

Başkent University
Department of Electrical and Electronics Engineering
EEM 311 Electronics II
Experiment II

Single Stage BJT Amplifier Design

Aim:

The aim of this experiment is to design and construct a single-stage bipolar junction transistor (BJT) amplifier.

Theory :

The *npn* transistor which is connected in a common emitter configuration, shown in Fig.1. The input and output voltage signals are coupled to and from the amplifier with the use of coupling capacitors C_1 and C_2 . The biasing network consisting of resistors R_1 and R_2 biases the transistor to a DC Q-point. The emitter resistor $R_E=R_{E1}+R_{E2}$ provides bias stability against variations in β . The output of the amplifier is connected to a load that has a resistance of R_L .

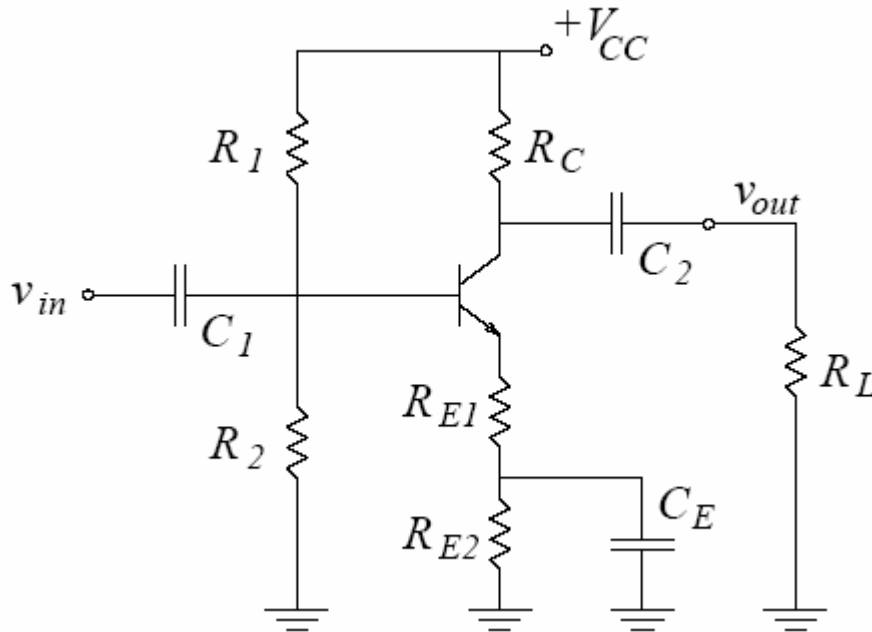
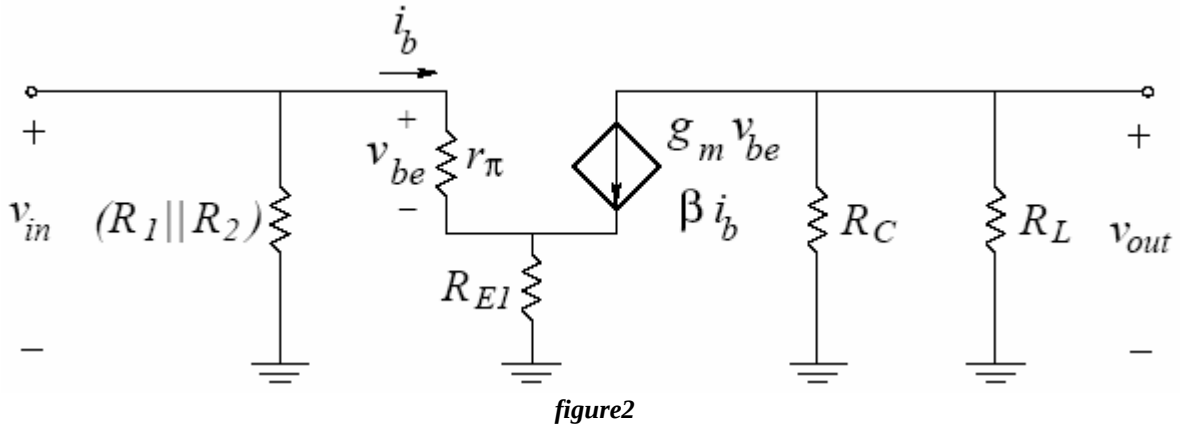


figure1

The total emitter resistance R_E is provided by two separate resistors in series. The second emitter resistor R_{E2} is bypassed with a capacitor C_E in order to increase the voltage gain. However, a small amount of emitter resistance (R_{E1}) is left in the AC circuit, the purpose of which is explained later.

