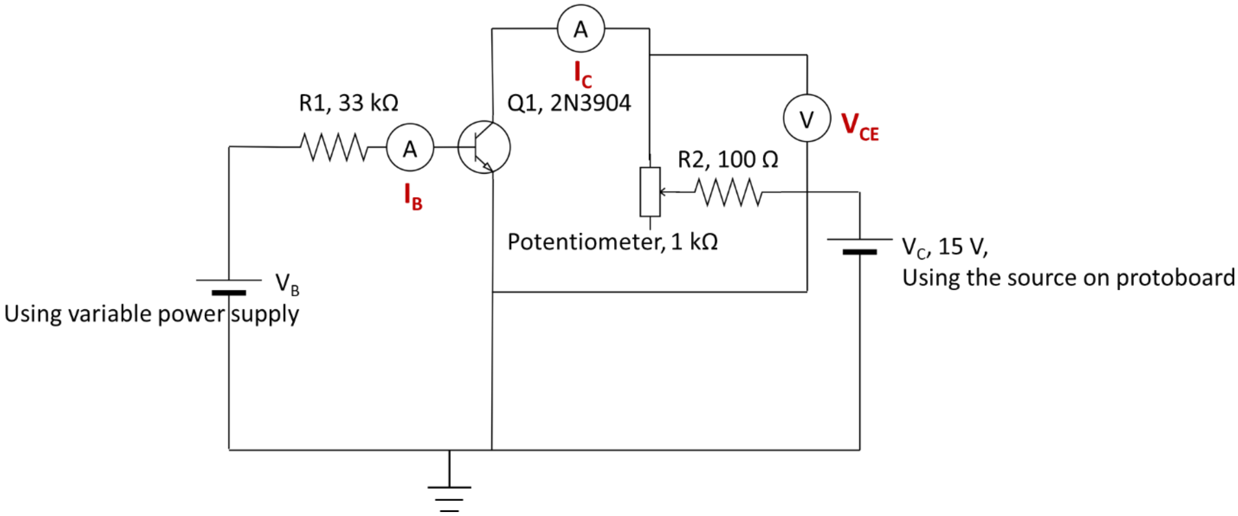

Figure 1-2 Circuit Set-up

2. Open the following instruments from Measurements Live:

- Digital Multimeter (DMM)
- Variable Power Supply 1-15 V DC (VPS)

Manually Observe the Behavior of a BJT

1. In the Variable Power Supply window, apply the following settings:

Table 1-2 Variable Power Supply settings

Power supply "+"	Static
Voltage (V_B)	2.38 V
Power supply "-"	Inactive

2. Measure the collector-emitter voltage (V_{CE}) using the DMM measuring DC voltage. Manually adjust the potentiometer until the reading is 6 V. <u>If the V_{CE} cannot been adjusted to 6 V, you can start it from a higher voltage, such as 6.5 V or 7 V.</u>
3. Read the collector-emitter voltage (V_{CE}), as well as the collector's current (I_C), and write the data in Table 1-3.
4. Change the voltage V_C using the data in the table below, repeat the V_{CE} and I_C readings, and write the data in the table.

Repeat for voltage (V_B) of 4.08 V and 5.76 V, until you complete the table below:

Table 1-3

V_B = 2.38 V (I_B = 50 μA)		V_B = 4.08 V (I_B = 100 μA)		V_B = 5.76 V (I_B = 150 μA)	
V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)
6		6		6	
7		7		7	
8		8		8	
9		9		9	
10		10		10	
11		11		11	
12		12		12	

Generate a Collector Current vs. Collector-Emitter Voltage Graph

1. Using the data from the Table 1-3 in the previous step, generate a Collector-Emitter Voltage (x) vs. Collector Current (y) graph. Include it with your lab report.

You have two options:

- You can create the graph by clicking on the Excel file below and submit a screenshot or photograph of your graph.

OR

- You can manually draw the graph and submit a photo of the graph with your lab.

1-3 Is β relatively constant on all points?

A. Yes
B. No

If not, what is different?

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1-4 What is the transistor's approximate β? **Tip:** Use a base current I_B = 100 µA at V_{CE} = 8 V.

