Experiment : 5

COMMON EMITTER AMPLIFIER

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EE102: Basic Electronics Laboratory

Expt. No. 5: Common Emitter Amplifier

Objectives:

1. To carry out an approximate DC and AC analysis of a Bipolar Junction Transistor (BJT) Common Emitter amplifier.
2. To determine the voltage gain, the "maximum undistorted peak-to-peak output voltage swing" (MUOVS) and the maximum input voltage for an 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 BJT: BC547 (One); Resistors: 220 Ω (One), 820 Ω (One), 1 kΩ (One), 5.6 kΩ (One); Capacitors: 10µF (Three)

Pre-Lab Work:

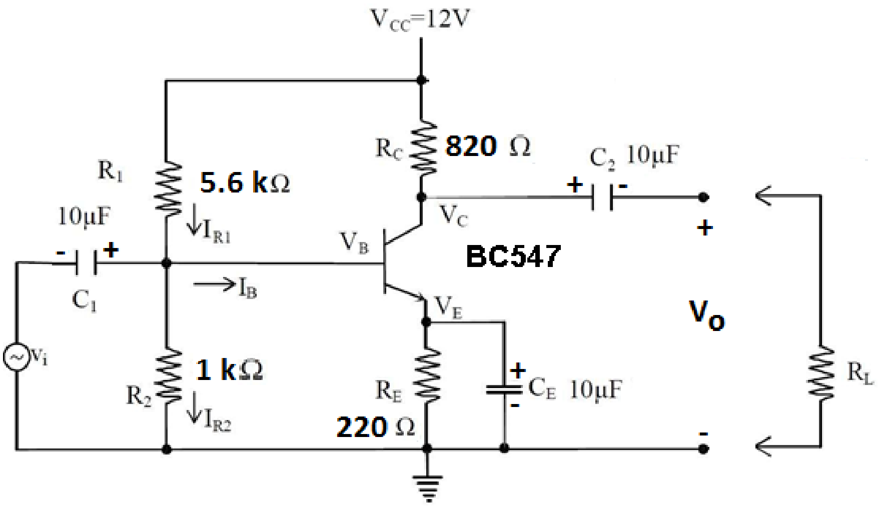

Fig.1 Common Emitter Amplifier Circuit

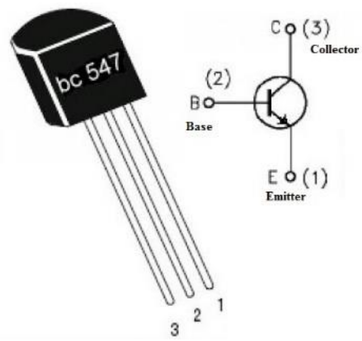

Fig 2. BC 547 transistor Pin Configuration

1. Carry out an approximate DC analysis by using the values given in Fig.1 and by making use of the assumptions
   a) I_{R1}, I_{R2} >> I_B, so that $I_{R1} \approx I_{R2}$ and
   b) $V_{BE} \approx 0.65$ V.

   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

   $A_V = -(\beta.R_C)/r_b = R_C/(r_b/\beta) \approx -(R_C)/(r_e) = -(R_C.I_E)/(V_T) \approx -(R_C.I_C)/(V_T)$,

   Take $V_T \approx 25$ mV (at room temp).

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

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

Part A: Measuring DC Quantities (Quiescent Values)

1. Before assembling the circuit, measure the actual values of all resistors except 220 Ω (not supported in Labsland) by means of a Digital Multimeter (DMM). The actual values thus determined are to be used in calculating the currents.
2. Assemble the circuit as shown in Fig. 1 without connecting the function generator as well as the capacitors. The pin configuration of the BC547 transistor is shown in Fig. 2. Apply V_{CC} = +12V from the DC power supply and note the following:

   (a) Measure base-to-emitter voltage (V_{BE}) using a DMM and it should be around 0.6 - 0.7 V indicating that BE junction is forward biased.

