EE 102 (Exp-6)

Regular session & group - Afternoon session, L-8

Experiment no - 06

Date of experiment - 09/03/2016

Student-1 - Kumar Indramani (150107028)

Student-2 - K.Y. Ashok (150107027)

TABLE OUT - 14

2.5

Objective

1. To carry out an approximate DC and AC analysis of given CE amplifier.
2. To determine the voltage gain, the "maximum undistorted peak-to-peak outpout voltage swing" (MUOVS) and the maximum input voltage for undistorted output.
3. To study the effect of emitter bypass capacitor on voltage gain.

Circuit Diagram

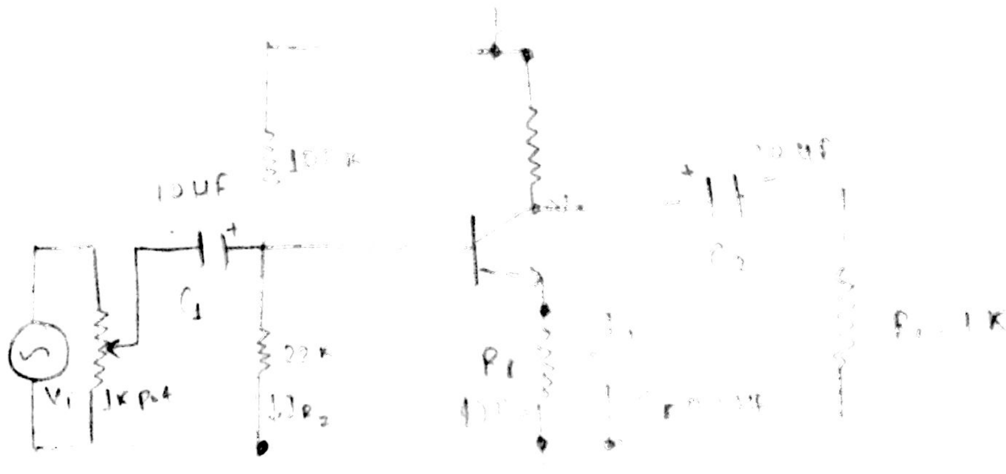
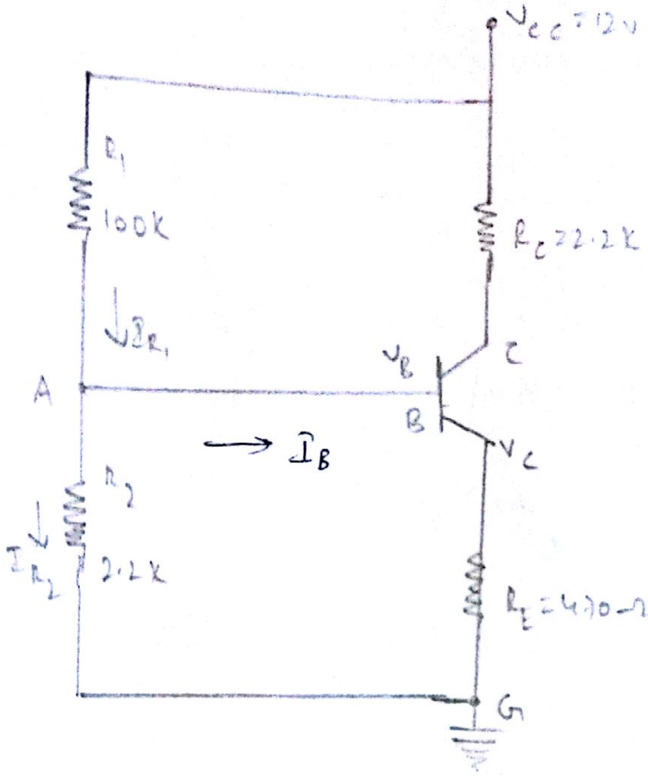


