



Mbarara University of Science & Technology
Faculty of Applied Sciences and Technology
Department of Electrical and Electronics Engineering



Laboratory Procedures, Instructions and Manual

Course Name:	Electronic Circuits
Course Code:	BME 2102
Academic Year:	2017/2018



Table of Contents

1. Laboratory Rules and Regulations	3
2. Laboratory Notes	5
3. Lab Report Format.....	5
4. Lab 1: Building Half Wave and Full Wave Rectifiers with Diodes.....	6
4.1 Aims and Objectives	6
4.2 Equipment.....	7
4.3 References.....	7
4.4 Experiment Guidelines and Instructions.....	7
4.4.1 Half-wave Rectifier	7
4.4.2 Full-wave Rectifier	9
5. Lab 2: Designing Audio Amplifiers with BJT Transistors	11
5.1 Aims and Objectives	11
5.2 Equipment.....	11
5.3 References.....	11
5.4 Experiment Guidelines and Instructions.....	11
5.5 Obtaining a Suitable DC Bias	12
5.6 Amplification	12
6. Lab 3: Simulation of Low and High Frequency Response of BJT Amplifiers	13
6.1 Circuit Topology.....	13
6.2 DC Biasing and Mid-band Frequency Response	13
6.3 Low Frequency Response	13
6.4 High Frequency Response.....	14
6.5 Pre-Lab.....	14
6.6 Experiment Guidelines and Instructions.....	15



1. Laboratory Rules and Regulations

A. Accessing the Laboratories

- a) Unauthorized entry into laboratories is strictly prohibited. No entry into the labs will be granted after closing hours and before opening hours
- b) Entry and use of any laboratory and/or equipment is subject to availability, and timetabled practical sessions take precedence over personal work.
- c) The lab technician reserves the right to refuse entry and access to the laboratory or to certain sections of the lab.
- d) No equipment or furniture should be carried out of the laboratory without authorisation.
- e) Vandalising and damaging lab equipment and furniture is strictly prohibited. Any such reckless activity will lead to the invocation of serious disciplinary action.
- f) Strictly no food or drinks should be taken into the laboratory
- g) Emergency exits should be kept clear at ALL times.

B. Laboratory Rules and Safety

1. Before the Lab Session

- a) Always wait for instructions from your instructor before proceeding with the lab exercise
- b) Risk assessment and identifying hazardous material: always assess the riskiness of equipment and materials by studying the danger and warning labels. Always read identification labels:
 - What is it?
 - What harm can it cause?
 - Basic precautions for storage, handling, and useNever handle any substance unless:
 - You know what it is
 - You know how to handle it
- c) Compressed air
 - Hoses under pressure have to be secured.
 - Only use appropriate air nozzles with relief valves
 - Improper nozzles can inject air into the skin
 - Air can enter the blood stream, reach the heart, and cause heart failure and/or death





2. During the Lab Session

- a) Turn off and unplug equipment before removing the protective cover to clear a jam, replace a part, or troubleshoot. Always ask a qualified person to open equipment if this will create exposure to energized parts operating at 50 volts or more.
- b) Ensure that the power is OFF before you start connecting up a circuit. Get your circuit diagram approved by the instructor first, and then connect up the circuit strictly as per the approved circuit
- c) Do not use an electrical outlet or switch if the protective cover is ajar, cracked or missing.
- d) Only use DRY hands and tools and stand on a DRY surface when using electrical equipment, plugging in an electric cord.
- e) Never put conductive metal objects into energized equipment. Avoid wearing metallic, loose jewellery such as rings, watches, neck chains, bracelets, etc.
- f) Always pick up and carry portable equipment by the handle and/or base. Carrying equipment by the cord damages the cord's insulation.
- g) Unplug cords from electrical outlets by pulling on the plug instead of pulling on the cord.
- h) Re-route electrical cords or extension cords so they are not run across the floor, under rugs or through doorways, etc. Stepping on, pinching, or rolling over a cord will break down the insulation and will create shock and fire hazards.
- i) Do not overload extension cords, multi-outlet strips and wall outlets.
- j) Heed the warning signs, barricades and/or guards that are posted when

equipment or wiring is being repaired or installed or if electrical components are exposed.

