Problem Set 4 Solutions

6.101 Analog Electronics Lab

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Problem 1 First calculate the Thevenin equivalent of the input circuit to the opamp:

$$V_{Th} = 11V\frac{4k\Omega}{4k\Omega + 2k\Omega} = 7.3V$$

$$R_{Th} = 6k\Omega + (2k\Omega||4k\Omega) = 7.3k\Omega$$

The op-amp gain is then:

$$A_v = -\frac{12k\Omega}{7.3k\Omega}$$

Therefore,

$$V_O = V_{Th}A_v = 7.3V\left(-\frac{12k\Omega}{7.3k\Omega}\right) = -12V$$

Problem 2 Let V_{out1} be the output of the first opamp. By matching the magnitude of the current, we have:

$$\frac{V_i}{R_1} = -\frac{V_{out1}}{R_2||\frac{1}{sC}} \Rightarrow = \frac{V_{out1}}{V_i} = -\frac{R_2}{R_1(sR_2C+1)}$$

The transfer function of the second opamp is simply:

$$\frac{V_o}{V_{out1}} = -2$$

Then:

$$\frac{V_o}{V_i} = 2\frac{R_2}{R_1(sR_2C+1)}$$

Problem 3 Let V_A be the voltage at the output of the lower-left opamp and V_B be the output of the upper opamp. We have the following relationships:

$$V_o = -\frac{\frac{1}{s(.01\mu F)}}{10k\Omega} = -\frac{1}{s(0.1\mu F)(10k\Omega)} = -\frac{1000F^{-1}\Omega^{-1}}{s}V_A$$

$$V_B = -\frac{10k\Omega}{10k\Omega}V_o = -V_o$$

$$\frac{V_i}{1k\Omega} + \frac{V_B}{2k\Omega} = -\frac{V_A}{5k\Omega||\frac{1}{s(0.1\mu F)}} = -\frac{s(0.1\mu F)(5k\Omega)+1}{5k\Omega}V_A$$

Solving these equations yields:

$$\frac{V_o}{V_i} = \frac{1}{\frac{1}{2} + \frac{s}{5000} + \frac{s^2}{10^7}}$$

Problem 4 Define the node of the T network as v_x. Define the currents as shown in the figure.

$$V_{minus} = V_I$$

$$i_1 = \frac{v_i}{R} = i_2$$

$$v_x = i_2 R + v_i = \frac{v_i}{R}R + v_i = 2v_i$$

$$i_3 = \frac{v_x}{R} = \frac{2v_i}{R}$$

$$i_4 = i_2 + i_3 = \frac{v_i}{R} + \frac{2v_i}{R} = \frac{3v_i}{R}$$

$$v_o = i_4 R + v_x = \frac{3v_i}{R}R + 2v_i$$

$$\frac{v_o}{v_i} = 5$$

Problem 5 Assuming the zener diode is in breakdown:

$$V_O = -\frac{R_2}{R_1}V_z = -6.8V$$

$$i_2 = \frac{0 - v_o}{R_2} = 6.8mA$$

$$i_z = \frac{10 - V_z}{R_s} - i_2 = -6.2mA$$

The Zener is not in breakdown because i_z is negative. The zener must be off:

$$i_2 = \frac{10 - 0}{R_s + R_1} = 1.52mA$$

$$v_o = -i_2 R_2 = -1.52V$$

$$i_z = 0$$

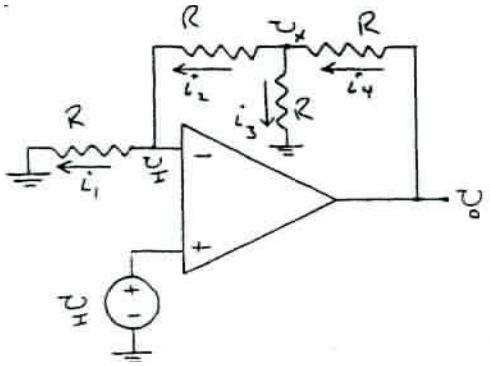

Figure 1: Problem 4