4

Indian Institute of Technology, GUWAHATI

IIT, GUWAHATI

Table No. - 08 / Group No. - 08 / Lab group - L-9(B)

EE 102: Basic - Electronics Laboratory.

Expt. No. 7 & 8 : Common Emitter Amplifier

Date:- 5th, April, 2019

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Pre-Lab. - attached with this.—

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Department of Electronics & Electrical Engineering

EE102: Basic Electronics Laboratory

Expt.No. 7 & 8: 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:

1. Equipment: Breadboard, Function Generator, Oscilloscope, Multi-Output Power Supply, Digital Multimeter.
2. Components: NPN type 2N2222A (One), 470Ω (One), 1kΩ (One), 2.2kΩ (One), 22kΩ (One), 100kΩ (One), 10μF (Two), 22μF (One), 1kΩ Pot (One)

Precautions and Guidelines:

1. You are expected to come to the Lab with a neat report showing all calculations regarding the Pre Lab Work.
2. You will be allowed to perform the experiment only after the instructor has checked the report.

Pre-Lab Work:

1. Carry out an approximate DC analysis by using the values given in Fig.1 and by making use of the assumptions $I_{R1}, I_{R2} >> I_B$, so that $I_{R1} \approx I_{R2}$ and $V_{BE} \approx 0.65V$. Estimate the DC quantities (quiescent values) V_B, V_E, V_C, I_E ($\approx I_C$).
2. Draw the small signal equivalent of the circuit in Fig.1 and compute the voltage gain as
$$A_V = -(\beta.R_C)/(r_b) \approx -(R_C)/(r_e) = -(R_C.I_E)/(V_T) \approx -(R_C.I_C)/(V_T)$$
Take $V_T \approx 25mV$ (at room temp).
3. Compute MUOVS = 2 x Min $\{V_{CC} - V_C, V_C - V_E\}$.
4. How do you decide that the + terminal of C_1 (an electrolytic capacitor) 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 ~~A~~: Measuring DC Quantities (Quiescent Values)

~~1~~. Before assembling the circuit, measure the actual values of the resistors by means of a Digital Multimeter (DMM). The actual values thus determined are to be used in calculating the currents.

~~2~~. Assemble the circuit, apply V_{CC} and note the following: (a) measure V_{BE} using a DMM and it should be around 0.6V ~ 0.7V indicating that BE junction is forward biased. (b) 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.

3. Measure V_B, V_E, V_C and V_{CC} and determine I_B, I_E, I_C and hence β ($\beta = I_C/I_B$).
4. Compute A_V using the experimentally determined values of R_C and I_C. Use V_T=25mV.

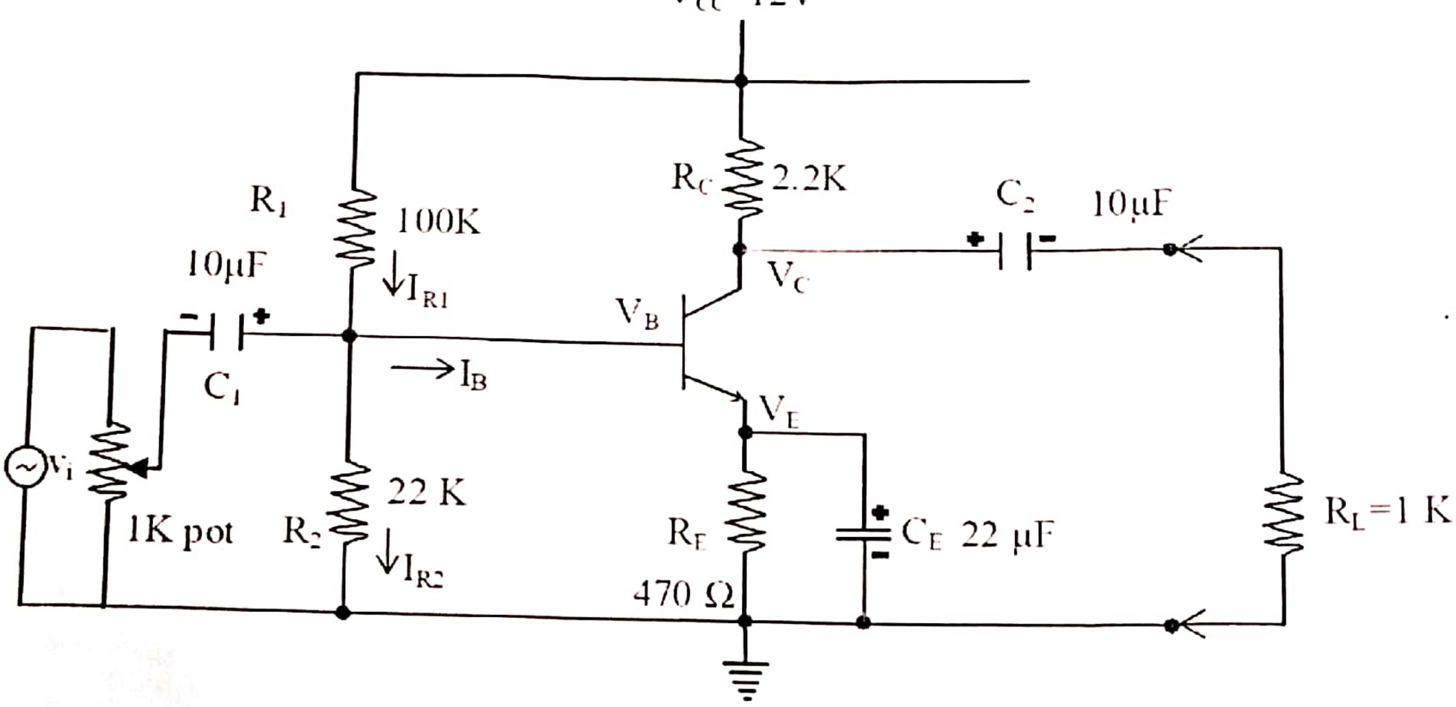


Fig.1

Part B: Voltage Gain Without Load Resistance

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

$$A_V = -(V_{C,p-p})/(V_{I,p-p}).$$

Part C: Maximum Undistorted Output Voltage Swing (MUOVS)

1. Increase $V_{I,p-p}$ slowly till you observe a slight flattening of $V_{C,p-p}$ 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 $V_{I,p-p}$, the peak-to-peak input voltage.
2. Now increase $V_{I,p-p}$ 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).