- k) Always wear closed, rubber-soled flat shoes in the laboratory. Restrain long hair and refrain from wearing loose clothing.
- l) Only handle volatile chemicals under a fume hood and use mechanical transfer devices for toxic chemicals.
- m) In case you notice any abnormal condition in your circuit (like insulation heating up, resistor heating up, etc.) switch off the power to your circuit immediately and inform the instructor immediately
- n) Always keep hot soldering irons in their holders when not in use.

3. After the Lab Session

- a) Clean up all workspaces and properly dispose of waste in the waste bins
- b) Return any equipment and apparatus to their designated storage positions
- c) Lock/tag out any equipment found to be defective
- d) Turn off:
 - Water, gas, and power supplies
 - Heating apparatus
 - Lights
- e) Lock the door upon exiting

C. Handling Emergencies

- a) Ensure that you know the location of all emergency exits, and keep these clear of obstacles at all times
- b) In case of a fire, exit the laboratory and building immediately. Do not attempt to put out the fire using materials other than the fire extinguisher.
- c) Contact your instructor/lab technician immediately in case of any injuries or accidents



2. Laboratory Notes

All students are encouraged to purchase a Laboratory Notebook. As a part of training to be a scientist, students should maintain a personal notebook just as a research scientist does. This lab notebook will not be graded, but the student must have one and use it. A lab notebook with a sewn-together binding is preferred.

Here is a guideline for lab notebooks: a notebook should contain sufficient detail so that useful information and data can be obtained at a later time when you are writing your lab report, which will be marked. In the notebook, the student should:

- Draw a schematic diagram for every circuit that is built. Label this diagram with part numbers, pin designations, output/input designations, show the major connections to external power supplies, etc.
- List the instruments used by type and model, oscilloscope, multimeters, function generators, etc.
- Draw the appearance of the oscilloscope display, if used and indicate the vertical and horizontal scales, with units record a table of all measurements. include units (e.g. mV) for inputs and outputs.
- Always list more than one measurement as an error check

3. Lab Report Format

For each Lab, students will individually prepare a lab report for grading. This report is **not** the same as the lab notebook, and the notebook is not a substitute. Reports should be organized as a brief introduction, and then an experimental section that is organized according to the section number.

- **Preface:** a brief introductory paragraph, ≈ 30 words, describing the report's theme
- **Experiment:** Apparatus, Procedure (a maximum of three sentences to explain: what was **measured**, how it was measured, what was varied, how errors were estimated*
- **Results:** where it is appropriate, this should include: table and/or graph of results, label each curve and draw smooth curves through data points, label axes and indicate units, sketch or print of the oscilloscope display, if one was used.
- **Discussion:** Briefly answer the questions (if any) posed in the lab procedure. Also discuss, in a few sentences the features of the outputs to demonstrate that you understand their significance
- **Conclusions:** Draw conclusions from the results you obtained and give reasons/explanations for any discrepancies noted. Provide recommendations (if any).
- **Appendix:** In this section, attach any screenshots, photos of graphs, etc that are too long to fit in the main body of your report.

Handwritten lab reports are adequate, but typewritten reports are also welcome. Be brief, but write in clear, complete sentences.



Report Grading Breakdown

Executive summary	20%
Discussion of results	20%
Sample calculations	20%
Conclusions	20%
Appendix	10%
English usage, completeness, neatness	10%

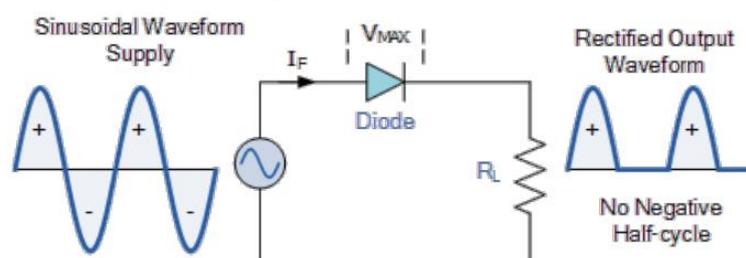
4. Lab 1: Building Half Wave and Full Wave Rectifiers with Diodes

4.1 Aims and Objectives

The main purpose of this lab is to make students familiar with the concepts and some applications of diodes in AC to DC signal conversion.

