Pre-Lab 5:
Operational Amplifiers – Part III

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Calculation

Lossy Integrator:

① $V_o = -\frac{R_2/R_1}{1+sR_2C} V_i$

$V_o(t) = V_i(t)\frac{R_1}{R_1+R_2}\cdot e^{-t/\tau}$ $\tau = \frac{R_1R_2C}{R_1+R_2}$

$$\boxed{V_o(t) = V_i(t)\frac{R_1}{R_1+R_2} e^{-t(R_1+R_2)/R_1R_2C}}$$

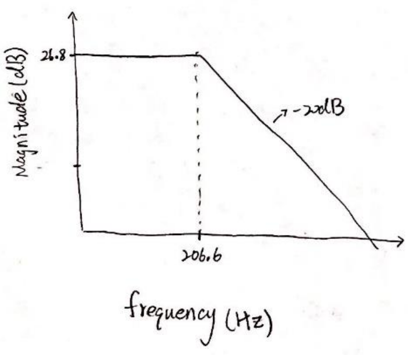
② $V_o = -\frac{R_2}{R_1}\frac{1}{1+sR_2C}V_i \Rightarrow \frac{V_o}{V_i} = -\frac{R_2}{R_1}\frac{1}{1+sR_2C}$

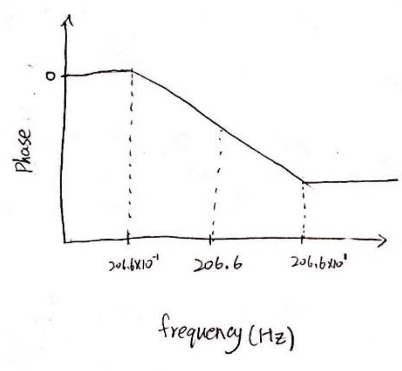
Low-frequency gain: $-\frac{R_2}{R_1} = -22 = \frac{-22k}{R_1} \Rightarrow \boxed{R_1 = 1k\Omega}$

3dB-frequency $= \frac{1}{\tau} = \frac{R_1+R_2}{R_1R_2C} = \frac{1k+22k}{1k\cdot 22k\cdot 220n} = \boxed{4752.07\ Hz}$

③ $\left|\frac{V_o}{V_i}\right| = \frac{R_2}{R_1}\frac{1}{1+sR_2C} = \frac{22k}{1k}\frac{1}{1+\frac{s}{1/R_2C}} = \frac{22}{1+\frac{s}{206.6}}$

$20\log(22) = 26.8\ dB$ $P_1 = -206.6$





④ $$\frac{V_o}{V_i} = \frac{-22}{1+\frac{s}{206.6}} = \frac{-22}{\sqrt{1+\frac{\omega^2}{206.6^2}}} \angle \tan^{-1}\frac{\omega}{206.6}, \quad \omega = 2000\pi$$

$$\frac{V_o}{V_i} = -0.73\angle 88.12^\circ \qquad V_i = 0.5\sin(2\pi 1000t) = 0.5\angle 0^\circ$$

$$V_o = -0.73\angle 88.12^\circ \cdot 0.5\angle 0^\circ = -0.365\angle 88.12^\circ$$

$$\boxed{V_o(t) = -0.365\sin(2\pi 1000t + 88.12^\circ)}$$

Pseudo Differentiator:

① $V_o = -\frac{R_2}{R_1}\frac{s}{s+\frac{1}{R_1C}}V_i$

$V_o(t) = V_i(t)\frac{R_2}{R_1+R_2}e^{-t/\tau}$, $\tau = (R_1+R_2)C$

$$\boxed{V_o(t) = V_i(t)\frac{R_2}{R_1+R_2}e^{-t/(R_1+R_2)C}}$$

② $\frac{V_o}{V_i} = -\frac{R_2}{R_1}\frac{s}{s+\frac{1}{R_1C}}$

High-frequency gain: $-22 = -\frac{R_2}{R_1} = -\frac{R_2}{1k} \Rightarrow \boxed{R_2 = 22k\Omega}$