Part D: Voltage Gain With Load Resistance

1. 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 stage of the amplifier.

2. Connect R_L (see Fig.1) 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).
3. Measure A_V with R_L connected. (you would observe a reduced Av since $R_{C,eff} = R_C || R_L$.

Part E: Effects of C_E on A_V

1. Get back to the conditions in Part B i.e. V_I at 1 kHz, its amplitude adjusted to get $V_{C,p-p} \approx 2V$.
2. Now, remove C_E (with circuit powered) and note the drastic reduction in $V_{C,p-p}$. You have to change to appropriate V/div in your CRO. Determine the gain of the CE amplifier with unbypassed R_E.
3. Compare your observation with the theoretical value
$$A_V = -\alpha R_C/(R_E+r_e) \approx -R_C/R_E.$$
4. Display and sketch $V_{I,p-p}$ and V_E waveforms. Note the amplitudes and the phase-relationship between them.
5. 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 Channel 1 and Channel 2, both the horizontal traces (of the channels) are coinciding. Also ensure that the V/div of Channel 1 is equal to V/div of Channel 2.
6. Increase $V_{I,p-p}$ gradually and observe how V_E and V_C change. Continue to increase $V_{I,p-p}$ 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 ($V_{CE} \approx 0$).
7. What do you observe if $V_{I,p-p}$ is increased beyond this point?

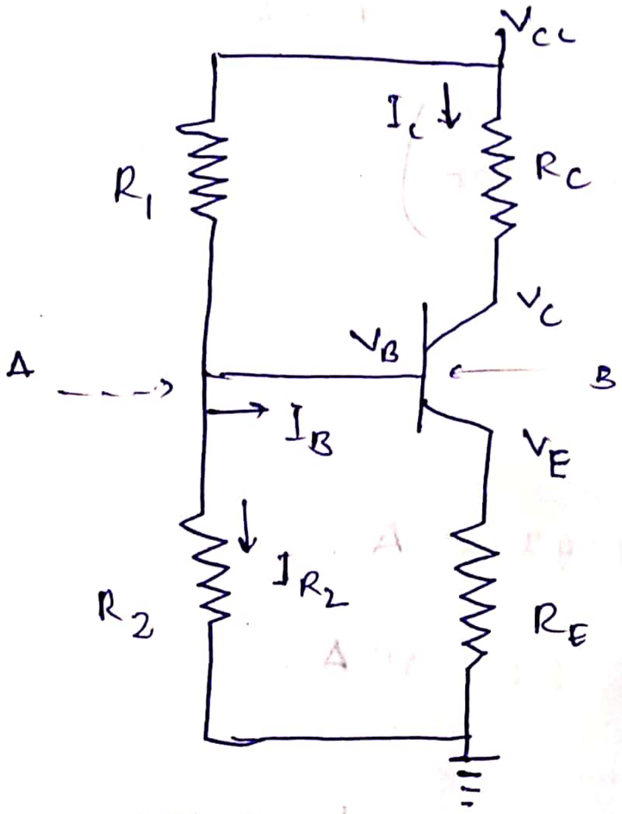
Part F: Lab Report

Prepare and submit a lab report as specified in the general instructions regarding the lab. Include the answers to the following questions in the report:

1. Why is V_C such that $V_E < V_C < V_{CC}$ a preferred value in step 2 of Part A?
2. Compare the experimentally determined values of the currents and voltages in step 3 of part A with those you obtained through approximate analysis.
3. Compare the experimentally determined value of β in step 3 of part A with the approximate value given by the Lab Instructor.
4. Compare the experimentally determined value of the voltage gain A_V in step 4 of Part B with the computed values obtained in step 4 of Part A. Also compare this value with the value estimated in the Pre Lab Work.
5. What is the utility of knowing MUOVS in the design of an amplifier?

PRE-LAB WORK

1) The DC circuit is:



$V_{CE} = 12V$
$R_1 = 100k\Omega$
$R_2 = 22k\Omega$
$R_C = 2.2k\Omega$
$R_E = 470\Omega$

$I_{R_1} \simeq I_{R_2} >> I_B$

$V_{B_1} \approx 0.65V$

$I_E \simeq I_C$

At point B

$I_C + I_B = I_E$

Now $V_B = I_{R_2} R_2$

$V_c = V_{cc} - I_C R_c = V_{cc} - I_E R_c + I_B R_c$

$V_E = V_B - V_{BE} = I_E R_E$

Using kirchoff's Law:

$V_{cc} = I_{R_1} R_1 + I_{R_2} R_2 = I_{R_2} R_2 + (I_{R_2} + I_B) R_1$

$V_{cc} = I_E R_E + V_{BE} + (I_{R_2} + I_B) R_1$

$I_B = \frac{I_E}{B+1}$

Applying given Approximations of ($\beta \to \infty$, $\therefore I_{R_1} = I_{R_2}$)

$$V_{CC} = I_{R_2}(R_1 + R_2) \Rightarrow I_{R_2} = \frac{V_{CC}}{R_1 + R_2}$$

$$I_E = \frac{1}{R_E}\left(V_{CC} - \left(\frac{V_{CC}}{R_1 + R_2}\right) R_1 - V_{BE}\right)$$

$$= \frac{1}{R_E}\left(\frac{R_2}{R_1 + R_2} V_{CC} - V_{BE}\right)$$

using values $\Rightarrow$ $I_{R_2} = 0.098$ mA.

$I_E = 3.221$ mA.

