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SKEE 2742
BASIC ELECTRONICS LAB

EXPERIMENT 2

<u>BJT SMALL-SIGNAL AMPLIFIER</u>

WEEK 1: BJT AMPLIFIER DC BIASING

OBJECTIVES:

1. To apply the basic laws, theorem and methods of analysis to design an amplifier circuit.
2. To verify the design parameters experimentally.

PARTS AND EQUIPMENT:

- BJT (2N3904)
- 12 V IC regulator (LM7812)
- Capacitor: 100 µF
- Breadboard
- Transformer: 2.25 A, 15 Vrms
- Digital Voltmeter (DVM)
- Oscilloscope
- Function Generator

THEORY

Small-signal Amplifier

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, we can put a small ac-voltage 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 or simply dB.

PRE-LAB WEEK 1:

Figure P2.1 is a voltage divider circuit. Referring to Figure P2.1, produce the design equations for each resistor (R_1, R_2, R_C and R_E) based on the following information:

V_{CE} = 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)

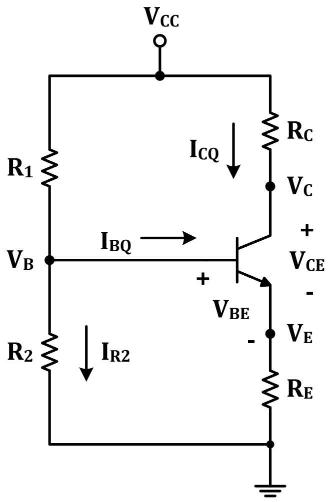

Figure P2.1

Note: Use datasheet 2N3904 for your reference.

IN-LAB PROCEDURES:

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

Construct the circuit shown in Figure E2.1 to determine the value of β_{DC} at the given Q-point.

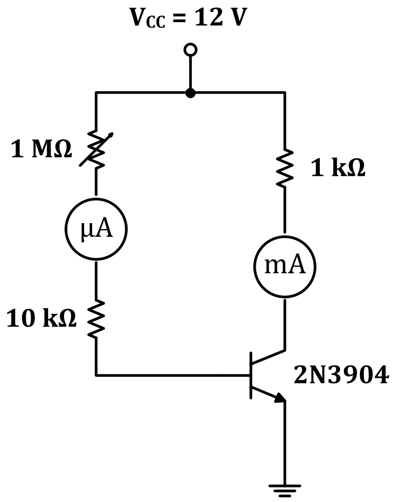

Figure E2.1

PART B: DESIGN OF BIASING CIRCUIT

1. Based on the calculated value of β_{DC} from Part A, 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 P2.1) and measure the Q-point (V_{CEQ}, I_{CQ}). Compare your answers to the calculated values and discuss.

PART C: SMALL-SIGNAL AMPLIFIER

1. Wire up the capacitors to your circuit in Part B as shown in Figure E2.2. The capacitors' values will be assigned to you based on the listed values in Table 2.1.

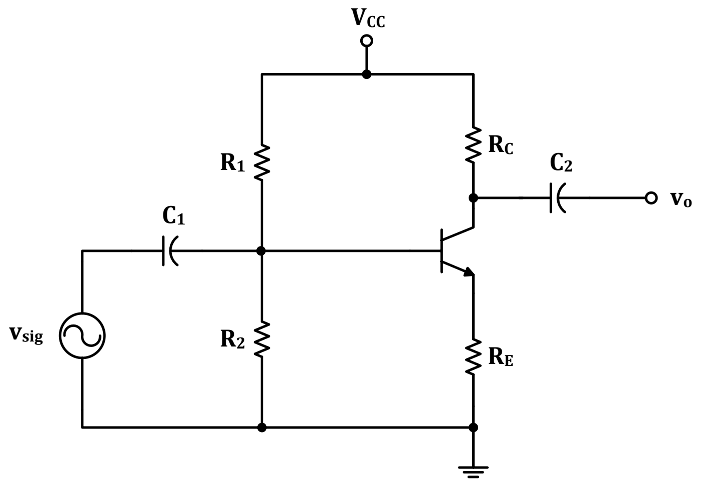

Figure E2.2

2. Apply AC signal v_{sig} (10 kHz, 100 mV_{pp}) at the input of your circuit.
3. Observe the output waveform on the oscilloscope to be sure that there is no distortion (if there is, reduce the input signal). Measure the input voltage, v_i, and the output voltage, v_o.
4. Calculate the no-load AC voltage gain ($A_{v(NL)}$) of the amplifier using the measured values. (*Show all the working steps)*
5. Modify the circuit in Figure E2.2 by adding C_3 as shown in Figure E2.3. Repeat steps 3-4.
6. Discuss the effect of C_3 to the amplifier circuit.