Diodes are widely used in switching circuits to *clamp* or *clip* input voltages to ensure that they do not go negative. Diodes used for this purpose are known as *small signal diodes* and are designed to switch small currents at high speed. Diodes are also used extensively in power supply circuits where they are used to *rectify* the alternating mains supply to produce a DC output. The process of converting a sinusoidal AC voltage to a DC voltage consists of two steps: (i) The first step is to remove or invert the negative half-cycles of the input voltage. Diodes are used for this purpose. (ii) The second step is to reduce the fluctuations of positive half-cycles. Capacitors are used for this purpose. Such a system is generally referred to as a rectifying bridge.

Diodes are one of the most basic electronic devices that have many applications. They are used as rectifiers (rectifying diodes), voltage regulators (Zener diodes), light sources (LEDs and Laser Diodes), photodetectors, and optical power generators (solar cells). The most basic application of diodes is for AC to DC signal conversion. By definition, an AC signal fluctuates with time. Imagine a sinusoidal AC signal that half of the time provides positive current (voltage), and the other half negative current (voltage) as shown on the left side of the figure below.





We employ a rectifying device (diode) to filter out the negative current and pass through the positive current as shown on the right hand side. Of course, in order to observe the signal, we need to monitor the voltage across a resistor which is called a load resistor indicated by R_L in the figure. The diode allows only the forward current I_F to go through and it blocks the reverse current which leads to the elimination of the negative parts of the waveform. When a positive voltage is applied to the diode it allows current to flow through it. The current increases with the "forward biased" voltage. It turns out that the current increases exponentially with the applied voltage. When a negative voltage is applied, the diode allows very little current to pass through. The diode appears to block the current when a "reverse bias" voltage is applied. Note that a diode will "turn on" at threshold voltage which depends on the diode material. For example, for silicon diodes, the threshold voltage is about 0.7 volts. Recall also that the diode will break down and not conduct if the negative voltage is increased beyond a maximum allowed value. The "breakdown" voltage and other characteristics of diodes are often described in their manufacturer's specification sheets.

4.2 Equipment

- Oscilloscope
- Function generator
- Conventional diodes
- 10 k Ω resistors
- 560 Ω resistors
- Capacitors
- Breadboard
- BNC cables

4.3 References

This lab handout is intended for use with the following textbook:

Horowitz and Hill
The Art of Electronics
2nd Edition, 1989/1990
Cambridge University Press

4.4 Experiment Guidelines and Instructions

4.4.1 Half-wave Rectifier

- Build and connect up the half-wave rectifier circuit as shown in Figure 1, where $R_1 = 10\text{k}\Omega$. Switch on the scope, and prior to making any connections, use the AUTO SET button to initialize both channels.