The voltages can now be calulated

$$V_B = I_{R_2} R_2 = \frac{R_2}{R_1 + R_2} V_{CC}$$

With given Approx. $I_E \approx I_C$ i.e. $I_B = 0$

$$V_C = V_{CC} - \frac{R_C}{R_E}\left[\frac{R_2}{R_2 + R_1} V_{CC} - V_{BE}\right]$$

$$= \left[1 - \frac{R_C}{R_E} \cdot \frac{R_2}{R_1 + R_2}\right] V_{CC} + \frac{R_C}{R_E} V_{BE}$$

Putting values $V_B = 2.164$ V

$V_C = (1.8709 + 3.0425)$ V

$V_C = 4.1938$ V ? 4.91

Also, $V_{BE} = V_B - V_E$

$V_E = V_B - V_{BE} = 2.164\ V - 0.65\ V = 1.514\ V$

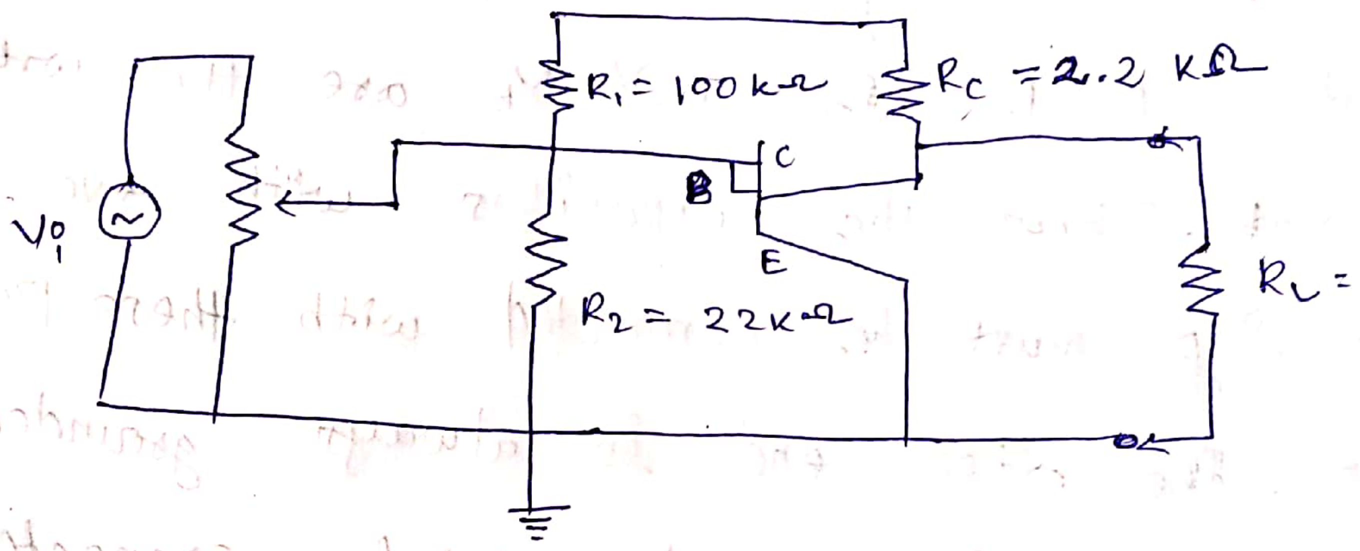
Thus $V_B = 2.164\ V$

$V_E = 1.514\ V$

$V_C = 4.1938\ V$

$I_E = 3.221\ mA$

2) Small signal Equivalent circuit.



Voltage gain, $A_v = -\dfrac{(\beta R_C)}{r_b} = \dfrac{-(R_C)}{r_e} = -\dfrac{(R_C \cdot I_E)}{V_T}$

$= -\dfrac{(R_C \cdot I_C)}{V_T}$

Where, $V_T = 25mV$ (Thermal voltage at R.T)

$I_C = I_E = 3.221\ mA$ (Quisent values)

$R_C = 2.2k\Omega$ (given)

Thus $A_V = \dfrac{-2.2\ k\Omega \times 3.22mA}{25\ mV}$

$A_V \simeq 283.448$

3) Given $MUOVS = 2 \times \min(V_{CC} - V_C, V_C - V_E)$

Using quiscent values :

$V_{CC} - V_C = (12 - 4.1938)\,V = 7.8062\ V$

$V_C - V_E = (4.1938 - 1.514)\,V = 2.6798\ V$

Thus $MUOVS = 2 \times 2.6798\ V$

$= 5.3596\ V$

4) While performing DC analysis, the voltages of points B, C, E, i.e. V_B, V_C, V_E are the wrt ground. Thus the capacitors with +ve polarity must be connected with these points, as the other end is always grounded, −ve of polarity can be safely connected to the opposite ends.

05/07/2019

Measuring DC Quantities (Quiescent Values)

1.)

Approx values	Real Values (DMM) → Digital Multimeter
470 Ω	454 Ω
1 KΩ	0.97 KΩ
2.2 KΩ	2.12 KΩ
22 KΩ	21.6 KΩ
100 KΩ	98.3 KΩ

2.) (a) $V_{cc} = 11.95V$

$V_{BE} = V_B - V_E = 0.642\,V$ (forward bias)

(b) $V_c = 5.93\,V$

$V_E = 1.278V$

$V_B = 1.916\,V$

$\Rightarrow V_E < V_c < V_{cc}$

3.) $V_B = 1.916V$;

$V_E = 1.278\,V$;

$V_c = 5.93V$;

$V_{cc} = 11.95V$;

$$I_E = \frac{V_E}{R_E} = \frac{1.278}{454} = 2.812\ mA$$

$$I_{R_1} = \frac{V_{cc} - V_B}{98.3} = \frac{11.95 - 1.916}{98.3} = 0.102mA$$

$$I_c = \frac{V_{cc} - V_c}{2.12} = \frac{11.95 - 5.93}{2.12} = 2.839mA$$

$$I_{R_2} = \frac{V_B}{21.6} = \frac{1.916}{21.6} = 0.088\,mA$$

$$I_B = I_{R_1} - I_{R_2} = 0.102 - 0.089 = 0.013\,mA$$

4) $\beta = \frac{I_c}{I_B} = \frac{2.839}{\cancel{0.102}\ 0.013} = \cancel{27.83}\ \cancel{28.0}\ 218.38$

4) $A_v = -\frac{R_c I_c}{V_T}$

$V_T = 25\,mv$; $R_c = 2.12\,K\Omega$; $I_c = 2.839\,mA$

$$A_v = \frac{-2.12 \times 2.839}{25} \times 10^3 = -240.75$$

Part B : Voltage Gain Without Load Resistance :-

After Disconnecting C_2 :- 1) frequency ⇒ 1 KHz. set approximately ⇒ 15 mV.