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1-5 What would be the collector's I_C current if V_{CE} = 9 V at I_B= 75 µA?

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1.3 Conclusion

These questions will help you review and interpret the concepts learned in this section of the lab.

1-4 Use the chart below to compare the procedures from the simulation, the IV Analyzer and the instrumentation measurement activities. What are their advantages and disadvantages?

Table 1-4

	Advantages	Disadvantages
Simulation		
IV Analyzer		
Instrumentation		

1-6 Which procedure was easiest to implement and why?

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1-7 Were there any procedures that generated an unexpected challenge? Explain what you did to overcome the challenges you faced.

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Section 2: Bipolar Junction Transistor as a Switch

2.1 BJT as a Switch

Instructions

1. For the illustration below, you will need to calculate the following:

- Cutoff collector-emitter voltage V_{CE}
- Saturation collector-emitter voltage V_{CE}
- Saturation voltage across the collector resistor V_{RC}
- Saturation current at collector I_C

2. Complete Table 2-1 with the values you calculated.

Note: A few things to remember for this question:

- The LED voltage for cutoff and saturation purposes is 1.8 V.
- During the saturation stage, the transistor will be in full operation.
- V_{CE} is 0.1 V (typical value).

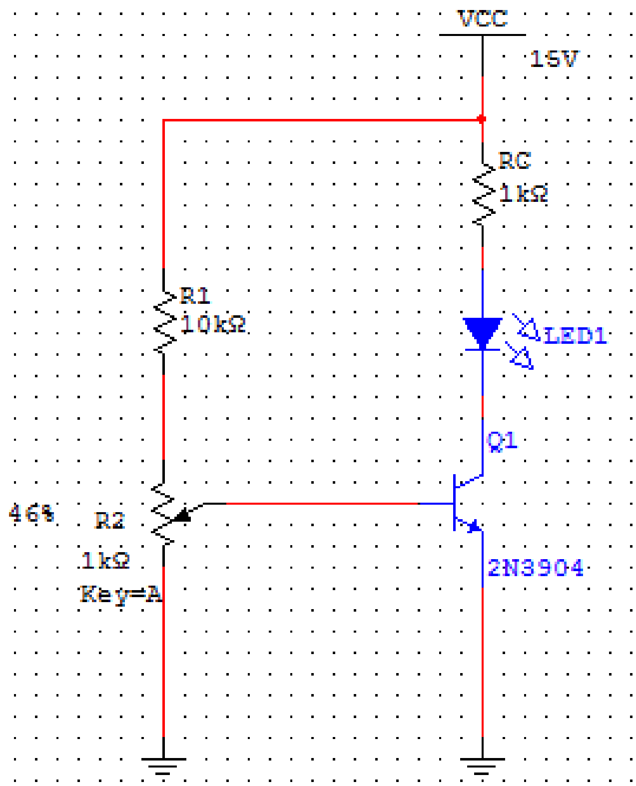

Figure 2-1

2-2 Record your calculated values in the table below:

Calculate V_{RC} by applying Kirchhoff's voltage law to the transistor's collector.

Calculate saturation I_C using Ohm's law in VRC.

Table 2-1

Data	Calculated Values
VCE (cut-off)	
VCE (saturation)	
VRC (saturation)	
IC (saturation)	

2.2 Conclusion

These questions will help you review and interpret the concepts learned in the lab.

2-1 Summarize any observations from the lab that haven’t been addressed elsewhere.

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2-2 List the most important characteristics and applications of bipolar junction transistors.

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2-3 Explain the different regions of operation of a bipolar junction transistor.

2-4 Discuss the operation of the BJT as a switch through the manipulation of its inputs.

Section 3: Transistor Amplifiers

3.1 Transistor Amplifiers

You will now expand what you know about transistor amplifiers by completing the following activity.

