Microelectronic Circuits I (Midterm)

date: 2008/11/13 (Thur)

time:15:30 ~ 17:20

1. (20%) A p^+-n diode is one in which the doping concentration in the p region is much greater than that in the n region. In such a diode, the forward current is mostly due to hole injection across the junction. Show that

$$I \approx I_P = Aqn_i^2 \times \frac{D_p}{L_p N_D}\left(e^{\frac{V}{V_T}} - 1\right)$$

For the specific case in which $N_D = 3\times10^{16}/cm^3$, $D_p = 10cm^2/s$, $\tau_p = 0.05\mu s$,

and $A = 10^4\,\mu m^2$, find I_s and the voltage V obtained when $I = 0.2mA$.

Assume operation at 300K where $n_i = 1.5\times10^{10}/cm^3$. Also, calculate the excess minority-carrier ~~change~~ charge and the value of the diffusion capacitance at $I = 0.2mA$.

$C_d = \frac{\tau I}{V_T}$

2. (20 pts) An ideal differentiator is implemented as Fig (a). Note that R_FC_1=1μs.
   (1) With such input waveform, please draw the output waveform. Please label all of the voltage and time information in your waveform. Note that transition time means that the time that it needs to take for the input voltage to change from 0V to 1V, 1V to 2V and 2V to 0V. Also, assume the input voltage stays at 0V, 1V and 2V for a time much longer than 1μs. (6 pts)
   (2) Now, the circuit in Fig (a) is modified as that in Fig (b), please repeat part (1). (2 pts)
   (3) The slew rate of the op amp is only 0.5V/μs, repeat part (1). You don't need to consider the 50mV voltage in (b). (5 pts)
   (4) The capacitor C_1 is not ideal such that it has a series resistor R_S(as Fig (c)), please repeat part (1). Here, R_SC_1=0.1μs. (7 pts)

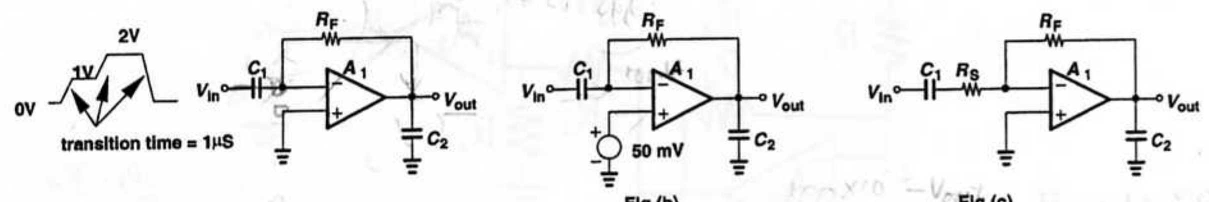


Fig (a) Fig (b) Fig (c)

$-V_{out} = \cancel{+C_1R_F V_{in} + CC_1R_F}$

$\left|\frac{V_o}{V_i}\right| = -j\omega C_1 R_F = -j\omega\cdot10^{-6}$

$V_{in} + C = 0$

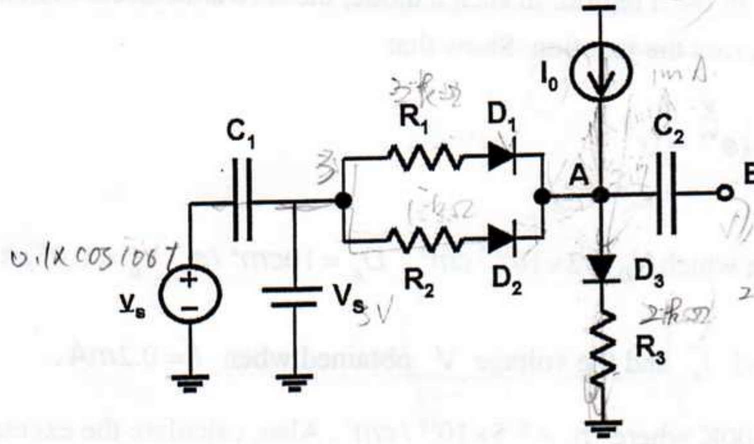
$V_{out} = -C_1R_FV_{in}$

3. (20%) For the circuit in Fig (d), the parameters are given as $V_S = 3$ V, $v_s = 0.1\times\cos(100t)$ V, $R_1 = 2$ kΩ, $R_2 = 1$ kΩ, $R_3 = 2$ kΩ, n =1 (for all diodes), and the capacitors C_1 and C_2 are sufficiently large.