Fig Common-emitter amplifier

EXPERIMENT PREPRATION

PART-1 →



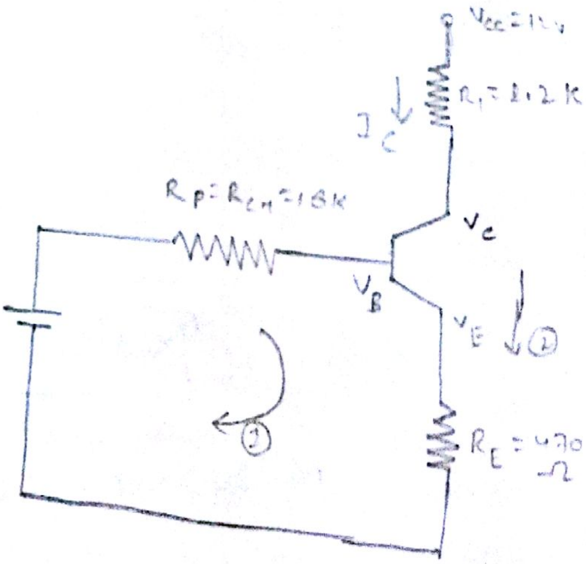
Applying thevenin's theorem. b/w AB [$\because I_B = 0$]

$$\therefore V_{Th} = \frac{22}{122} \times 12 = 2.16V.$$

$$\therefore R_{Th} = \frac{22 \times 100}{22+100} = 18K\Omega.$$

$V_{B'E} \simeq 0.65V$

$I_E = I_C + I_B$



Applying . KVL in ① & ②;

$$V_{Th} - I_B R_B - V_{BE} - I_E R_E = 0$$

$$2.16 - \cancel{I_B} \times 18 - 0.65 - I_E(0.47) = 0$$

$$I_E = 3.912 \text{ mA}$$

$$I_C \simeq I_E = 3.2 \text{ mA}$$

$V_E - I_E R_E = 0$

$\Rightarrow V_E - I_E R_E = 3.212 \times 0.47 = 1.51V.$

$V_{BE} = V_B - V_E$

$0.65V = V_B - 1.51V$

$\boxed{\therefore V_B = 2.16V}$

$V_{CC} - I_C R_C = V_C$

$V_C = 12 - 3.212 \times 2.2$

$\boxed{\therefore V_C = 4.33V}$

Voltage gain ; $A_V = \frac{\beta R_C}{r_b} = -\frac{R_C}{r_B/\beta} \simeq \frac{-R_C}{r_C}$

$= \frac{-R_C}{V_T/I_E} = -\frac{R_C I_E}{V_T} \simeq \frac{-R_C I_C}{V_T}$

$V_T = \frac{kT}{2} \simeq 25mV \cdot$ (at $T = 20^\circ C$)

$\boxed{\therefore A_V = -282.6}$

MUOVS = $2 \times$ Min $\{V_{CC} - V_C, V_C - V_E\}$

$V_{CC} - V_C = 7.07V$

$V_C - V_E = 3.42V$

$\therefore$ MUOVS $= 2 \times 3.42$

$= \underline{6.84V}.$

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Observations

2.1. Experimental Determination of the quiescent Voltage & currents:

Using DMM, we found following values of actual resistance:-

Rated value	Actual value
1 KΩ	0.91 KΩ
2.2 KΩ	2.12 KΩ
22 KΩ	21.2 KΩ
100 KΩ	85 KΩ
470 Ω	465 Ω

$V_{BE} = 0.63\,V$, $V_{CC} = 12\,V$

$V_C = 6.25\,V$

$V_E = 1.28\,V$

$V_B = 1.92\,V$

$$I_E = \frac{V_E}{R_E} = \frac{1.28}{470} = 2.72 \times 10^{-3}\,A = 2.72\,mA$$

$$I_C = \frac{V_{CC} - V_C}{R_C} = \frac{12 - 6.25}{2.2K} = \frac{5.75}{2.2K} = 2.613\,mA$$

$$I_B = I_{R_1} - I_{R_2}$$
$$= 0.1008 - 0.087$$
$$= 0.0138\,A.$$

$$\therefore \boxed{\beta = \frac{I_C}{I_B} = 189.34}$$

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$\therefore A_V = \frac{-R_C I_C}{V_T} = \frac{2.2\times10^{+3}\times2.6\times10^{-3}}{25\times10^{-3}}$

$= -228$

2.2 Voltage gain without load Resistance R_L

$V_c = 2V$

$V_i = 20mV$

$\therefore A_V = \frac{-V_{c\,ipp}}{V_{i\,ipp}} = -\frac{2}{20\times10^{-3}} = \underline{\underline{-100V}}$

