Lab 9. Transistor Amplifier Part 1

In this lab, you will examine how transistors can be used to create amplifiers and will identify the important characteristics and applications of a transistor amplifier. You will investigate the behavior of a different transistor amplifier configuration.

Learning Objectives

After completing this lab, you will be able to complete the following activities:

1. Learn to polarize a transistor correctly so it can be used to amplify an AC voltage signal.
2. Learn to use the Bode Analyzer (AC Sweep) to find the amplifier gain.
3. Generate simulation results showing amplifier behavior.

Required Tools and Technology

Platform: NI ELVIS II/II+ Instruments used in this lab: ● Instrument 1: Function Generator ● Instrument 2: Oscilloscope ● Instrument 3: Variable Power Supply **Note:** The NI ELVIS Cables and Accessories Kit (purchased separately) is required for using the instruments.	View User Manual: https://bit.ly/36DFFrv https://bit.ly/36CnQZH (Credit to Clemson University) View Tutorials: https://bit.ly/35Ae9Kc (Credit to Colorado State University) Install Soft Front Panel support: https://bit.ly/2NbhTv6
Hardware: NI ELVIS II/II+ Default Prototyping Board	View Breadboard Tutorial: http://www.ni.com/tutorial/54749/en
Hardware: Electronics Kit	• Various values of resistors • NPN transistor, 2N3904 or similar
Software: NI Multisim Live	Access online http://multisim.com View Help http://multisim.com/help/

1. Background Information

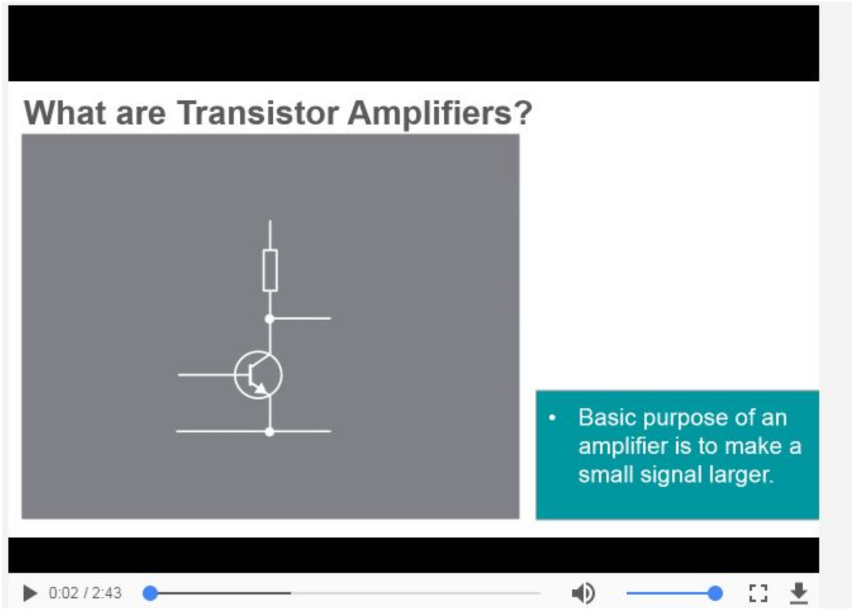


Figure 1-1 Video Screenshot. View the video here: youtu.be/ZCj_WE30oHQ

Video Summary

- An amplifier is designed to make smaller input signals larger by increasing the signal voltage.
- Transistor amplifiers are common to most electronics we use every day.
- There are three types of common amplifiers: common collectors, common base amplifier, and the common emitter amplifier.

1.1. What Are Transistor Amplifiers?

The main role of an amplifier is to take a relatively small input signal and make it larger by increasing the signal voltage. There are many different varieties of amplifiers. There are three standard configurations for Bipolar Junction Transistors (BJT): the common base amplifier, the common collector amplifier and the common emitter amplifier.

1.2. Why Are Transistor Amplifiers Important?

Transistor amplifiers are commonly found in a variety of electronics, and many applications would not exist without them.

1.3. How Can We Use Transistor Amplifiers?

The common collector amplifier, known as an emitter follower, is one of the three basic single-stage BJT topologies. This configuration is typically used as a voltage buffer. In this configuration, the base is used as the input, the emitter as the output, and the collector is common to both. The circuit's impedance particularities make it ideal to use it as a voltage buffer, where the circuit provides current gain instead of voltage gain. A small change to the input current results in a large change in output current. This configuration is often used in combination with a Zener diode to create a voltage regulator. You will build an emitter follower amplifier in *Section 2*.

