EE 334 - Homework 4 Report

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1)

$R_{sig} = 1\ k\Omega\,,\quad R_1 = 33\ k\Omega\,,\quad R_2 = 17\ k\Omega\,,\quad R_C = 2\ k\Omega\,,\quad R_E = 1\ k\Omega\,,\quad \mathrm{R_L} = 10\ k\Omega$

$C_{C1} = 10\ \mu F\,,\quad C_{C2} = 10\ \mu F\,,\quad C_E = 10\ \mu F$

$I_C = 1.00792\ mA\,,\quad I_B = 4.08791\ \mu A\,,\quad I_E = 1.01201\ mA\,,\quad V_T = 26\ mV$

$$R_B = R_1||R_2 = \frac{R_1R_2}{R_1+R_2} = \frac{33k\cdot 17k}{33k+17k} = \boxed{11.22\ k\Omega = R_B}$$

$$\beta_{DC} = \frac{I_C}{I_B} = \frac{1.00792m}{1.01201m} = \boxed{246.561 = \beta_{DC}}\,,\qquad g_{m_{DC}} = \frac{I_C}{V_T} = \frac{1.00792m}{26m} = \boxed{38.7662\ mS = g_{m_{DC}}}$$

$$\beta = \beta_{AC} = \boxed{294 = \beta}\,,\qquad g_m = g_{m_{AC}} = \boxed{24.5\ mS = g_m}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{294}{24.5m} = \boxed{12\ k\Omega = r_\pi}$$

$$R_{in1} = R_B||r_\pi = \frac{R_Br_\pi}{R_B+r_\pi} = \frac{11.22k\cdot 12k}{11.22k+12k} = \boxed{5.79845\ k\Omega = R_{in1}}$$

$$R_{in2} = R_B||(r_\pi+(\beta+1)R_E) = \frac{R_B(r_\pi+(\beta+1)R_E)}{R_B+(r_\pi+(\beta+1)R_E)} = \frac{11.22k\cdot(12k+295\cdot 1k)}{11.22k+(12k+295\cdot 1k)}$$
$$= \boxed{10.8244\ k\Omega = R_{in2}}$$

$$\omega_{P1_1} = \frac{1}{C_{C1}(R_{in1}+R_{sig})} = \frac{1}{10\mu\cdot(5.79845k+1k)} = \boxed{14.7092\ \frac{rad}{s} = \omega_{P1_1}}$$

$$\omega_{P1_2} = \frac{1}{C_{C1}(R_{in2}+R_{sig})} = \frac{1}{10\mu\cdot(10.8244k+1k)} = \boxed{8.45709\ \frac{rad}{s} = \omega_{P1_2}}$$