(1) For $I_0 = 0$ mA, find the total voltage $v_A(t)$ and $v_B(t)$. (14%)

(2) For $I_0 = 1$ mA, find the total voltage $v_A(t)$ and $v_B(t)$. (6%)

[Hint: Please use constant-voltage-drop model with $V_D = 0.7$ V for DC analysis]



$$\frac{3-V_A-0.7}{2000} + \frac{3-V_A-0.7}{1000} = \frac{V_A-0.7}{2000}$$

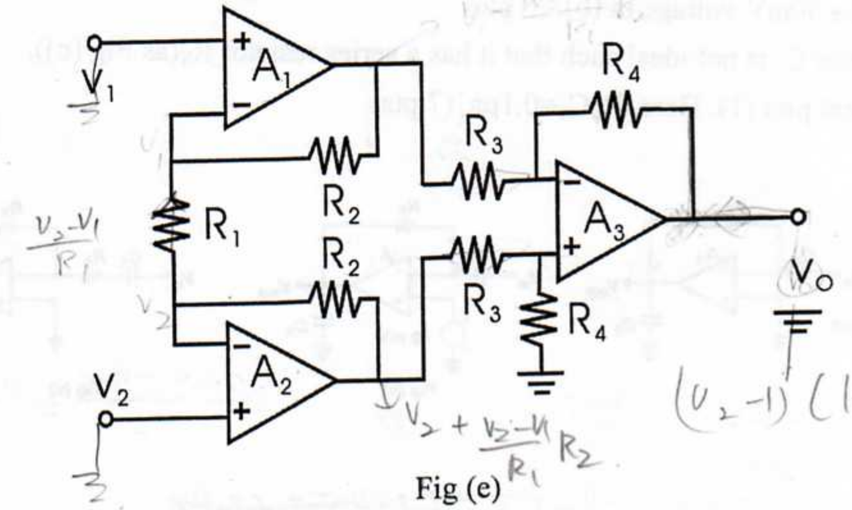
Fig (d)

4. (20%) The instrument amplifier, shown as Fig (e), is widely used in various applications especially in the interface circuit of sensors. Please answer the following questions and derive the expression.

(1) Please derive the differential gain of the instrument amplifier. (8%)

(2) Please write the input resistance and the output resistance of the instrument amplifier. (4%)

(3) If we want to measure the difference of ΔR shown as Fig (f), can we use the instrument amplifier to be its interface circuit? If so, please draw the connection and derive the output voltage, v_O, of the amplifier. (8%)



$$(v_2-v_1)\left(1+\frac{2R_2}{R_1}\right)\frac{R_4}{R_3}$$

Fig (e)

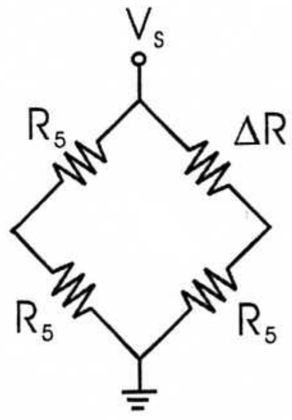


Fig (f)

5. (20%) For the circuit shown in Fig (g), $V_i = 10 \sin \omega t$. Assuming the diodes are ideal.

(1) If $R_1 = 2\ k\Omega$, $R_2 = 3\ k\Omega$, $R_L = 6\ k\Omega$, analyze the circuit and sketch V_o versus time (also show V_i in the same plot). (5%)

(2) Continue from (1), sketch V_i versus V_o. (3%)

(3) Continue from (1), what is the peak inverse voltage of each diode? (4%)

(4) If $R_1 = R_2 = 3\ k\Omega$, $R_L = 6\ k\Omega$, and the constant-voltage-drop model (with $V_D = 0.6$ V) is used for the diodes, sketch V_o versus time (also show V_i in the same plot) in this case. (5%)

(5) Continue from (4), sketch V_i versus V_o. (3%)

(Please indicate key voltage values at your plots.)

$\frac{V_i - V}{2} + \frac{V}{6} + \frac{V}{3}$

$\frac{V_i}{2} > V$

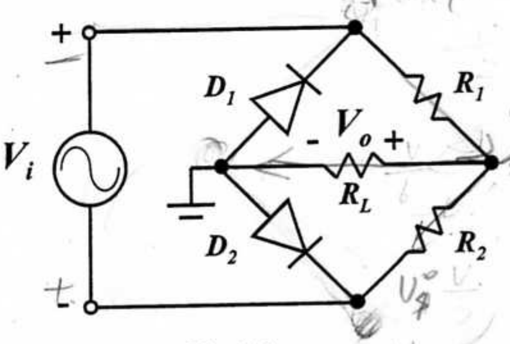


Fig (g)

$\frac{V_i - V}{2} = \frac{V}{6} + \frac{V}{3}$

$\frac{V_i}{2} = V$

$\frac{V_i - V}{3} = \frac{V}{6} + \frac{V}{2}$

$\frac{V_i}{3} = V$

$V_i > 2V$