EW2 Project 1 final report

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OBJECTIVE:

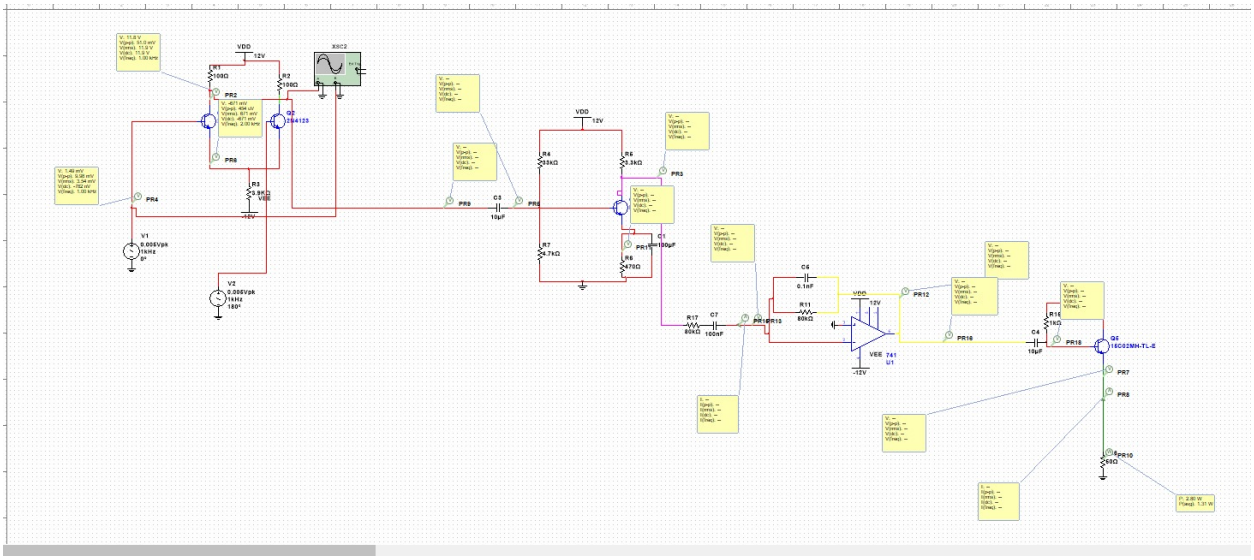
Make an audio amplifier with a gain of 500 or more and remove noise using a 12V or less voltage supply.

Material Required:

12 V DC supply, opamp, power transistor, Mic, speaker(10ohm), bjt, capacitors, and resistors of various values.

Topology used:

Mic → Pre-amplifier → gain → filter → power-amplifier → speaker



BJT VS MOSFET:

→ BJTs have lower input impedance, and MOSFETs high.

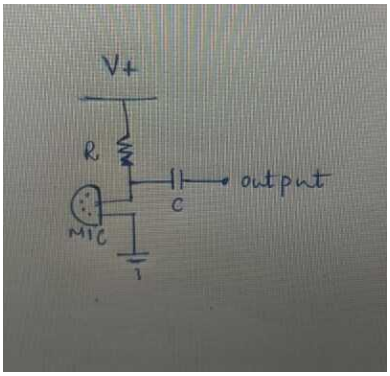
→ While on MOSFETs it can be considered negligible, BJTs need higher gate currents to work.

→ BJTs produce large current changes for a small input voltage change, which allows for easier design, linear-wise, of wide bandwidth amplifiers

→ Also bjt offers better output swings.

Procedure:

Microphone:

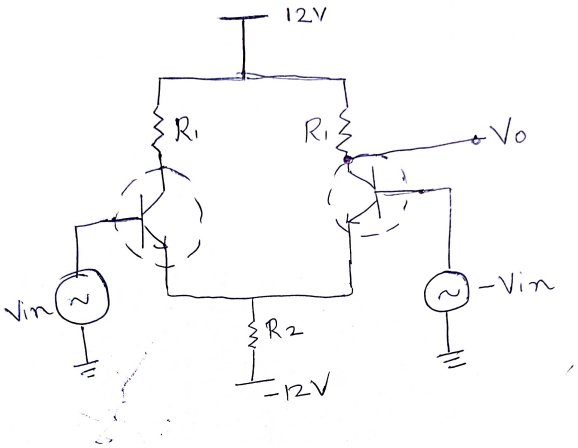


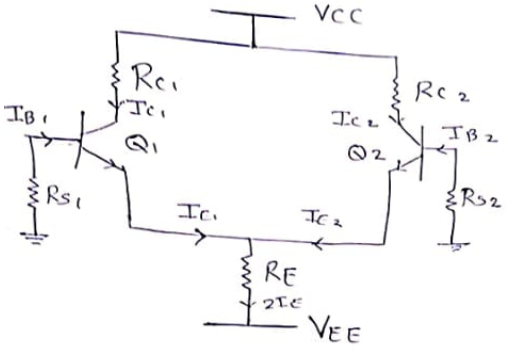
→ capacitor present there is for blocking the dc voltage to pass on .