The small-signal AC equivalent circuit for this amplifier is shown in the Fig.2.



It is assumed that $r_o = \infty$. It is also assumed that all capacitors can be considered to be short circuit at the frequency of operation. The value of the small signal input resistance is determined by the DC base current; $r_\pi = nV_T / I_{BQ}$. The transistor small-signal transconductance is given by $g_m = I_{CQ} / nV_T$.

It is important to note that the presence of the bypass capacitor C_E and the output coupling capacitor C_2 result in the AC load line to be different than the DC load line. In designing the biasing network, it is important to set the Q-point at the center of the AC load line for maximum symmetrical output voltage swing. It is advisable to leave some margin of safety when considering the maximum peak-to-peak undistorted (unclipped) output voltage swing while setting the Q-point.

The unbypassed emitter resistor R_{EI} serves three functions:

1. Adjust the voltage gain to a desired value: When $R_{EI} = 0$, the voltage gain of the amplifier is as high as it can be for the circuit at hand. Setting R_{EI} to a nonzero value provides a mechanism to decrease the gain to a desired value.
2. Provide stability against variations in r_π due to variations in the emission coefficient n : The emission coefficient of a transistor may show a variation from transistor to transistor much like the transistor β . This variation influences the value of r_π , which in turn affects the voltage gain and the input resistance of the amplifier. If R_{EI} is relatively large so that $r_\pi \ll (\beta + 1) R_{EI}$, the voltage gain and the input resistance are not influenced by changes n .
3. Provide linear (undistorted) operation for larger input signals: When $R_{EI} = 0$, the input voltage is limited to values that are much smaller than V_T for linear (undistorted) operation. This is so because the small-signal approximation $\exp(v_{be}/V_T) \approx 1 + v_{be}/V_T$ fails unless $v_{be} \ll V_T$. However, if R_{EI} is relatively large so that $r_\pi \ll (\beta + 1) R_{EI}$, the base current is mainly determined by the linear resistance $(\beta + 1) R_{EI}$, rather than the nonlinear i - v curve approximated by the resistance r_π .

Preliminary Work:

Review the sections 13.6.3, 13.8, 13.10.1, 13.10.3 from the Course Book.

In preliminary work you will design single stage BJT amplifier which has the circuit topology in Fig.1 using the transistor BC238B. The Pin Diagram of the BC238B is in Fig.3. The DC supply voltage, the load resistance, and the coupling and bypass capacitor capacitances are given as:

V_{CC}	R_L	C_1	C_2	C_E
15 V	3.3 k Ω	10 μ F	10 μ F	100 μ F

The BC238B has a $200 < \beta < 320$, $V_{CE(SAT)} = 0.2V$ and $V_{BE(ON)} = 0.6V$. Use the emission coefficient as $n = 1$ even though BC238B transistors may exhibit an emission coefficient in the range ($1 \leq n \leq 2$). You may assume the small signal output resistance $r_o = \infty$. (You can download data sheet [BC238B.pdf](#) from course web page).

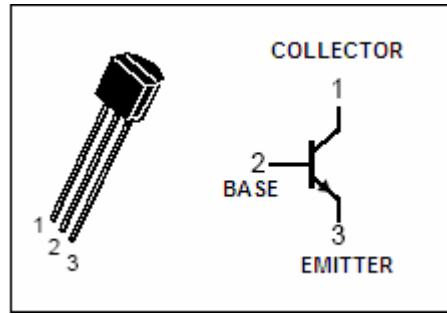


figure3

1. Design the amplifier and determine the values of R_1 , R_2 , R_C , R_{E1} and R_{E2} . The design requirements are listed in the following table. **Show all your work clearly.** (Use only [Standard Resistor Values](#))

	min	max
Voltage Gain A_v (linear scale)	22 dB	24 dB
Input Resistance R_{in}	5k Ω	
Peak-to-peak undistorted output swing	6 V	
Quiescent collector current I_{CQ} variation with β		3%
Voltage Gain $A_{v,dB}$ variation with β (200 - 320)		0.5 dB
Voltage Gain $A_{v,dB}$ variation with n (1 - 2)		1 dB

You are asked to design this amplifier in such a way that variations in β will cause minimal changes in the Q-point and the voltage gain. Specifically, if β changes in the range 200 to 320, I_{CQ} should not change more than 3%, and A_v should not change more than 0.5 dB. Also, if the emission coefficient n changes in the range 1 to 2, A_v should not change more than 1.0 dB.