1. Use the NI ELVIS III to set up the circuit shown in the following illustration:

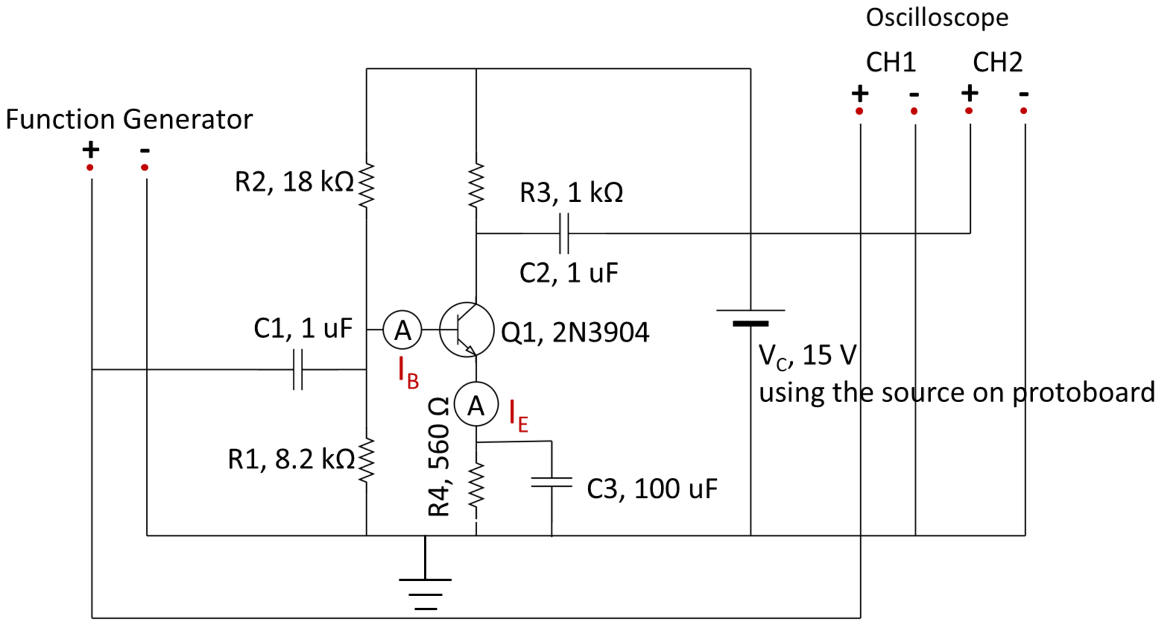

Figure 3-1 Circuit Set-up

Pay attention to the polarity of the capacitor (注意电容的极性，长进短出)

2. From the Instruments tab of Measurements Live, open the following instruments:

   - Digital Multimeter (DMM)
   - Function Generator (FGen-Arb)
   - Oscilloscope

Note: For more information about accessing Measurements Live and launching instruments, visit http://www.ni.com/documentation/en/ni-elvis-iii/latest/getting-started/launching-soft-front-panels/.

3. Start the Function Generator with the following settings:

Table 3-1 Function Generator settings

Frequency	100 Hz
Amplitude	0.2 Vpp

Given a β of 100 and V_{BE} of 0.7, calculate I_B and I_E, and write the calculated results in Table 3-2 below.

After you have calculated your results, use the DMM to measure I_B and measure I_E. You can measure from the exposed metal leads or create a measurement point using a wire or header pin. Write the measured values in Table 3-2 below.

Table 3-2

Data	Calculated Value	Measured Value
I_B		
I_E		

Test the V_{BE} and calculated the β, and fill in the Table 3-3 below.

Table 3-3

Data	Given Value	Measured/calculated Value
β	100	
V_{BE}	0.7	

3-1 Do the measured values correspond to the calculates values? Why or why not?

Determine Gain Using the Oscilloscope

1. Using your oscilloscope measure:
    - The function generator's signal at one channel
    - The amplifier's output on the other channel
2. Adjust the Time/Div and Volts per division to see both signals at once.
3. Include the figure in your lab report.

3-2 Calculate linear gain (Output Vpp/ Input Vpp). Calculate gain in dB and write the results below.

Oscilloscope Gain (dB) =

3.2 Frequency Response of the Amplifier

1. Click **Stop** on the Function Generator and the Oscilloscope.
2. Open the Bode Analyzer.
3. Set the Bode Analyzer as indicated below:

Table 3-3 Bode Analyzer Settings

Stimulus Channel	
Start Frequency	10 Hz
Stop Frequency	5 kHz
Cursors	On

4. Perform the reading and analyze the results by pressing **Run**.

3-3 Use the cursors to find the gain at 100 Hz and write it down. **Mention this result in your lab report.**
Bode Gain (dB) =

3-4 Does the measured gain coincide with the gain found using the oscilloscope? **Mention this result in your lab report.**

3.3 Conclusion

These questions will help you review and interpret the concepts learned in this section of the lab.