3. Maximum undistorted output voltage swing (MUOVS)

Input V_i of MUOVS = $\underline{90mV}$

$\therefore$ MUOVS = $\underline{9.2V}$

4. Voltage-gain with load resistance R_L –

$V_i = 20mV$

$V_c = 0.64V$

$\therefore A_V = -\frac{V_c}{V_i} = \frac{-0.64}{20\times10^{-3}} = \underline{\underline{-32V}}$

5. Effect of C_E on A_V

Gain of CE amplifier with unbypassed $R_E = -\frac{V_c}{V_i} = -5V$

Theoritical value of gain $\Rightarrow A_V = -\frac{\alpha R_C}{R_E + V_E} \simeq -\frac{R_C}{R_E}$

$= -\frac{2200}{470} = -4.66V$

Precautions

1. Actual values of resistors must be measured by DMM before starting experiment
2. Forward biasing of BE Junction must be checked before proceedding the experiment circuit
3. Ensure that wiring of CRO is not loose.
4. Ensure that polarity of capacitor is right
5. C_E must be removed with circuit powered
6. V/div of CH_1 must be equal to V/div of CH_2.

Answer to questions

1. What do you observe if V_i is increased beyond the point where we observe the +ve peak of V_C almost touching the -ve peak of V_C?

Ans→ If V_i is increased beyond the value corresponding to MUOVS, the output wavefronts gets distorted & is no longer an amplified form of input signal. With further increase in V_i, the wave front becomes a "SQUARE WAVE"

~~Results~~

Results

2.1 $V_{BE} = 0.63V$ $I_E = 2.72mA$

$V_C = 6.25V$ $I_C = 2.613 mA$

$V_E = 1.28V$ $I_B = 0.0138A$

$V_B = 1.92V$

β (Calculated using experiment) $= 189.34$

$\beta_{theoritical} = 197$

* Hence β calculated using experiment is approximately equal to theoritical value of β

Voltage gain $A_V = -228$

2.2 $V_C = 2V$; $V_i = 20mV$

$A_V = -100V$.

~~2.3~~

3. MUOVS $= 9.2V$

Input V_i for MUOVS $= 90mV$.

4. Voltage gain with load resistance R_L

$= A_V = -32V$

5 Theoritical value of gain

$= A_V = -4.66V$.

Value obtained using experiment

$= -5V$

Hence values are approximately same.

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~~2.3~~

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$= A_V = -32V$

5 Theoritical value of gain

$A_V = -4.66V.$

Value obtained using experiment

$= -5V$

Hence values are approximately same.

Post experimental Analysis

We found that the values of resistance obtained using DMM were slightly different than the rated values. It happened because the resistors have some tolerence.

The value of β calculated from experiment were approximately equal to rated value. Slight change in value may have occured because of some error in calculating I_E & I_B.

The maximum undistorted output Voltage swing (MUOVS) is 9.2 V

On removing C_E a drastic reduction in $V_{c\,p-p}$ is observed. Increasing V_i, we get +ve peak of V_E almost touching the -ve peaks of V_c.

This is saturation point of BJT.

OBSERVATIONS:

PART II →

2.1 → a) DMM →

BBRG → 0.91 Ω

RRRG → 2.12 Ω

RROG → 21.2 kΩ

BBYG → 65 kΩ

YVBG → 465 Ω

b) $V_{BE} = 0.63V$; $V_{CC} = 12V$

$V_C = 6.25V$.

$V_E = 1.26V$.

$V_B = 1.92V$

$\boxed{\therefore V_E < V_C < V_{CC}}$

c) $I_E = \dfrac{V_E}{R_E} = \dfrac{1.26}{470\Omega} = 2.72 \times 10^{-3}\ A = 2.723mA$.

$I_C = \dfrac{V_{CC} - V_C}{R_C} = \dfrac{12 - 6.25}{2.2K} = \dfrac{5.75}{2.2K} = 2.61 \times 10^{-3} A = 2.613mA$.

~~$I_B = I_E - I_C = 2.72 - 2.61 = 0.11mA$~~

~~$\beta = \dfrac{I_C}{I_B} = 23.72$~~

$I_B = IR_1 - IR_2$

$= 0.1008 - 0.087$

$= 0.0138$.