→ Voltage Vcc is dividing between mic and resistor R. Hence on increasing R the output voltage would decrease.

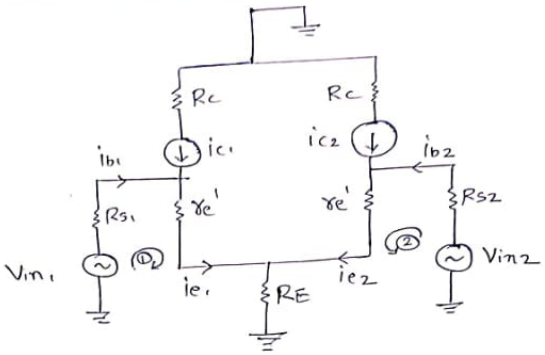
$$V(Output) = \frac{k}{R}$$

Pre-Amplifier:





DC MODEL



AC MODEL

KVL in Base emitter loop

$-I_B R_s - V_{BE} - 2I_E R_E + V_{EE} = 0$ — ①

$I_B = \frac{I_E}{\beta} = \frac{I_C}{\beta}$ — ②

using ①, ②

$-\frac{I_E R_s}{\beta} - V_{BE} - 2I_E R_E + V_{EE} = 0$

$-I_E \left(\frac{R_s}{\beta} - 2R_E\right) + V_{EE} - V_{BE} = 0$ — ③

$V_{BE} = 0.7\,V$ — ④

$\frac{R_s}{\beta} <<< 2R_E$

Hence: $I_E = \frac{V_{EE} - V_{BE}}{2R_E}$ — ⑤

∵ Drop across R_s is too small

$V_E \approx -V_{BE}$ — ⑥

$V_c = V_{cc} - I_c R_c$ — ⑦

KVL in loop ① & ②

$V_{in1} = R_{s1} i_{b1} + i_{e1} r_e' + (i_{e1} + i_{e2}) R_E$

$V_{in2} = R_{s2} i_{b2} + i_{e2} r_e' + (i_{e1} + i_{e2}) R_E$

$i_{b1} \propto \frac{i_{e1}}{\beta}$ & $i_{b2} = \frac{i_{e2}}{\beta}$

$V_{in1} = \left(\frac{R_{s1}}{\beta}\right) i_{e1} + i_{e1} r_e' + (i_{e1} + i_{e2}) R_E$

$V_{in2} = \left(\frac{R_{s2}}{\beta}\right) i_{e2} + i_{e2} r_e' + (i_{e1} + i_{e2}) R_E$

R_{s1}/β & R_{s2}/β <<< R_E & r_e'

$V_{in1} = i_{e1}(r_e' + R_E) + i_{e2} R_E$

$V_{in2} = i_{e2}(r_e' + R_E) + i_{e1} R_E$

$i_{e1} = \left(V_{in1}(r_e' + R_E) - V_{in2} R_E\right) \Big/ \left((r_e' + R_E)^2 - R_E^2\right)$

$i_{e2} = \left(V_{in2}(r_e' + R_E) - V_{in1} R_E\right) \Big/ \left((r_e' + R_E)^2 - R_E^2\right)$

$V_o = V_{c2} - V_{c1}$

$= R_c i_{c1} - R_c i_{c2}$

$= R_c (i_{e1} - i_{e2})$

$V_o = \frac{R_c}{r_e'} (V_{in1} - V_{in2})$

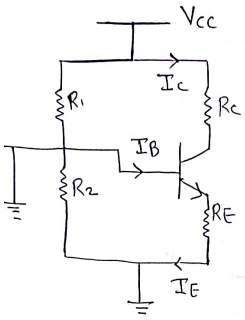
Gain = $\frac{R_c}{r_e'}$

$$r_e' = \frac{V_T}{I_C} = \frac{25 \times 10^{-3} V}{2.9 \times 10^{-3} A}$$

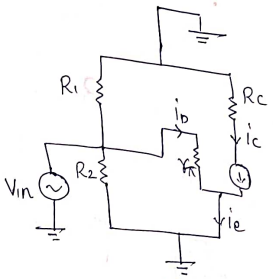
$$\approx 10$$

$$\text{Gain} = \frac{R_C}{r_e'} = \frac{100}{10} = 10$$

Common-Emitter:



DC MODEL



AC MODEL

$$g_m = \frac{I_C}{V_T}$$

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

$$V_E = V_B - 0.7$$

$$I_E = V_E / R_E \approx I_C$$

$$I_C = \frac{V_B - 0.7}{R_E}$$

Let $R_1 = 33K$ $R_2 = 4.7K$
$R_E = 470\Omega$

$I_C = 1.6\ mA$

$$g_m = \frac{1.6}{25} \approx 0.064$$

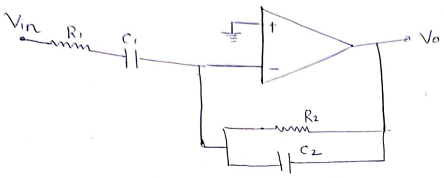
$$r_\pi = \beta / g_m$$

$$v_o = i_c R_C = \beta i_b R_C$$

$$\frac{v_o}{v_{in}} = \beta \frac{R_C}{r_\pi} = g_m R_C = (0.064) \times (3.3k) \approx 160$$

Hence Let $R_C = 3.3K$

Filter:



$$\frac{1}{2\pi R_1 C_1} = 20$$

$$R_1 C_1 = \frac{1}{40\pi}$$

$$= 7.9 \times 10^{-3}$$

Let $R_1 = 1\,k\Omega$

$C_1 = 8\,\mu F$

Low Pass

$$\frac{1}{2\pi R_2 C_2} = 20000$$

$$R_2 C_2 = \frac{1}{40000\pi}$$

$$R_2 C_2 = 8 \times 10^{-6}$$

Let $R_2 = 1\,k\Omega$

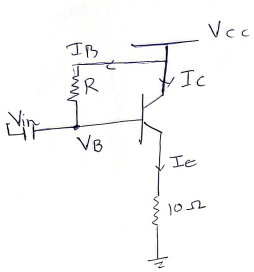
$C_2 = 8\,nF$

High Pass

Power-Amplifier:

We need a power amplifier to operate the speaker because the speaker needs at least 1-watt power to work correctly and power=IV, we have amplified the voltage but the current is still in milli amperes, hence we need it to amplify the current which eventually amplifier the power to few Watts.

We have used a class C power amplifier because it is highly efficient and better to use for audio amplifiers.



$$V_{CC} - I_B R - 0.7 = 10 I_E$$

$$V_{CC} = 0.7 + \left(10 + \frac{\beta R}{\beta}\right) I_E$$

$$I_E = \frac{V_{CC} - 0.7}{\left(10 + \frac{R}{\beta}\right)}$$

$$10 + \frac{R}{100} = \frac{11.3}{132 \times 10^{-3}}$$

$$R = 5\,k\Omega$$

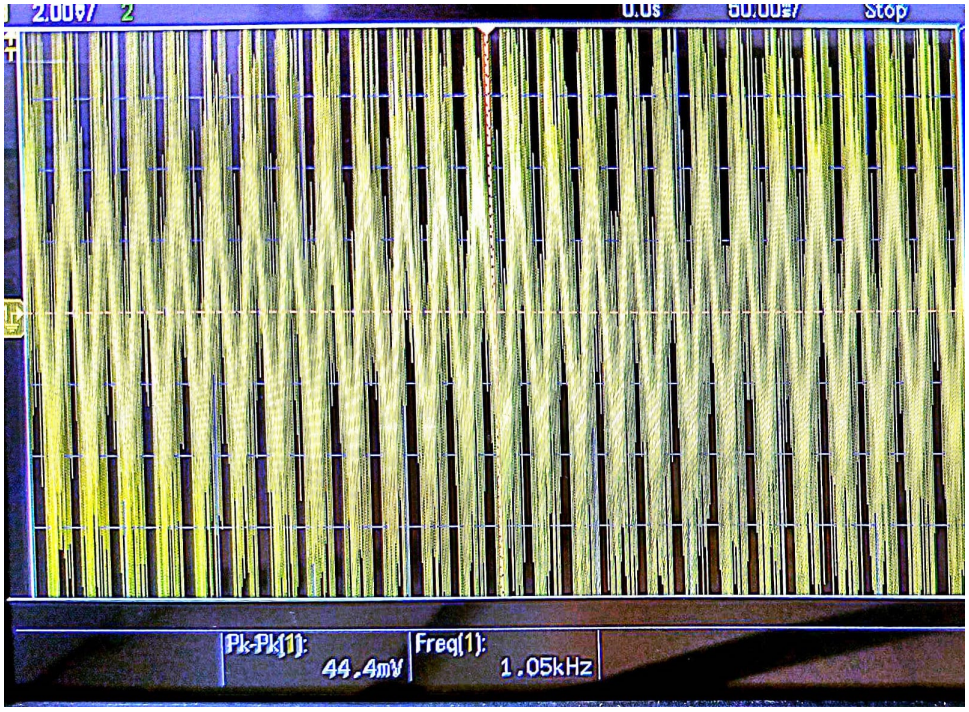
OBSERVATIONS:

Pre-Amplifier:

→ Observed a gain of 10.