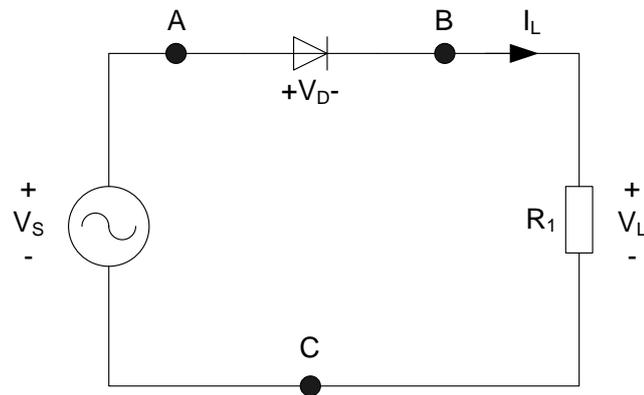


Figure 1: Half wave rectifier circuit

- Set up V_s using the Function Generator, and use the appropriate controls and a BNC-BNC cable to obtain a sine wave signal with a frequency of 50Hz and a peak to peak voltage 4.0V, using the 50Ω output. Ensure that the DC OFFSET button on the frequency generator control panel has been pushed in. Use the SEC/DIV and VOLTS/DIV dials to obtain a suitable display on the screen, so that you can adequately see two cycles. Note down the corresponding settings.
- Once you have set up V_s , draw this signal in your lab book, noting down the waveform's dimensions and scope settings.
- Apply this signal to your circuit, by connecting a BNC-croc clip cable from the Frequency Generator to points A (red) and C (black – this is the earth/common point), and use another lead to observe this signal on CH1 of the scope. On Channel 2, observe the waveform at B (red) with respect to earth at C (black). Use the same VOLTS/DIV as you used when setting up V_s .
- Draw V_{BC} in your lab book, noting down the dimensions (peak-to-peak voltage, period) and scope settings. Note how V_{BC} is periodic (i.e. repetitive at equal time intervals).
- **Questions:** Based on your observations from this Section (3.1), explain why the circuit you constructed performs *half wave* rectification? Explain what would happen if you placed a capacitor in parallel with the resistor R_1 in Figure 1. What does the waveform look like now? Draw it in your lab handbook.



4.4.2 Full-wave Rectifier

- A full wave rectifier will be constructed by adding a second diode to the circuit as shown in Figure 2 below.

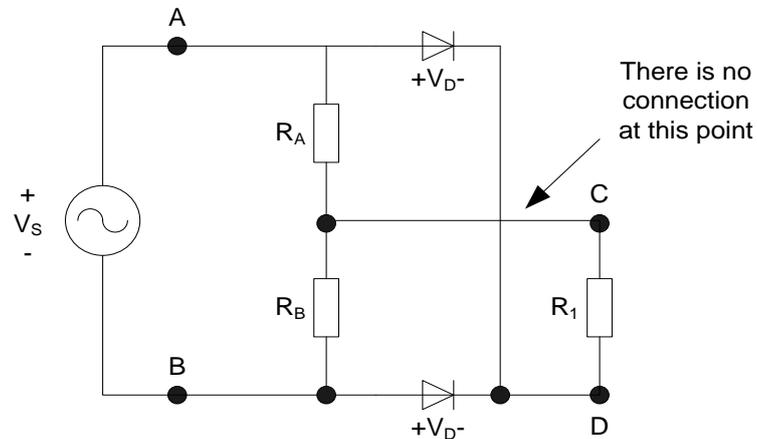


Figure 2: Full wave rectifier circuit

- You will need to set up V_s by using the function generator so that it produces a sine wave from its 50Ω output, with a frequency of 50Hz , and a peak to peak voltage of 12V . Use the appropriate controls and leads to set up and test the required waveform, which should be displayed on Channel 1.
- Draw this sine wave in your lab book, noting down its dimensions (period, frequency, amplitude), and the corresponding scope settings.
- Because the earth of both the oscilloscope and Function Generator are not isolated, scope measurements for the circuits of Figures 1 and 2 are not possible using the known conventional techniques. Thus, the scope has to be set up to function in differential mode. A consequence of this set up is that you will only be able to use the scope to measure one waveform, which in this case will be the output of the circuits. Therefore, make sure you have set up your input waveform correctly before making the following adjustments to the way the scope operates.
- To set the scope up in differential mode, follow these steps. If you are unsure about the above procedure, ask a member of staff for help.
 - Set both Channel 1 and Channel 2 to DC coupling
 - Enable the red trace, i.e. press the red MATH MENU button
 - Set the scope to display CH1 – CH2
 - Connect BNC-croc clip cables from both channels
 - Connect the black ends of the cables together



Mbarara University of Science & Technology
Faculty of Applied Sciences and Technology
Department of Electrical and Electronics Engineering