$\beta = \dfrac{I_C}{I_B} = 189.34$.

d) $A_V = \dfrac{-R_C I_C}{V_T}$

~~$= \dfrac{-(464)(2.6 \times 10^{-3})}{(25 \times 10^{-3})}$~~ $= \dfrac{(2.2 \times 10^{-3}) \times (2.6 \times 10^{-3})}{(25 \times 10^{-3})}$

~~$= -48.25$~~.

$= -228$

2.2 →

$v_c = 2V$

$v_i = 20 \text{ mV}$

$\therefore A_v = \dfrac{-v_{c;pp}}{v_{i;pp}} = \dfrac{-2}{20 \times 10^{-3}} = -100 V$.

3 → (MUOVS) →

Input v_i of MUOVS = 90mV

$\therefore$ MUOVS = 9.2V.

4 → Voltage-gain with load resistance R_L →

$v_i = 20mV$

$v_c = 0.64V$

$\therefore A_v = \dfrac{-v_c}{v_i} = \dfrac{-0.64}{20 \times 10^{-3}} = -32V$.

5 → Effect of C_E on A_v →

Gain of CE amplifier with unbypassed $R_E = \dfrac{-V_{c,pp}}{V_{i,pp}}$

$= \dfrac{-100 \times 10^{-3}}{20 \times 10^{-3}}$

$= -5V$.

Theoretical value of gain ⇒ $A_v = \dfrac{-\alpha R_C}{(R_E + r_e)} \approx \dfrac{-R_C}{R_E}$

$= \dfrac{-2200}{470} = -4.68 V$.

