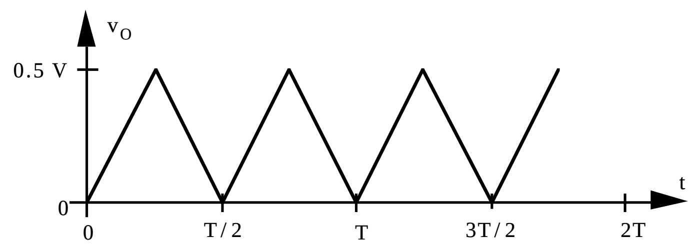
**Homework Assignment No. 15 - Solutions**

1.) Problem 12.122 of the text.




2.) Problem 12.128 of the text.

$$\text{For } V_O = 4.3 + 0.6 = 4.9\text{V}: \ V_+ = 4.9\frac{4.3\text{k}\Omega}{4.3\text{k}\Omega + 39\text{k}\Omega} = 0.487 \text{ V}$$

$$\text{For } V_O = -4.3 - 0.6 = -4.9\text{V}: \ V_+ = -4.9\frac{4.3\text{k}\Omega}{4.3\text{k}\Omega + 39\text{k}\Omega} = -0.487 \text{ V}$$

$$V_N = 0.487 - (-0.487) = 0.974 \text{ V}$$

3.) Problem 12.130 of the text.

$$\text{For } v_O = +12\text{V}: \ V_+ = 6\frac{24\text{k}\Omega}{3.4\text{k}\Omega + 24\text{k}\Omega} + 12\frac{3.4\text{k}\Omega}{3.4\text{k}\Omega + 24\text{k}\Omega} = 6.74 \text{ V}$$

$$\text{For } v_O = 0\text{V}: \ V_+ = 6\frac{24\text{k}\Omega}{3.4\text{k}\Omega + 24\text{k}\Omega} = 5.26 \text{ V}$$

$$v(t) = V_F - (V_F - V_I)\exp\left(-\frac{t}{RC}\right)$$

$$6.74 = 12 - (12 - 5.26)\exp\left(-\frac{T_1}{RC}\right) \rightarrow T_1 = 6200(3.3\text{x}10^{-8})\ln\frac{6.74}{5.26} = 50.7 \ \mu\text{s}$$

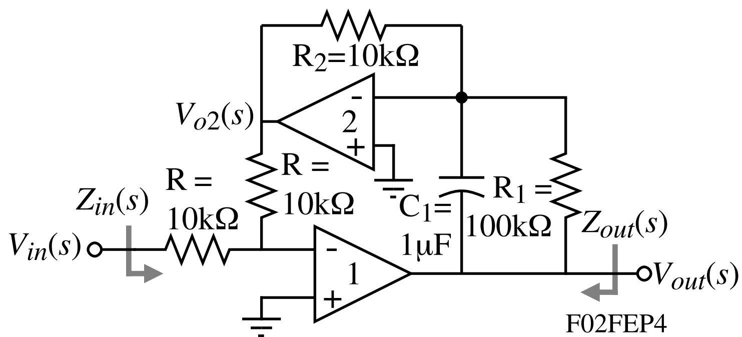
$$5.26 = 0 - (0 - 6.74)\exp\left(-\frac{T_2}{RC}\right) \rightarrow T_2 = 6200(3.3\text{x}10^{-8})\ln\frac{6.74}{5.26} = 50.7 \ \mu\text{s}$$

$$f = \frac{1}{50.7\mu\text{s} + 50.7\mu\text{s}} = 9.86 \text{ kHz}$$

4.) Problem 12.131 of the text.

f = 0. The circuit does not oscillate. $V_O = 0$ is a stable state.

5.) If the op amps shown are ideal (infinite voltage gain, infinite differential input resistance, and zero output resistance) find the voltage transfer function, $V_{out}(s)/V_{in}(s)$, the input impedance, $Z_{in}(s)$, and the output impedance, $Z_{out}(s)$. Sketch an asymptotic plot for the magnitude and phase shift of the voltage transfer function, $V_{out}(i\omega)/V_{in}(j\omega)$ as a function of $\log_{10}\omega$.

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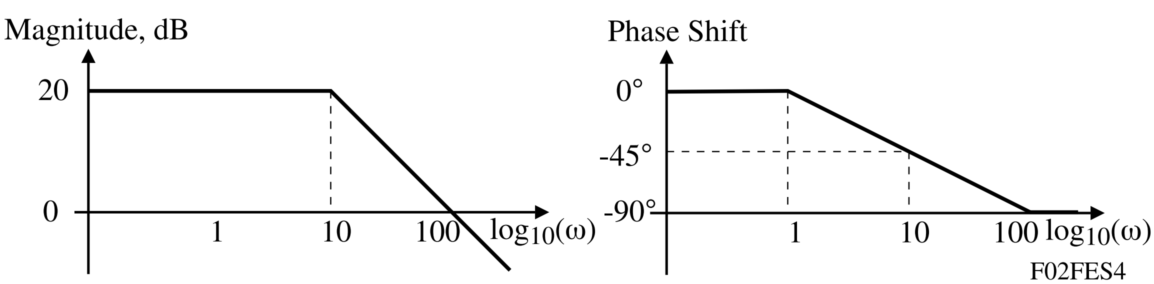
*Solution*

$V_{o2}(s)$ can be written as $V_{o2}(s) = -\dfrac{R_2}{Z_1}v_{out}(s)$ . Thus, the currents flowing toward the inverting terminal of the 1st op amp are, $\dfrac{V_{in}(s)}{R} + \dfrac{V_{o2}(s)}{R} = \dfrac{V_{in}(s)}{R} - \dfrac{R_2}{Z_1(s)}\dfrac{V_{out}(s)}{R} = 0$

$$\therefore \quad \frac{V_{out}(s)}{V_{in}(s)} = \frac{Z_1(s)}{R_2} = \frac{1}{R_2}\frac{R_1(1/sC_1)}{R_1+(1/sC_1)} = \frac{R_1}{R_2}\frac{1}{sR_1C_1+1} \qquad \boxed{\frac{V_{out}(s)}{V_{in}(s)} = \frac{R_1}{R_2}\frac{1}{sR_1C_1+1}}$$

By inspection, $\boxed{Z_{in}(s) = R = 10\text{k}\Omega \text{ and } Z_{out}(s) = 0}$

For the Bode plot we want to plot the magnitude and phase of $\dfrac{V_{out}(j\omega)}{V_{in}(j\omega)} = \dfrac{10}{1+j\omega/10}$ .

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