Lab 11. Frequency Response of Amplifier

You are required to evaluate frequency response of a transistor amplifier for the lab 11. Your objective is to simulate common source and common emitter amplifiers and examine their frequency response using various ways. You are free to choose any components and parameters. As for the lab report, you are required to submit simulation results and experimental results. Brief explanations of design and procedure are also required.

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 III 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 • MOSFET
Software: NI Multisim Live	Access online http://multisim.com View Help http://multisim.com/help/

1. Background

In addition to being classified by function, amplifiers are classified by frequency response. The frequency response of an amplifier refers to the band of frequencies or frequency range that the amplifier was designed to amplify. You may wonder why the frequency response is important. Why doesn't an amplifier designed to amplify a signal of 1000 Hz work just as well at 1000 MHz? The answer is that the components of the amplifier respond differently at different frequencies. The amplifying device (electron tube, transistor, magnetic amplifier, etc.) itself will have frequency limitations and respond in different ways as the frequency changes. Capacitors and inductors in the circuit will change their reactance as the frequency changes. Even the slight amounts of capacitance and inductance between the circuit wiring and other components (interelectrode capacitance and self-inductance) can become significant at high frequencies. Since the response of components varies with the frequency, the components of an amplifier are selected to amplify a certain range or band of frequencies.

The three broad categories of frequency response for amplifiers are AUDIO AMPLIFIER, RF AMPLIFIER, and VIDEO AMPLIFIER. An audio amplifier is designed to amplify frequencies between 15 Hz and 20 kHz. Any amplifier that is designed for this entire band of frequencies or any band of frequencies contained in the audio range is considered to be an audio amplifier. In the term rf amplifier, the "rf" stands for radio frequency. These amplifiers are designed to amplify frequencies between 10 kHz and 100,000 MHz. A single amplifier will not amplify the entire rf range, but any amplifier whose frequency band is included in the rf range is considered a rf amplifier. A video amplifier is an amplifier designed to amplify a band of frequencies from 10 Hz to 6 MHz. Because this is such a wide band of frequencies, these amplifiers are sometimes called WIDE-BAND AMPLIFIERS. While a video amplifier will amplify a very wide band of frequencies, it does not have the gain of narrower-band amplifiers. It also requires a great many more components than a narrow-band amplifier to enable it to amplify a wide range of frequencies.

Frequency Response of an electric or electronics circuit allows us to see exactly how the output gain (known as the *magnitude response*) and the phase (known as the *phase response*) changes at a particular single frequency, or over a whole range of different frequencies from 0Hz, (d.c.) to many thousands of mega-hertz, (MHz) depending upon the design characteristics of the circuit.

Generally, the frequency response analysis of a circuit or system is shown by plotting its gain, that is the size of its output signal to its input signal, Output/Input against a frequency scale over which the circuit or system is expected to operate. Then by knowing the circuits gain, (or loss) at each frequency point helps us to understand how well (or badly) the circuit can distinguish between signals of different frequencies.

The frequency response of a given frequency dependent circuit can be displayed as a graphical sketch of magnitude (gain) against frequency (f). The horizontal frequency axis is usually plotted on a logarithmic scale while the vertical axis representing the voltage output or gain, is usually drawn as a linear scale in decimal divisions. Since a systems gain can be both positive or negative, the y-axis can therefore have both positive and negative values.

In Electronics, the *Logarithm*, or “log” for short is defined as the power to which the base number must be raised to get that number. Then on a Bode plot, the logarithmic x-axis scale is graduated in $\log_{10}$ divisions, so every decade of frequency (e.g, 0.01, 0.1, 1, 10, 100, 1000, etc.) is equally spaced onto the x-axis. The opposite of the logarithm is the antilogarithm or “antilog”.

Graphical representations of frequency response curves are called **Bode Plots** and as such Bode plots are generally said to be a semi-logarithmic graphs because one scale (x-axis) is logarithmic and the other (y-axis) is linear (log-lin plot) as shown.