→ input=10mV pk-pk.

→ output=100mV pk-pk.

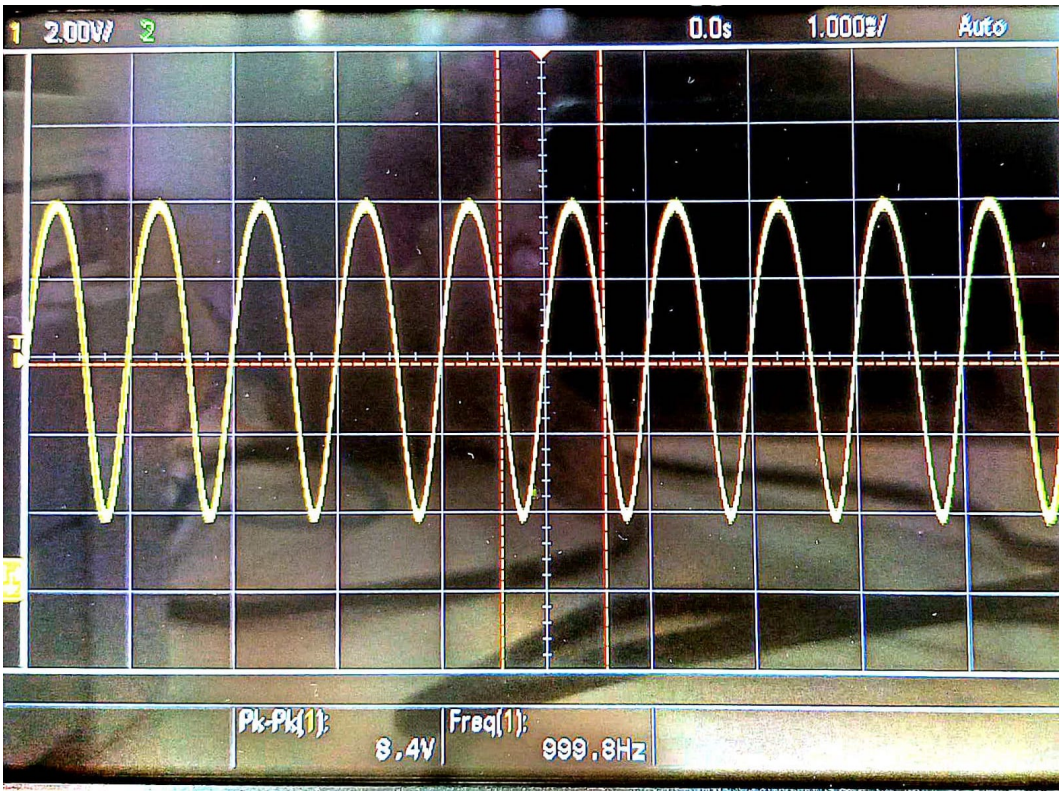


Gain Stage (common emitter) :

→ Observed a gain of 160.

→ input=50mV pk-pk.