$V_{c,\,p-p} = 2V$

[Multiplier 1 → input = 10 mV
Multiplier 2 → output = 1 V]

3) $V_{i,\,p-p}(mv) = 17\,mV$

[Time scale = 0.5 ms]

4) $A_v = -\frac{(V_{c\ p-p})}{(V_{i\ p-p})} = \frac{-2}{17\,mV} = -117.64$

2) → graph.

:- Maximum Undistorted Output Voltage Swing (MUOVS)

1. Peak-to-Peak input voltage:-

$V_{i(p-p)} = 1.5 \times \underset{(mV)}{50} = 75mV$ (Multiplier = 50mV)

Corresponding, $V_{c\,(p-p)} = 8.3V$

for 180° output graph:-

Multiplier 1 → input = 50mV

Multiplier 2 → output = 5v.

graph →.

Part D :- Voltage gain with load Resistance:-

$R_L = 0.97k\Omega$ $R_c = 2.12\,k\Omega$

$V_{i\,(p-p)} = 45mV$

$V_{c\,(p-p)} = 2V$

R_c become → $R_{c(eff)} = R_c \parallel R_L$

$\boxed{R_{c_{eff}} = \frac{R_c \cdot R_L}{R_c + R_L}}$

$A_v = -\left(\frac{-2}{45\,mV}\right) = 44.44$ → reduced A_v.

Part E :- Effects of C_E On A_v ⇒

1) $V_{c\,(p-p)} = 2V$ 1KHz = frequency. 2) Remove C_E

3) $V_{i\,-(pp)} = 3.2 \times 50mv = 160mv$ $V_{C-pp} = 3.5 \times 0.2V = 0.7v = 700mv$.

4) $V_{i\,(p-p)} = 152mV$

$V_{E\,(p-p)} = 7.4 \times 20 = 148mV$

→ graph

$A_v = -\frac{700}{160} = 4.375$.

$A_{v.theoritical} = \frac{-R_c}{R_c} = \frac{2.12k\Omega}{454\Omega} = 4.67$

→ Both have same phase.

5)

5. Multiplier $= 0.1$

$V_E = 1.6 \times 0.1 = 0.16V$

$V_C = 7 \times 0.1 = 0.7V$

V_E and V_C are <u>180°</u> out of phase.

6. On further increasing of V_1 (p-p), V_E becomes square wave from both side.

At touch (-ve & +ve)

$V_C = 3.8 \times 2 = 7.6V$

$V_E = 3\cancel{.2 \times 0.5 = 1.6V}$ $2 \times 1 = 2V$

Part-B Point (2)

Scale :- x- axis - time axis

1 unit = 0.5 msec/div.