- vi. Set both channels to 2V/DIV
 - vii. Connect the red cable from Channel 1 to point D
 - viii. Connect the red cable of Channel 2 to point C (earth point).
- Construct the circuit of Figure 2 on your breadboard, where $R_A = R_B = 560\Omega$ and are resistors that provide a mid-point reference node at C. $R_1 = 10k\Omega$, and C is the earth point. Connect V_s to your circuit, but do not use the scope to measure it, as the scope's earth will affect what is displayed on the output, so it is only necessary to measure the output, using the procedure outlined above.
 - To measure the output, use steps (vii) and (viii) as mentioned above. Draw the waveform in your lab book, noting the dimensions and scope settings. Based on your observations, can you explain why this circuit performs full wave rectification?
 - **Questions:** Based on your observations from this Section (3.2), explain why this circuit performs full wave rectification? What would happen to your output signal and circuit if you used resistors of bigger resistances or smaller resistances than is instructed in the procedures above?



5. Lab 2: Designing Audio Amplifiers with BJT Transistors

5.1 Aims and Objectives

The purpose of this lab is to enhance your understanding of BJT amplifiers in the common-emitter configuration. A single stage amplifier will be designed and analyzed from an applications perspective rather than a theoretical perspective.

An amplifier is an electronic circuit that is used to raise the strength of a weak signal. The process of raising the strength of a weak signal is known as amplification. One important requirement during amplification is that only the magnitude of the signal should increase and there should be no change in signal shape. A long time ago, before the invention of and proliferation of easy to use op-amps, electrical engineers had to build amplifiers out of discrete transistors, resistors and capacitors. While this is seldom done anymore except for specialized applications involving low-noise or RF, it is important to be able to design single-stage amplifiers to get a good understanding of circuit design fundamentals. Furthermore, a good foundation with discrete amplifiers is essential if one wishes to pursue a career as an IC design engineer or an RF engineer. In this lab, the scope will be limited to just BJTs of the Common Emitter (CE) configuration for the sake of time.

5.2 Equipment

- Dual Output Power Supply
- Resistors
- Oscilloscope
- Capacitors
- Breadboard
- NPN transistors (BC107 or similar) of $\beta = 190$
- Jumper Wires
- Scope Probes
- Digital multimeter

5.3 References

This lab handout is intended for use with the following textbook:

Electronics Analysis and Design Laboratory Part 1
Professor Neil Goldsman
Department of Electrical and Computer Engineering
University of Maryland
College Park, MD 20742

5.4 Experiment Guidelines and Instructions

When a transistor is used as an amplifier, the first step is to choose a proper configuration in which the device is to be used. Then the transistor is biased to get the desired Q-point/operating point. The signal is applied to the amplifier input and gain is achieved by way of an amplified signal at the output.



5.5 Obtaining a Suitable DC Bias

- Set up the circuit on your breadboard as shown Figure 1 below, with $V_{CC} = 15V$
- Use the preceding equations to theoretically determine V_C , V_B , V_E , and I_C , I_E .
- Now measure the voltages at V_C , V_B and V_E , and then determine I_C , I_B , and I_E
- Compare the measured and calculated values. If the DC voltages measured are not satisfactory (not the same as the calculated values); they must be corrected before proceeding further.

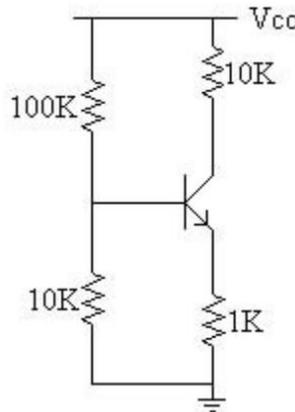


Figure 1

5.6 Amplification

- To the circuit you already built in Figure 1, add capacitors to the input and output as shown in Figure 2.
- Apply an input signal to the circuit as shown in the Figure. For V_{in} , use a 0.1V, 100KHz signal from your wave generator.
- **Question:** Determine the voltage gain. Sketch V_{out} versus V_{in}
- Increase the input signal amplitude until the output gets clipped. This clipping represents distortion which usually means that the output signal is not an exact replica of the input. The output amplitude right before clipping occurs is called the swing of the amplifier.
- **Questions:** What is the swing of your circuit? Why does clipping occur?
- **Question:** Replace RC with a 5 k Ω resistor and determine the new voltage gain and new swing.