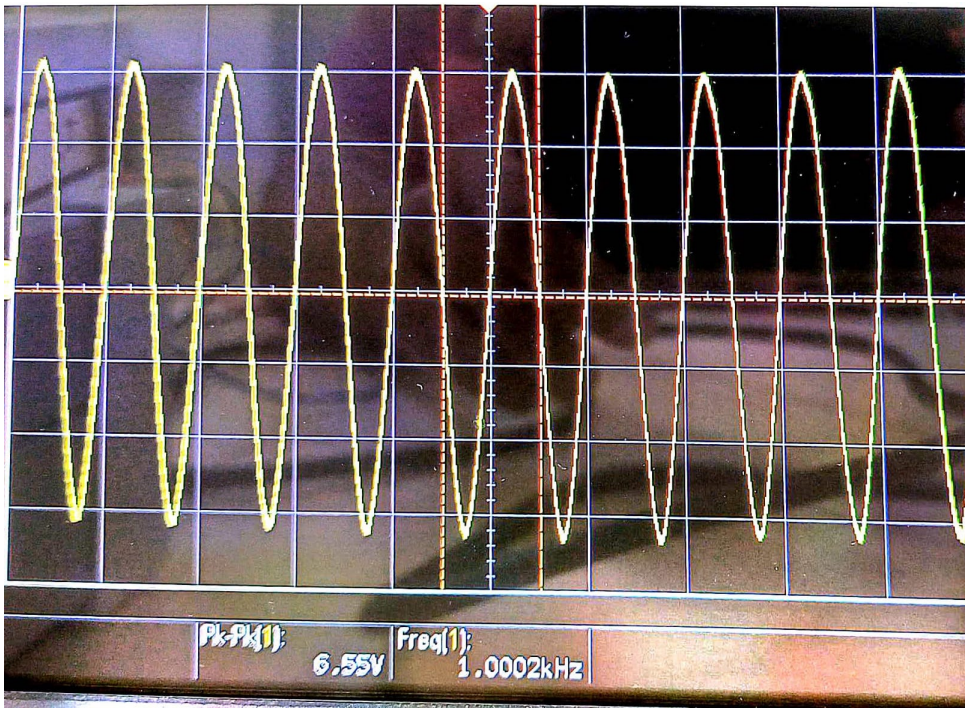
→ output=8V pk-pk.



Filter:

→ Band passed the input signal from 20Hz to 20kHz as per the values of resistance and capacitance used.

→ output attenuated a bit due to hardware complications.



Power-Amplifier:

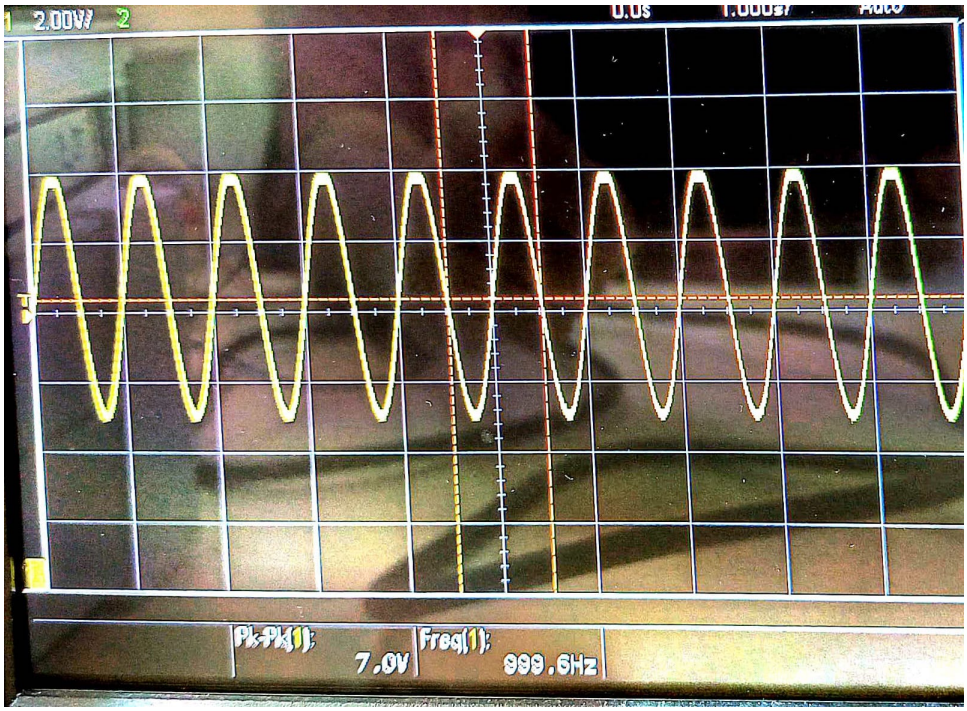
→ Current got amplified by 5 times.

→ input current = 32mV pk-pk.

→ output current = 162mV pk-pk.

→ output voltage is same as input i.e. 6.75V pk-pk.

→ Output power was 2 watts.



Conclusions:

→ We observed a gain of 1600 overall and output power of 2 W.

→ No clipping is observed.

→ No output Noise.

→ Clear sound.

→ Decent current gain.

→ No heating effect.

→ Proper transfer of signal at each step.

Common Mistakes:

→ One might get clipping at some stages.

→ There might be attenuation after the filter.

→ Power amplifier might get overheated.

→ Power amp might distort the output.

→ Speaker or Mic could be faulty.

→ Input output impedance might not match

Common Solutions:

→ Properly Bias Your transistors with proper and clear calculations.

→ Use an Active filter.

→ Use a high resistor to reduce current and avoid overheating.

→ Check each stage sequentially before cascading.

→ Use buffers if impedance is an issue.