   (b) Fill the Table given below with at least 3 measurements of V_B, V_E, V_C and V_{CC} using the Oscilloscope rather than DMM. (**Note:** Use DC coupling mode and keep highest possible vertical sensitivity (V/div) setting for each channel by shifting the channel reference line to the bottom of the screen using vertical shift knob. Use the '*Average*' function from the measurement menu of the Oscilloscope for measuring the DC voltages.)

   For each measurement:

   (i). Check if $V_E < V_C < V_{CC}$. A value of V_C midway between V_E and V_{CC} should be observed.

   (ii). Determine the circuit currents I_B, I_C and hence β ($\beta = I_C/I_B$).

V_{CC} (V)	V_E (V)	V_C (V)	V_B (V)	$I_{R1} = (V_{CC}-V_B)/R_1$ (mA)	$I_{R2} = V_B/R_2$ (mA)	$I_B = I_{R1}-I_{R2}$ (μA)	$I_C = (V_{CC}-V_C)/R_C$ (mA)	$\beta = I_C/I_B$	$A_V = -(R_C.I_C)/(V_T)$
							Average value		

Part B: Voltage Gain under No-Load condition

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. No-load condition refers to R_L being infinity or nothing connected across the output of the CE amplifier.

1. In the assembled circuit, connect all capacitors (C_1, C_2 and C_E) as shown in Fig. 1. Adjust Function Generator to get 50mV peak-to-peak sinusoid at 1 kHz (display in Channel 1 of Oscilloscope). Apply this voltage as amplifier input vi through C1.
2. Display the output voltage v_o in Channel-2 of Oscilloscope (use AC coupling mode). Note for the phase difference between the input and the output voltages which should be approx. 180°.
3. Adjust $v_{i,p\text{-}p}$ amplitude to get a convenient value for peak-to-peak output voltage $v_{o,p\text{-}p}$ (say 4V). Use appropriate vertical sensitivity (V/div). Note the corresponding $v_{i,p\text{-}p}$ (mV).
4. Experimentally obtained voltage gain is therefore computed as:

$$A_V = -(v_{o,p\text{-}p})/(v_{i,p\text{-}p}).$$

Part C: Maximum Undistorted Output Voltage Swing

1. Increase $v_{i,p\text{-}p}$ slowly till you observe a slight flattening of $v_{o,p\text{-}p}$ 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 experimental MUOVS. Measure the corresponding $v_{i,p\text{-}p}$, the peak-to-peak input voltage.
2. Now increase $v_{i,p\text{-}p}$ 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 (**Not to be performed on LabsLand**)

(Refer to the web-link available at http://www.iitg.ac.in/eee/ee102/)

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

Part E: Effects of C_E on A_V (**Not to be performed on LabsLand**)

(Refer to the web-link available at http://www.iitg.ac.in/eee/ee102/)

1. Get back to the conditions in Part-B i.e. v_i at 1 kHz, its amplitude adjusted to get $v_{i,p\text{-}p} \approx 20$ mV.
2. Now, remove C_E (with circuit powered) and note the drastic reduction in $v_{o,p\text{-}p}$. You have to change to appropriate V/div in your Oscilloscope. 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 $v_{i,p\text{-}p}$ 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 Oscilloscope. 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 $v_{i,p\text{-}p}$ gradually and observe how v_E and v_C change. Continue to increase $v_{i,p\text{-}p}$ 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 $v_{i,p\text{-}p}$ 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 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.
4. What is the utility of knowing MUOVS in the design of an amplifier?