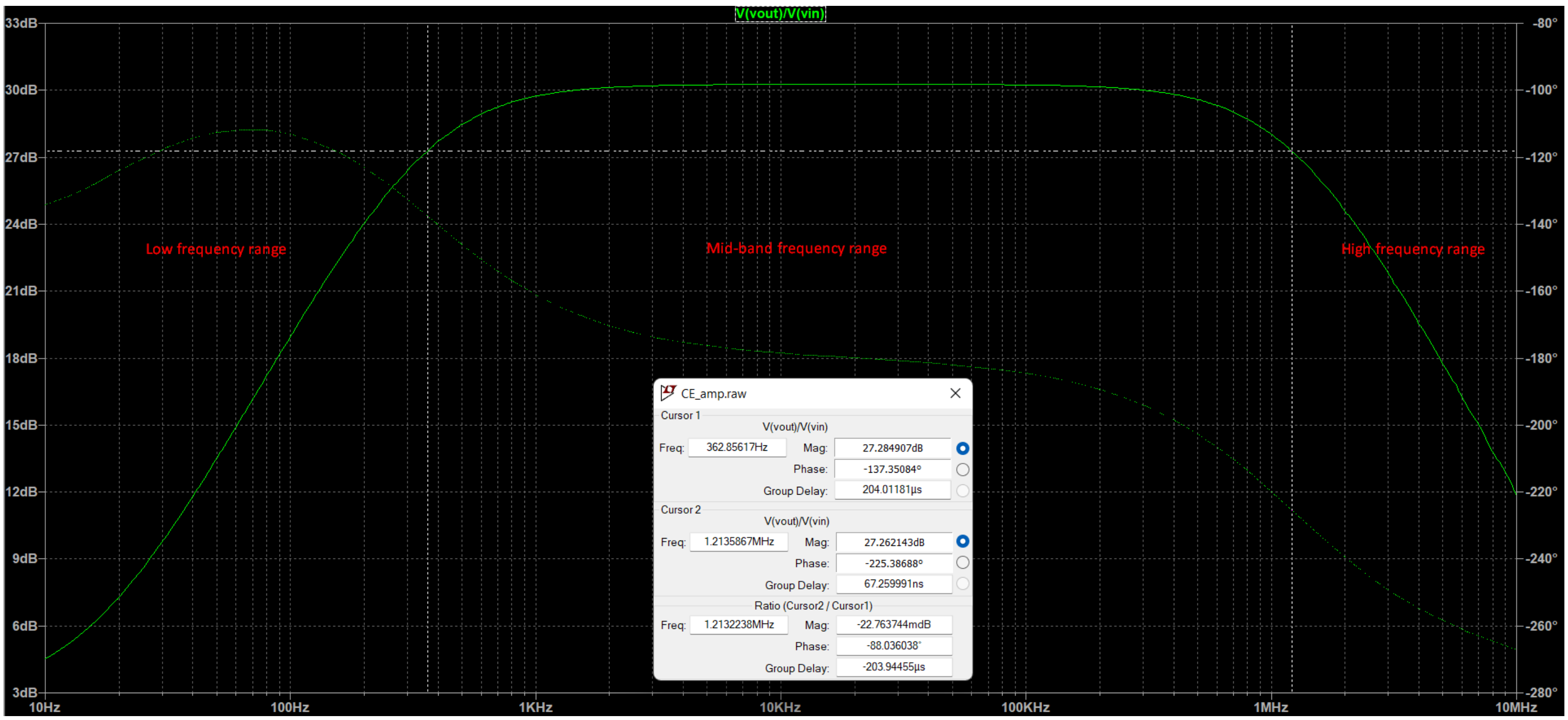
$$\omega_{P2} = \frac{1}{C_{C2}(R_C+R_L)} = \frac{1}{10\mu\cdot(2k+10k)} = \boxed{8.33333\ \frac{rad}{s} = \omega_{P2}}$$

$$\omega_Z = \frac{1}{R_EC_E} = \frac{1}{1k\cdot 10\mu} = \boxed{100\ \frac{rad}{s} = \omega_Z}$$

$$\omega_{P3_1} = \frac{1}{C_E\left[R_E || \frac{r_\pi + (R_B || R_{sig})}{\beta + 1}\right]} = \frac{1}{10\mu \cdot \left[1k || \frac{12k + (11.22k || 1k)}{295}\right]} = \boxed{2383.61\ \frac{rad}{s} = \omega_{P3_1}}$$

$$\omega_{P3_2} = \frac{1}{C_E\left[R_E || \frac{r_\pi + R_B}{\beta + 1}\right]} = \frac{1}{10\mu \cdot \left[1k || \frac{12k + 11.22k}{295}\right]} = \boxed{1370.46\ \frac{rad}{s} = \omega_{P3_2}}$$

2)