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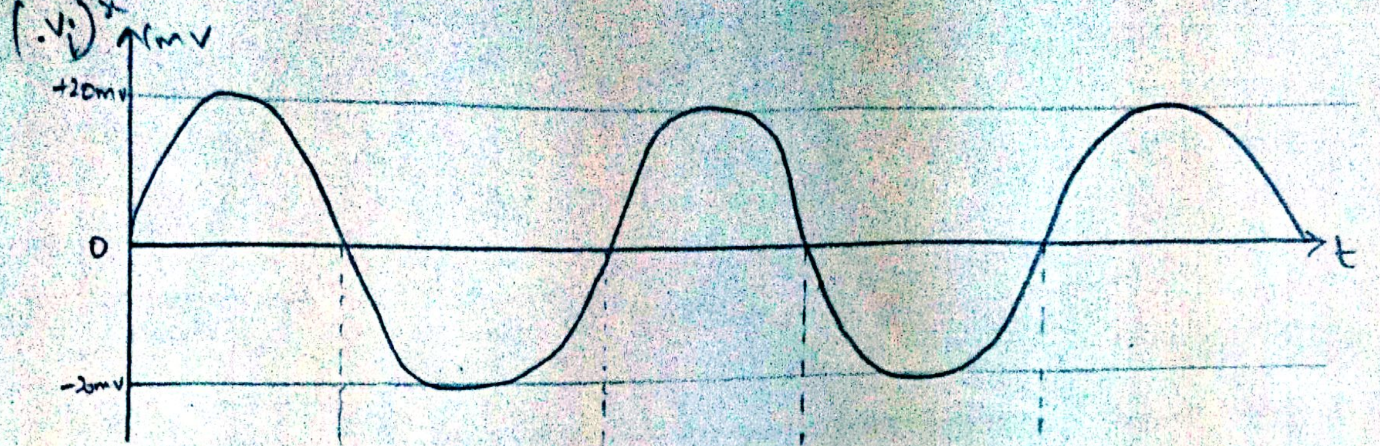
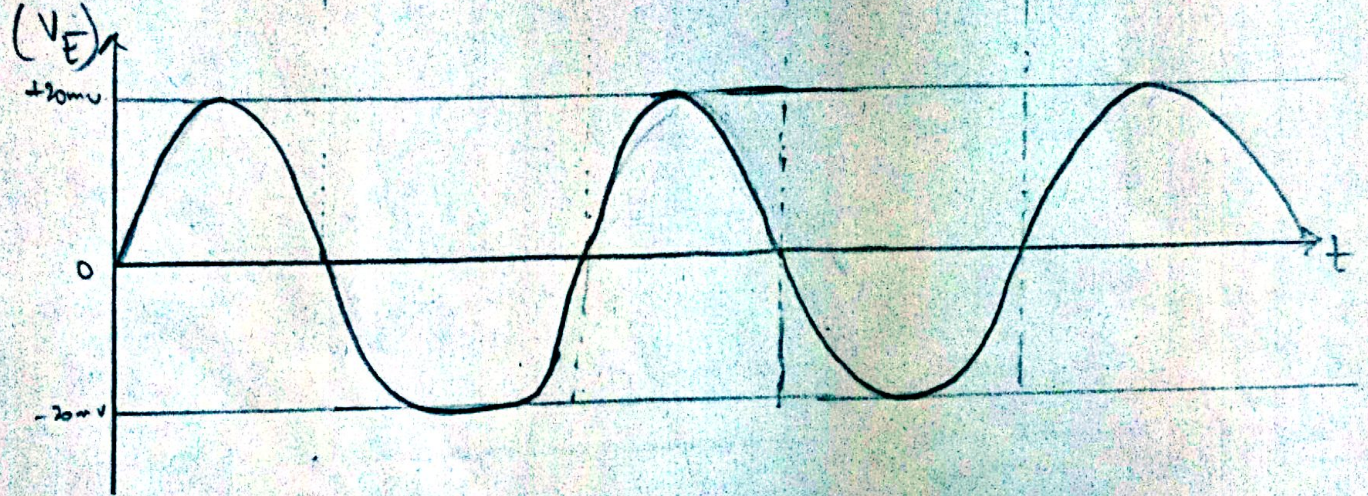
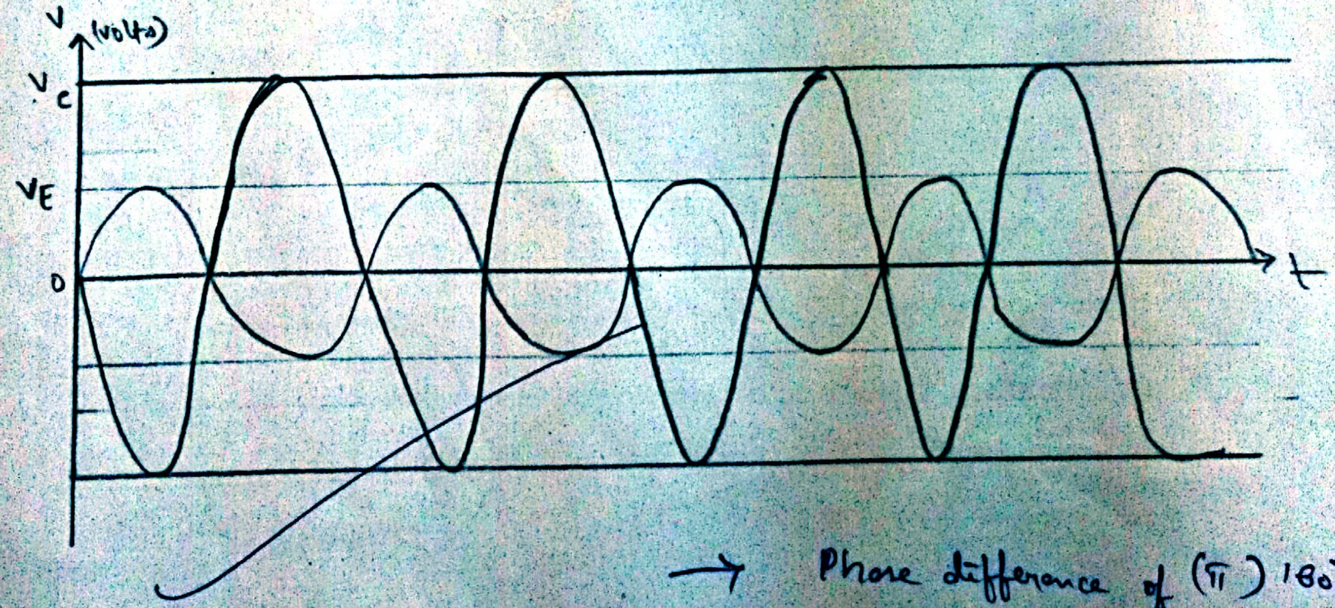
a) V_i & V_E will be in the same phase;







→ Phase difference of (π) 180°.