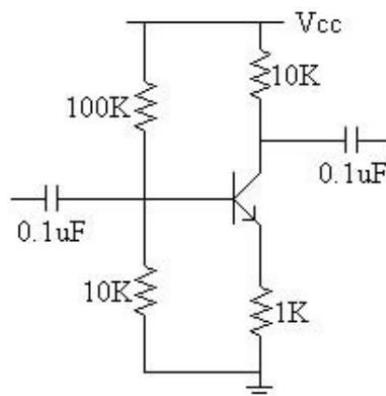


Figure 2

6. Lab 3: Simulation of Low and High Frequency Response of BJT Amplifiers

6.1 Circuit Topology

Circuit Topology Circuit schematic of the common-emitter amplifier is shown in Fig. 1. Capacitors C_B and C_C are used for AC coupling, whereas C_E is an AC bypass capacitor used to establish an AC ground at the emitter of Q_1 . C_F is a small capacitance that will be used to control the higher 3-dB frequency of the amplifier.

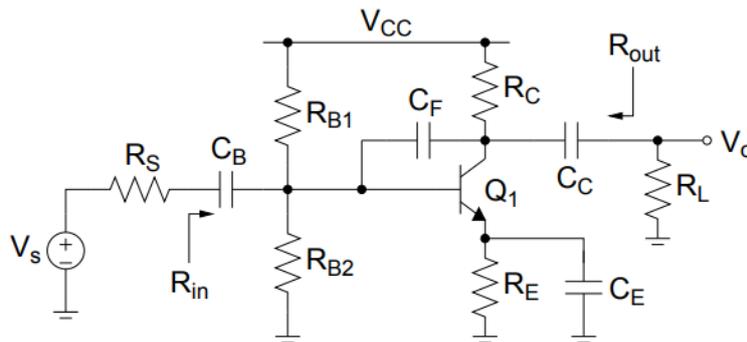


Figure 1: Common-emitter BJT amplifier.

6.2 DC Biasing and Mid-band Frequency Response

For this section, assume that $C_B = C_C = C_E = \infty$ and $C_F = C_\pi = C_\mu = 0$. You can find the DC collector current (I_C) and the resistor values following the analysis provided in Lab #1. Since the topology and the requirements are slightly different, you need to make minor modifications to the design procedure and equations.

6.3 Low Frequency Response

Figure 2 shows the low-frequency small-signal equivalent circuit of the amplifier. Note that C_F is ignored since its impedance at these frequencies is very high.

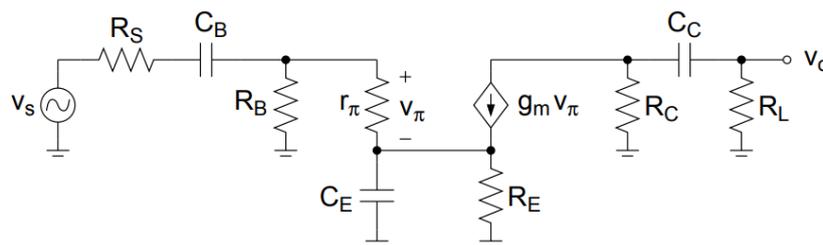


Figure 2: Low-frequency equivalent circuit.

Using short-circuit time constant analysis, the lower 3-dB frequency (ω_L) can be found as:



$$\omega_L \approx \frac{1}{R_{1s}C_B} + \frac{1}{R_{2s}C_E} + \frac{1}{R_{3s}C_C} \quad (1)$$

where

$$R_{1s} = R_S + (R_B \parallel r_\pi) \quad (2)$$

$$R_{2s} = R_E \parallel \left(\frac{r_\pi + (R_B \parallel R_S)}{\beta + 1} \right) \quad (3)$$

$$R_{3s} = R_C + R_L \quad (4)$$

6.4 High Frequency Response

At high frequencies, C_B , C_C and C_E can be replaced with a short circuit since their impedances become very small. Figure 3 shows the high-frequency small-signal equivalent circuit of the amplifier.