Prelab - 5

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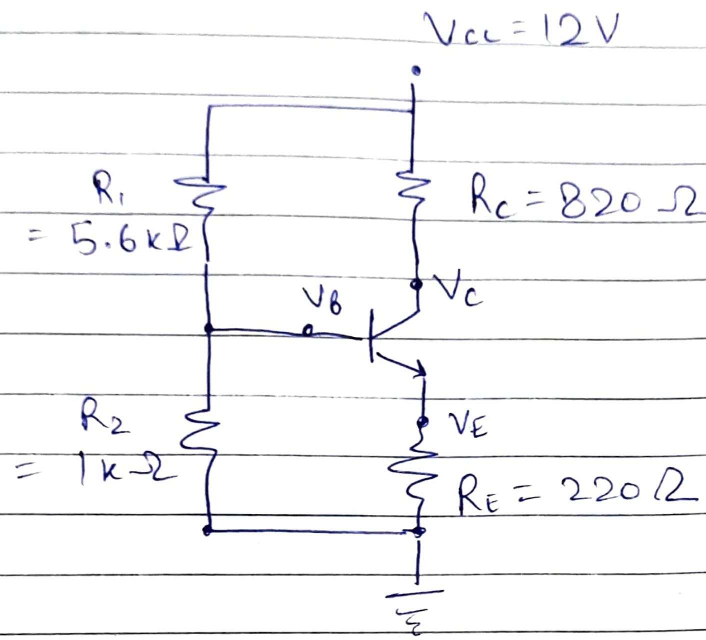
1.



DC Analysis

Given $I_{R_1} \simeq I_{R_2} = I_R$

$$12 - 5.6 I_R - 1 I_R = 0$$

$$I_R = \frac{12}{6.6} = 1.818 \text{ mA}$$

$$V_B = I_R \cdot 1k\Omega = 1.818 \text{ V}$$

$$V_E = V_B - V_{BE} = (1.818 - 0.65) \text{ V}$$

$$V_E = 1.168 \text{ V}$$

$$I_E \simeq I_c = \frac{1.168}{220} = 0.00531\,A = 5.31\,mA$$

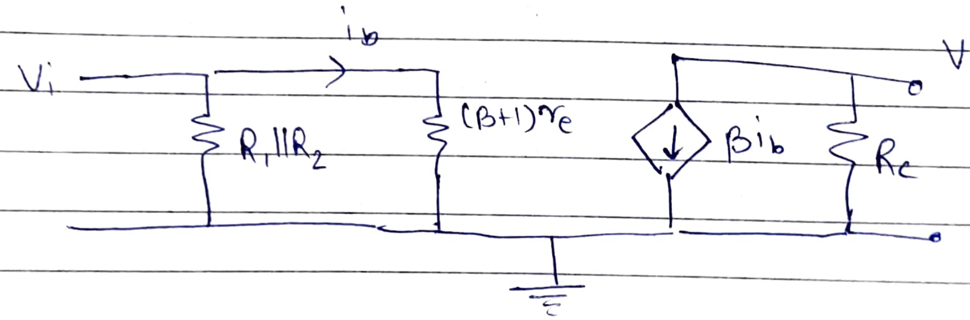
$$V_c = V_{cc} - I_c R_c$$

$$= 12 - \frac{5.31}{10^3} . 820 = 7.646V$$

Thus

$$\boxed{\begin{aligned} V_B &= 1.818V \\ V_E &= 1.168V \\ V_c &= 7.646V \\ I_E(\simeq I_c) &= 5.31\,mA \end{aligned}}$$

2



$$A_v = -\frac{R_c I_c}{V_T} = -\frac{820 \times 5.31 \times 10^{-3}}{25 \times 10^{-3}}$$

$$\boxed{A_v = -174.68}$$

$$R_1 \| R_2 = \frac{1 \times 5.6}{1+5.6} = 0.848\,k\Omega$$

(3) $MUOVS = 2 \times \min\{V_{cc} - V_c, V_c - V_t\}$

$= 2 \times \min\{12 - 7.646, \cancel{6-4}\ 7.646 - 1.168\}$

$= 2 \times \min\{4.354, 6.478\}$

$= 2 \times 4.354$

$\boxed{MUOVS = 8.708}$

(4) The capacitor C_1 & C_2 are used to pass the input signal and capture the output signal while blocking the dc voltage from the ~~amplifier~~ preceding circuit. This prevents dc in the circuitry of input-output circuits from affecting the ~~bias~~ bias.

The capacitor C_3 is used to bypass the R_E and short circuits the ac signal through C_3 since voltage gain decreases because of presence of ~~R_3~~ R_E.

