K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
Low & High-frequency response of single-stage amplifier

Numerical 1:

Determine the lower cut off frequency for the network given in figure 1 using the following parameters:

$C_{C_1} = 10\mu F$, $C_E = 20\mu F$, $C_{C_2} = 1\mu F$, $R_E = 2k\Omega$, $R_S = 1k\Omega$, $R_1 = 40k\Omega$, $R_2 = 10k\Omega$, $R_L = 2.2k\Omega$, $\beta = 100$, $r_o = 40k\Omega$, $V_{CC} = 20V$, $R_C = 4k\Omega$

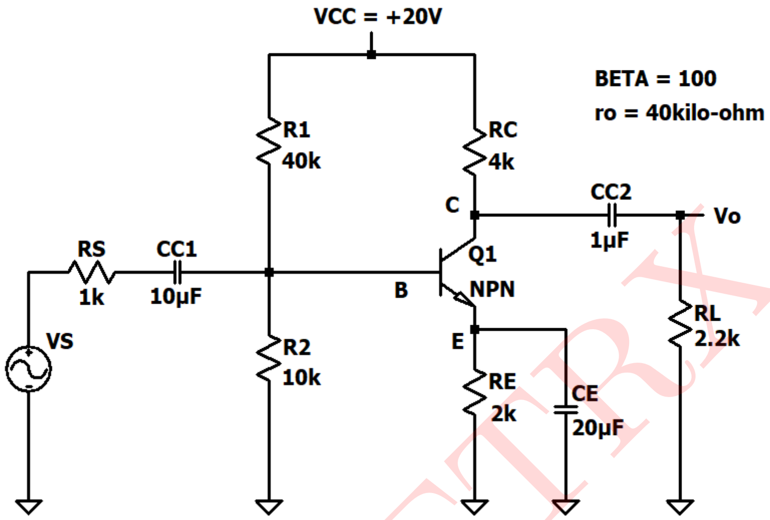

Figure 1: Circuit 1

Solution:

DC Analysis:

Since frequency is $0Hz$ hence all the capacitors are open circuited.

Thus the circuit becomes,

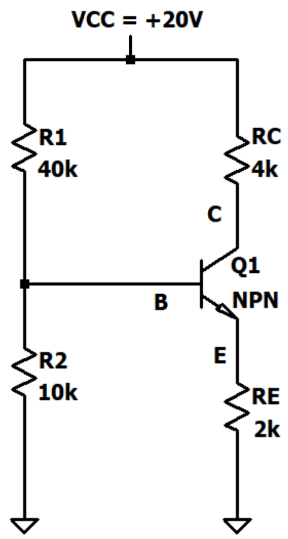

Figure 2: DC Equivalent Circuit

Applying Thevenin's theorem to input side of the circuit at base,

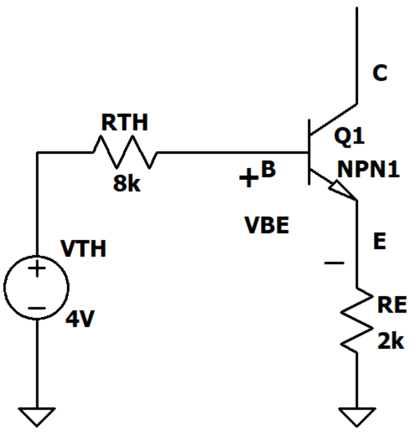

Figure 3: Thevenin's Equivalent Circuit

$$
\begin{aligned}
V_{TH} &= \frac{R_2 \times V_{CC}}{R_1 + R_2} \\
&= \frac{10k\Omega \times 20V}{40k\Omega + 10k\Omega} \\
&= \mathbf{4V}
\end{aligned}
$$

$$
\begin{aligned}
R_{TH} &= R_1 \parallel R_2 \\
&= 40k\Omega \parallel 10k\Omega \\
&= \mathbf{8k\Omega}
\end{aligned}
$$

Applying KVL to B-E loop,

$V_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$

$V_{TH} - I_B R_{TH} - V_{BE} - (1+\beta) I_B R_E = 0$ [Since, $I_E = (1+\beta) I_B$]

$$
\begin{aligned}
I_{BQ} &= \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E} \\
&= \frac{4 - 0.7}{8k\Omega + (101) \times 2k\Omega} \\
&= \mathbf{15.71\mu A}
\end{aligned}
$$

$I_{CQ} = \beta I_{BQ} = 100 \times 15.71\mu A = \mathbf{1.571mA}$

Small Signal Analysis:

$$
\begin{aligned}
r_\pi &= \frac{\beta V_T}{I_{CQ}} \\
&= \frac{100 \times 26mA}{1.571mA} \\
&= \mathbf{1.655k\Omega}
\end{aligned}
$$

$$
g_m = \frac{I_{CQ}}{V_T} = \mathbf{60.42mA/V}
$$

$$r_o = \frac{V_A}{I_{CQ}} \implies V_A = r_o \times I_{CQ}$$

$$V_A = 40k\Omega \times 1.571mA = \mathbf{62.84V}$$

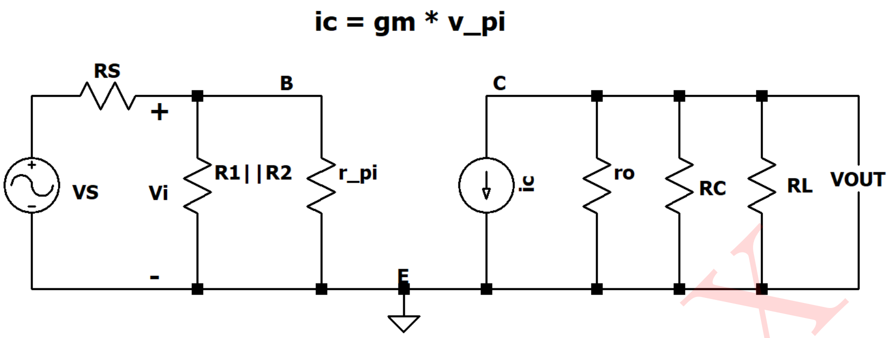

Figure 4: Small Signal Equivalent Circuit for mid frequency

$$\text{Mid Band Gain } (Av_{s(mid)}) = \frac{V_o}{V_S}$$

$$Av_{s(mid)} = \frac{V_o}{V_i} \times \frac{V_i}{V_S}$$

$$Av_{s(mid)} = Av_{(mid)} \times \frac{V_i}{V_S}$$

$$Av_{(mid)} = \frac{V_o}{V_i} = -g_m(R_C \parallel R_L \parallel r_o)$$

$$V_i = \frac{R_1 \parallel R_2 \parallel r_\pi}{R_1 \parallel R_2 \parallel r_\pi + R_S} \times V_S$$

$$Av_{s(mid)} = Av_{(mid)} \times \frac{R_1 \parallel R_2 \parallel r_\pi}{R_1 \parallel R_2 \parallel r_\pi + R_S}$$

$$\begin{aligned} Av_{(mid)} &= -g_m(R_C \parallel R_L \parallel r_o) \\ &= (-60.42mA)(4k\Omega \parallel 2.2k\Omega \parallel 40k\Omega) \\ &= \mathbf{-82.8186} \qquad \text{[Mid Band Gain without } R_S\text{]} \end{aligned}$$

$$\begin{aligned} Av_{s(mid)} &= -82.8186 \times \frac{8k\Omega \parallel 1.655k\Omega}{8k\Omega \parallel 1.655k\Omega + 1k\Omega} \\ &= -82.8186 \times 0.578 \\ &= \mathbf{-47.869} \qquad \text{[Mid Band Gain considering } R_S\text{]} \end{aligned}$$

$$\left|Av_{s(mid)}\right| \text{ in dB} = 20\log_{10}(47.869) = \mathbf{33.6}\text{dB}$$

Low Frequency Equivalent Circuit:

a. Lower cutoff frequency due to C_{C_1} alone:

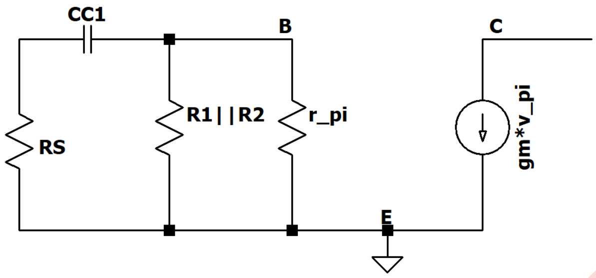

Figure 5: Low frequency AC Equivalent Circuit for C_{C_1}

$$f_{LC_{C_1}} = \frac{1}{2\pi(R_S + R_1 \parallel R_2 \parallel r_\pi)C_{C_1}}$$

$$R_S + R_1 \parallel R_2 \parallel r_\pi = 1k\Omega + 8k\Omega \parallel 1.655k\Omega$$
$$R_S + R_1 \parallel R_2 \parallel r_\pi = 1k\Omega + 1.37k\Omega = 2.37k\Omega$$

$$f_{LC_{C_1}} = \frac{1}{2\pi \times 2.37k\Omega \times 10\mu F} = \mathbf{6.715Hz}$$

b. Lower cutoff frequency due to C_{C_2} alone:

