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SKEE 2752
BASIC ELECTRONICS LAB

EXPERIMENT 1 & 2
PCB DESIGN AND FABRICATION OF BJT SMALL-SIGNAL AMPLIFIER

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OBJECTIVES:

1. To apply the basic laws, theorem and methods of analysis to design an amplifier circuit.
2. To verify the design parameters experimentally.
3. To analyze the amplifier's frequency response.
4. To design layout and construct PCB
5. To compare between the designed and the experimental result of the frequency response.

PARTS AND EQUIPMENT:

- BJT (2N3904)
- Resistors
- Capacitors
- Breadboard
- Multimeter
- Oscilloscope
- Function Generator
- DC Power Supply
- PCB Design Software
- Copper-Clad Board
- Male Connector Header
- Female Connector Header
- Glossy Paper
- Sand Paper
- Laser Jet Printer
- Heat Transfer Laminator
- Drill Press
- Soldering Iron
- Solder wire
- Personal protective equipment: mask, gloves, eyeglasses

INTRODUCTION

An amplifier is an electronic circuit which is used to make the magnitude of the signal applied to its input bigger. In "Electronics", small signal amplifiers are commonly used circuits as they have the ability to amplify a relatively small input signal into a much larger output signal.

In order to amplify all of the input signal with distortion free, DC base biasing is required. The purpose is to establish a Q-point about which variations in current and voltage can occur in response to an AC signal. The biasing of a transistor is purely a DC operation. In applications where very small signal voltages must be amplified, variations about the Q-point are relatively small.

The transistor amplifier is non-linear and an incorrect bias setting will produce large amounts of distortion to the output waveform. Incorrect positioning of the Q-point on the load line will produce either Saturation Clipping or Cut-off Clipping. Thus, it is desirable to set the Q-point of the amplifier half way along the load line.

After the transistor has been biased with the Q-point near the middle of the load line, a small ac-voltage could be applied on the base (v_{in}) (note that large input signal may produce large amounts of amplitude distortion due to clipping). That produces a large ac voltage at the collector (v_{out}). This increase is called amplification.

The amount by which the amplifier "amplifies" the input signal is called gain. Gain is a ratio of output divided by input. Therefore, it has no units but is given the symbol (A): Voltage Gain (A_v), Current Gain (A_i) and Power Gain (A_p). The gain of the amplifier can also be expressed in Decibels (dB).

Frequency response of an amplifier shows how the gain of the output responds to input signals at different frequencies. Generally, the frequency response analysis of a circuit is shown by plotting its gain against a frequency scale over which the circuit is expected to operate. Then by knowing the circuits gain at each frequency point, it helps us to understand how well (or badly) the circuit is affected by the frequency of the input signal.

Fabricating the amplifier circuit enhances learning and technical skills. Hands-on experience with component selection, PCB design, and soldering provides valuable insights into electronics and circuit behavior. It also enables testing and troubleshooting, allowing engineers to identify and resolve performance issues directly. The fabrication process starts with designing and simulating the circuit using software like KiCAD or LTSpice to ensure it functions correctly. Once the design is verified, a PCB (Printed Circuit Board) is prepared by transferring the circuit layout onto a copper-clad board. This involves printing the design, laminating it onto the board, and etching away unwanted copper, leaving only the necessary traces. After etching, components are soldered onto the PCB.

In conclusion, amplifiers play a crucial role in electronics by boosting the magnitude of small input signals. Proper biasing, especially the placement of the Q-point, is essential to avoid distortion and achieve a linear response. The hands-on process of fabricating an amplifier, from designing to soldering, enhances technical skills and practical knowledge. By simulating the circuit, preparing the PCB, and carefully selecting components, engineers can ensure the circuit performs optimally.

PRE-LAB WEEK 1:

A) Figure 1.1 is a voltage divider circuit. Referring to Figure 1.1, produce the design equations for each resistor (R_1, R_2, R_C and R_E) based on the following information:

$V_{CEQ} = ½ V_{CC}$	(1)
$V_{BE(ON)} = 0.65$ V	(2)
$V_E = 0.1 V_{CC}$	(3)
$I_{R2} = 10 I_{BQ}$	(4)
$I_{CQ} = 6$ mA	(5)
$V_{CC} = 12$ V	(6)

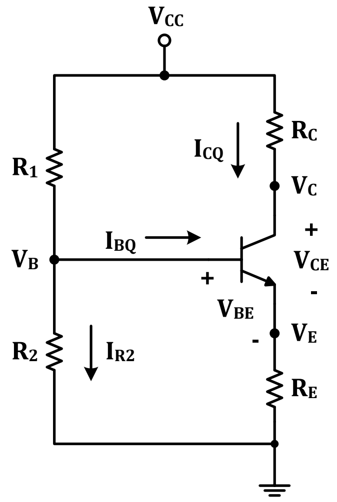

Figure 1.1

Note: Use datasheet 2N3904 for your reference.