$f = 1KHz$

$T = 1mS$

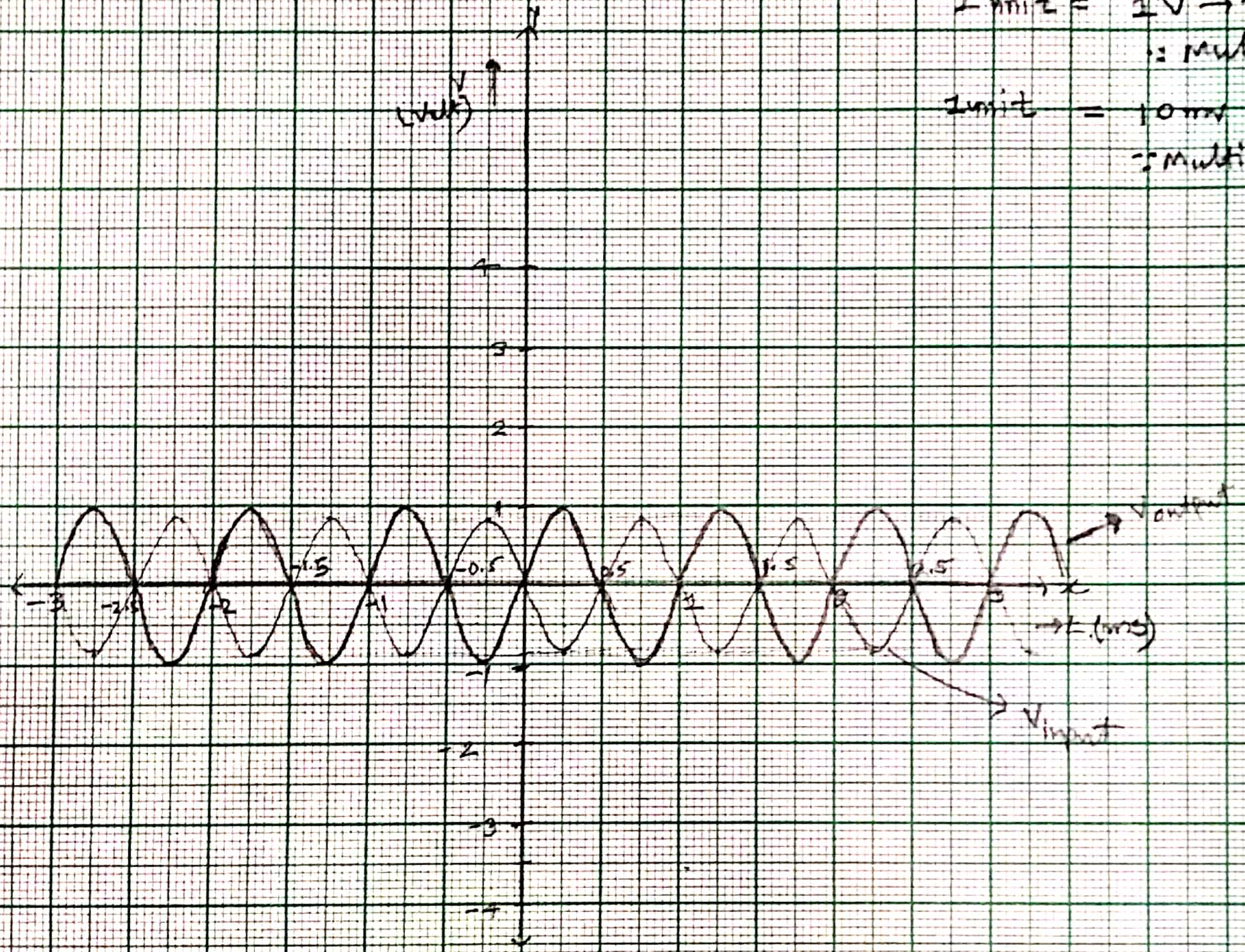
Y axis - Voltage axis

1 unit = 1V → for output

∴ multiplier = 1V

1 unit = 10mV → for input

∴ multiplier = 10mV



$V_{output\ P-P} = 2 \times 1V = 2V$

We observed 180° phase difference

$V_{input\ P-P} = 17 \times (10mV) = 170mV$

Collector voltage ⇒ $V_c = 2V$

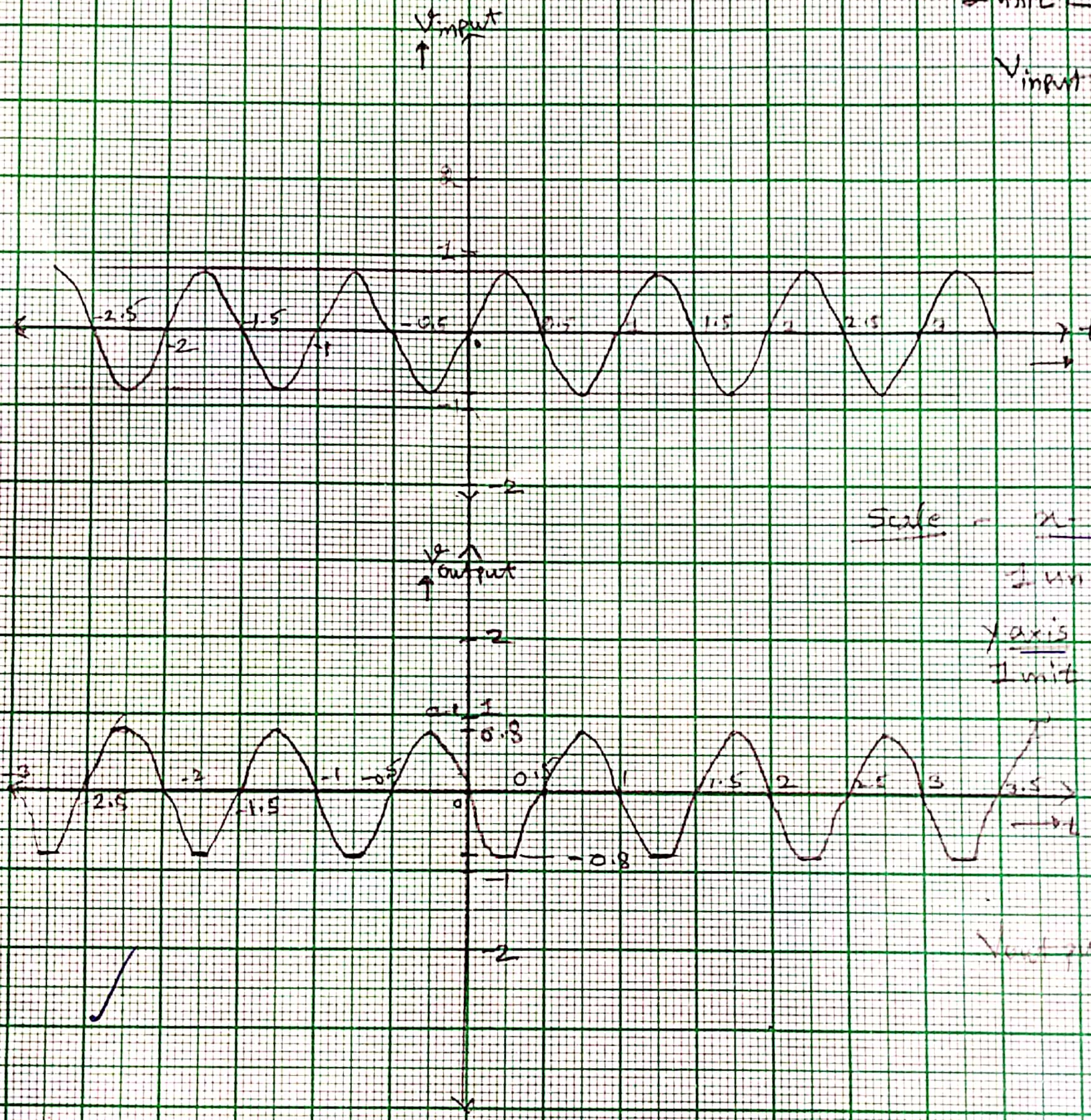
input → $V_{P-P} = \pm 170mV$

Part C - Point 1 ⇒

slight flattening of V_{c-pp}

Scale - x-axis - time axis
1 unit = 0.5 mSec
y-axis → voltage axis.
1 unit = 50mV

$V_{input} = 50 \times 1.5$
$= 7.5mV.$



Scale - x-axis
1 unit = 0.5 mSec
y axis
1 unit = 5V

$V_{output} = 5 \times 1.66 = 8.3$

We observed 180° out of Phase.