In this amplifier circuit, the slope of the AC load line depends on R_{E1} in addition to R_C and R_L . However, R_{E1} is usually quite small, and can be neglected during the design stage.

2. Analyze your circuit and find the following values for three different β values ($\beta=200$, $\beta=250$, $\beta=320$) using the resistor values found in the previous part. Take $n = 1.4$. **Show all your work clearly.**

- I_{BQ}
- I_{CQ}
- V_{CEQ}
- r_π
- Input Resistance R_{in}
- Voltage Gain A_v (linear scale)
- Voltage Gain A_v (dB scale)
- Peak-to-peak undistorted output swing

3. Analyze your circuit and find the following values for two different n values ($n = 1$, $n = 2$) using the resistor values found in part1. Take $\beta = 250$. **Show all your work clearly.**

- r_π
- Input Resistance R_{in}
- Voltage Gain A_v (linear scale)
- Voltage Gain A_v (dB scale)

Experimental Work:

Before constructing the circuit, verify the values of the resistors that you are going to use by measuring their resistances with a multimeter. Make sure that all resistors are within 2% of their marked values. This will assure that your current measurements are accurate.

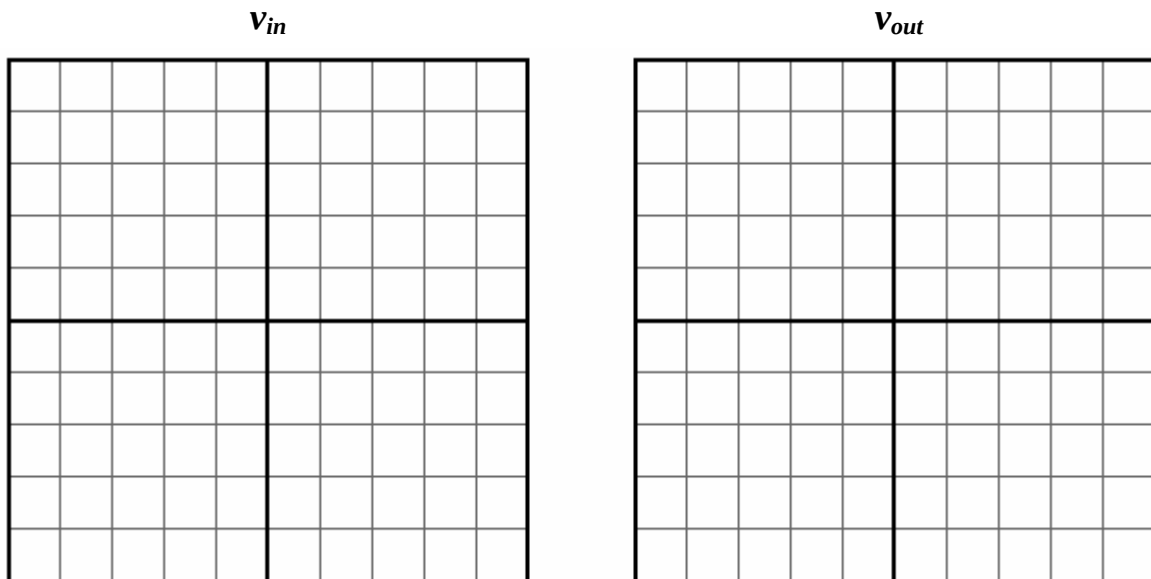
During your measurements, make sure that your oscilloscope is DC-coupled. This will make it easier for you to note asymmetric waveforms.

Construct the amplifier circuit using the values indicated in the preliminary work section.

