CENG4480 Homework 1

Due: Oct. 21, 2018

- **Small-Signal Gain:** For given amp circuits, small changes of input ΔV_{in} will cause output change of ΔV_{out}. Small-signal gain is defined by $\frac{\Delta V_{out}}{\Delta V_{in}}$.

Q1 (10%) Given a non-inverting amplifier as shown in Figure 1, $R_1 = 3R_2$ and $A_0 = 1000$, calculate the exact finite gain. Then determine the gain difference if the circuit is expected to have an ideal gain under $A_0 = \infty$.

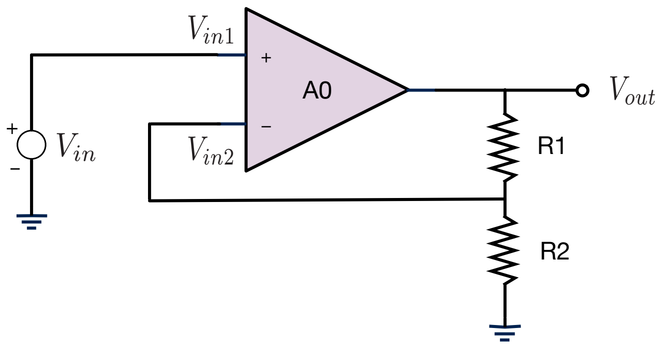

Figure 1: Non-inverting Amplifier.

Q2 (10%) An op-amp exhibits the following nonlinear characteristic:

$$V_{out} = \alpha \arctan[\beta(V_{in1} - V_{in2})]. \tag{1}$$

Determine the small-signal gain of the op amp in the case $V_{in1} \approx V_{in2}$. (Hint: use Taylor expansion of arctan and definition of aforementioned small-signal gain.)

Q3 (10%) In the circuit of Figure 2, $R_1 = R_2 = R' = R_f = R = 100\text{k}\Omega$ and $C = 1\mu\text{F}$. Assume the op-amps are ideal.

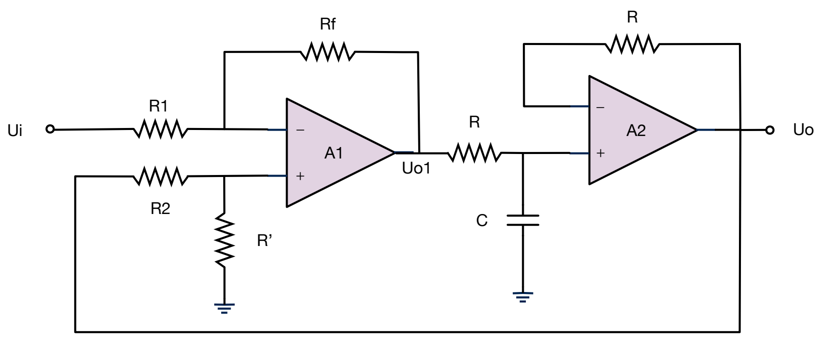

Figure 2: Voltage Follower.

1. (6%) The relationship between U_i and U_o (U_{o1} is unknown).
2. (4%) Assume that when the time $t = 0$, $U_o = 0V$ and U_i jumps from $0V$ to $-1V$. How long will the U_o take to change from $0V$ to $6V$?

Q4 (15%) Determine the output voltage (i.e. the mathematical expression of $V_{out}(t)$) for the integrator circuit of Figure 3a if the input is a square wave of amplitude $\pm A$ and period T shown in Figure 3b. Assume $T = 10ms$, $C_F = 1\mu F$, $R_s = 10k\Omega$ and ideal op-amp. The square wave starts at $t = 0$ and therefore $V_{out}(0) = 0$.

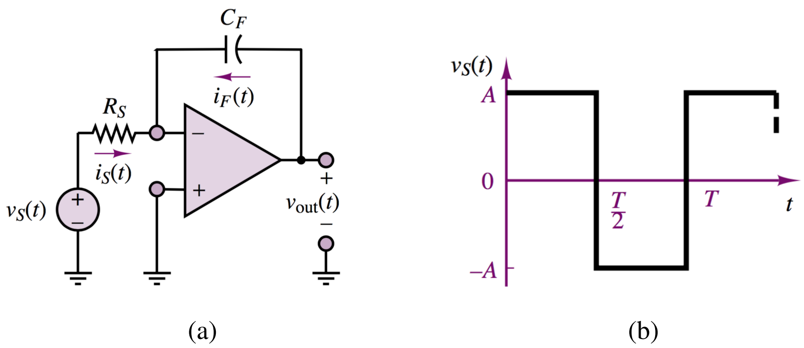

Figure 3: (a) Op-amp integrator; (b) Input of a square wave.