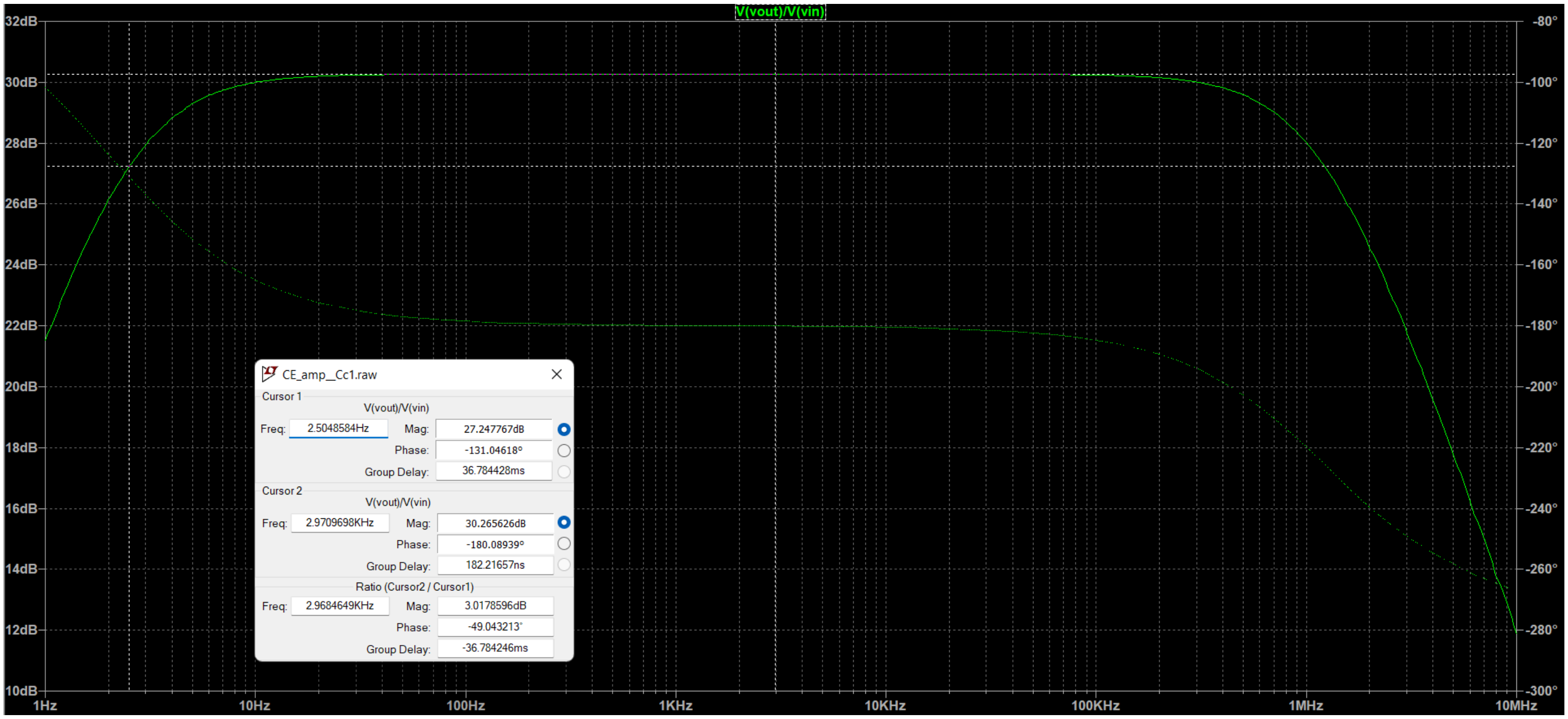


Low frequency range is between 10 Hz and around 363 Hz.