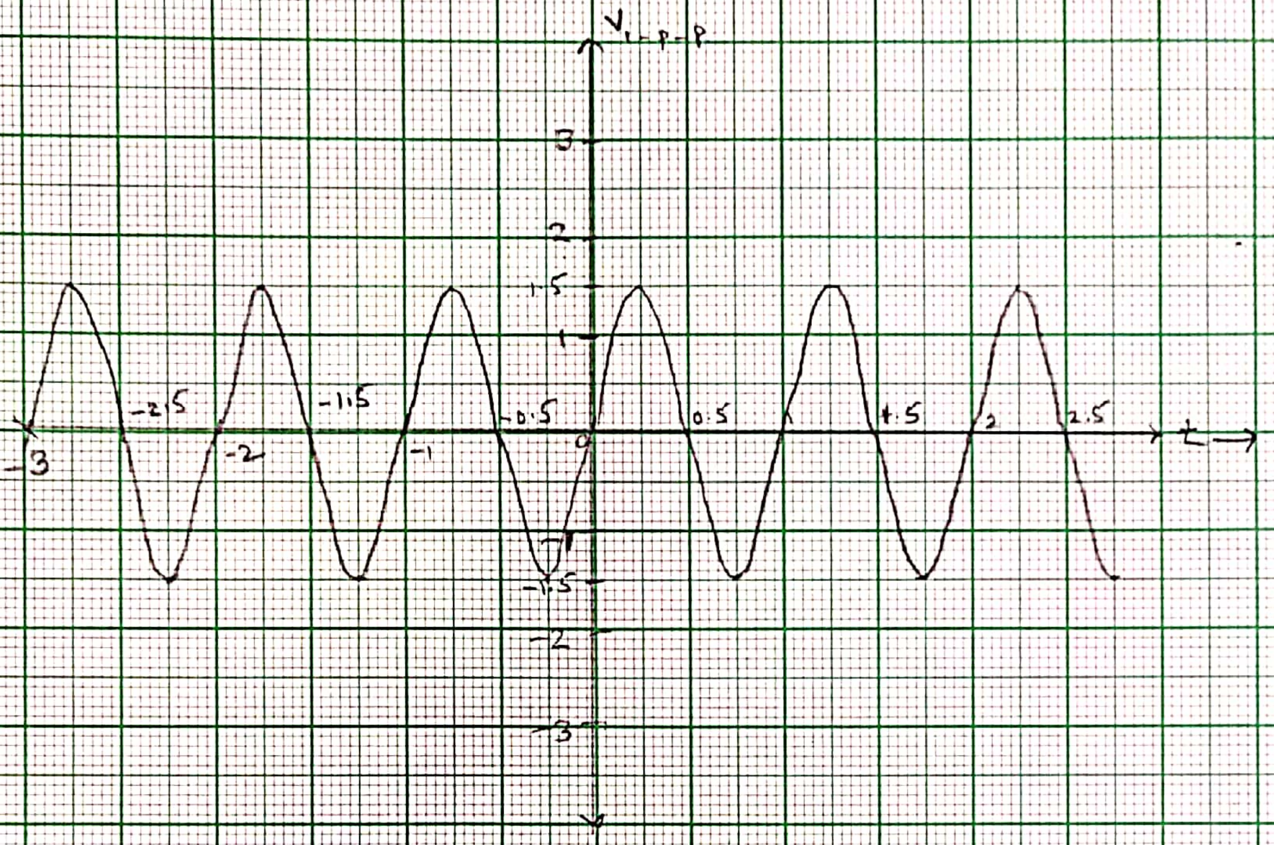
Collector voltage ⇒ $V_{c_{pp}} = 8.3V$

input → $V_{i_{pp}} = 7.5mV.$

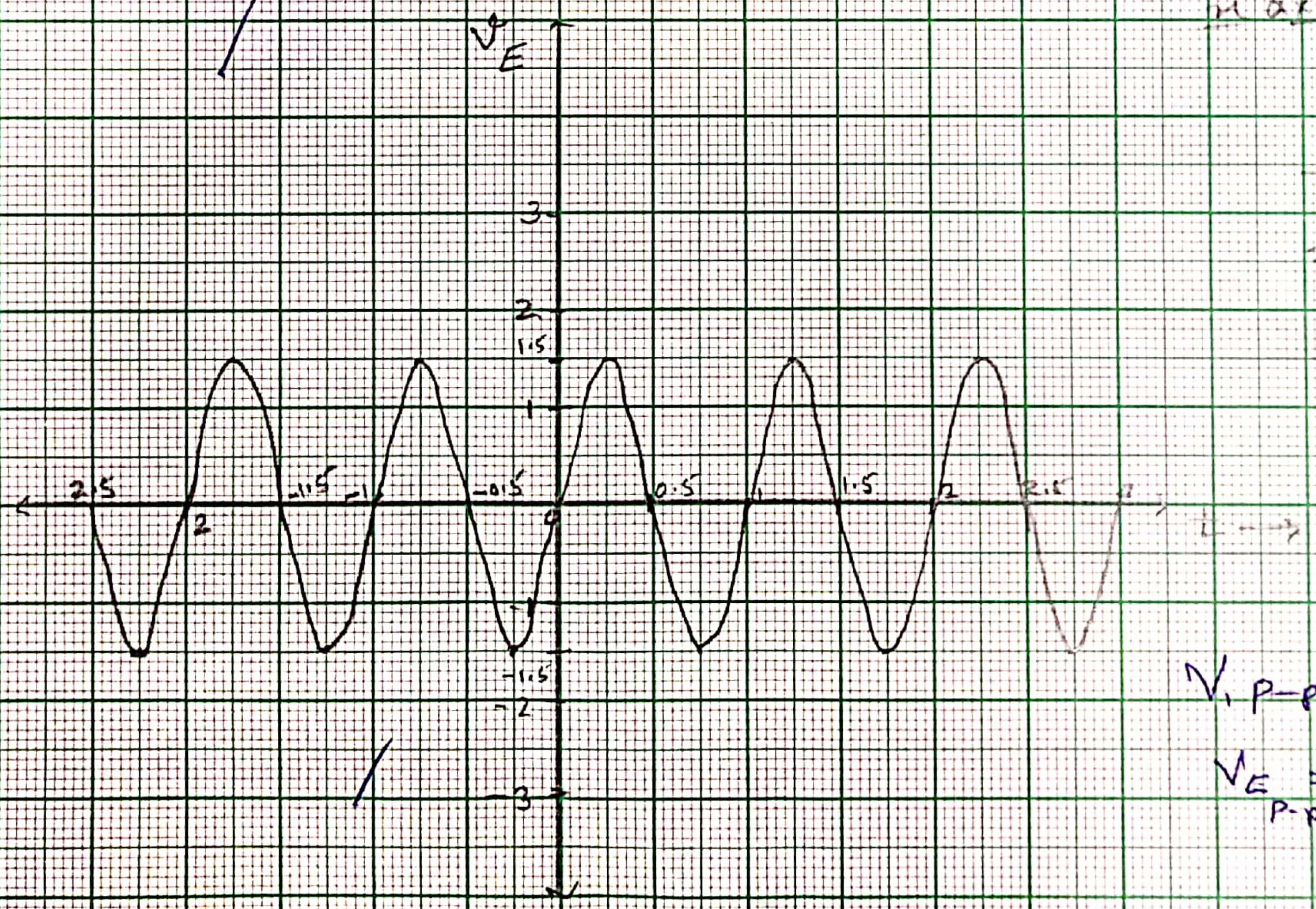
Part - (E) Point (4)