The common base amplifier is another one of the three basic single-stage BJT amplifier topologies. This configuration is typically used as a current buffer or a voltage amplifier. This amplifier uses the emitter terminal as the input and the collector terminal as the output. The base is connected to ground or "common". This type of amplifier is occasionally used as a microphone preamp due to its unusually low input impedance. It is more popular in high frequency amplifiers in the VHF and UHF ranges, where its isolation between input and output help to prevent feedback and lead to higher stability.

The common emitter amplifier is the last of the three basic single-stage BJT amplifier topologies. This configuration is typically used as a voltage amplifier and this is the type of amplifier you will build in lab 9. This type of amplifier uses the base terminal as the input and the collector as the output. The emitter is common to both: either tied to a group reference or a power supply rail. Common uses for these types of amplifiers are in radio frequency circuits and low-noise amplifiers.
Note: Each of the three types of single-stage BJT amplifiers have different circuits that they are best suited for. Very often, one type of amplifier is used in conjunction with another depending on the needs of the circuit.

1.4. How Does a Transistor Amplifier Work?
When operating in the active region, a transistor can be used as an AC signal amplifier. Consider the following example of a common-emitter amplifier:

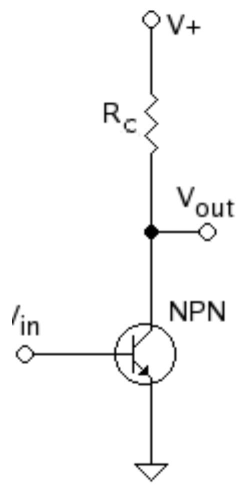


Figure 1-2

In the ***active region***, the transistor behaves in a linear manner, so the following formula applies:

(*Equation 1-1)*

$$I_C = \beta I_B$$

where β is the transistor's current gain.

It is necessary to polarize the transistor for it to amplify properly. A transistor's polarization consists in the application of a base voltage that ensures it will operate in the active region. A voltage divider connected to the power supply V_{CC} is usually used.

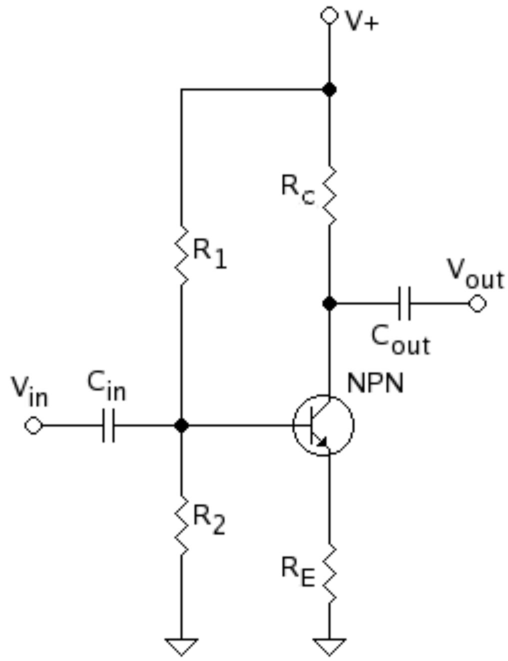


Figure 1-3

To find the base voltage, Thevenin's equivalent is applied to calculate Thevenin's voltage (V_{Th}) and resistance (R_{Th}).
In this case, V_{Th} is simply the divided voltage of V_{CC} between resistors R_1 and R_2:

$$V_{Th} = V_{CC} \frac{R_2}{R_1 + R_2}$$

(Equation 1-2)

R_{Th} for this circuit is the parallel resistance of R1 and R2:

$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2}$$

(Equation 1-3)

You can calculate the emitter current I_E using the following expression:

$$I_E = \frac{V_{Th} - V_{BE}}{R_E + \frac{R_{Th}}{\beta}}$$

(Equation 1-4)

Taking $I_E \approx I_C$ we can say that I_E is βI_B. If you replace I_E in the formula above, and use 0.7 V as V_{BE}, you get the following expression:

$$I_B = \frac{V_{Th} - 0.7}{\beta R_E + R_{Th}}$$

(Equation 1-5)