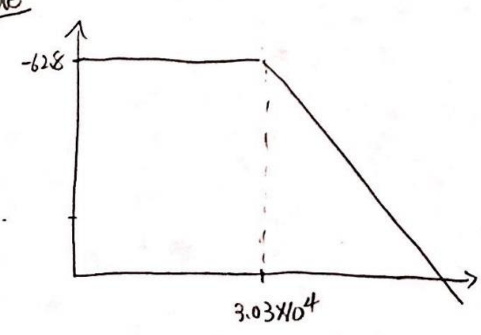
3-dB frequency $= \frac{1}{\tau} = \frac{1}{(R_1+R_2)C} = \frac{1}{23k\cdot 33n} = \boxed{1317.52\ Hz}$

③ $\left|\frac{V_o}{V_i}\right| = \frac{R_2}{R_1}\frac{s}{s+\frac{1}{R_1C}} = \frac{R_2}{R_1}\frac{R_1Cs}{\frac{s}{1/R_1C}+1} = \frac{R_2Cs}{\frac{s}{1/R_1C}+1} = \frac{22k\cdot 33n\cdot s}{\frac{s}{1/1k\cdot 33n}+1}$

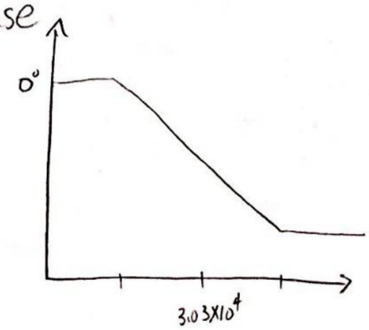
$= \frac{7.26\times10^{-4}s}{1+\frac{s}{3.03\times10^4}}$ $20\log(7.26\times10^{-4}) = -62.8dB$

$Z_1 = 0$ $P_1 = -3.03\times10^4$

Magnitude



Phase



④

$$|H(s)| = \frac{7.26\times10^{-4}s}{1+3.03\times10^{-4}s} = \frac{7.26\times10^{-4}}{\sqrt{1+(3.03\times10^{-4}\omega)^2}} \angle 90° - \tan^{-1}\frac{\omega}{3.03\times10^{4}} \quad , \quad \omega = 2000\pi$$

$$= 0.000338 \angle 78.28°$$

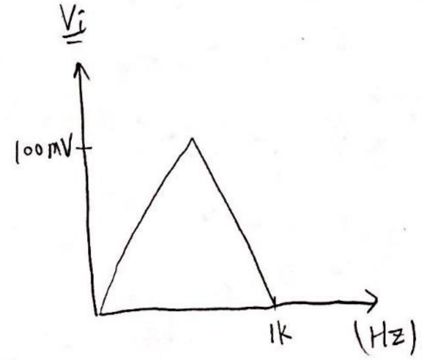
$$V_i = 0.1\sin(2\pi1000t) = 0.1\angle0°$$

$$V_o(t) = 0.000338\angle78.28° \cdot 0.1\angle0°$$

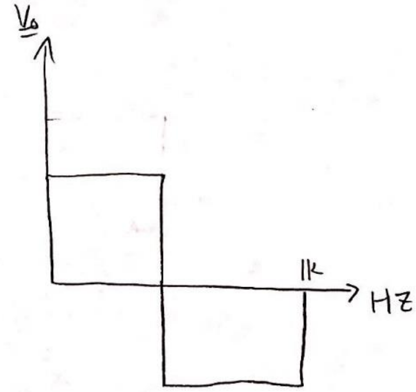
$$= 0.000034\angle78.28°$$

$$= \boxed{3.4\times10^{-5}\sin(2\pi1000t - 78.28°)}$$

⑤



$\xrightarrow{\frac{d}{dt}}$



Finite GBW Limitations:

① $\frac{V_o}{V_i} = \frac{G_o}{1+\frac{S}{\omega_o}}$ $\quad G_o = 1 + \frac{R_2}{R_1}$ $\quad \omega_o = \omega_t / G_o$

Gain = 23

$23 = 1 + \frac{R_2}{1k} \Rightarrow \boxed{R_2 = 22k\Omega}$

Gain = 57

$57 = 1 + \frac{R_2}{1k} \Rightarrow \boxed{R_2 = 56k\Omega}$

Gain = 83

$83 = 1 + \frac{R_2}{1k} \Rightarrow \boxed{R_2 = 82k\Omega}$

②

Gain = 23

$$\frac{V_o}{V_i} = \frac{23}{1+\frac{S}{\omega_t/23}} = \boxed{\frac{\omega_t}{S + \omega_t/23}}$$

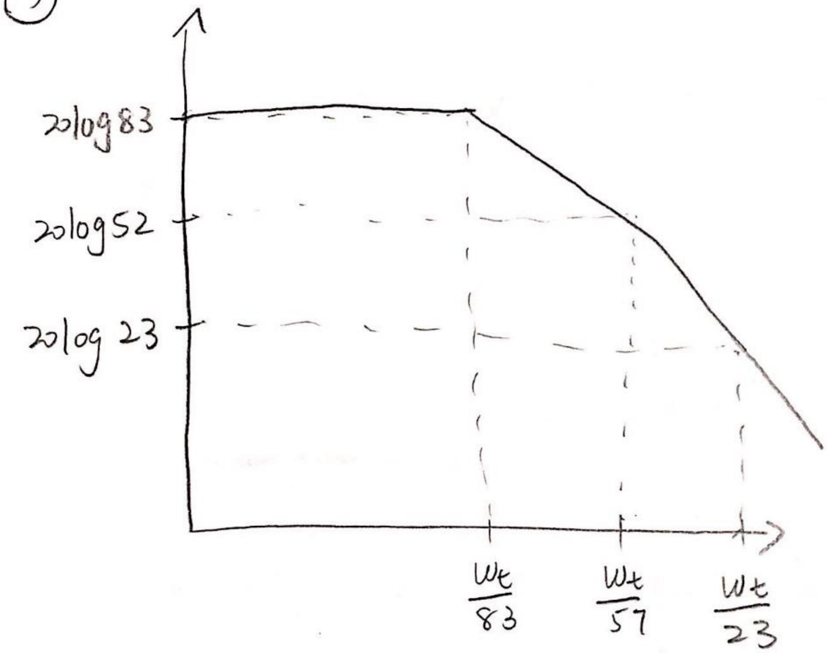
Gain = 57

$$\frac{V_o}{V_i} = \boxed{\frac{\omega_t}{S + \omega_t/57}}$$

Gain = 83

$$\frac{V_o}{V_i} = \boxed{\frac{\omega_t}{S + \omega_t/83}}$$

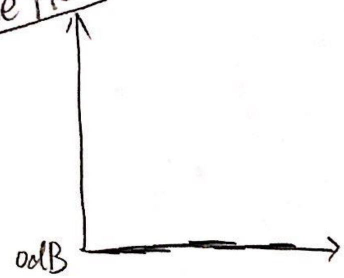
③



Slew Rate Limitations:

① $\frac{V_o}{V_i} = 1$

Bode Plot



② Slew rate $= 0.5\ V/\mu s = 0.5\times10^6\ V/s$

$V_i = 1\sin(t)$

$V_o = V_i = 1\sin(t)$

$V_{o,max} = \sqrt{2}\cdot1 = \sqrt{2}\ V$

$f_{max} = \frac{0.5\times10^6}{2\pi\cdot\sqrt{2}} = \boxed{56269.8\ Hz}$

③ slew rate $= 0.5\ V/\mu s = 0.5\times10^6\ V/s$

$f_{max} = 75kHz$

$V_{o,max} = \frac{0.5\times10^6}{2\pi\cdot75K} = \boxed{1.06V}$

Simulations