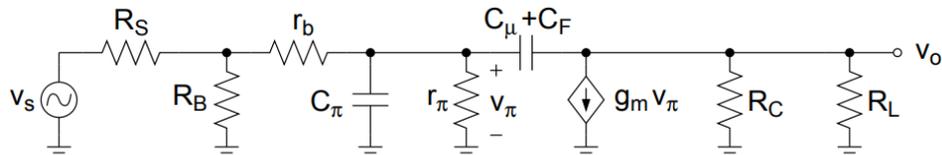


Figure 3: High-frequency equivalent circuit.

The higher 3-dB frequency (ω_H) can be derived as:

$$\omega_H = \frac{1}{R_T \left[C_\pi + (C_\mu + C_F) \left(1 + g_m R_{CL} + \frac{R_{CL}}{R_T} \right) \right]} \quad (5)$$

where

$$R_T = r_\pi \parallel (r_b + (R_S \parallel R_B)) \quad (6)$$

$$R_{CL} = R_C \parallel R_L \quad (7)$$

Thus, if we assume that the common-emitter amplifier is properly characterized by these dominant low and high frequency poles, then the frequency response of the amplifier can be approximated by:

$$\frac{v_o}{v_s}(s) = A_v \frac{s}{s + \omega_L} \frac{1}{1 + \frac{s}{\omega_H}} \quad (8)$$

6.5 Pre-Lab

Assuming $C_B = C_C = C_E = \infty$ and $C_F = C_\pi = C_\mu = 0$, and using a Q2N2222 BJT, design a common-emitter amplifier with the following specifications:

$V_{CC} = 5 \text{ V}$; $R_S = 50 \Omega$; $R_L = 1 \text{ k}\Omega$; $R_{in} \geq 250 \Omega$; $I_{supply} \leq 8 \text{ mA}$; $|A_v| \geq 50$; 0-to-peak unclipped output swing $\geq 1.5 \text{ V}$

1. Show all your calculations, design procedure, and final component values.



2. Verify your results using PSPICE. Submit all necessary simulation plots showing that the specifications are satisfied. Also provide the circuit schematic with DC bias points annotated.
3. Using PSPICE, find the higher 3-dB frequency (f_H) while $C_F = 0$.
4. Determine C_{π} , C_{μ} and r_b of the transistor from the PSPICE output file (in Probe, choose View \rightarrow Output File, scroll down to the section OPERATING POINT INFORMATION, C_{π} , C_{μ} and r_b are listed as CBE, CBC and RX, respectively). Calculate f_H using Eq. (5) and compare it with the simulation result obtained in Step 3.
5. Calculate the value of C_F to have $f_H = 20$ kHz. Simulate the circuit to verify your result, and adjust the value of C_F if necessary.
6. Calculate C_B , C_C , C_E to have $f_L = 500$ Hz. Simulate the circuit to verify your result, and adjust the values of capacitors if necessary.
7. Be prepared to discuss your design at the beginning of the lab period with your TA.

6.6 Experiment Guidelines and Instructions

1. Construct the amplifier you designed in the pre-lab.
2. Measure I_C , V_E , V_C and V_B . If any DC bias value is significantly different than the one obtained from Pspice simulations, modify your circuit to get the desired DC bias before you move onto the next step.
3. Measure I_{supply} .
4. Obtain the magnitude of the frequency response of the amplifier and determine the lower and higher 3-dB frequencies f_L and f_H .
5. At mid-band frequencies, measure A_v , R_{in} , and R_{out} .
6. Measure the maximum un-clipped output signal amplitude.
7. Prepare a data sheet showing your simulated and measured values.
8. Be prepared to discuss your experiment with your TA. Have your data sheet checked off by your TA before leaving the lab.