Observations

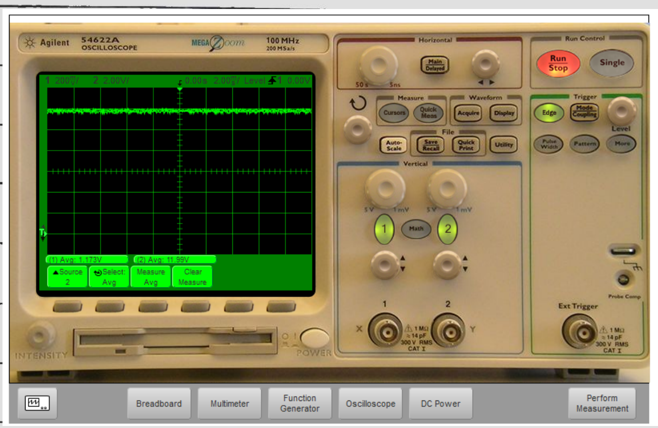
Part A:

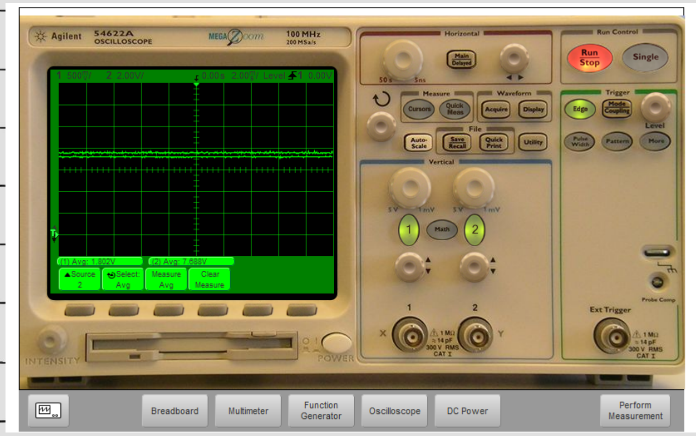
Measuring resistances:

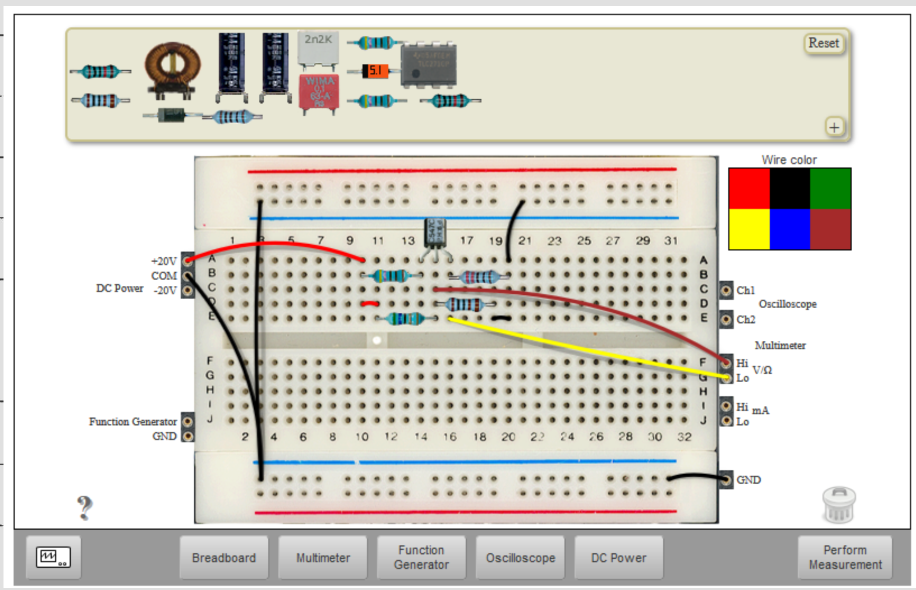
820 → 818.4 Ω

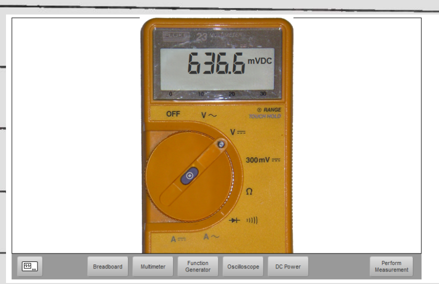
1k → 1.001 KΩ

5.6k → 5.496 KΩ







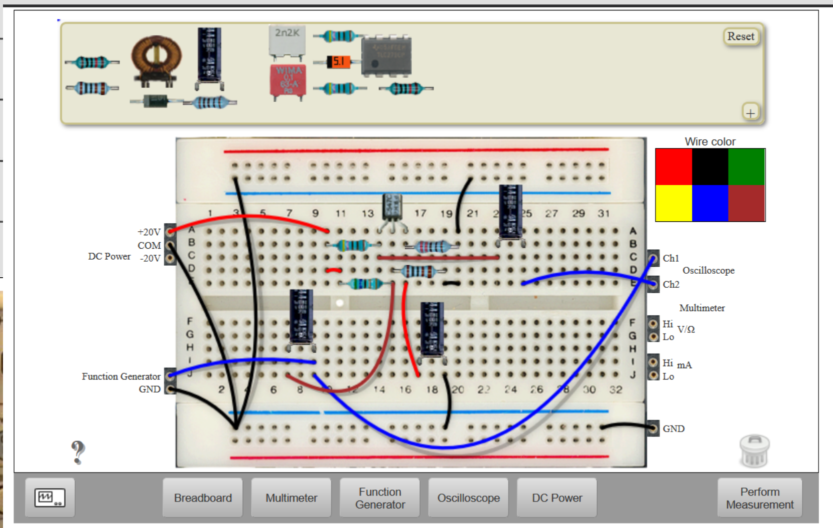


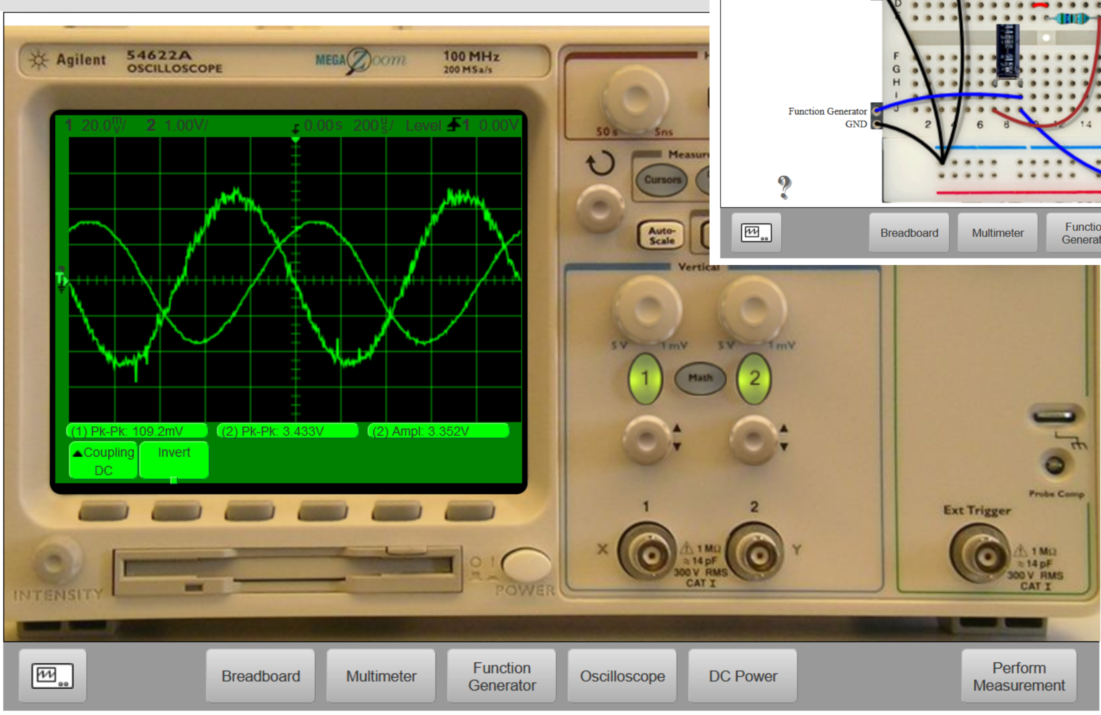
Measuring BE junction voltage → $V_{BE} = 636.6\ mV$