All of these equations are used to design a circuit that works within the linear operation limits of an amplifier and allow us to select the proper resistor and capacitor values.
Voltage Gain

Voltage gain is the relationship between the output and input voltages of the amplifier:

$$A_v = \frac{V_{out}}{V_{in}}$$

(Equation 1-6)

For an amplifying circuit to work properly, it must operate in the linear region without saturating the transistor.
Gain is also expressed in dB:

$$A_v = 20 \log \frac{V_{out}}{V_{in}}$$

(Equation 1-7)

Note: It is important to remember that you are working with AC signals and that the amplifier gain changes based on the frequency. A Bode graph (AC Sweep) is used to find the gain variation.

2. Exercises

2.1. Simulation

In this exercise, you will simulate the behavior of a transistor amplifier in Multisim. You will compare the simulated results with real world results later in the lab.

1. Launch Multisim and build the circuit in figure 2-1
2. Use a 0.1 V peak sine wave for V2 frequency at 100Hz, which can be adjusted by double clicking it.

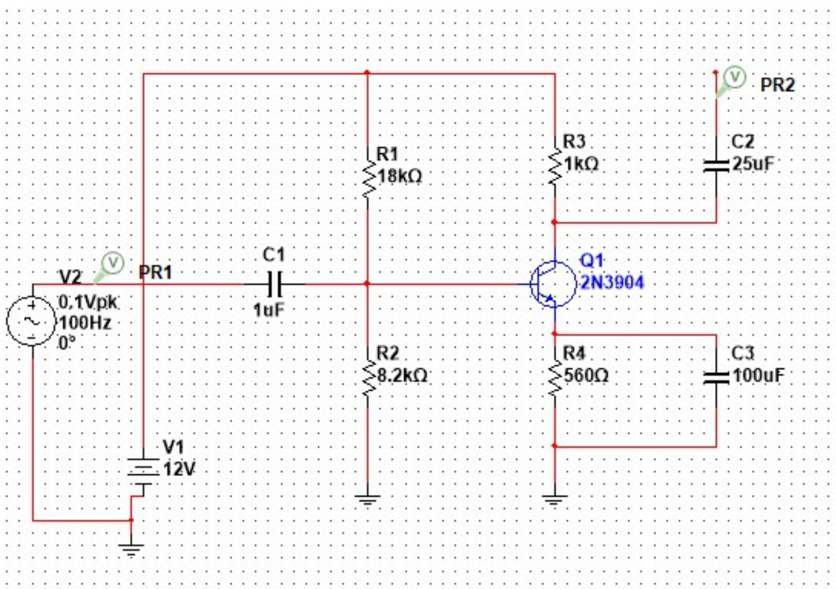
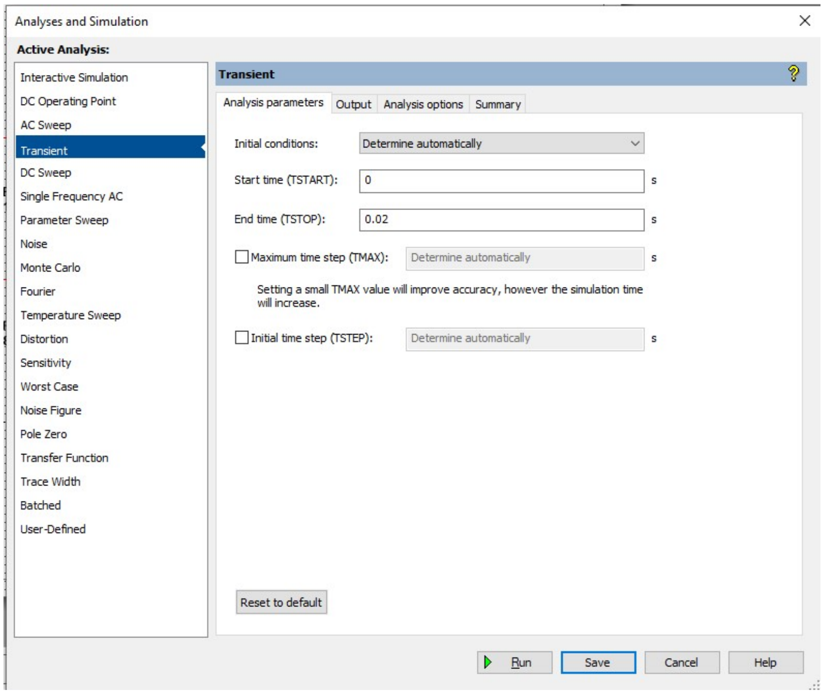
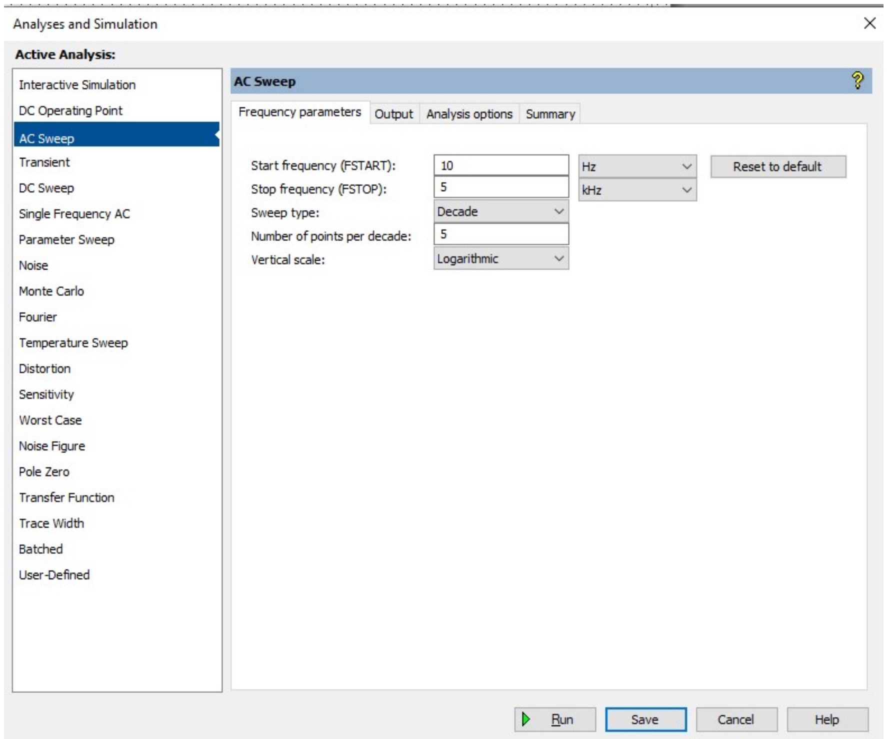


