# CENG4480 Homework 1

**Due**: Oct. 25, 2017

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

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

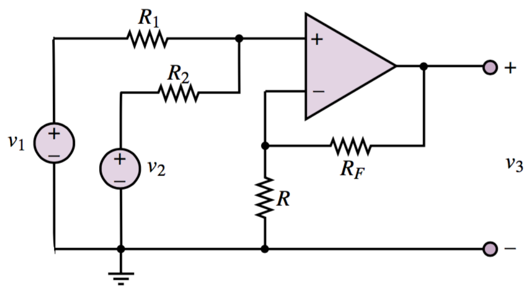


Figure 1: Non-inverting Summer

**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 $6V$?

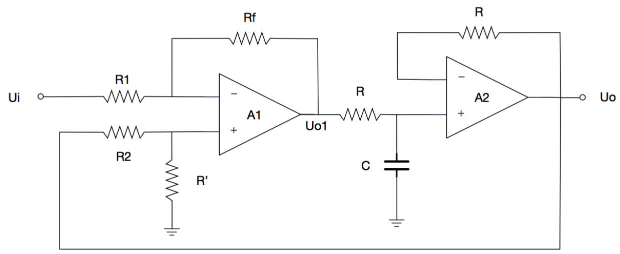


Figure 2: Voltage Follower

**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.

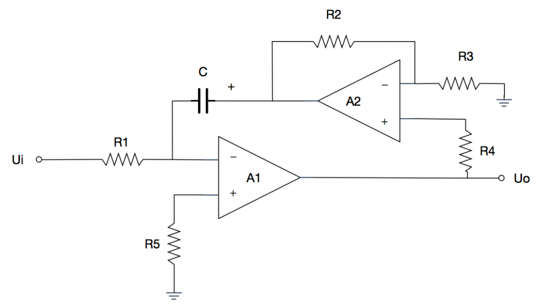


Figure 3

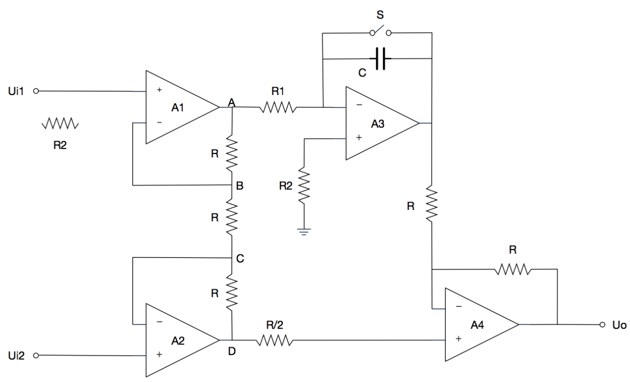


Figure 4

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 $0V$?

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

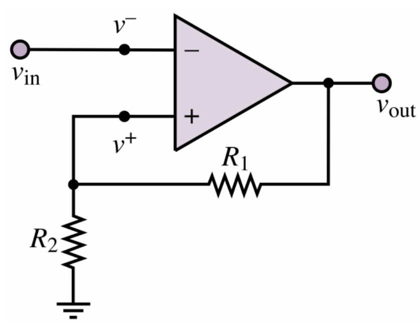


Figure 5: Schmitt Trigger

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

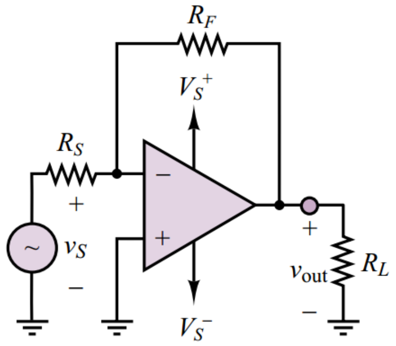


Figure 6: Inverting Amplifier

**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.

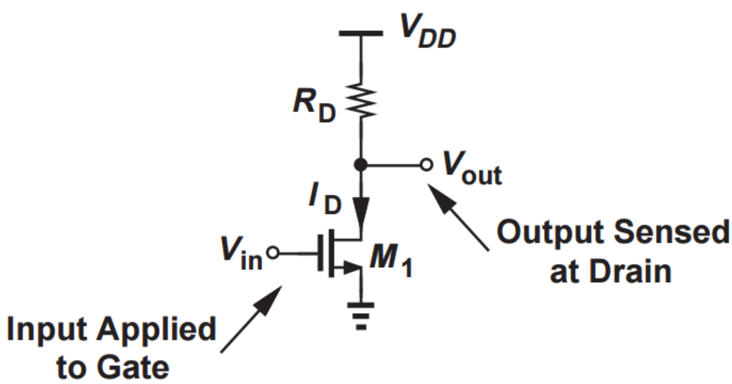


Figure 7: Common Source Amplifier