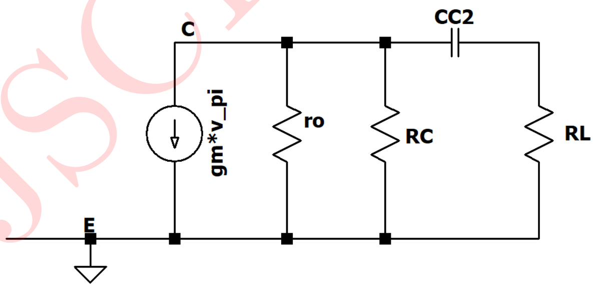

Figure 6: Low frequency AC Equivalent Circuit for C_{C_2}

$$f_{LC_{C_2}} = \frac{1}{2\pi \times R_{eq} \times C_{C_2}}$$

$$\begin{aligned} R_{eq} &= R_C \parallel r_o + R_L \\ &= 4k\Omega \parallel 40k\Omega + 2.2k\Omega \\ &= 3.363k\Omega + 2.2k\Omega \\ &= 5.836k\Omega \end{aligned}$$

$$f_{LC_{C_2}} = \frac{1}{2\pi \times 5.836k\Omega \times 1\mu F} = \mathbf{27.27Hz}$$

c. Lower cutoff frequency due to C_E alone:

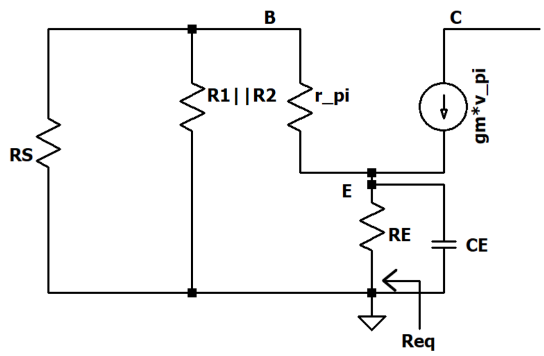

Figure 7: Low frequency AC Equivalent Circuit for C_E

$$
\begin{aligned}
R_E &= R_E \parallel \left(\frac{R_S \parallel R_1 \parallel R_2 + r_\pi}{\beta} \right) \\
&= 2k\Omega \parallel \left(\frac{1k\Omega \parallel 8k\Omega + 1.655k\Omega}{100} \right) \\
&= 2k\Omega \parallel 25.438 \\
&= \mathbf{25.118\Omega}
\end{aligned}
$$

$$
\begin{aligned}
f_{L_{C_E}} &= \frac{1}{2\pi \times R_{eq} \times C_E} \\
&= \frac{1}{2\pi \times 25.118\Omega \times 20\mu F} \\
&= \mathbf{316.81Hz}
\end{aligned}
$$

Since $f_{L_{C_E}} = 316.81Hz$ is the largest among $f_{L_{C_{C_1}}}$ & $f_{L_{C_{C_2}}}$

$\therefore f_L = \mathbf{316.81Hz}$

SIMULATED RESULTS

The above circuit is simulated in LTspice and results are presented below:

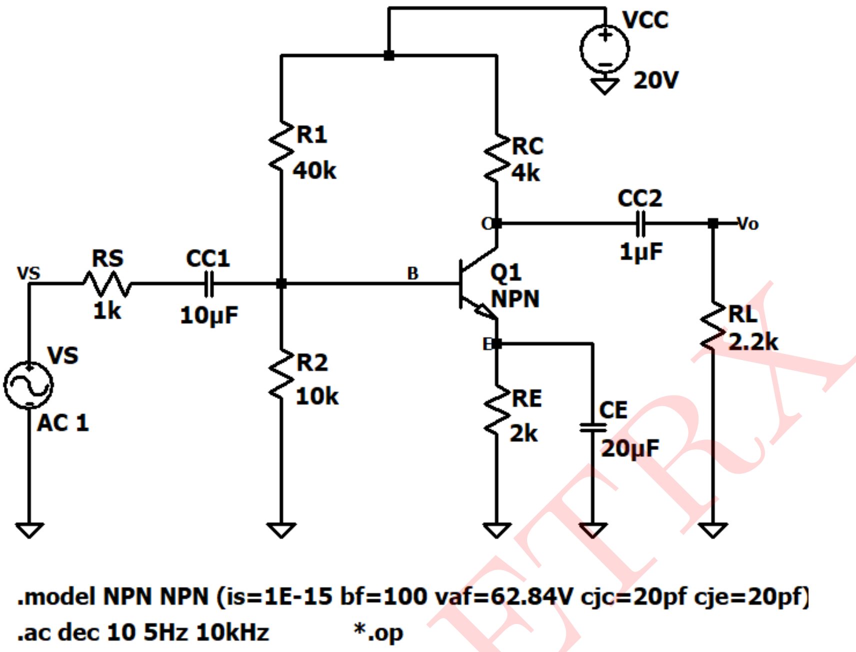

Figure 8: Circuit Schematic

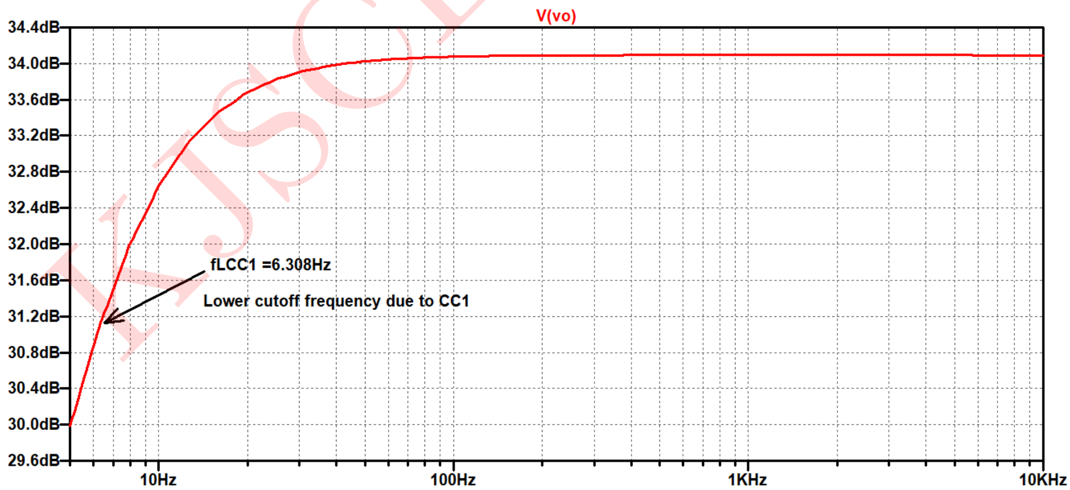

Figure 9: Low frequency response for C_{C_1}

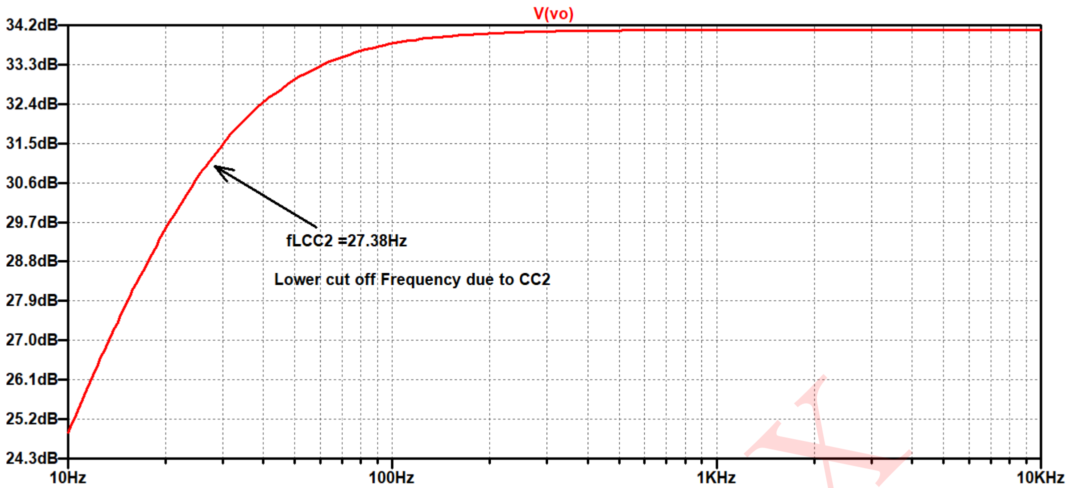

Figure 10: Low frequency response for C_{C_2}

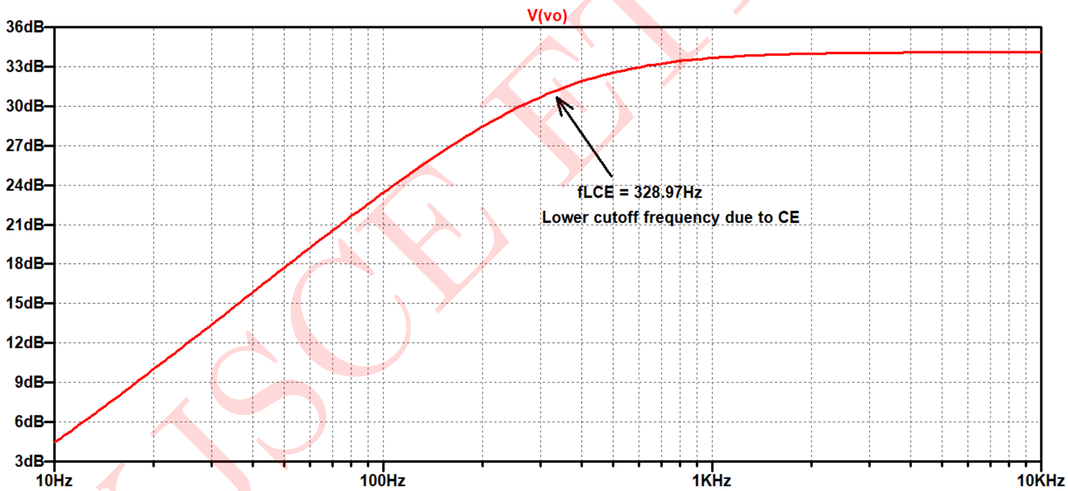

Figure 11: Low frequency response for C_E

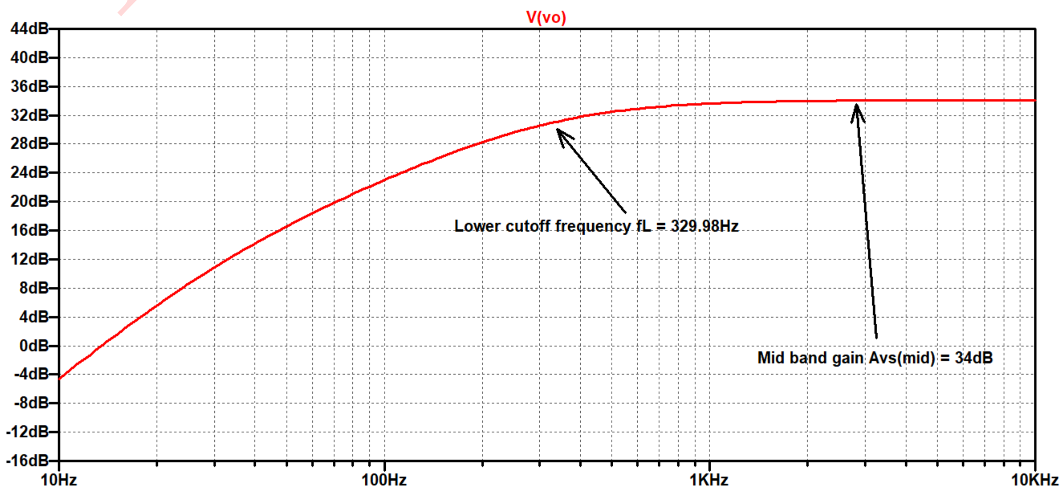

Figure 12: Complete Low frequency response

Comparison of Theoretical and Simulated results:

Parameters	Theoretical	Simulated
I_{CQ}	$1.571mA$	$1.570mA$
Lower cut off frequency due to C_{C_1}	$6.715Hz$	$6.308Hz$
Lower cut off frequency due to C_{C_2}	$27.27Hz$	$27.38Hz$
Lower cut off frequency due to C_E	$316.81Hz$	$328.97Hz$
Overall cutoff frequency f_L	$316.81Hz$	$329.98Hz$
Mid band voltage gain $\lvert Av_{s(mid)} \rvert$ in dB	33.6dB	34dB

Table 1: Numerical 1

Numerical 2:

For the PMOS common source circuit shown in figure 13, the transistor parameters are: $V_{TP} = -2V$, $k_p = 1mA/V^2$, $\lambda = 0$

a. Determine the lower cutoff frequency of the circuit.

b. Find the midband voltage gain.

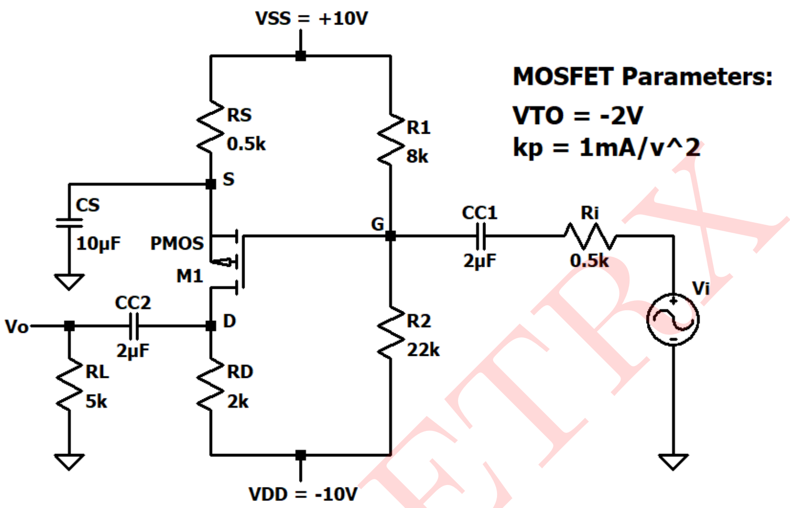

Figure 13: Circuit 2

Solution:

DC Analysis:

Since frequency is $0Hz$ hence all the capacitors are open circuited.

Hence the circuit becomes,

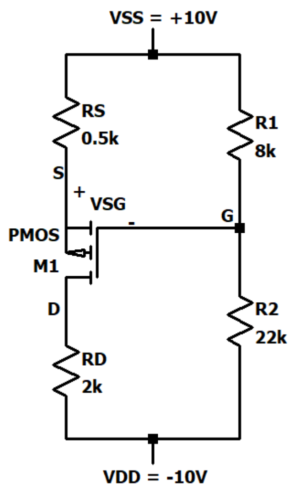

Figure 14: DC Equivalent Circuit

$$V_G = \frac{R_2}{R_1 + R_2}(V_{SS} - V_{DD}) + V_{DD}$$

$$= \frac{22k\Omega}{8k\Omega + 22k\Omega}(20) - 10 = \mathbf{4.67V}$$

Applying KVL to Gate Source Loop,

$V_{SS} - I_D R_S - V_{SG} = V_G$

$10 - I_D R_S - V_{SG} = 4.67$

$V_{GS} = 5.33 - I_D R_S$ .....(1)

Now,

$I_D = k_p(V_{SG} + V_{TP})^2$

$= (1mA/V^2)(V_{SG} - 2)^2$ .....(2)

Substituting equation (2) in equation (1),

$V_{SG} = 5.33 - (1)(0.5)(V_{SG}^2 - 4V_{SG} + 4)$

$0.5V_{SG}^2 - V_{SG} - 3.33 = 0$

$V_{SG} = 3.77V \quad \text{or} \quad V_{SG} = -1.76V$

For the device to be biased in saturation,

$V_{SG} > |V_{TP}|$

$\therefore V_{SGQ} = \mathbf{3.77V}$

$I_{DQ} = k_p(V_{SG} + V_{TP})^2$

$= (1mA/V^2)(3.77 - 2)^2$

$= \mathbf{3.13mA}$

Small Signal Parameters:

$g_m = 2k_p(V_{SG} + V_{TP})$

$= 2 \times (1mA/V^2)(3.77V - 2V)$

$= \mathbf{3.54mA/V}$

Low Frequency AC Equivalent Circuit:

a. Lower cutoff frequency for C_{C_1} alone:

Short V_i, C_S & C_{C_2}

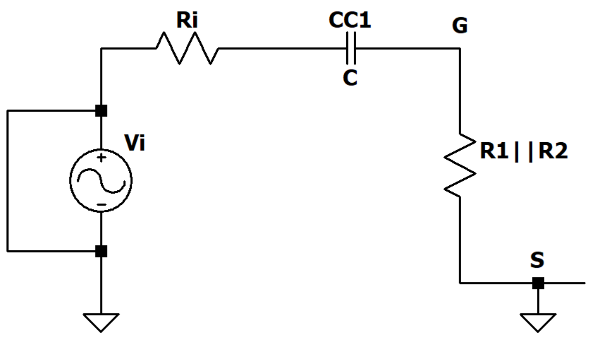

Figure 15: Low frequency AC Equivalent Circuit for C_{C_1}

$$f_{L_{C_{C_1}}} = \frac{1}{2\pi(R_i + R_1 \parallel R_2)C_{C_1}}$$

$$R_1 \parallel R_2 = 8k\Omega \parallel 22k\Omega = 5.87k\Omega$$

$$\therefore f_{L_{C_{C_1}}} = \frac{1}{2\pi \times (0.5k\Omega + 5.87k\Omega) \times 2\mu F} = \mathbf{12.4925Hz}$$

b. Lower cutoff frequency for C_{C_2} alone:

Short V_i, C_S & C_{C_1}

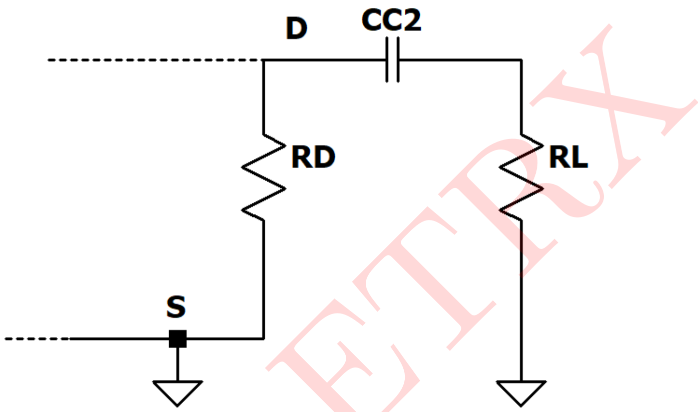

Figure 16: Low frequency AC Equivalent Circuit for C_{C_2}

$$f_{L_{C_{C_2}}} = \frac{1}{2\pi \times (R_D + R_L) \times C_{C_2}}$$
$$= \frac{1}{2\pi \times (2k\Omega + 5k\Omega) \times 2\mu F}$$
$$= \mathbf{11.368Hz}$$

c. Lower cutoff frequency for C_S alone:

Short V_i, C_{C_1} & C_{C_2}

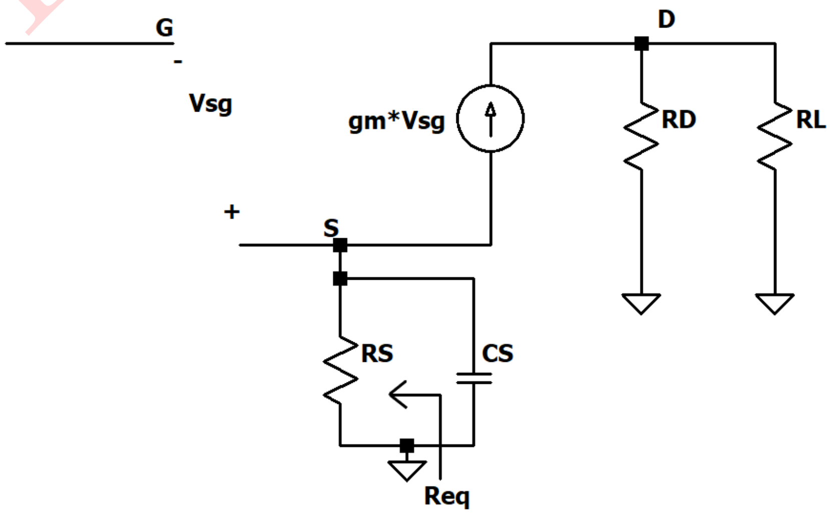

Figure 17: Low frequency AC Equivalent Circuit for C_S

$$f_{L_{C_S}} = \frac{1}{2\pi \times R_{eq} \times C_S}$$

$$R_{eq} = R_S \parallel \frac{1}{g_m}$$
$$= 0.5k\Omega \parallel \frac{1}{3.54mA/V}$$
$$= \mathbf{180.505\Omega}$$

$$\therefore f_{L_{C_S}} = \frac{1}{2\pi \times 180.505\Omega \times 10\mu F} = \mathbf{88.172Hz}$$

Since $f_{L_{C_S}}$ is the largest among $f_{L_{C_{C_1}}}$ & $f_{L_{C_{C_2}}}$

$$\therefore f_L = \mathbf{88.172Hz}$$

Mid Frequency AC Equivalent Circuit:

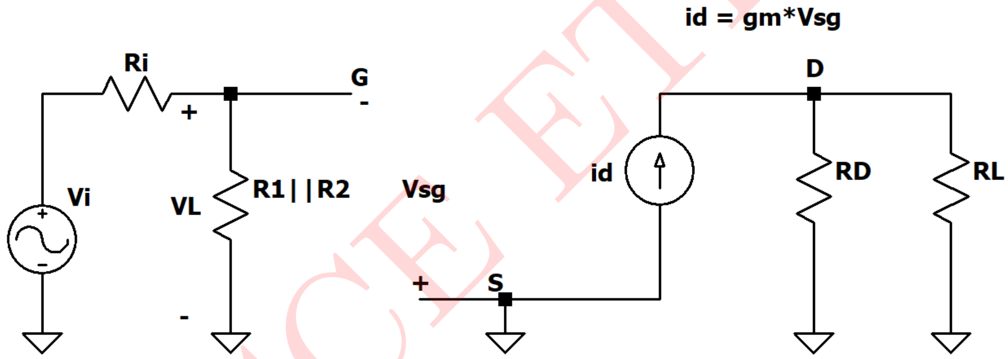

Figure 18: Small signal Equivalent Circuit for mid frequency

$$Av_{s(mid)} = \frac{V_o}{V_i}$$
$$Av_{s(mid)} = \frac{V_o}{V_L} \times \frac{V_L}{V_i}$$
$$Av_{s(mid)} = Av_{(mid)} \times \frac{V_L}{V_i}$$
$$Av_{(mid)} = \frac{V_o}{V_L} = -g_m(R_D \parallel R_L)$$

$$V_L = \frac{R_1 \parallel R_2}{R_1 \parallel R_2 + R_i} \times V_i$$
$$\frac{V_L}{V_i} = \frac{R_1 \parallel R_2}{R_1 \parallel R_2 + R_i}$$

$$Av_{s(mid)} = Av_{(mid)} \times \frac{R_1 \parallel R_2}{R_1 \parallel R_2 + R_i}$$

$$Av_{(mid)} = -(3.54mA/V)(2k\Omega \parallel 5k\Omega) = -\mathbf{5.057}$$

$$
\begin{aligned}
Av_{s(mid)} &= -5.057 \times \frac{8k\Omega \parallel 22k\Omega}{8k\Omega \parallel 22k\Omega + 0.5k\Omega} \\
&= -5.057 \times \frac{5.87k\Omega}{5.87k\Omega + 0.5k\Omega} \\
&= \mathbf{-4.66}
\end{aligned}
$$

$$
\left|Av_{s(mid)}\right| \text{ in dB} = 20\log_{10}(4.66) = \mathbf{13.3677dB}
$$

SIMULATED RESULTS

The above circuit is simulated in LTspice and results are presented below:

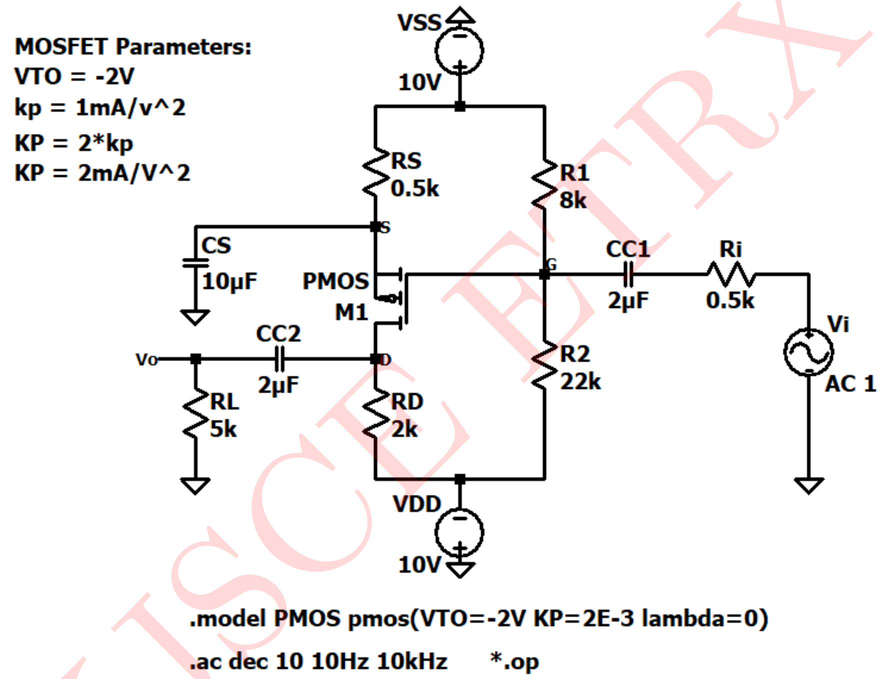

Figure 19: Circuit Schematic

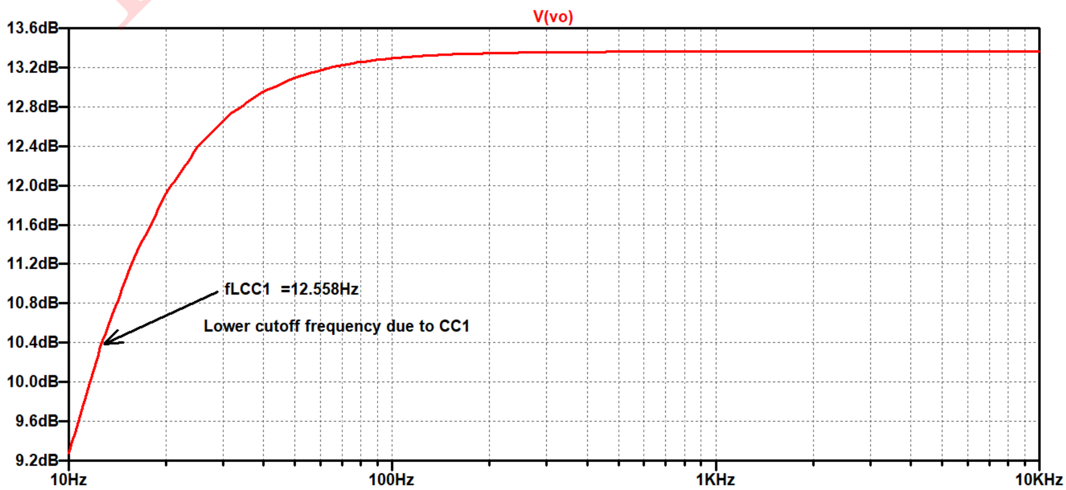

Figure 20: Low frequency response for C_{C_1}

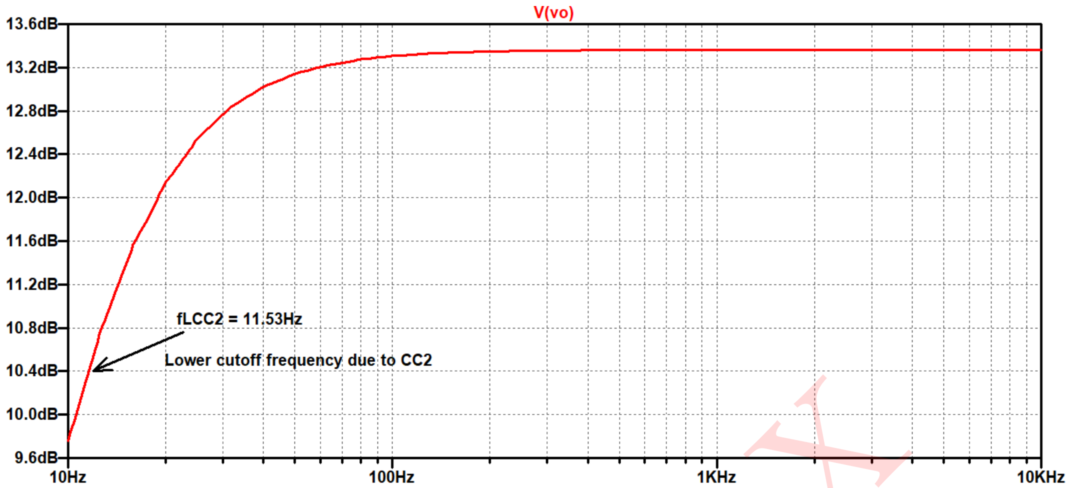

Figure 21: Low frequency response for C_{C_2}

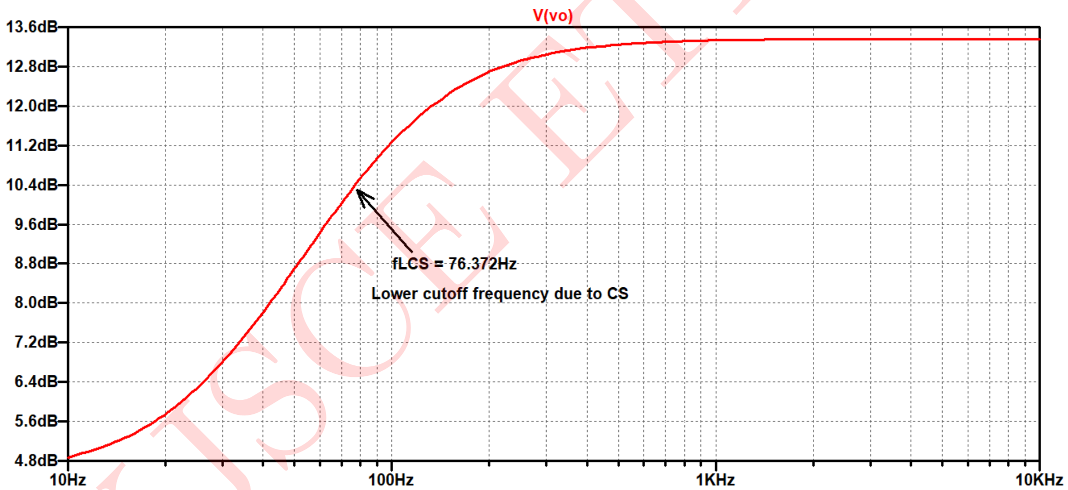

Figure 22: Low frequency response for C_S

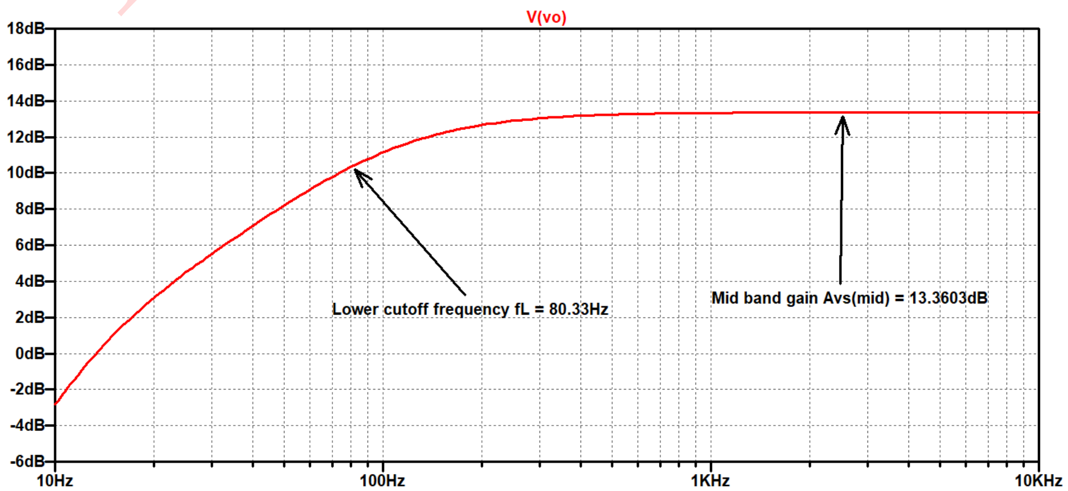

Figure 23: Complete Low frequency response

Comparison of Theoretical and Simulated results:

Parameters	Theoretical	Simulated
I_{DQ}	$3.13mA$	$3.1289mA$
V_{SGQ}	$3.77V$	$3.7688V$
Lower cut off frequency due to C_{C_1} alone	$12.4925Hz$	$12.558Hz$
Lower cut off frequency due to C_{C_2} alone	$11.368Hz$	$11.53Hz$
Lower cut off frequency due to C_S alone	$88.172Hz$	$76.372Hz$
Overall cutoff frequency f_L	$88.172Hz$	$80.33Hz$
Mid frequency voltage gain $Av_{s(mid)}$ in dB	13.3677dB	13.3603dB

Table 2: Numerical 2

Numerical 3:

Find the lower & higher cut off frequency of the circuit given in the figure 24 using the following parameters:

$C_{C_1} = 10\mu F$, $C_E = 20\mu F$, $C_{C_2} = 1\mu F$, $R_E = 2k\Omega$, $R_S = 1k\Omega$, $R_1 = 40k\Omega$, $R_2 = 10k\Omega$, $R_L = 2.2k\Omega$, $\beta = 100$, $r_o = 40k\Omega$, $V_{CC} = 20V$, $R_C = 4k\Omega$, $C_{wi} = 4pF$, $C_{w_o} = 8pF$, $C_{bc} = 10pF$, $C_{be} = 35pF$ & $C_{ce} = 8pF$

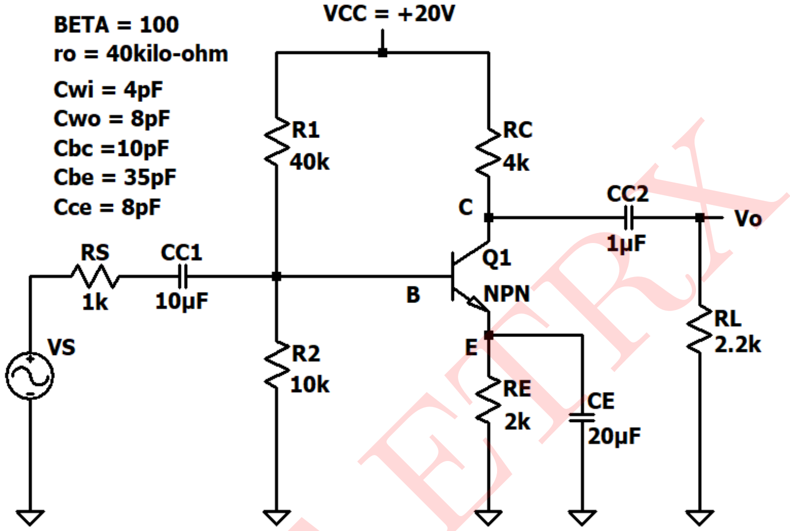

Figure 24: Circuit 3

Solution:

DC Analysis:

Since frequency is $0Hz$ hence all the capacitors are open circuited.

Thus the circuit becomes,

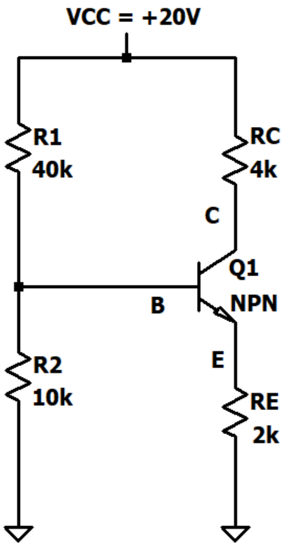

Figure 25: DC Equivalent Circuit

Applying Thevenin's theorem to input side of the circuit at base,

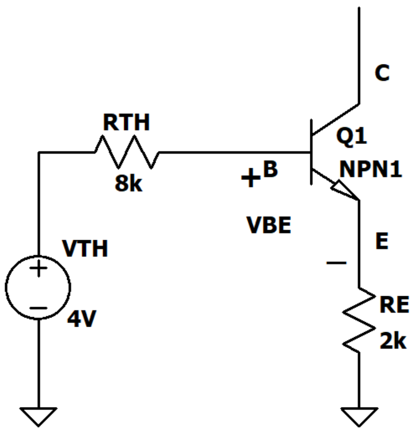

Figure 26: Thevenin's Equivalent Circuit

$$
\begin{aligned}
V_{TH} &= \frac{R_2 \times V_{CC}}{R_1 + R_2} \\
&= \frac{10k\Omega \times 20V}{40k\Omega + 10k\Omega} \\
&= \mathbf{4V}
\end{aligned}
$$

$$
\begin{aligned}
R_{TH} &= R_1 \parallel R_2 \\
&= 40k\Omega \parallel 10k\Omega \\
&= \mathbf{8k\Omega}
\end{aligned}
$$

Applying KVL to B-E loop,

$V_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$

$V_{TH} - I_B R_{TH} - V_{BE} - (1+\beta) I_B R_E = 0$ [Since, $I_E = (1+\beta) I_B$]

$$
\begin{aligned}
I_{BQ} &= \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E} \\
&= \frac{4 - 0.7}{8k\Omega + (101) \times 2k\Omega} \\
&= \mathbf{15.71\mu A}
\end{aligned}
$$

$I_{CQ} = \beta I_{BQ} = 100 \times 15.71\mu A = \mathbf{1.571mA}$

Small Signal Analysis:

$$
\begin{aligned}
r_\pi &= \frac{\beta V_T}{I_{CQ}} \\
&= \frac{100 \times 26mA}{1.571mA} \\
&= \mathbf{1.655k\Omega}
\end{aligned}
$$

$$
g_m = \frac{I_{CQ}}{V_T} = \mathbf{60.42mA/V}
$$

$$r_o = \frac{V_A}{I_{CQ}} \implies V_A = r_o \times I_{CQ}$$

$$V_A = 40k\Omega \times 1.571mA = \mathbf{62.84V}$$

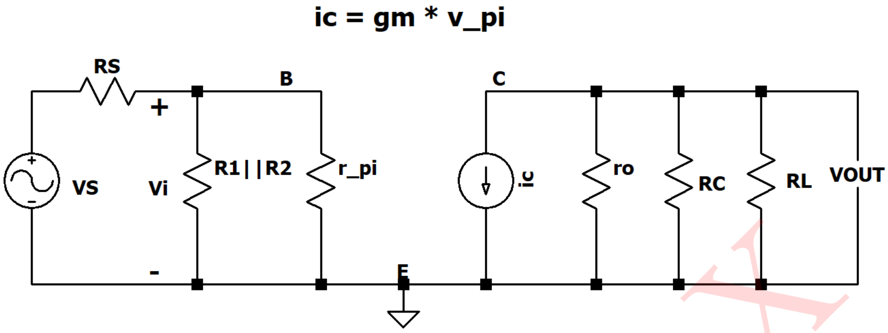

Figure 27: Small Signal Equivalent Circuit for mid frequency

$$\text{Mid Band Gain } (Av_{s(mid)}) = \frac{V_o}{V_S}$$

$$Av_{s(mid)} = \frac{V_o}{V_i} \times \frac{V_i}{V_S}$$

$$Av_{s(mid)} = Av_{(mid)} \times \frac{V_i}{V_S}$$

$$Av_{(mid)} = \frac{V_o}{V_i} = -g_m(R_C \parallel R_L \parallel r_o)$$

$$V_i = \frac{R_1 \parallel R_2 \parallel r_\pi}{R_1 \parallel R_2 \parallel r_\pi + R_S} \times V_S$$

$$Av_{s(mid)} = Av_{(mid)} \times \frac{R_1 \parallel R_2 \parallel r_\pi}{R_1 \parallel R_2 \parallel r_\pi + R_S}$$

$$\begin{aligned} Av_{(mid)} &= -g_m(R_C \parallel R_L \parallel r_o) \\ &= (-60.42mA)(4k\Omega \parallel 2.2k\Omega \parallel 40k\Omega) \\ &= -\mathbf{82.8186} && \text{[Mid Band Gain without } R_S\text{]} \end{aligned}$$

$$\begin{aligned} Av_{s(mid)} &= -82.8186 \times \frac{8k\Omega \parallel 1.655k\Omega}{8k\Omega \parallel 1.655k\Omega + 1k\Omega} \\ &= -82.8186 \times 0.578 \\ &= -\mathbf{47.869} && \text{[Mid Band Gain considering } R_S\text{]} \end{aligned}$$

$$\left|Av_{s(mid)}\right| \text{ in dB} = 20\log_{10}(47.869) = \mathbf{33.6}\text{dB}$$

Low Frequency Equivalent Circuit:

a. Lower cutoff frequency due to C_{C_1} alone:

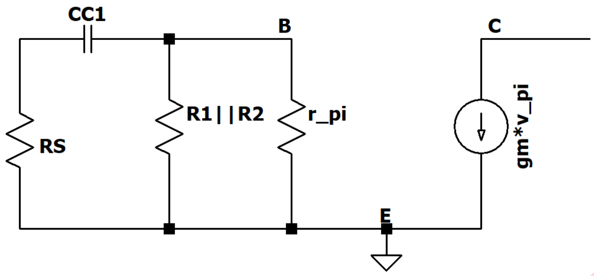

Figure 28: Low frequency AC Equivalent Circuit for C_{C_1}

$$f_{LC_{C_1}} = \frac{1}{2\pi(R_S + R_1 \parallel R_2 \parallel r_\pi)C_{C_1}}$$

$$R_S + R_1 \parallel R_2 \parallel r_\pi = 1k\Omega + 8k\Omega \parallel 1.655k\Omega$$
$$R_S + R_1 \parallel R_2 \parallel r_\pi = 1k\Omega + 1.37k\Omega = 2.37k\Omega$$

$$f_{LC_{C_1}} = \frac{1}{2\pi \times 2.37k\Omega \times 10\mu F} = \mathbf{6.715Hz}$$

b. Lower cutoff frequency due to C_{C_2} alone:

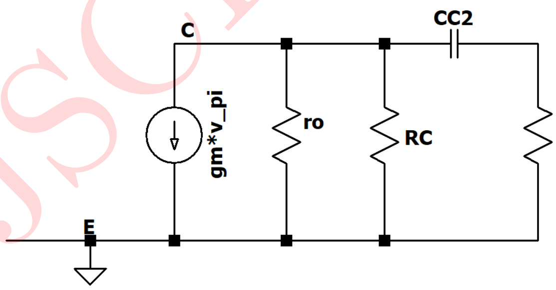

Figure 29: Low frequency AC Equivalent Circuit for C_{C_2}

$$f_{LC_{C_2}} = \frac{1}{2\pi \times R_{eq} \times C_{C_2}}$$

$$\begin{aligned} R_{eq} &= R_C \parallel r_o + R_L \\ &= 4k\Omega \parallel 40k\Omega + 2.2k\Omega \\ &= 3.363k\Omega + 2.2k\Omega \\ &= 5.836k\Omega \end{aligned}$$

$$f_{LC_{C_2}} = \frac{1}{2\pi \times 5.836k\Omega \times 1\mu F} = \mathbf{27.27Hz}$$

c. Lower cutoff frequency due to C_E alone:

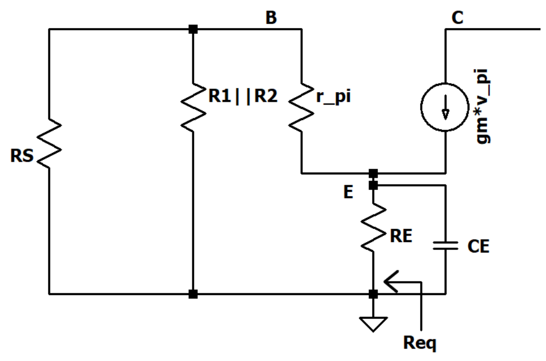

Figure 30: Low frequency AC Equivalent Circuit for C_E

$$
\begin{aligned}
R_E &= R_E \parallel \left(\frac{R_S \parallel R_1 \parallel R_2 + r_\pi}{\beta}\right) \\
&= 2k\Omega \parallel \left(\frac{1k\Omega \parallel 8k\Omega + 1.655k\Omega}{100}\right) \\
&= 2k\Omega \parallel 25.438 \\
&= \mathbf{25.118\Omega}
\end{aligned}
$$

$$
\begin{aligned}
f_{L_{C_E}} &= \frac{1}{2\pi \times R_{eq} \times C_E} \\
&= \frac{1}{2\pi \times 25.118\Omega \times 20\mu F} \\
&= \mathbf{316.81Hz}
\end{aligned}
$$

Since $f_{L_{C_E}} = 316.81Hz$ is the largest among $f_{L_{C_{C_1}}}$ & $f_{L_{C_{C_2}}}$

$\therefore f_L = \mathbf{316.81Hz}$

Hight Frequency Equivalent Circuit:

a. Higher cutoff frequency due to C_i alone:
Short C_o & V_S

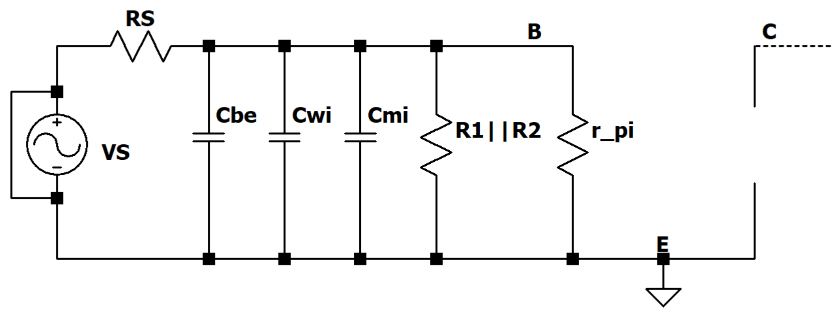

Figure 31: High frequency AC Equivalent Circuit for C_i

$$C_i = C_{be} + C_{wi} + C_{mi}$$

$$\begin{aligned} C_{mi} &= C_{bc}(a - Av_s) \\ &= 10pF\ (1 - (-47.869)) \\ &= \mathbf{488.69pF} \end{aligned}$$

$$C_i = 35pF + 4pF + 488.69pF = \mathbf{527.69pF}$$

$$\begin{aligned} R_{eq} &= R_S \parallel R_1 \parallel R_2 \parallel r_\pi \\ &= 1k\Omega \parallel 8k\Omega \parallel 1.655k\Omega \\ &= \mathbf{578.29\Omega} \end{aligned}$$

Now,

$$\begin{aligned} f_{H_i} &= \frac{1}{2\pi R_{eq} C_i} \\ &= \frac{1}{2\pi \times (578.29\Omega) \times (527.69pF)} \\ &= \mathbf{0.521MHz} \end{aligned}$$

b. Higher cut off frequency due to C_o alone:

Short C_i & source V_S

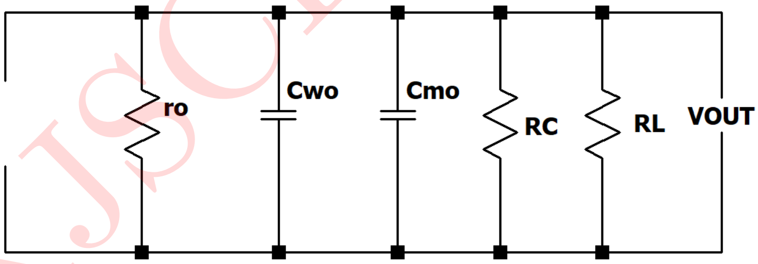

Figure 32: High frequency AC Equivalent Circuit for C_o

$$\begin{aligned} C_{mo} &= C_{bc}\left(1 - \frac{1}{Av_{s(mid)}}\right) \\ &= 10pF\left(1 - \frac{1}{-47.869}\right) \\ &= \mathbf{10.2pF} \end{aligned}$$

$$\begin{aligned} R_{eq} &= r_o \parallel R_C \parallel R_L \\ &= 40k\Omega \parallel 4k\Omega \parallel 2.2k\Omega \\ &= \mathbf{1.37k\Omega} \end{aligned}$$

$$\begin{aligned} C_o &= C_{mo} + C_{wo} \\ &= 10.2pF + 8pF \\ &= \mathbf{18.2pF} \end{aligned}$$

Now,

$$f_{H_o} = \frac{1}{2\pi R_{eq} C_o}$$

$$= \frac{1}{2\pi \times (1.37k\Omega) \times (18.2pF)}$$

$$= \mathbf{6.383MHz}$$

Select the lowest among f_{H_o} & f_{H_i} as the higher cut off frequency of the circuit

$f_H = \mathbf{0.521MHz}$

SIMULATED RESULTS

The above circuit is simulated in LTspice and results are presented below:

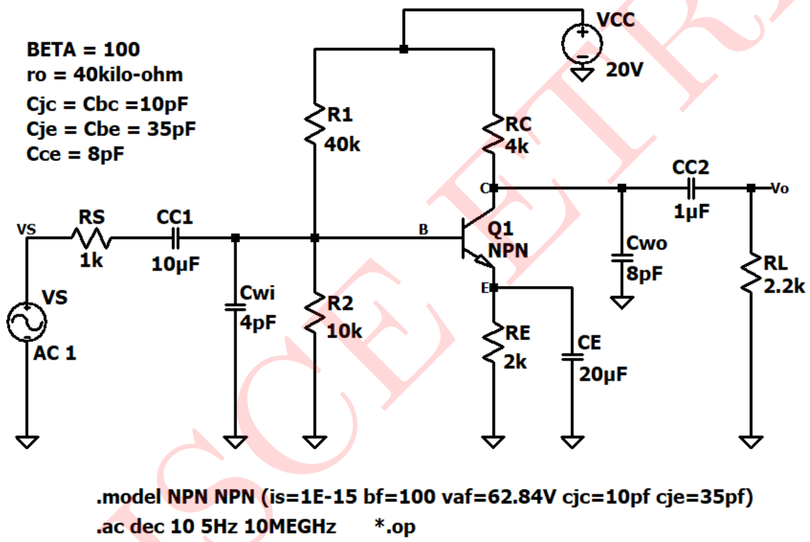

Figure 33: Circuit Schematic

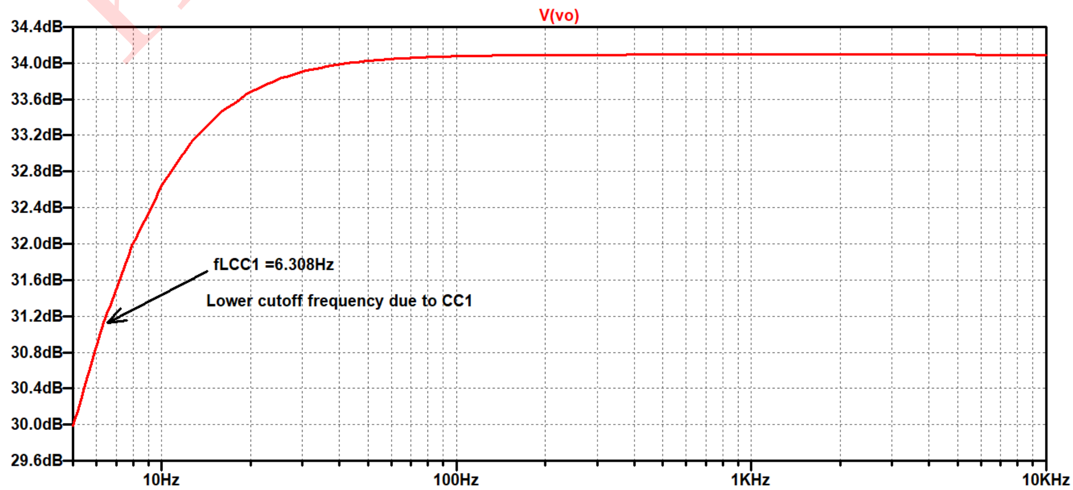

Figure 34: Low frequency response for C_{C_1}

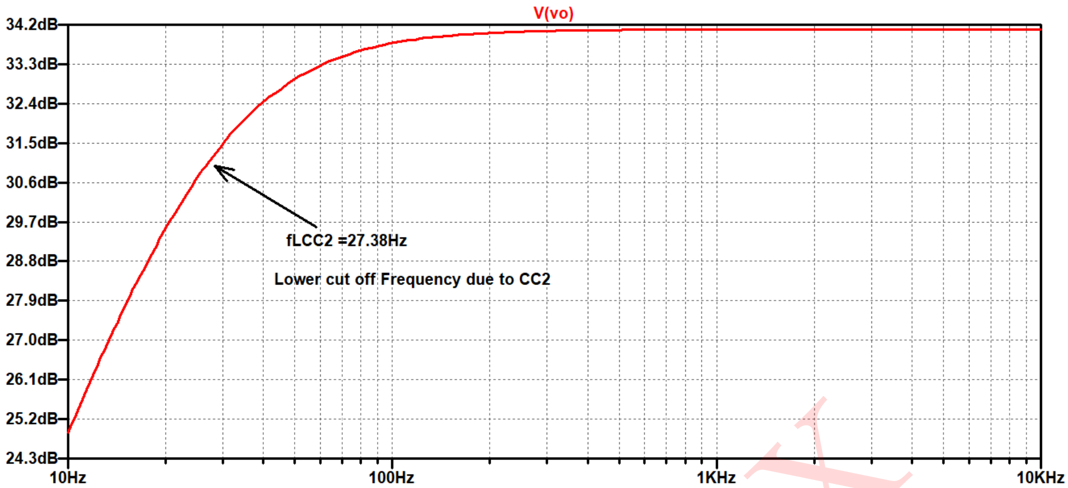

Figure 35: Low frequency response for C_{C_2}

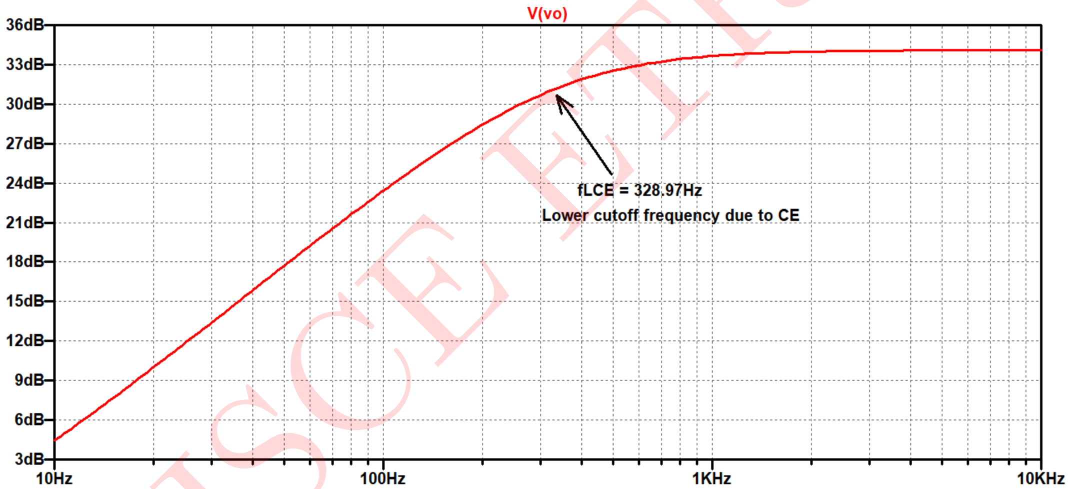

Figure 36: Low frequency response for C_E

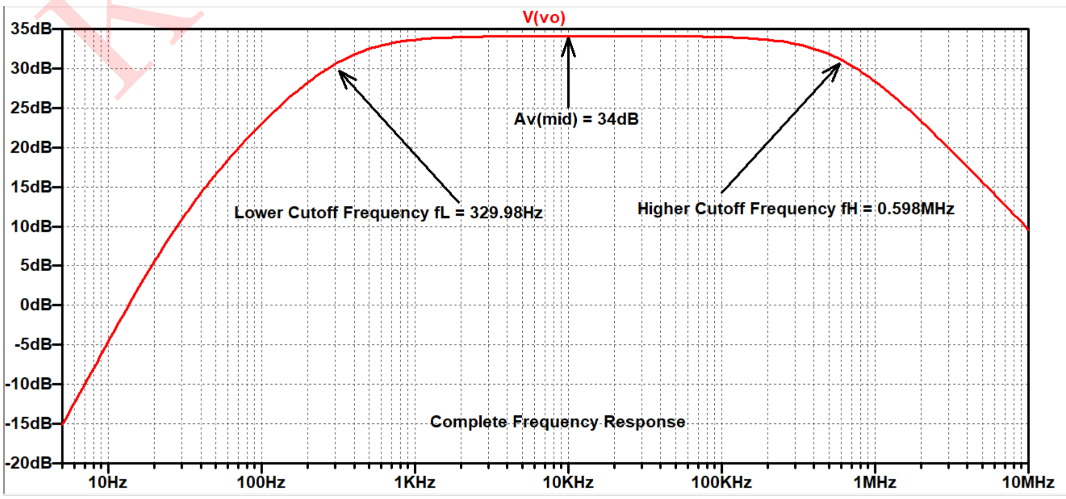

Figure 37: Complete frequency response

Comparison of Theoretical and Simulated results:

Parameters	Theoretical	Simulated
I_{CQ}	$1.571mA$	$1.570mA$
Lower cut off frequency due to C_{C_1}	$6.715Hz$	$6.308Hz$
Lower cut off frequency due to C_{C_2}	$27.27Hz$	$27.38Hz$
Lower cut off frequency due to C_E	$316.81Hz$	$328.97Hz$
Overall cutoff frequency f_L	$316.81Hz$	$329.98Hz$
Overall cutoff frequency f_H	$0.521MHz$	$0.598MHz$
Mid band voltage gain $Av_{s(mid)}$ in dB	33.6dB	34dB

Table 3: Numerical 3

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