graph between - V_E and V_{1-P-P} :

Scale -
x-axis time axis
1 unit = 0.5 ms
Y-axis - Voltage axis
1 unit = 50 mV.



x axis : time scale
1 unit = 0.5 ms
Y axis - voltage axis
1 unit = 50 mV



$V_{1\,p-p} = 152\,mV$

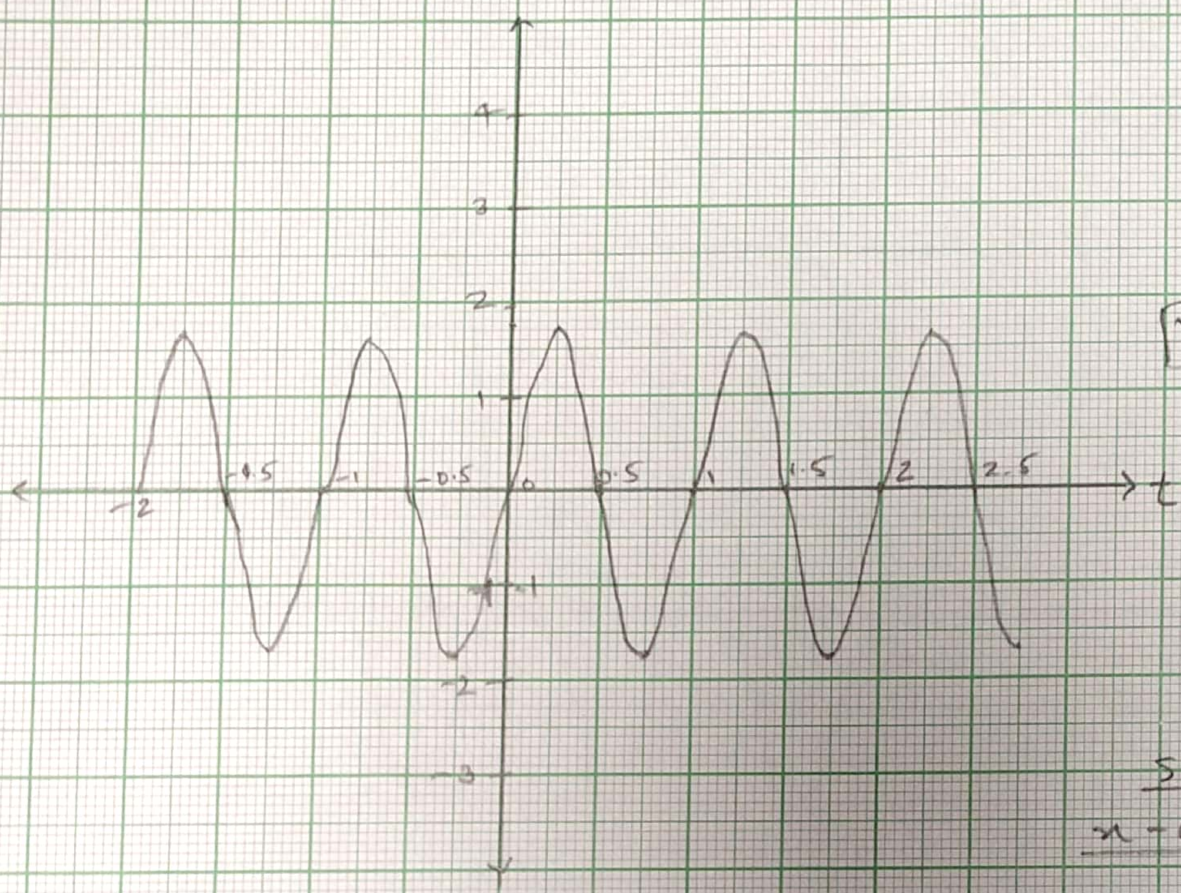
$V_{E_{p-p}} = 148\,mV.$

We observed same phase

Part (E) Part -(5) :-

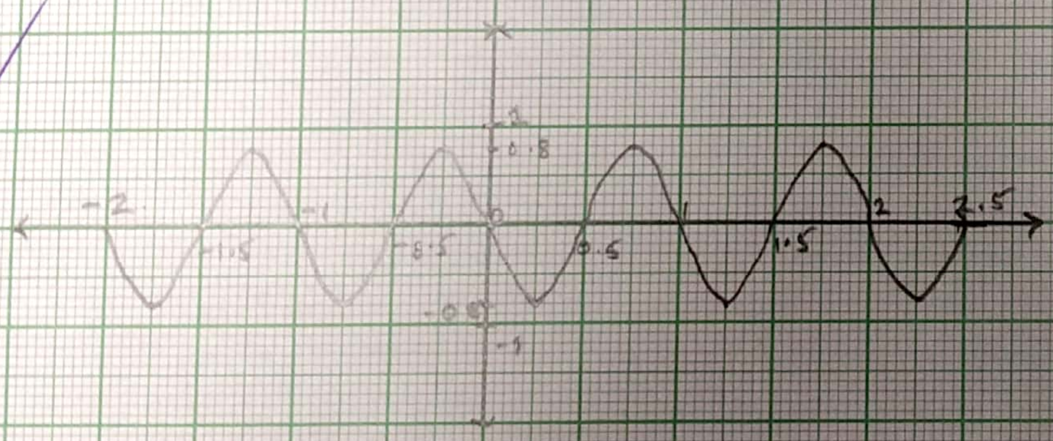
graph between V_E and V_C :-

Scale
x-axis time axis
1 unit = 0.5 ms
Y-axis - voltage axis
1 unit ⇒ 0.2 Volt



$V_c = 3.5 \times 0.2 = 0.7$ Volt

Scale
x-axis time axis
1 unit = 0.5 ms
Y-axis - voltage axis
1 unit = 0.1 Volt
$V_E = 1.6 \times 0.1 = 0.16V$



We observed out of phase.