V_{cc} (V)	V_E (V)	V_c (V)	V_B (V)	I_{R_1} $=(V_{cc}-V_B)/R_1$ (mA)	I_{R_2} $= V_B/R_2$ (mA)	I_B $I_{R_1}-I_{R_2}$ (mA)	I_c $(V_{cc}-V_c)/R_c$ (mA)	β $= I_c/I_B$	A_v $-R_c I_c/V_T$
11.99	1.173	7.679	1.802	1.854	1.800	0.054	5.267	97.537	-172.42
11.98	1.72	7.688	1.802	1.852	1.800	0.052	5.244	100.846	-171.67
12.00	1.72	7.683	1.801	1.856	1.799	0.057	5.275	92.544	-172.68
							Average:	96.976	-172.26

- from the table its clear $V_E < V_c < V_{cc}$ with V_c being midway between V_E & V_{cc}.

PART B





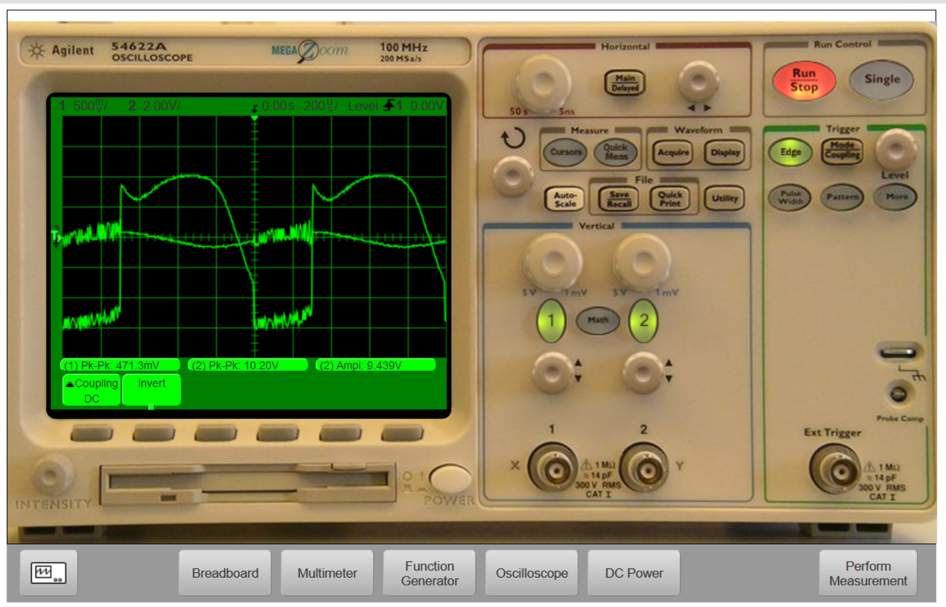
At $V_{o,pp} = 4.078V$ we get $V_{i,p-p} = 0.079$ V

Thus $A_v = -V_{o,p-p}/V_{i,p-p} = -51.62$

Part-C

MUOVS = 9.5 V

with corresponding input voltage = 0.13 V



At voltage higher than MUOVS.