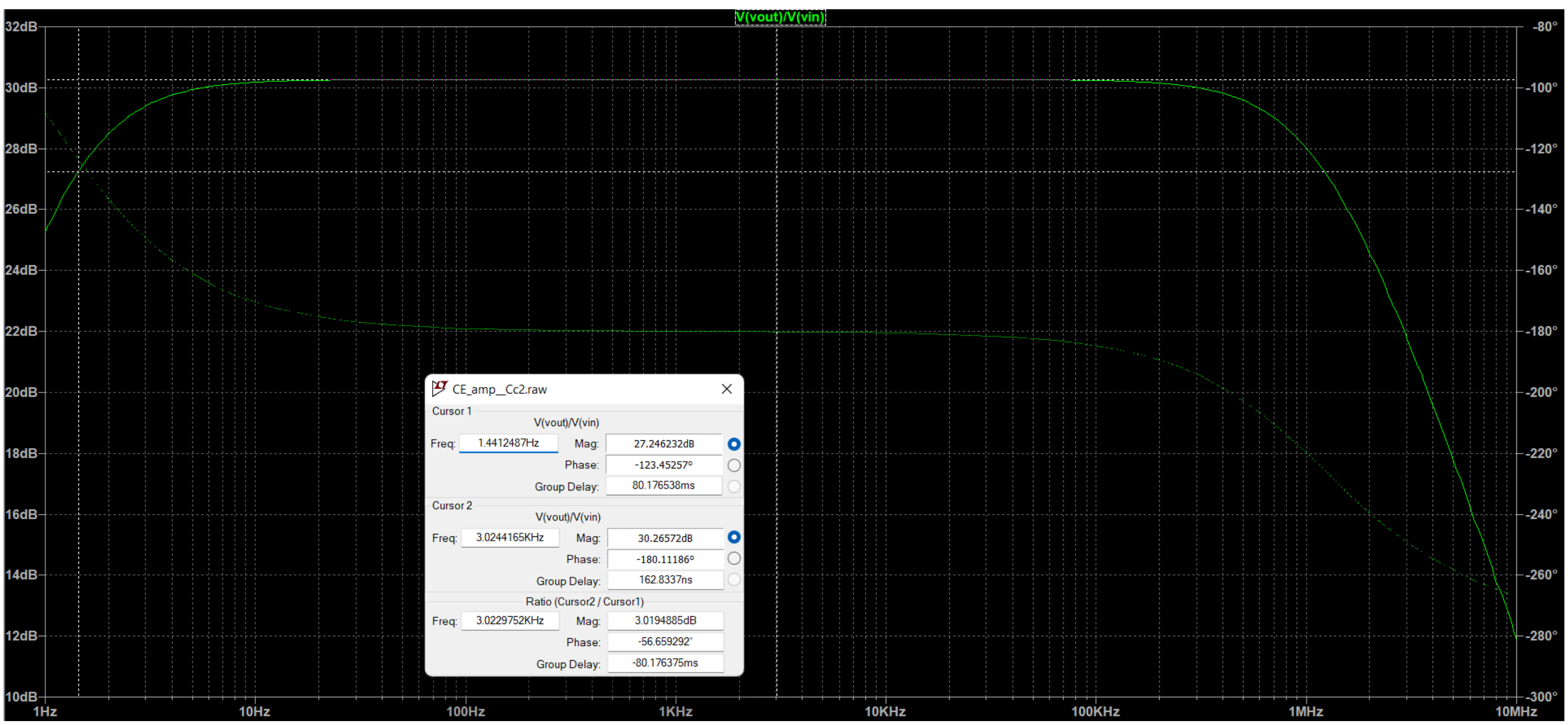
Mid-band frequency range is between around 363 Hz and around 1.21 MHz.

High frequency range is between around 1.21 MHz and 10 MHz.

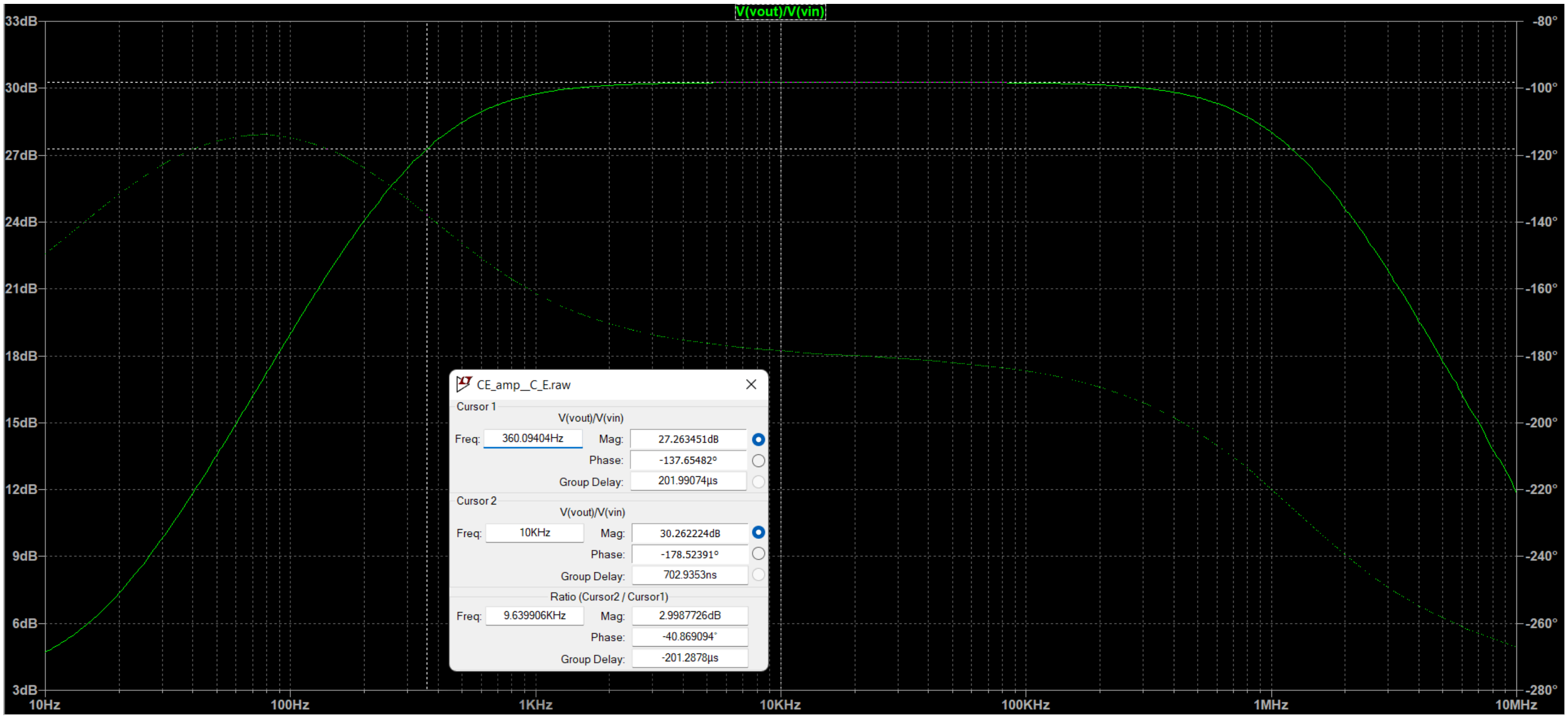
3)