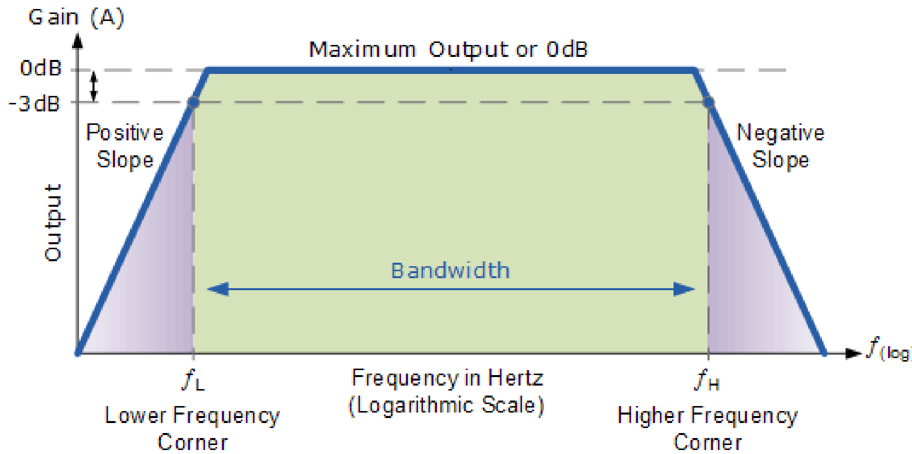

Figure 1. Frequency response (i.e., Bode plot) of typical amplifier

Then we can see that the frequency response of any given circuit is the variation in its behaviour with changes in the input signal frequency as it shows the band of frequencies over which the output (and the gain) remains fairly constant. The range of frequencies either big or small between f_L and f_H is called the circuits bandwidth. So from this we are able to determine at a glance the voltage gain (in dB) for any sinusoidal input within a given frequency range.

As mentioned above, the Bode diagram is a logarithmic presentation of the frequency response. Most modern audio amplifiers have a flat frequency response as shown above over the whole audio range of frequencies from 20 Hz to 20 kHz. This range of frequencies, for an audio amplifier is called its Bandwidth, (BW) and is primarily determined by the frequency response of the circuit.

Frequency points f_L and f_H relate to the lower corner or cut-off frequency and the upper corner or cut-off frequency points respectively were the circuits gain falls off at high and low frequencies. These points on a frequency response curve are known commonly as the -3dB (decibel) points. So the bandwidth is simply given as:

$$\text{Bandwidth (BW)} = f_H - f_L$$

The decibel, (dB) which is 1/10th of a bel (B), is a common non-linear unit for measuring gain and is defined as $20\log_{10}(A)$ where A is the decimal gain, being plotted on the y-axis. Zero decibels, (0dB) corresponds to a magnitude function of unity giving the maximum output. In other words, 0dB occurs when $Vout = Vin$ as there is no attenuation at this frequency level and is given as:

$$\frac{Vout}{Vin} = 1. \qquad\qquad 20\log(1) = 0\ dB$$

We see from the Bode plot above that at the two corner or cut-off frequency points, the output drops from 0dB to -3dB and continues to fall at a fixed rate. This fall or reduction in gain is known commonly as the roll-off region of the frequency response curve. In all basic single order amplifier and filter circuits this roll-off rate is defined as 20dB/decade, which is an equivalent to a rate of 6dB/octave. These values are multiplied by the order of the circuit.

2. Simulation

2.1. Frequency response of common source amplifier

In this simulation activity, you are going to explore the frequency response of common source amplifier by measuring the output at various frequencies, as well as using Bode analyzer.

