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Homework 6: Due 2/24/2020

5. Calculate the rise time T_{CL} associated with the following gain values:
    1. $A_{CL} = 500$

$$\begin{aligned} A_{CL} = \frac{V_o}{V_i} = 1 - e^{-2\pi B_{CL} t} \\ A_{CL} - 1 = e^{-2\pi B_{CL} t} \\ ln(A_{CL} - 1) = -2\pi B_{CL} t \\ \frac{ln(A_{CL} - 1)}{-2\pi B_{CL}} = t;\ B_{CL} = 4kHz \\ \frac{ln(499)}{-2\pi(4kHz)} = t \\ \underline{\overline{|t = 247.2\mu s|}} \end{aligned} \tag{1}$$

    2. $A_{CL} = 50$

$$\begin{aligned} \frac{ln(A_{CL} - 1)}{-2\pi B_{CL}} = t;\ B_{CL} = 40kHz \\ \frac{ln(49)}{-2\pi(40kHz)} = t \\ \underline{\overline{|t = 15.5\mu s|}} \end{aligned} \tag{2}$$

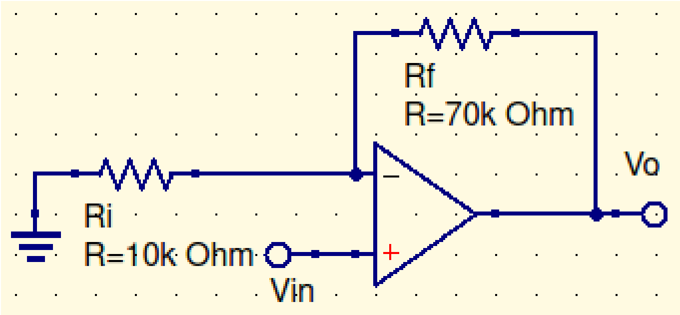
    3. $A_{CL} = 5$

$$\begin{aligned} \frac{ln(A_{CL} - 1)}{-2\pi B_{CL}} = t;\ B_{CL} = 400kHz \\ \frac{ln(4)}{-2\pi(400kHz)} = t \\ \underline{\overline{|t = 551.6ns|}} \end{aligned} \tag{3}$$

    4. $A_{CL} = 1$

$$\begin{aligned} \frac{ln(A_{CL} - 1)}{-2\pi B_{CL}} = t;\ B_{CL} = 2MHz \\ \frac{ln(0)}{-2\pi(2MHz)} = t \\ ln(0) = -\infty \\ \therefore \\ \underline{\overline{|t = unknown|}} \end{aligned} \tag{4}$$

9. Consider the following circuit:



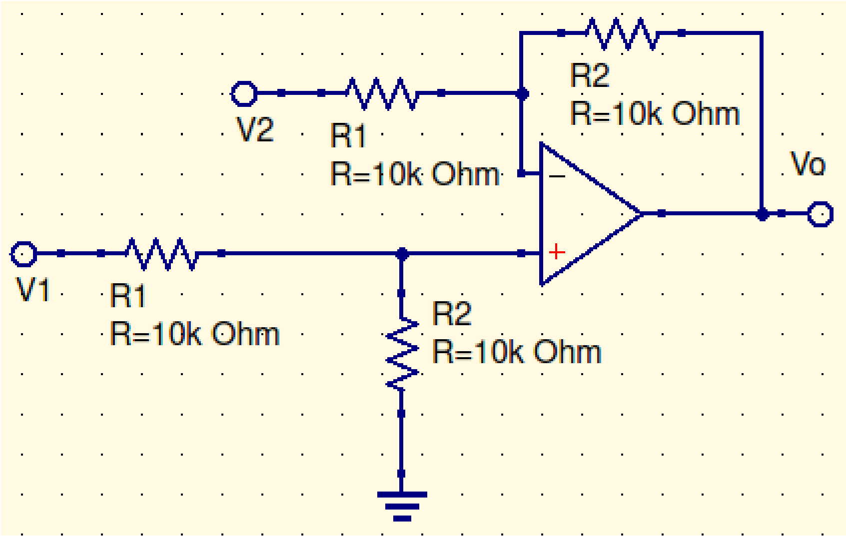
If the unity-gain frequency of the op amp is 1.6MHz, determine the closed loop 3-dB bandwidth.

$$A_{CL} = 1 + \frac{R_i}{R_f} = 1 + \frac{10k\Omega}{70k\Omega} = 1.1428 \tag{5}$$
$$B_{CL} = \frac{B}{A_{CL}} = \frac{1.6MHz}{1.1428}$$
$$\boxed{B_{CL} = 1.12MHz}$$

13. Calculate the rise time T_{CL} for the circuit stated above.

$$\frac{ln(A_{CL} - 1)}{-2\pi B_{CL}} = t; \; B_{CL} = 1.12MHz \tag{6}$$
$$\frac{ln(0.1418)}{-2\pi(1.12MHz)} = t$$
$$\boxed{t = 276.5ns}$$

19. Consider the circuit below:



If the unity-gain frequency of the op-amp is 1MHz, determine the closed-loop 3-dB bandwidth.