For C_{C1} = 10 μF and $C_{C2} = C_E$ = 10 mF, $f_L \cong 2.51$ Hz.



For C_{C2} = 10 μF and $C_{C1} = C_E$ = 10 mF, $f_L \cong 1.44$ Hz.



For C_E = 10 µF and $C_{C1} = C_{C2}$ = 10 mF, $f_L \cong$ 360 Hz.

4)

$$f_L = 50\ Hz, \qquad \tau_{C1} = C_{C1}R_{C1}\,, \qquad \tau_{CE} = C_E R_{CE}\,, \qquad \tau_{C2} = C_{C2}R_{C2}$$

$$\omega_L = 2\pi f_L = 2\pi\left(\frac{1}{\tau_{C1}} + \frac{1}{\tau_{CE}} + \frac{1}{\tau_{C2}}\right) = 2\pi\left(\frac{1}{C_{C1}R_{C1}} + \frac{1}{C_E R_{CE}} + \frac{1}{C_{C1}R_{C2}}\right) = 2\cdot 3.141592\cdot 50$$

$$= \boxed{314.159\ \frac{rad}{s} = \omega_L}$$

$$R_{C1} = (R_B||r_\pi) + R_{sig} = (R_B||r_\pi) + R_{sig} = (11.22k||12k) + 1k = \boxed{6.79845\ k\Omega = R_{C1}},$$

$$R_{CE} = R_E||\left[\frac{r_\pi + R_B||R_{sig}}{\beta + 1}\right] = 1k||\left[\frac{12k + 11.22k||1k}{295}\right] = \boxed{41.9532\ \Omega = R_{CE}},$$

$$R_{C2} = R_C + R_L = 10k + 2k = \boxed{12\ k\Omega = R_{C2}}$$

$$Selecting\ C_E\ so\ that\ it\ contributes\ 80\%\ of\ the\ value\ of\ \omega_L\ gives:$$

