CENG4480 Homework 1

Due: Oct. 25, 2017

- **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 $\dfrac{\Delta V_{out}}{\Delta V_{in}}$.

Q1 (10%) Show that the circuit of Fig. 1 is a non-inverting summer. Assume the op-amp is ideal.

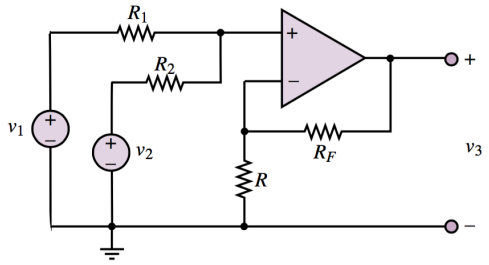

Figure 1: Non-inverting Summer

Q2 (10%) In the circuit of Fig. 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.

a. The relationship between U_i and U_o (U_{o1} is unknown).

b. 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 $6V$?

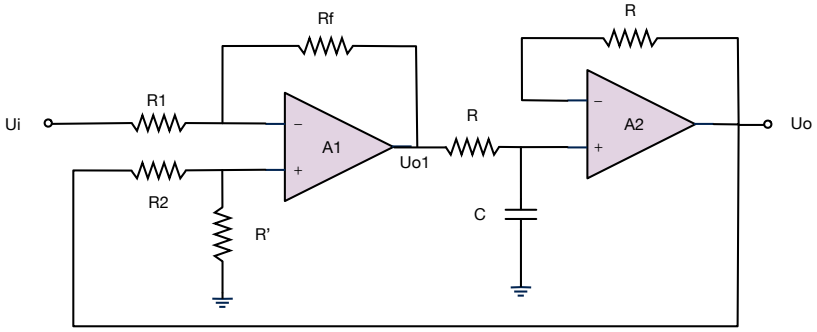

Figure 2: Voltage Follower

Q3 (10%) Try to analyze the relationship between U_i and U_o in the circuit of Fig. 3. $R_1 = R_2 = R_3 = R_5 = 50\text{k}\Omega$,$R_4 = 25\text{k}\Omega$ and $C = 10\mu\text{F}$. Assume the op-amps are ideal.

Q4 (15%) In the circuit of Fig. 4, assume that $U_{i1} = 4U_{i2} = 4V$, $R_1 = 50\text{k}\Omega$ and $C = 1\mu\text{F}$. The op-amps are ideal.

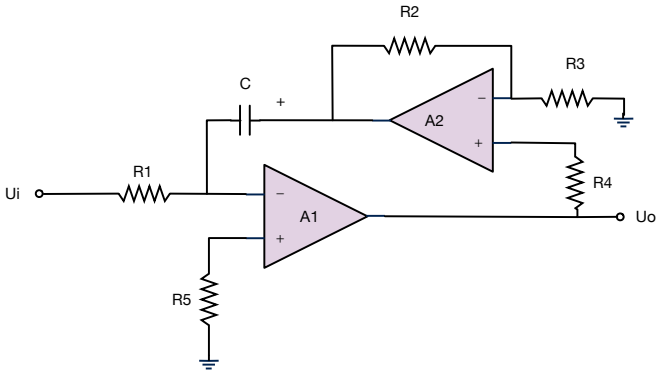

Figure 3

a. Calculate U_A, U_B, U_C, U_D and U_o, when the switch S is closed.

b. Assume that when the time $t = 0$, switch S is open. How long will the U_o take to become $0V$?

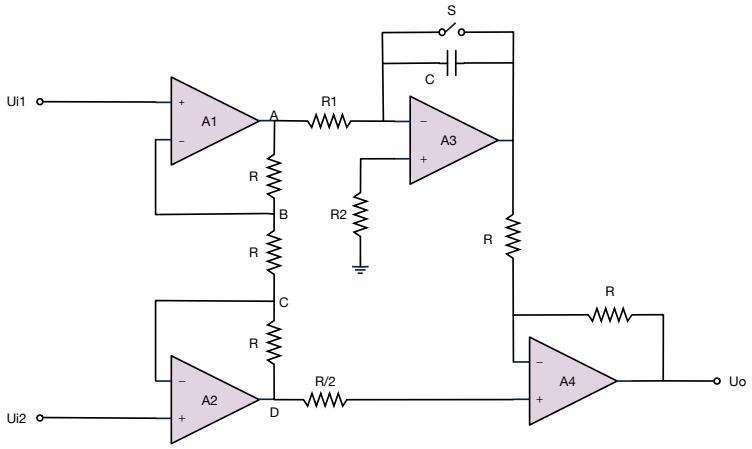

Figure 4

Q5 (10%) Let us consider the Schmitt Trigger shown in Fig. 5

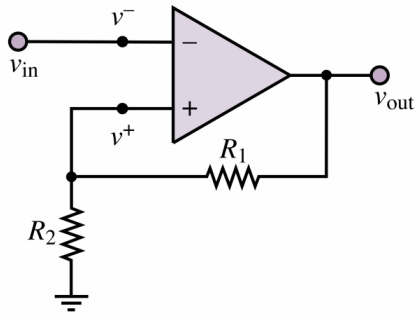

Figure 5: Schmitt Trigger

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.

Q6 (10%) Prove that current is split into two equal parts for $R-2R$ DAC.

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 $V_S^- = -20\text{V}$.

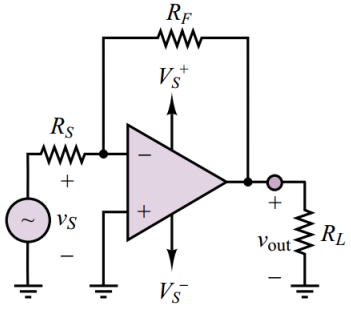

Figure 6: Inverting Amplifier

Q8 (10%) What is the minimum number of bits required to digitize an analog signal with a resolution of 1%, 10%, 20%, respectively. (**Resolution**: Ratio between minimum voltage that can be sensed and the input voltage range.)

Q9 (15%) Mental-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET) is the core component of a variety of amplifiers. Fig. 7 shows a common source amplifier circuit with N-type MOS (M1). Typically, when M1 works as amplifier, drain current I_D has the following relationship with bias voltage V_{in}:

$$I_D = k(V_{in} - V_{th})^2, \tag{1}$$

where k is positive and related to material properties of MOSFET and V_{th} is threshold voltage to turn the device on. Calculate small-signal gain of common source amplifier and show that this amplifier is an inverting amplifier.

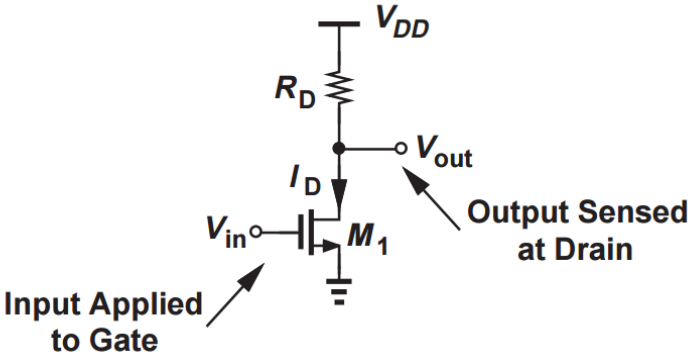

Figure 7: Common Source Amplifier