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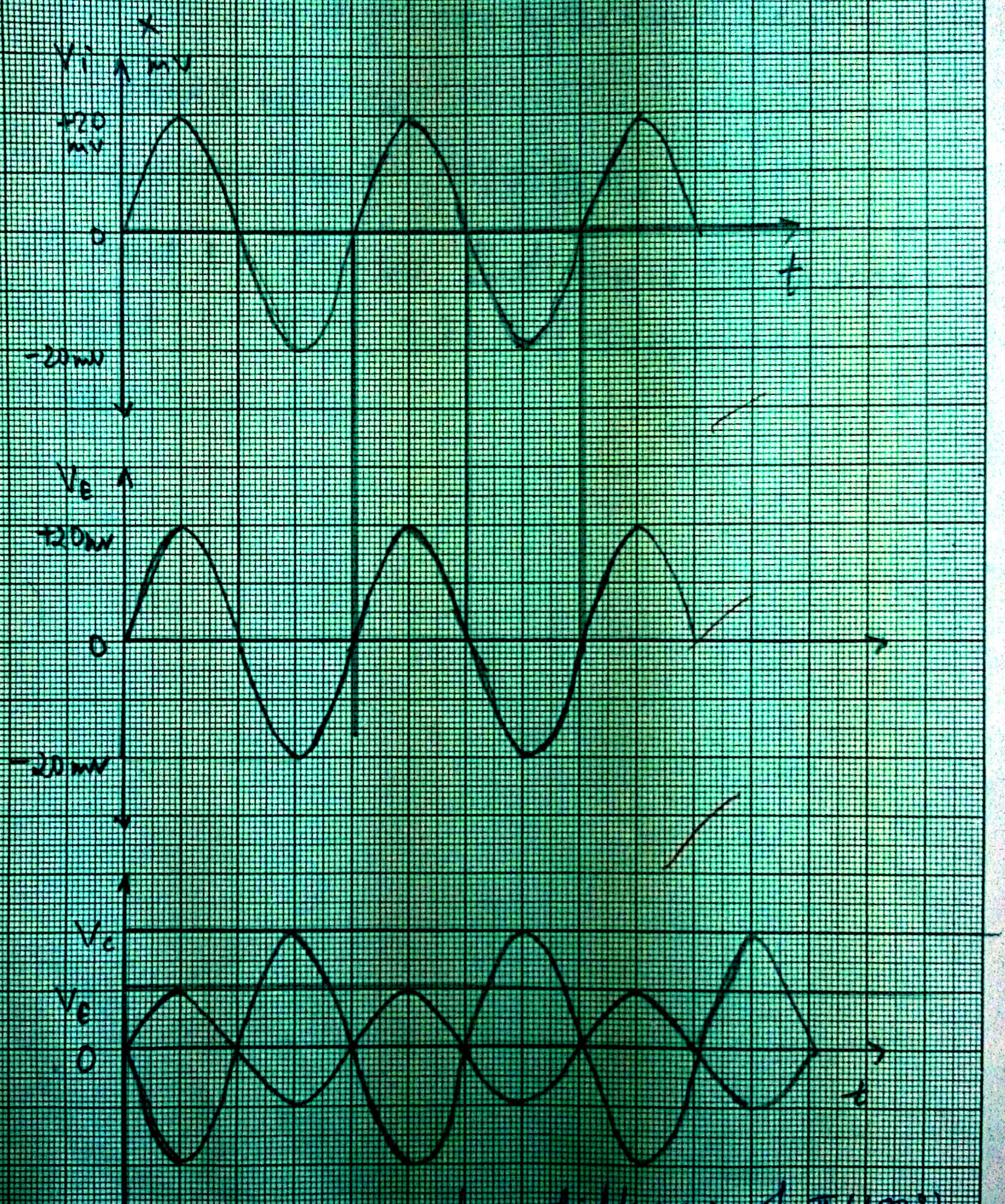
a) Vi and Ve will be in same phase



phase difference of π (180°)

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INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
DEPARTMENT OF ELECTRONICS & ELECTRICAL ENGINEERING
EE102 : BASIC ELECTRONICS LABORATORY

Expt. No. 6 : Study of Common-emitter Amplifier

OBJECTIVES :

1. To carry out an approximate DC and AC-analysis of the given CE amplifier.
2. To determine the voltage gain, the "maximum undistorted peak-to-peak output voltage swing" (MUOVS) and the maximum input voltage for undistorted output.
3. To study the effect of emitter bypass capacitor on voltage gain.