Part D

A_v here is $\dfrac{-4.2 \text{ div} \times 0.2 \text{ V/div}}{2 \text{ div} \times 10 \text{ mV/div}} = -\cancel{21}\ 42$

Answers to Questions for Part D

Q1) Exp value of voltage gain under no load condition

$V_{o,pp} = 5.6 \text{ div} \times 0.5 \text{ V/div} = 2.8 \text{ V}$
$V_{i,pp} = 2 \text{ div} \times 10 \text{ mV/div} = 2 \times 10^{-2} \text{ V}$

$A_v = -\dfrac{2.8}{2 \times 10^{-2}} = \cancel{122.5}\ -140$

Q2) Nominal & actual values of load resistance R_L

Nominal $= 1 \text{ k}\Omega$
Actual $= 0.983 \text{ k}\Omega$

Q3) A_v under load applied

$\rightarrow \quad A_v = \dfrac{-4.2 \times 0.2}{2 \times 10} = -42$

Q4)

% reduction $= \dfrac{-140 + 42}{-140} \times 100$

$= 70\%$

Part E

Q5) Voltage gain with unbypassed R_E

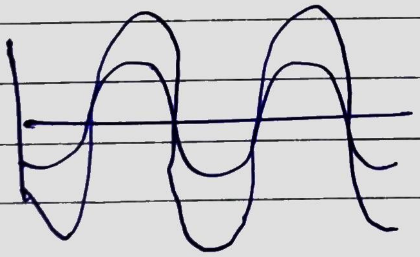
$$A_V = -\frac{2 \times 50\,mV}{2.1 \times 10\,mV} = -4.76$$

Q6) Theoretical value

$$A_V = -\frac{R_C}{R_E} = -\frac{2.150\,k\Omega}{0.458\,k\Omega} = -4.69$$

Thus the 2 values are quite close.

Q7) Amplitute & phase relationship betw v_i & v_e waveforms



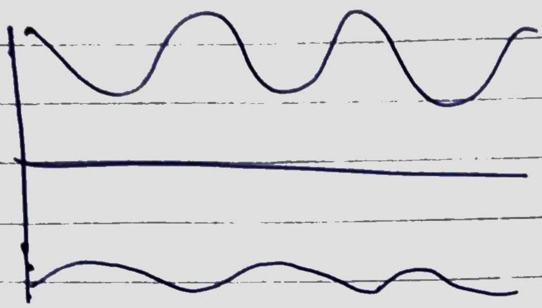
These 2 have no phase difference

$V_{i\,p\text{-}p} = 2 \times 10\,mV = 20\,mV$

$V_{e\,p\text{-}p} = 4 \times 5\,mV = 20\,mV$

Thus, amplitude of v_i & v_e are approx same.

Q8) amplitude & phase relationship between V_e & V_c



They are 180° out of phase.

amplitude : $V_c = 2.4 \text{ div} \times 1V/\text{div} = 2.4\ V$

$V_e = 0.6 \text{ div} \times 1V/\text{div} = 0.6V$

Q9) When BJT has just gone into saturation

$V_{o,pp}$ is $V_c = 4.4 \text{ div} \times 2V/\text{div} = \underline{\underline{8.8\ V}}$

and since we know $A_v = -4.76$
for no-load unbypassed R_E

$V_i = \frac{V_c}{A_v} = -1.848\ V$

OR $V_{ipp} = \underline{\underline{1.848V}}$ (180° out of phase with $V_{o,pp}$)

On further increasing $V_{i(pp)}$, V_E becomes Square wave.

Part - F

1. Since the desired circuit is an amplifier with Common emitter configuration, hence $V_E < V_C < V_{cc}$ is prefered value in step 2 of part A.

2.

	Theoretical (determined in prelab)	Experimental
V_B	1.818V	1.802 V
V_E	~~1.172 V~~ 1.168V	1.172 ~~1.168~~ V
V_C	7.646 V	7.683 V
I_E	5.31 mA	5.267 V

Thus all values are quite close.

3. Prelab : −174.68
Part A : −172.26
Part B : −51.62

The big difference in values of part A & B is because of difference in values of input voltage. Thus the gain in A is much higher than that in B

And part A value is quite close to that determined in pre-lab work.

4. ~~MUOVS~~ In circuit designing, MUOVS gives us an idea of the maximum allowed power supply before which the output waveform become undistorted leading to undesirable results.