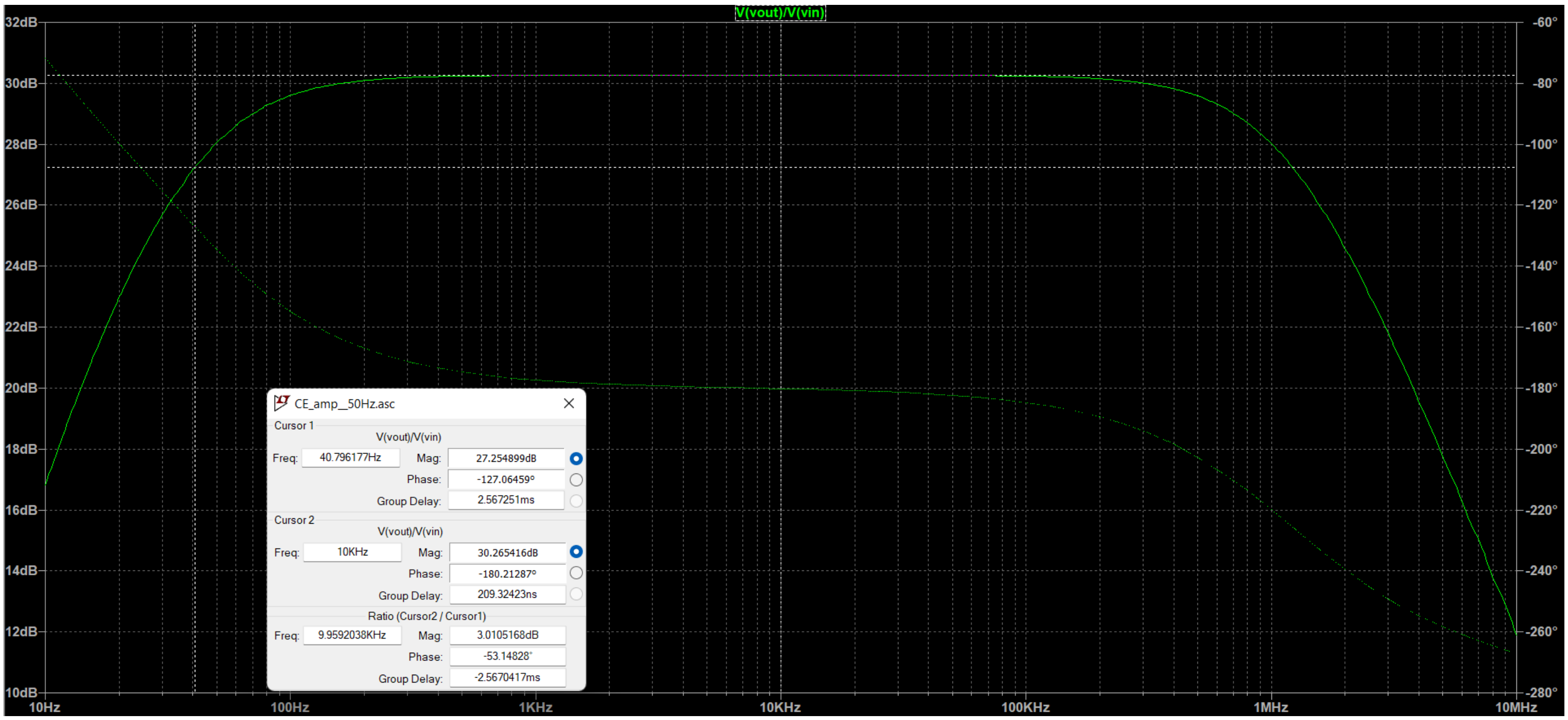
$$\frac{1}{C_E R_{CE}} = 0.8\omega_L \implies C_E = \frac{1}{0.8R_{CE}\omega_L} = \frac{1}{0.8\cdot 41.9532\cdot 100} = \boxed{94.8407\ \mu F = C_E}$$

$$Selecting\ C_{C1}\ so\ that\ it\ contributes\ 10\%\ of\ the\ value\ of\ \omega_L\ gives:$$

$$\frac{1}{C_{C1}R_{C1}} = 0.1\omega_L \implies C_{C1} = \frac{1}{0.1R_{C1}\omega_L} = \frac{1}{0.1\cdot 6.79845k\cdot 100} = \boxed{4.6821\ \mu F = C_{C1}}$$

$$\textit{Selecting } C_{C2} \textit{ so that it contributes } 10\% \textit{ of the value of } \omega_L \textit{ gives:}$$