1. Determine the Q-point: Before connecting the signal generator, measure I_{CQ} and V_{CEQ} and compare these with your calculations. Calculate the maximum peak-to-peak undistorted (unclipped) output voltage swing that you can expect for this Q-point.

$$I_{CQ} =$$
$$V_{CEQ} =$$

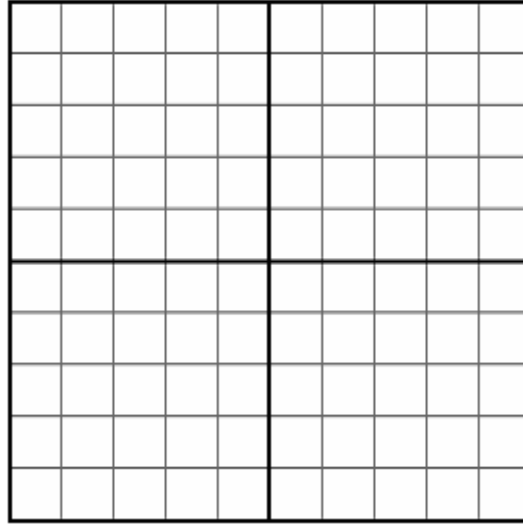
2. Measure the voltage gain of your amplifier: Set the input voltage signal to a sinusoid with 5 kHz frequency and 100 mV peak-to-peak amplitude. Observe the input and output voltage waveforms on the oscilloscope. Calculate the voltage gain of the amplifier and compare with your calculations in preliminary work.



$$A_v =$$

3. Keeping the output signal distortion free, slowly change the amplitude of the sinewave while observing the input and output signals (V_o/V_i) in X-Y mode of the oscilloscope. Is the amplifier response linear under small signal inputs? Measure the peak to peak output voltage where the linearity breakdowns.

$V_{out} =$



4. Determine the maximum peak-to-peak undistorted (unclipped) output voltage swing: Gradually increase the input signal amplitude and observe the onset of distortion (clipping) at the output. Set the signal generator to a triangular wave output; this will make it easier to observe clipping. Gradually vary the input signal amplitude and determine the onset of distortion (clipping) at the output. Measure the peak-to-peak maximum undistorted output voltage swing. Compare this with your calculations and comment on how this value is related to the location of the Q-point on the AC load line.

$V_{out, unclipped\ max} =$

5. Measure the input resistance of your amplifier: To do this, connect a 10 k Ω resistor between the signal generator and the input of your amplifier, thereby making a voltage divider between R_{in} and the 10 k Ω resistor, as shown in the Fig.3. By measuring v_{in} and you can deduce the value of v_d . Compare this value with your calculations. In this measurement, set input voltage signal to a sinusoid with 100 mV peak-to-peak amplitude.

$v_{in} =$

$v_d =$

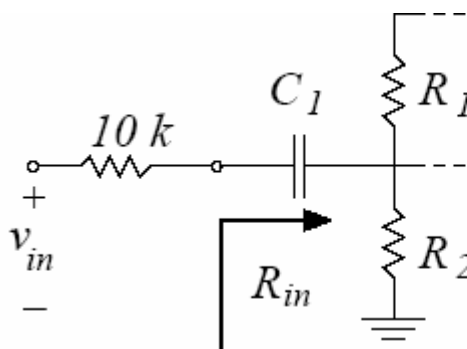
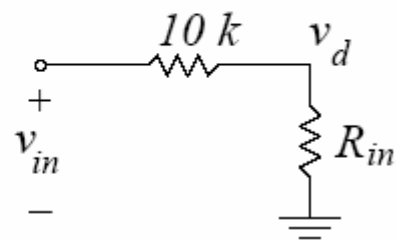


figure3



Experiment Instruments:	Experiment Components:
• Breadboard • Oscilloscope • Signal Generator • Multimeter • DC Power Source	1 BC238B 1 3.3 k Ω 2 10 μ F 1 100 μ F 1 50kPOT

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Experiment Results

Part1	$I_{CQ} =$ $V_{CEQ} =$	
Part2	$A_v =$	
Part3	$v_{out,} =$	
Part4	$v_{out,unclipped\ max} =$	
Part5	$v_{in} =$ $v_d =$	

Student Name :

Signature.....