1. Construct the network of Figure 2 using Multisim and circuit breadboard.

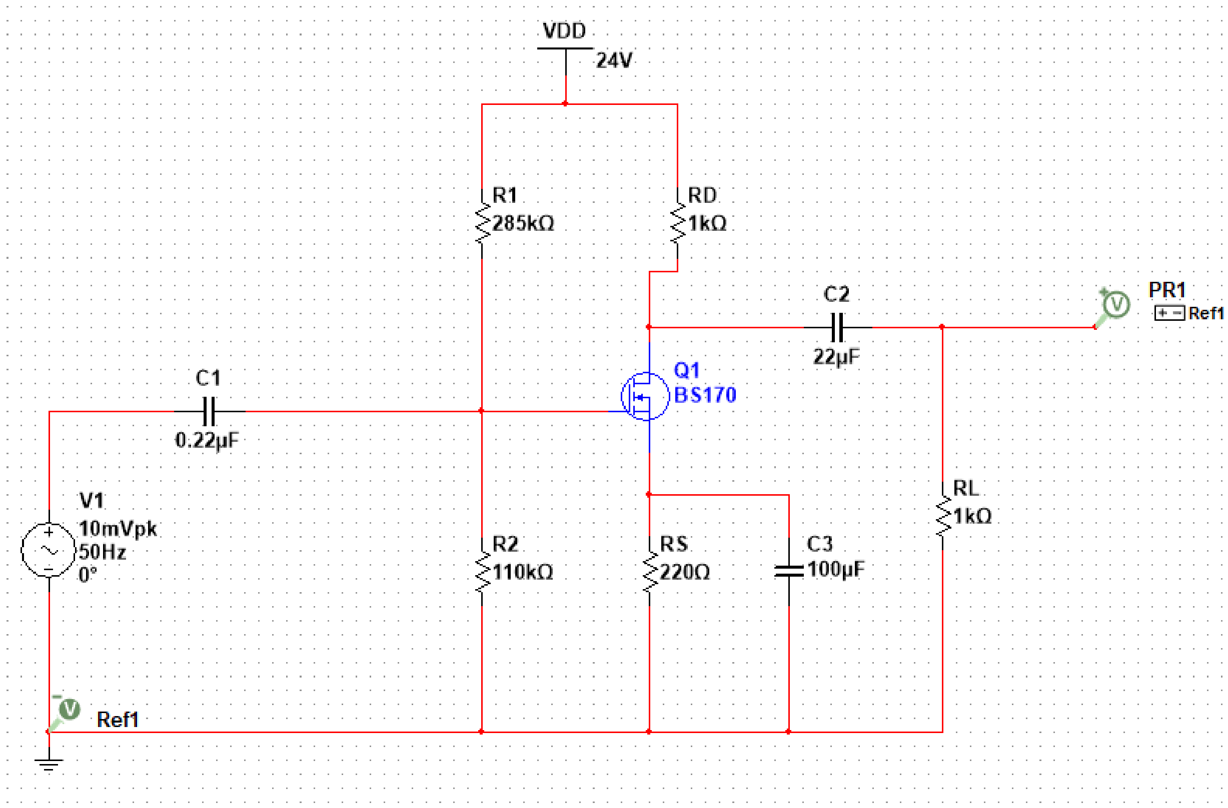

Figure 2 MOSFET Amplifier

2. Fill out Table 2.1 by measuring the output voltage with various input frequencies and calculating the gain in dB
    a. *Recommended to run a Transient Sweep for each case and take y-max*

Table 2.1: Data collection

Frequency (Hz)	V_{Out}	Av (Gain) = V_{Out}/V_{in}	20*log(Av) (dB)
20			
50			
100			
200			
1k			
500k			
1M			
10M			
20M			
50M			
100M			

3. Plot frequency response by calculating $V1 \times 20\log(Av)$
    a. Set the frequency axis to display logarithmically
4. Run an AC Sweep on the circuit using the settings shown in Figure 3.