3-5 Record any observations that you haven't noted above.

3-6 List the most important characteristics and applications of a transistor amplifier.

3-7 Discuss how, in the previous steps, you measured the voltage gain of a transistor amplifier circuit.

3-8 What happens to the amplified signal from a transistor amplifier if we increase the input signal amplitude?

Section 4: Emitter Follower Amplifiers

4.1 Simulate: Emitter Follower Amplifiers - Voltage Response

As you saw in *Section 3*, the main role of a transistor is to take a relatively small input signal and make it larger by increasing the signal voltage. You also looked at the three standard BJT amplifier configurations.

In this section, you will build a configuration of components that form a commonly-used transistor amplifier called the emitter follower or common collector. With this amplifier, the voltage gain is always slightly less than 1. This means the voltage will not increase but the current gain can be higher than 1. Emitter followers are commonly used to amplify the current of a signal, usually for a low impedance load such as a speaker.

In this activity, you will investigate the voltage response of an emitter follower circuit using Multisim Live.

1. Click the link below to open the Multisim Live circuit.
2. https://www.multisim.com/content/zGWUhynstWEfCHexu6GREc/emitter-follower-v/open

Observe the Voltage Response

1. Examine the emitter follower circuit, simulated with Multisim Live.

Note: The AC signal source produces a 10 kHz, 5 Vpp (2.5 V Pk) signal.

2. Click **Run**.

3. Measure the voltage response using the probes PR1 and PR2.

    - PR1 and PR2 should display essentially the same waveform. Hover your cursor over different points on the output curve and observe how the cursor shifts between the *blue input plot* and the *green output plot*.

Note: The output voltage has almost exactly the same phase and amplitude as the input voltage. This is the reason that this amplifier is called a follower. The voltage output follows the voltage wired to the base of the transistor

Observe the Current Response

1. You will now observe the current gain in an emitter follower amplifier.
2. Click the link below to open the Multisim Live circuit

3. https://www.multisim.com/content/B2DuX5YtreVZMtNVj6r2gW/emitter-follower-a/open

Record Peak-to-Peak Current Values

1. Click **Run**.
2. Measure the current response using the probes PR1 and PR2.

4-1 Use the table below to record the peak-to-peak current from Probe 1 and Probe 2.

Table 4-1

Probe	Peak-to-Peak Current (µA)
Probe 1 – Input Current	
Probe 2 – Output Current	

4-2 Calculate the current gain using the following equation:

$A_I = \frac{I_{out}}{I_{in}} =$

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Click **Stop** when you are done. **Mention this result in your lab report.**

4.2 Simulate: Identify the Relationship between Resistors and Current Gain

Typically, the load of a circuit (RL, in this simulation) is not going to change. If we assume that the load in a real-life example of this circuit is an audio speaker, the speaker is not going to change its physical properties.

It would be more appropriate to change the resistance RE to examine how the current gain will respond.

1. Modify the resistance of RE by clicking its value and typing or using the slider to select a new one.

4-3 Calculate the circuit gain for a range of resistance values by:

- Modifying the resistance (RE)
- Running the simulation
- Making the measurement
- Stopping the simulation

Then, complete Table 4-2 below:

Table 4-2

Resistance of RE	Probe 1 – Input Current (µA)	Probe 2 – Output Current (µA)	Gain
1k			
2k			
3k			
5k			

Mention this result in your lab report.

Note: The relationship between RE and gain is non-linear. Because the load is going to be different for every application, the combination of resistors in a transistor amplifier is often customized for a specific application.

4.3 Conclusion

These questions will help you review and interpret the concepts learned in the lab.

4-3 Summarize any observations from the lab that haven’t been addressed elsewhere.

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4-4 In your own words, talk about the purpose of an emitter follower amplifier.

4-5 Give a few application examples of a transistor amplifier.