MATERIALS REQUIRED

Breadboard

Equipment and parts : Multi-output Power Supply, Function Generator, Oscilloscope, Digital Multimeter.

Transistor	:	One- NPN type 2N2222A.
Resistor	:	Five - 470Ω, 1KΩ, 2.2 KΩ, 22 KΩ, 100KΩ.
Variable resistor	:	One - 1KΩ Pot. (Potentiometer).
Capacitor	:	Three - 10 μF, 10 μF, 22 μF

To Terminal D

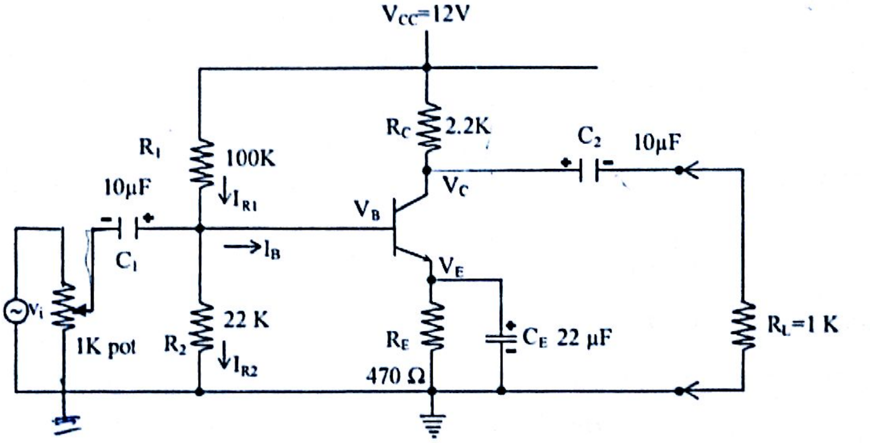

Fig. 1 : Common-emitter amplifier

Important: You are expected to complete Part 1 at home and come to the Lab with a neat report showing all calculations. You will be allowed to continue with the rest of the experiment only after the instructor has checked the report.

Part-I. Pre-experiment preparation

Approximate DC and AC-analysis:

Carry out an approximate DC-analysis by using the values given in Fig. 1 and by making use of the following assumptions:

(a) $I_{R1}, I_{R2} >> I_B$, so that $I_{R1} \approx I_{R2}$

(b) $V_{BE} \approx 0.65$ V

Under these assumptions, you should be able to estimate the

- DC quantities (quiescent values) $V_B, V_E, V_C, I_E (\approx I_C)$

- Voltage gain $A_v = -\frac{\beta R_C}{r_b} = -\frac{R_C}{r_b/\beta} \approx -\frac{R_C}{r_e} = -\frac{R_C}{V_T/I_E}$
$$= -\frac{R_C\, I_E}{V_T} \approx -\frac{R_C\, I_C}{V_T} \qquad \textbf{(6.1)}$$

where $V_T = \frac{kT}{q}$: the thermal voltage ; k= Boltzmann's constant = 1.38×10^{-23} J/K,
q = 1.6×10^{-19} Coulomb, T is temperature in °Kelvin.

Take $V_T \approx 25mV$ (at a room temp of 20° C)
In (6.1), we have used the approximation $r_b = (\beta+1)\ r_e \approx \beta r_e$
Note: The approximation does not require the knowledge of β

- MUOVS = 2 * Min{$V_{CC} - V_C$, $V_C - V_E$ }

Q: (connecting an electrolytic capacitor) How do you decide that the + terminal of C_1 should be connected to the R_1–R_2 node and the – terminal to the source v_i ? Likewise, for C_2 and C_E.

Part-II. Experimental Observations

2.1 Experimental determination of the quiescent voltages and currents:

a) Before assembling the circuit, measure the actual values of the resistors by means of a Digital Multi Meter (DMM). [Remember you are using resistors with 10% tolerance]. The actual values are to be used in determining the currents.
b) Now assemble the circuit, apply V_{CC} and note the following:
   - measure V_{BE} using DMM; it should be around 0.6 ~ 0.7 V indicating that BE-junction is forward biased.
   - Measure V_C and check if $V_E < V_C < V_{CC}$. A value of V_C midway between V_E and V_{CC} is preferable (**Q: Why is such a value preferable?**).