B) Design layout of small signal amplifier circuit as shown in Figure 1.2 using KiCAD. Refer to instruction file (Instruction for BJT Amplifier PCB Layout Design using KiCAD). Print the PCB layouts on A4 paper and show it to your supervisor for verification purpose.

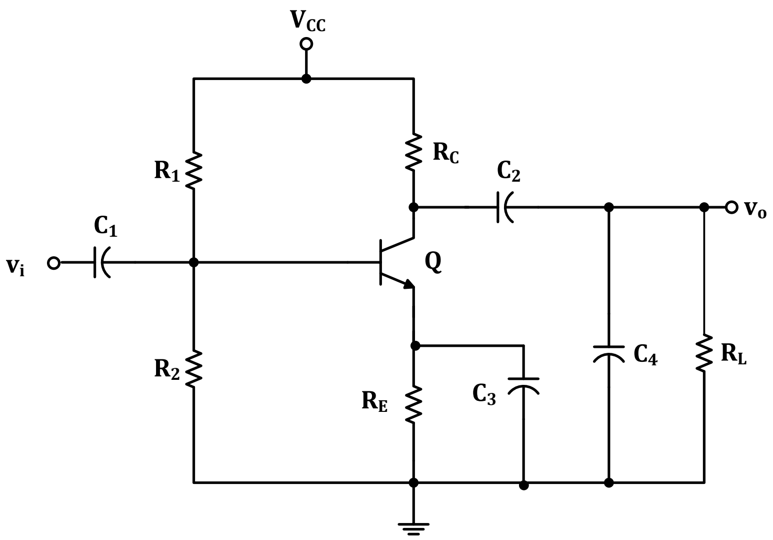

Figure 1.2

IN-LAB PROCEDURES WEEK 1: PCB PREPARATION, DC BIASING AND FREQUENCY RESPONSE

PART A.1: PCB PREPARATION

1. Verify layout with lab supervisor to ensure the PCB layout is error-free and matches the circuit design.
2. Print the verified layout design on a A4 glossy paper using LaserJet printer.
3. Smooth a copper-clad board with fine sandpaper until it is shiny.
4. Secure the printed layout to the copper-clad board using tape.
5. Laminate the board and layout for 15 minutes at 200°C. Ensure the layout is transferred onto the board. **Precaution**: Wear heat-resistant gloves while laminating the board.
6. Submit the board to the PCB lab for etching process to remove excess copper.
7. After 2 days, collect and inspect the etched PCB; if it is not properly fabricated, repeat the laminating and etching process with a new copper-clad board and layout.

PART A.2: DETERMINATION OF DC CURRENT GAIN, $\boldsymbol{\beta_{DC} = h_{FE} = \frac{I_C}{I_B}}$

1. Construct the circuit shown in Figure 1.3 on your own breadboard.
2. Adjust 1 MΩ potentiometer until the collector current, I_C approach to the given Q-point (I_{CQ} = 6 mA).
3. Determine the value of β_{DC}.

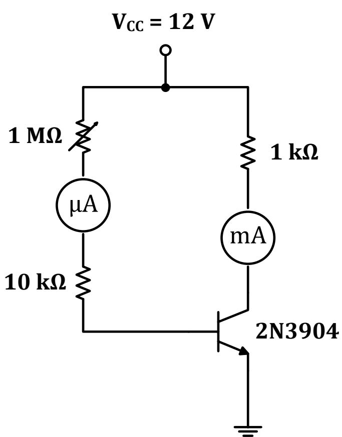

Figure 1.3

PART B: DESIGN OF BIASING CIRCUIT

1. Based on the calculated value of β_{DC} from Part A.2, calculate the values of R_1, R_2, R_C and R_E using your derived design equation in the pre-lab week 1.
2. Construct the circuit (Figure 1.1) and measure the Q-point (V_{CEQ}, I_{CQ}). Compare your results to the calculated values and discuss.

PART C: SMALL SIGNAL AMPLIFIER AND FREQUENCY RESPONSE

1. Wire up the capacitors to your circuit in Part B as shown in Figure 1.4. The capacitors' values will be assigned to you based on the listed values in Table 1.1.
2. Vary the input signal frequency from 100 Hz to 500 kHz. Measure and record the input voltage, v_i and output voltage, v_o. Calculate the voltage gain, $A_v = v_o/v_i$. It is advisable to maintain the amplitude of the input signal, v_i, to about 50 $mV_{(p\text{-}p)}$ for all frequencies. However, please make sure that the output is not clipped or distorted throughout the measurement.
3. You are required to create a frequency response table to tabulate your readings with frequency, input voltage, output voltage and voltage gain (in linear and dB), as the table entries. The table should have at least 10 sets of data (10 different frequencies).
4. Plot the frequency response of voltage gain (dB) versus frequency (logarithmic scale). Mark your cut-off frequencies.