Part (E) Point (b) →

Scale :-

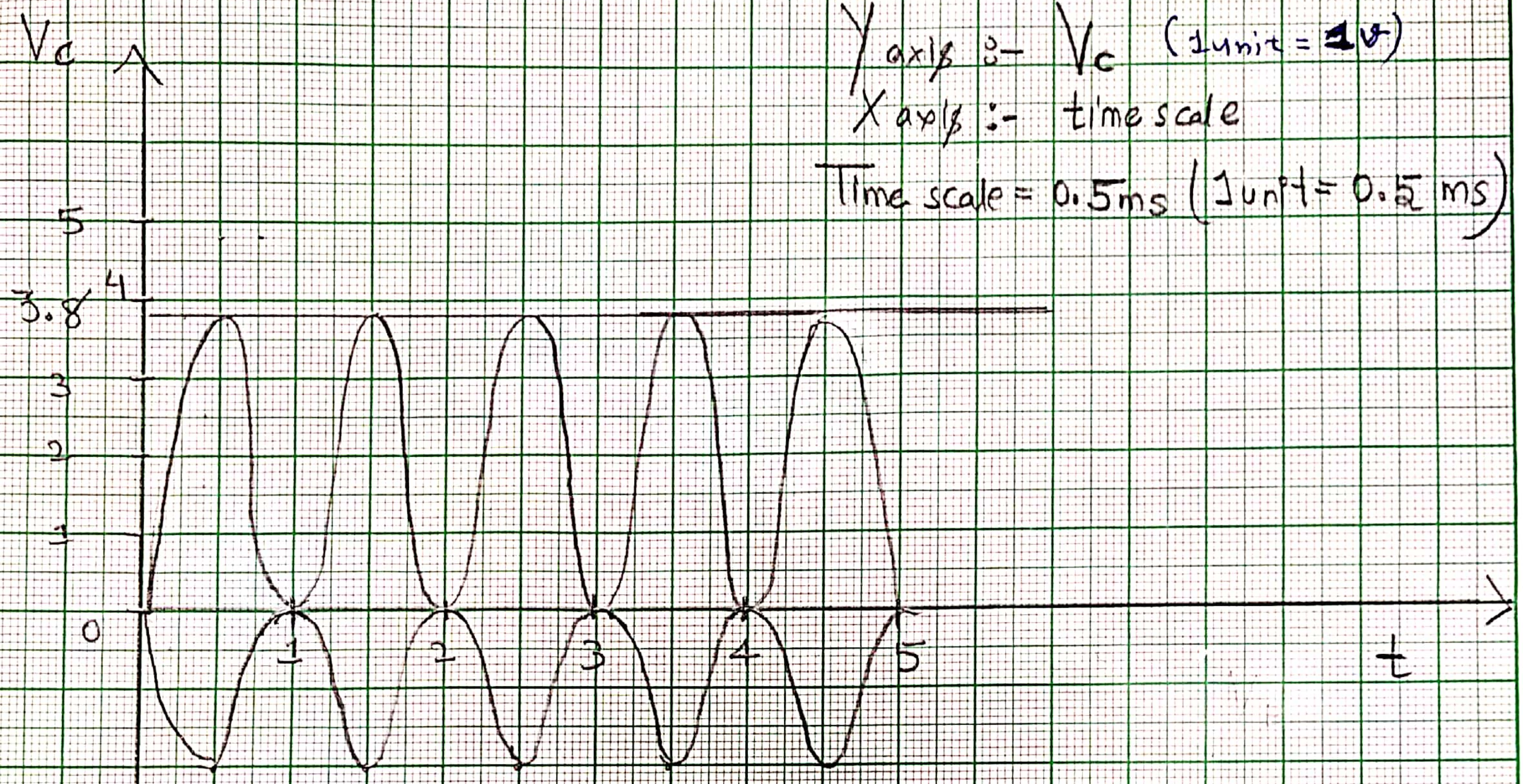
V_E and V_C almost touching.

Y axis :- V_E (1 unit = 1 V)

Y axis :- V_C (1 unit = 1 V)

X axis :- time scale

Time scale = 0.5 ms (1 unit = 0.5 ms)



$V_C = 3.8 \times 2 = 7.6$ Volt.

multiplier

1). $V_E = 1.278V$;
$V_C = 5.93V$
$V_{CC} = 11.95V$
$V_B = 1.916V$

$\because V_E < V_C < V_{CC}$

In case of active region of a transistor (npn), I_C should be moving into the transistor. For this to happen:-

$V_{CC} > V_C$ & $V_C > V_E$; $V_B > V_E$;

$\therefore V_{CC} > V_C > V_E$

2)

	Experimental	Theoretical
V_C	5.93V	~~5.93~~ 4.91V
V_E	1.278V	1.514V
V_B	1.916V	2.164 V
V_{CC}	11.95 V	12 V
I_E	2.812 mA	3.221 mA
I_C	2.839 mA	3.222 mA
I_B	0.013 mA	0.014 mA

(3.) $\beta_{experimental} = \frac{I_C}{I_B} = \cancel{21.83}\ 218.38$

$\beta_{Theoretical} = 200$

(4.) Part A :- $A_v = -240.75$

Part B :- $A_v = -117.64$

Theoretical value :-

In Pre-lab work :- $A_v = -283.448$

(5.) Through MUOVS, we get to know about the active region of the amplifier i.e below which voltage it follows a linear relationship.