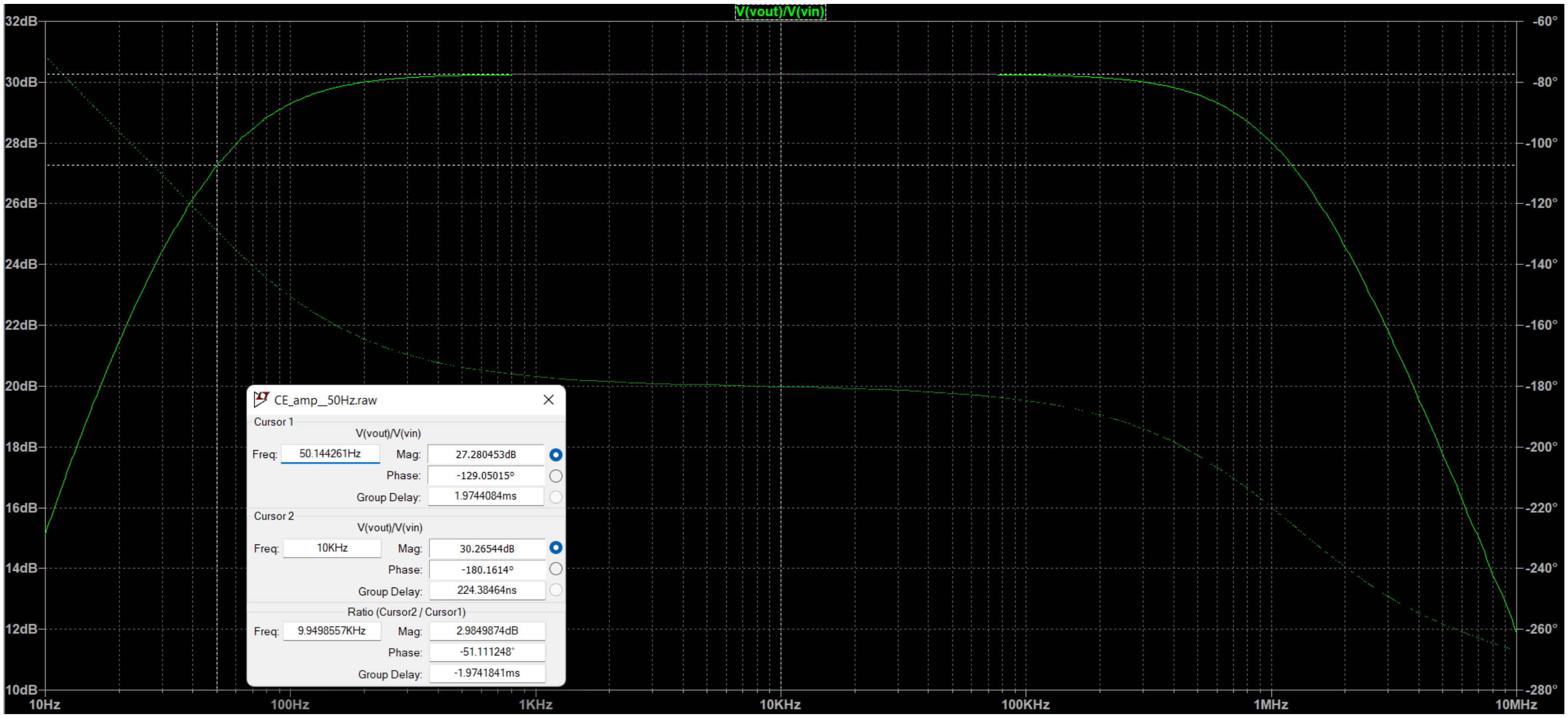
$$\frac{1}{C_{C2}R_{C2}} = 0.1\omega_L \implies C_{C2} = \frac{1}{0.8R_{C2}\omega_L} = \frac{1}{0.1 \cdot 12k \cdot 100} = \boxed{2.65258\ \mu F = C_{C2}}$$



For C_{C1} = 4.6821 μF, C_{C2} = 2.65258 μF, and C_E = 94.8407 μF; $f_L \cong$ 40.8 Hz.

$$\textit{Selecting } C_E \textit{ so that it contributes } 10 \textit{ times of } C_{C1} \textit{ and } C_{C2} \textit{ gives:}$$

$$\frac{1}{C_E R_{CE}} = \omega_L \implies C_E = \frac{1}{R_{CE}\omega_L} = \frac{1}{41.9532 \cdot 100} = \boxed{75.8725\ \mu F = C_E}$$