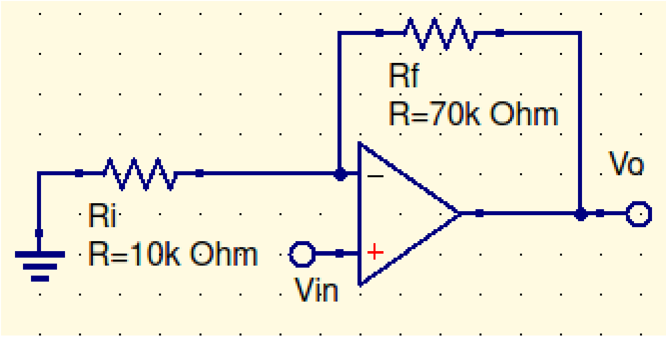
$$B_{CL} = \frac{B}{A_{CL}} \tag{7}$$

$$A_{CL} = \frac{R_2}{R_1} = \frac{10k\Omega}{10k\Omega} = 1$$

$$B_{CL} = \frac{1MHz}{1}$$

$$\boxed{B_{CL} = 1MHz}$$

21. Consider the following circuit:



Assume that the op-amp slew rate is $0.6V/\mu s$. Calculate the rise time T_{SR} due to the slew rate when the input is a pulse that changes from zero to the following values:

1. 10mV

$$
\begin{aligned}
T_{SR} &= \frac{V_o}{S} \\
T_{SR} &= \frac{V_i A_{CL}}{0.6V/\mu s} \\
A_{CL} &= 1 + \frac{R_i}{R_f} = 1 + \frac{10k\Omega}{70k\Omega} \\
T_{SR} &= \frac{(10mV)(1.1428)}{0.6V/\mu s} \\
&\boxed{T_{SR} = 23.8ns}
\end{aligned}
\tag{8}
$$

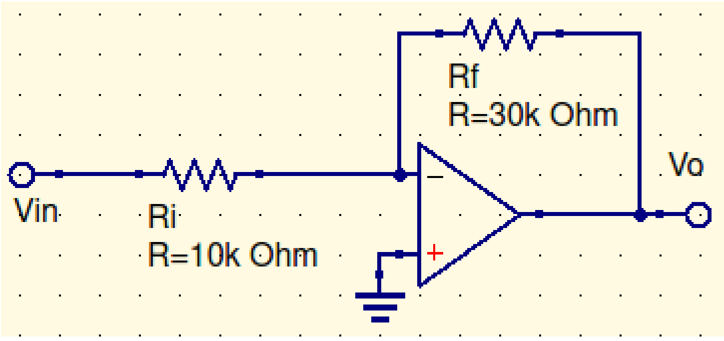
2. 0.1V

$$
\begin{aligned}
T_{SR} &= \frac{V_i A_{CL}}{0.6V/\mu s} \\
T_{SR} &= \frac{(100mV)(1.1428)}{0.6V/\mu s} \\
&\boxed{T_{SR} = 238ns}
\end{aligned}
\tag{9}
$$

3. 1V

$$
\begin{aligned}
T_{SR} &= \frac{V_i A_{CL}}{0.6V/\mu s} \\
T_{SR} &= \frac{(1V)(1.1428)}{0.6V/\mu s} \\
&\boxed{T_{SR} = 2.38\mu s}
\end{aligned}
\tag{10}
$$

23. Consider the following circuit:



Assume that the op-amp slew rate is $0.5V/\mu s$. Calculate the rise time T_{SR} due to the slew rate when the input is a pulse that changes from zero to each of the following values:

1. 0.2V

$$T_{SR} = \frac{V_o}{S} \tag{11}$$
$$T_{SR} = \frac{V_i A_{CL}}{0.5V/\mu s}$$
$$A_{CL} = -\frac{R_f}{R_i} = \frac{-3}{1} = -3$$
$$T_{SR} = \frac{(0.2V)(-3)}{0.5V/\mu s}$$
$$\boxed{T_{SR} = 1.2\mu s}$$

2. 1V

$$T_{SR} = \frac{V_i A_{CL}}{0.5V/\mu s} \tag{12}$$
$$T_{SR} = \frac{(1V)(-3)}{0.5V/\mu s}$$
$$\boxed{T_{SR} = 6\mu s}$$

3. 3V

$$T_{SR} = \frac{V_i A_{CL}}{0.5V/\mu s} \tag{14}$$
$$T_{SR} = \frac{(3V)(-3)}{0.5V/\mu s}$$
$$\boxed{T_{SR} = 18\mu s}$$