If your measurements agree, you are along the right path.

c) Now measure V_B , V_E , V_C and V_{CC} ; then using the measured resistance values, determine I_B, I_E, I_C and hence β ($\beta = I_C/I_B$).
d) Compare the experimentally determined values of the currents and voltages with those you obtained through approximate analysis.
e) Compare the experimentally determined value of β with the approximate value stated in the manual or given by the Lab Instructor.
f) Compute A_V (equation 4.1) using the experimentally determined values of R_C and I_C. Use V_T=25mV.

2.2 Voltage gain without load resistance R_L :

- Disconnect C_2.
- Adjust FG to get approximately 10-20 mV peak-to-peak sinusoid at 1 kHz (display in Ch-I). Apply this voltage at amplifier input (v_i).
- Display collector voltage in Ch-II of CRO(use DC-coupling). Note the 180° phase difference between the input and the output. Adjust v_{in} amplitude to get a convenient value for peak-to-peak collector voltage $v_{C,PP}$ (say 2 V). Use appropriate vertical sensitivity (V/div). Note the corresponding $v_{i,PP}$ (mV). Experimentally obtained voltage gain is therefore:

$$A_v = \frac{-v_{C,PP}}{v_{i,PP}}$$

$\frac{2}{20\times10^{-3}} = 100$
10
100

- Compare this value with the computed values obtained in step 2.1(f). Also compare this value with the value estimated in your pre-reading assignment.

3. Maximum undistorted output voltage swing (MUOVS)

- Increase v_i slowly till you observe a slight flattening of v_C waveform at its peaks (either positive peaks or negative peaks). The peak-to-peak value of the output signal (just at the onset of distortion/clipping) is the MUOVS. Measure the corresponding $v_{i,PP}$, the peak-to-peak input voltage. MUOVS = 9.2 V

  This information is useful in an amplifier: it tells the user that the input should not exceed this value for faithful amplification of the signal, else distortions sets in.
- Now increase v_i beyond this point and observe the output waveform. The sinusoid gets increasingly flattened and becomes more like a square wave.
  (overdriving an amplifier leads to heavy distortion)

  [!! Square-wave from a sine-wave]

4. Voltage-gain with load resistance R_L :

The output of an amplifier normally drives a load resistance R_L which may represent an actual load like an ear-phone or a loudspeaker, or the input impedance of another state of amplifier.

- Connect R_L (see circuit) to the collector through the coupling capacitor C_2 (C_2 blocks the DC voltage at the collector and allows only the AC i.e. the signal component to pass through).
- Measure A_V with R_L connected. (you would observe a reduced A_v since $R_{C,eff} = R_C \| R_L$).

5. Effect of C_E on A_v :

- Get back to the conditions in Part 2.2 i.e. v_i at 1 kHz, its amplitude adjusted to get $v_{C,PP} \approx$ 2V .
- Now, remove C_E (with ckt. powered) and note the drastic reduction in $v_{C,PP}$. You have to change to appropriate V/div in your CRO. Determine the gain of the CE amplifier with unbypassed R_E.
- Compare your observation with the theoretical value

$$A_v = -\frac{\alpha R_C}{(R_E + r_e)} \approx -\frac{R_C}{R_E} \qquad \textbf{(6.2)}$$

- Display and sketch v_i and v_E waveforms. Note the amplitudes and the phase-relationship between them.
- Display and sketch v_E and v_C. Note the amplitudes and the phase relationship. Please note that you are in DC coupling mode of the CRO. Please ensure that when you pressed the ground options in CH1 and CH2, both the horizontal traces (of CH1 and CH2) are coinciding. Also ensure that the V/div of CH1 is equal to V/div of CH2.
- Increase v_i gradually and observe how v_E and v_C change. Continue to increase v_i till you observe the +ve peak of v_E (almost) touching the negative peak of v_C. When this occurs, we say that the BJT has gone into saturation ($v_{CE} \approx 0$).

Q: What do you observe if v_i is increased beyond this point ?

$-22/4.8 = -4.58$ $\quad -2200/470 = -4.68$