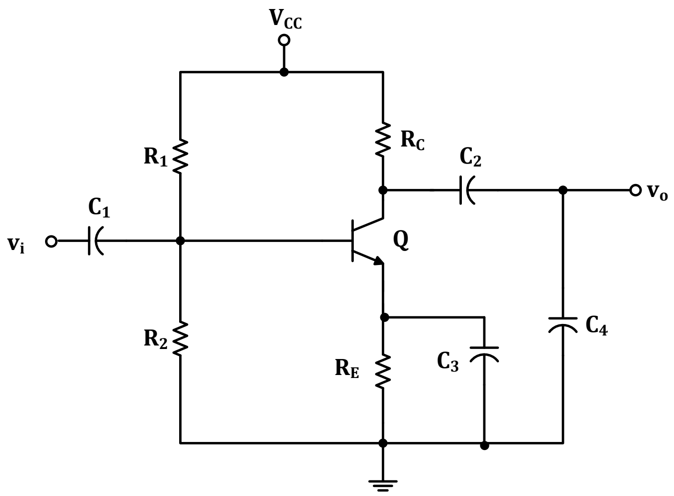

Figure 1.4

Table 1.1: Capacitor values for the small-signal amplifier

Cycle	C_1 (µF)	C_2 (µF)	C_3 (µF)	C_4 (pF)
1	1	22	47	1000
2	2.2	47	33	2200
3	4.7	10	22	4700

Discussion: Week 1

1. How does sanding the copper-clad board affect the adhesion of the printed layout during the laminating process?
2. What are the characteristics of the amplifier that you can observed?
3. What is the function of capacitor C_4?
4. Provide a summary of your observation upon the calculated, the simulated, and the measured results in parts B and C.

Reminding note:

Keep these components as it is going to be used in the following experiment (week 2).

PRE-LAB WEEK 2:

1. Collect the etched PCB after 2 days submitted to PCB lab. Visually inspect the PCB for any incomplete traces or shorts. Use a multimeter in continuity mode to check that all traces are correctly conducting. If there are defects in etched design, repeat the laminating and etching process with a new copper-clad board and layout.
2. Theoretically, determine the mid-band voltage gain, the input and output impedances, the dominant low cut-off frequency, and the high cut-off frequency due to C_4.
3. Simulate the circuit to get the frequency response and determine the mid-band voltage gain and the cut-off values with and without bypass capacitor, C_3 using LTSpice or any equivalent software.

IN-LAB PROCEDURES WEEK 2: PCB COMPLETION AND VERIFICATION

PART D: COMPLETING PCB

1. Drill holes for component leads on the etched PCB. Use a small drill bit (typically 1mm) to drill through the designated pads where the components will be placed.
2. Place the electronic components (used in experiment week 1) into their corresponding positions on the PCB. Use male connector header for test point (Vcc, Gnd, Vi and Vo), female connector header for C_3 (bypass capacitor) and R_L (load resistor).
3. Solder each component lead carefully. Inspect the solder joints and verify there are no unintended short circuits.
4. Trim any excess component leads on the underside of the PCB.

Precaution: Wear eye protection while drilling and soldering. Always work in a well-ventilated area or under a fume hood to avoid inhaling solder fumes. Use a soldering stand to safely rest the soldering iron when not in use.

PART E: SMALL-SIGNAL AMPLIFIER VERIFICATION

1. Ensure all components are attached to the PCB except load resistor, R_L.
2. Apply AC input signal, v_{sig} (50 mV_{pp}) at three different frequencies (low, middle and high). The selection of frequencies is based on the frequency response in Part C (week 1).
3. Observe the output waveform on the oscilloscope to be sure that there is no distortion (if there is, adjust the input signal). Measure the input voltage, v_i, and the output voltage, v_o.
4. Determine the AC voltage gain (A_v) of the amplifier.
5. Remove bypass capacitor, C_3. Repeat steps 2-4.
6. Attach R_L = 10 kΩ and reattach C_3. Repeat steps 2-4.

Discussion Week 2

1. How do you ensure there are no short circuits after soldering?
2. Discuss the effect of C_3 and R_L on the magnitude of voltage gain. Use your measured values to back up your statement.
3. Provide a summary of your observation upon the calculated, the simulated, and the measured results in parts E.
4. Looking at your design, what improvements or optimizations would you suggest for future versions of the PCB? How might these improve performance, manufacturability, or reliability?