Figure 2-1

3. Run a transient sweep for the input and output (stop time is 0.02s)



4. Observe:
   - The source sine wave on Probe 1 (red)
   - The output sine wave on Probe 2 (green)
   - Notice that the amplitude of the output sine wave is much larger than the amplitude of the source sine wave.
5. Calculate the gain of the simulated circuit.
   - $A_V = V_{output} / V_{source}$
6. Run an AC Sweep with the settings below to generate a Bode Plot
   - Set the Start Frequency to 10 Hz.
   - Set the Stop Frequency to 5 kHz.



7. Click the Run button
8. Move the cursor to measure the gain at 100 Hz (top graph).
   - Av=?

APPENDIX

The following is the template of the ECE 3313 report. Note that the report must be typed using Microsoft Words/Excel. Please download the template from the Canvas website.

ECE 3313 Lab X Report Your Name

<u>Title:</u> Lab 1: Observation, Modeling, and Communication

NAME: **Partner:**

General Objective: One or two sentences that describe the objective of this specific lab.

1.0 Prelab Activities: If there is any

2.0 Background Activities: Read background information and summarize important theory, equation, etc.

3.0 Procedure: Describe step-by-step procedure, including circuit schematic, calculation, and etc.

4.0 Results: A lab often includes questions. Please include your answer under the result sections.

- **4.1 Simulation Results:** Make sure to fully discuss about the results, figure, etc.
- **4.2 Experimental Results:** Make sure to fully discuss about the results, figure, etc.

5.0 Conclusions

Remark: Your lab report should include ALL relevant calculations, pictures and work needed for completion of the experiment. Circuit output validation using Multisim is also required. Detailed explanations for decisions made throughout the lab need to be included in the Discussion section of your report as outlined in the Report Guidelines.

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