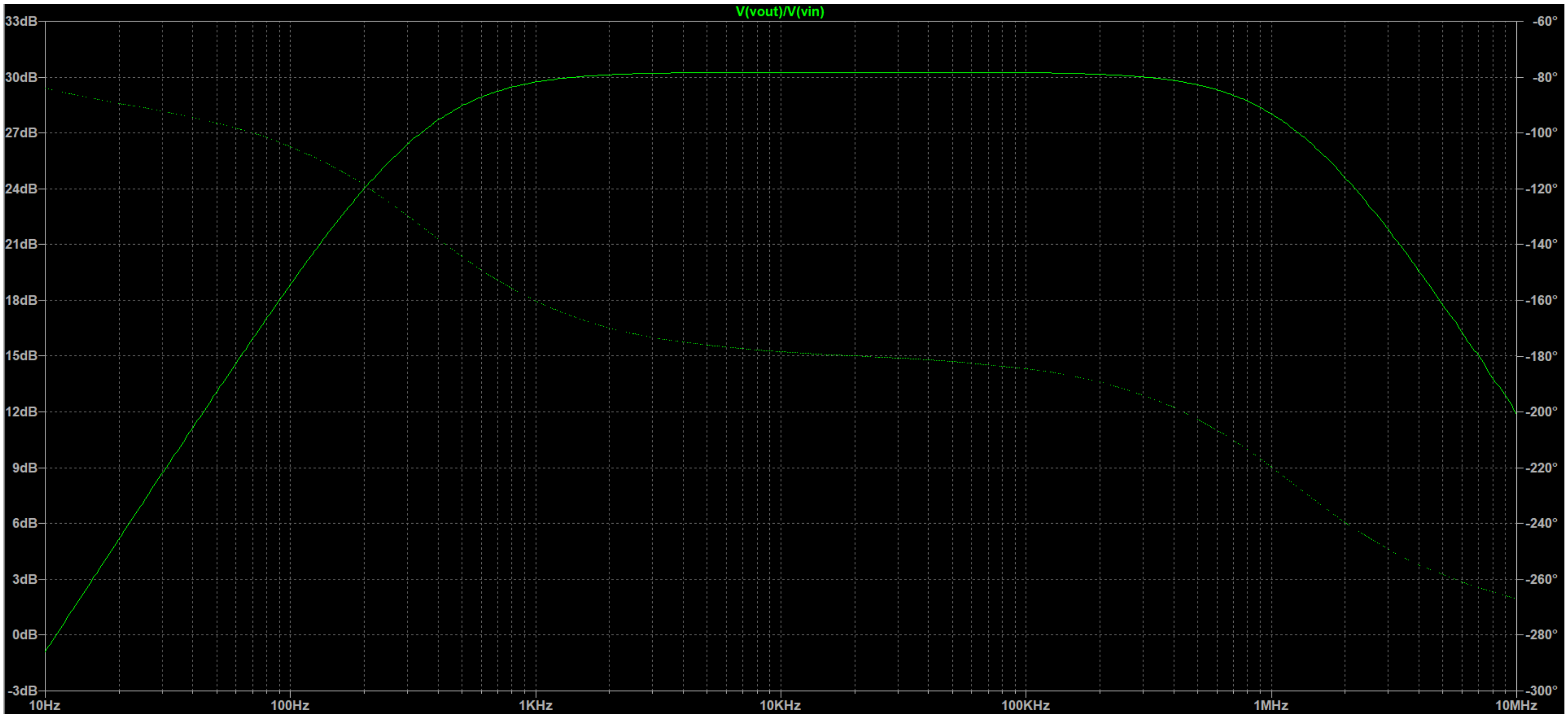
For C_{C1} = 4.6821 µF, C_{C2} = 2.65258 µF, and C_E = 75.8725 µF; $f_L \cong 50$ Hz.

5)

$$\omega_Z = \omega_{P1_1} = \frac{1}{C_{C1_1}(R_{in1} + R_{sig})} \implies C_{C1_1} = \frac{1}{\omega_Z(R_{in1} + R_{sig})} = \frac{1}{100 \cdot (5.79845k + 1k)}$$
$$= \boxed{1.47092\ \mu F = C_{C1_1}}$$

$$\omega_Z = \omega_{P1_2} = \frac{1}{C_{C1_2}(R_{in2} + R_{sig})} \implies C_{C1_2} = \frac{1}{\omega_Z(R_{in2} + R_{sig})} = \frac{1}{100 \cdot (10.8244k + 1k)}$$
$$= \boxed{845.709\ nF = C_{C1_2}}$$

$$\omega_Z = \omega_{P2} = \frac{1}{C_{C2}(R_C + R_L)} \implies C_{C2} = \frac{1}{\omega_Z(R_C + R_L)} = \frac{1}{100 \cdot (2k + 10k)} = \boxed{833.333\ nF = C_{C2}}$$



For C_{C2} = 833.333 nF and C_{C1} = C_E = 10 µF, since ω_Z is cancelled with ω_{P2}, we observe that there is a more linear dB gain increase in the low frequency region.