Q5 (20%) Assume op-amps are ideal. Given $R_1 = 0.4\text{M}\Omega$, $R_2 = R_3 = R_5 = 1\text{M}\Omega$, $R_4 = 2.5\text{k}\Omega$ and $C_1 = C_2 = 1\mu F$, derive the differential equation corresponding to the analog computer simulator of Figure 4, i.e. the mathematical relationship between f and x. Note that $f(t)$ is input signal, y and z are outputs of corresponding op-amps.

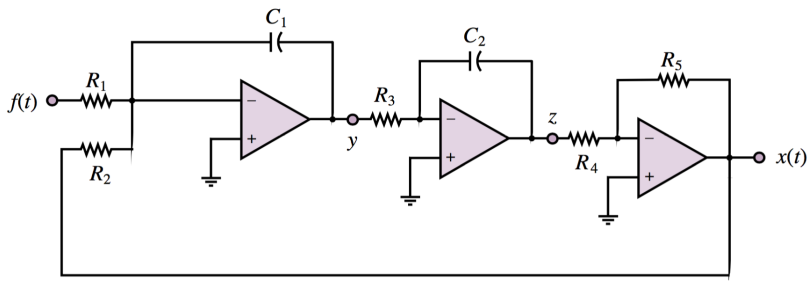

Figure 4: Analog computer simulation of unknown system.

Q6 (10%) Let us consider the Schmitt Trigger shown in Figure 5

1. (5%) Due to the manufacturing defects, a parasitic resister R_3 occurs between the output node and ground, calculate the reference voltages.
2. (5%) If the parasitic device is a capacitor C, sketch v_{out} versus v_{in}. Label the key coordinates on the curve.

Q7 (10%) Compute and sketch the output voltage of the op-amp in Fig. 6. Given $R_S = 1\text{k}\Omega$, $R_F = 10\text{k}\Omega$, $R_L = 1\text{k}\Omega$, $V_S^+ = 15\text{V}$, $V_S^- = -15\text{V}$, $v_s(t) = 2\sin(1000t)$. Repeat the problem if $V_S^+ = 20\text{V}$ and $V_S^- = -20\text{V}$. Assume the op-amp is supply voltage-limited.

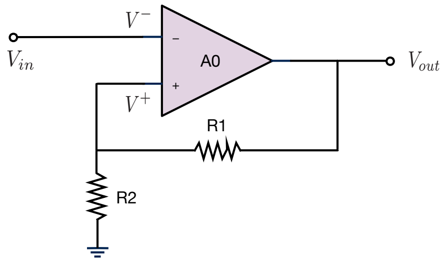

Figure 5: Schmitt Trigger.

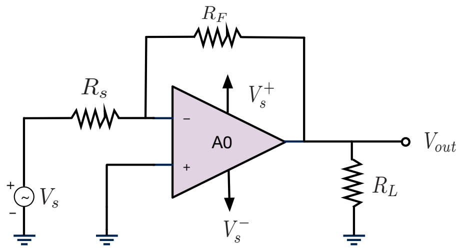

Figure 6: Inverting Amplifier.

Q8 (15%) Determine the closed-loop voltage gain as a function of frequency (i.e. $A(j\omega) = \frac{V_{out}(j\omega)}{V_s(j\omega)}$) for the op-amp circuit of Fig. 7. Assume the op-amp is ideal. Given only R_1, R_2 and ω_0, $R_2C = \frac{L}{R_1} = \omega_0$. (Hint: the impedance of a inductor L equals to $j\omega L$.)

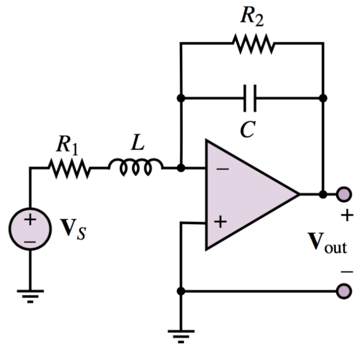

Figure 7: A second-order low-pass filter.