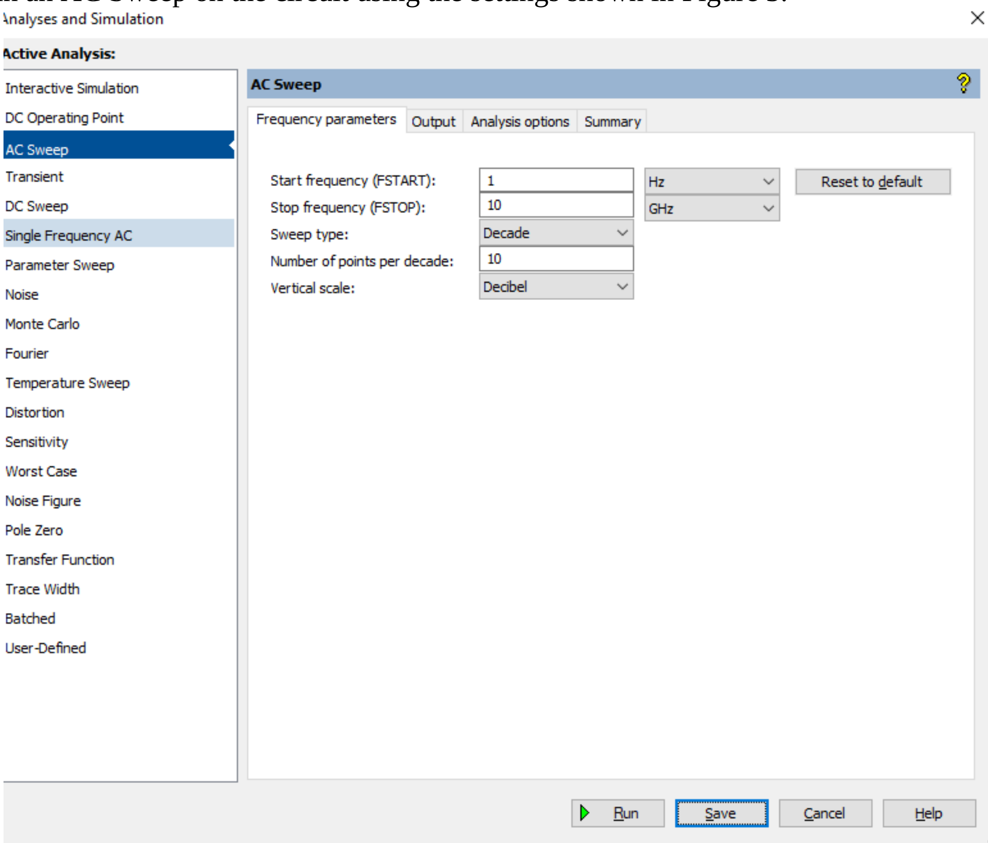

Figure 3: AC sweep setting

5. The output of the AC Sweep shows two graphs, compare the top graph to the one we generated in step 3

2.2. Frequency response of common emitter amplifier

1. Build the circuit in Figure 4.
    Note: This is the circuit we built for Lab 9, with some variations
2. Fill out Table 2.1 by measuring the output voltage with various input frequencies and calculating the gain in dB
    Note: set the scale for the Frequency axis to log

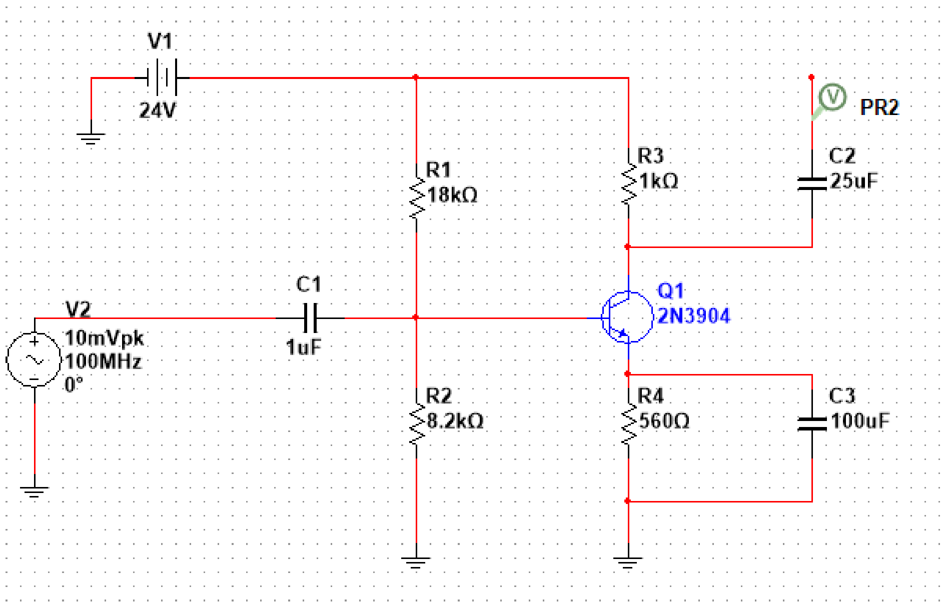

Figure 4: Common emitter amplifier

Table 2.2: Data collection

Frequency (Hz)	V_{Out}	Av (Gain) = V_{Out}/V_{in}	20*log(Av) (dB)
100			
200			
500			
1k			
2k			
10k			
50k			
100k			
1M			
10M			
20M			
50M			
100M			

3. Run an AC Sweep with the same settings as 2.1 (see Figure 3)
4. Compare the graph we generated by hand and the graph generated with the AC sweep

Additional Questions

- Compare Graphs from 2.1 and 2.2, does the frequency response differ between the MOSFET and the BJT?
- At what frequency does each graph seem to level off?
- If we changed the resistors and capacitors in either circuit do you expect the shape of the generated graphs to change? Why or why not?

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

Title: 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.