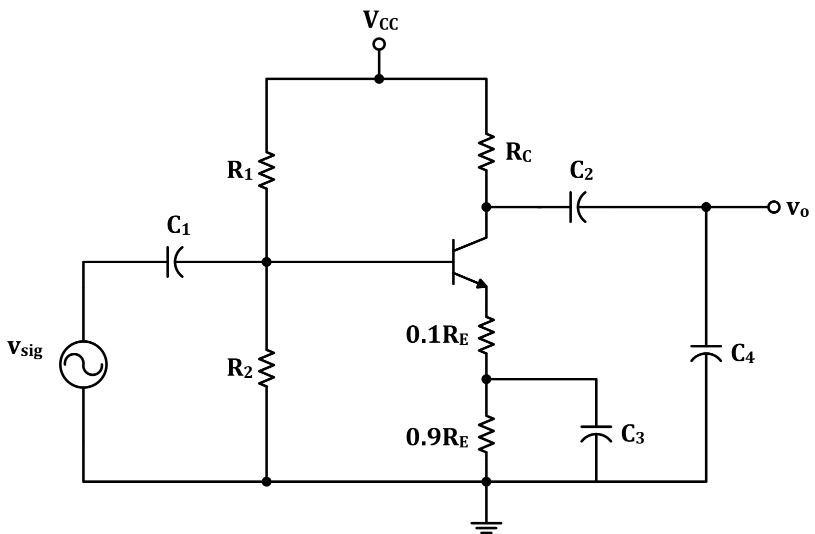

Figure E2.3

Table 2.1: 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. What are the characteristics of the amplifier that you can observed?
2. Write simple statement about the effect of C_3 on the magnitude of voltage gain. Use your measured values to back up your statement.

Reminding note:

Keep this final circuit connected on the breadboard as it is going to be used in the following experiment (week 2).

WEEK 2: BJT AMPLIFIER FREQUENCY RESPONSE

OBJECTIVES:

1. To determine the main properties (Z_i and Z_o) of the designed BJT amplifier.
2. To analyze the amplifier's frequency response.
3. To compare between the designed and the experimental result of the frequency response, the input impedance, and the output impedance.

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THEORY

Frequency Response, Input Impedance, and Output Impedance

Amplifiers and filters are widely used electronic circuits that have the properties of amplification and filtration. Amplifiers produce gain while filters alter the amplitude and/or phase characteristics of an electrical signal with respect to its frequency. As these amplifiers and filters use resistors and capacitor networks (RC) within their design, there is an important relationship between the use of the reactive components and the circuit's frequency response characteristics.

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.

In addition to gain, input impedance and output impedance are two other main properties of small signal amplifier. An amplifiers impedance value is particularly important for analysis especially when cascading individual amplifier stages together one after another to minimise distortion of the signal.

The input impedance of an amplifier, or input resistance as it is often called, is the input impedance "seen" by the source driving the input of the amplifier. If it is too low, it can have an adverse loading effect on the previous stage and possibly affecting the frequency response and output signal level of that stage. On the other hand, the output impedance of an amplifier can be thought of as being the impedance (or resistance) that the load sees "looking back" into the amplifier when the input is zero.

PRE-LAB WEEK 2:

1. 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.
2. Simulate the circuit to get the frequency response and determine the mid-band voltage gain and the cut-off values.

IN-LAB PROCEDURES:

PART A: FREQUENCY RESPONSE

1. Vary the input signal frequency from 50 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 100 $mV_{(p-p)}$ for all frequencies. However, please make sure that the output is not clipped or distorted throughout the measurement.
2. 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 has at least 10 sets of data (10 different frequencies).
3. Plot the frequency response of voltage gain in dB versus frequency on a semi-log graph paper. Mark your cut-off frequencies.

PART B: DETERMINE THE AC INPUT IMPEDANCE

1. Connect an input measurement resistor, R_x = 1kΩ as shown in Figure E2.4.

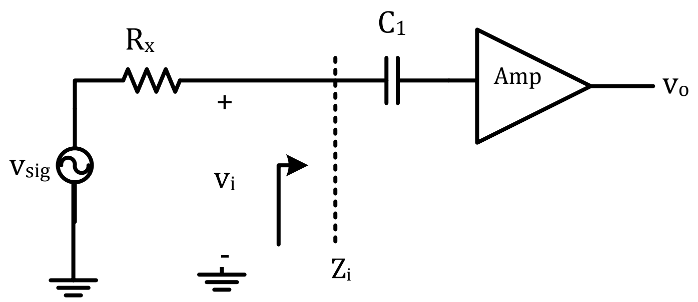

Figure E2.4

2. Apply the source signal, v_{sig} (10 kHz, 100 mV_{pp}).
3. Measure the source and input voltages.
4. Using the measured values (v_{sig}, v_i, and R_x), determine the ac input impedance, Z_i, of the amplifier. *Show all the working steps.*

PART C: DETERMINE THE AC OUTPUT IMPEDANCE

1. Remove the input measurement resistor, R_x.
2. Make sure that you still have a 10 kHz, 100 mV_{pp} ac signal at the input.
3. Measure the output voltage, $v_{o(NL)}$.
4. Connect load R_L = 10 kΩ between the output point and ground (parallel to C_4). Measure $v_{o(FL)}$.

5. Determine the value of output impedance, Z_o, of the amplifier using the measured values of $v_{o(NL)}$, $v_{o(FL)}$, and R_L. *Show all the working steps.*

Discussion Week 2

1. Discuss what you observed in Part A.
2. What would happen to the frequency response if you removed C_4?
3. Provide a summary of your observation upon the calculated, the simulated, and the measured results in parts A, B, and C.