Microelectronics III final exam

date: 2010/01/12

1. (20%)
   (1) (8%) Find the transfer function $T(s) \equiv V_o/V_i$ of the circuit in Fig. 1.
   (2) (8%) Given that $Q = 10$, $R = 100\ k\Omega$ and $C = 1\ nF$, find the voltage gain of a sinusoidal signal at $\omega = 10000\ rad$.
   (3) (4%) Use the device parameters in (2) to find the output voltage V_o for a dc input of 1 V.

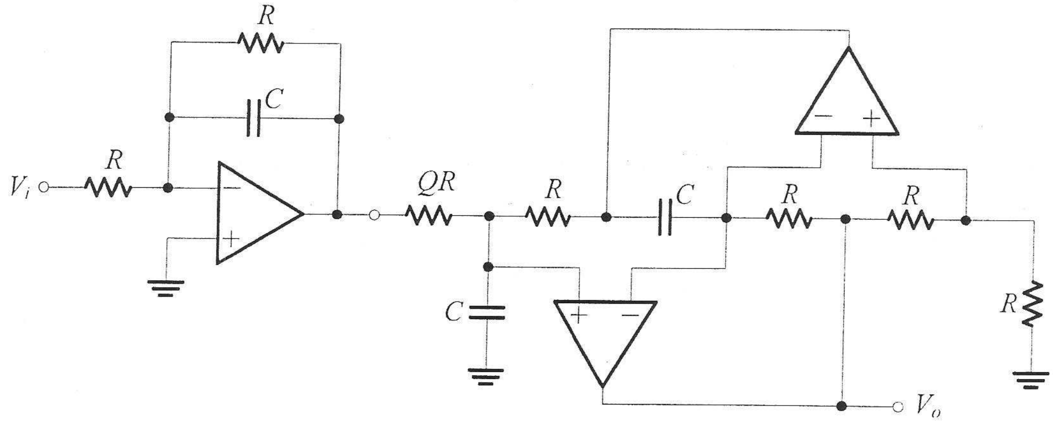

Fig. 1

2. (20%) Fig. 2 shows a Tow-Thomas biquad circuit.
   (1) (8%) Please derive the transfer functions V_A/V_{in} and V_B/V_{in}. If a low-pass response is designed, which node should be taken as the output node?
   (2) (8%) The circuit is designed as a low-pass filter (LPF) having a bandwidth $\omega_n = 2\pi\times 10\text{MHz}$ and a Q of 1. If $R_3 = 1\text{k}\Omega$, $R_2 = R_4$, and $C_1 = C_2$, determine the values of R_2 and C_1.
   (3) (4%) In this LPF, what is the amount of gain peaking in the magnitude response (in terms of dB).

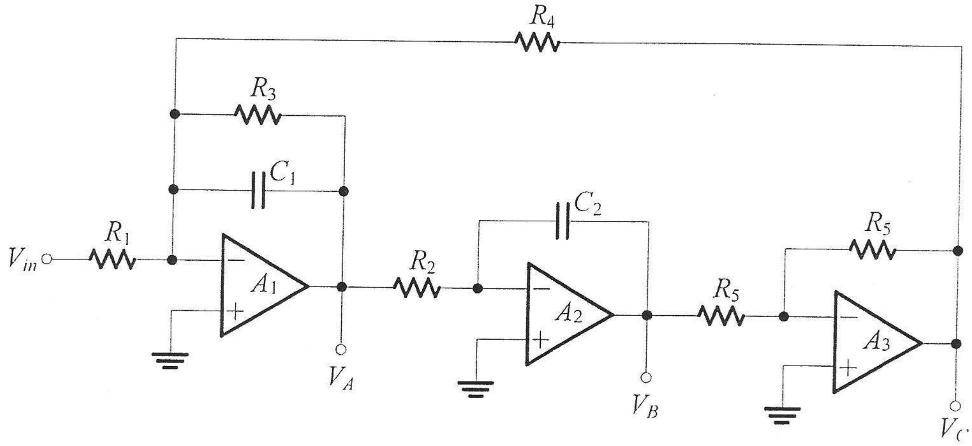

Fig. 2

3. (20%) In Fig. 3, we want to study quadrature oscillator design,
   (1) (5%) What R_f can make this oscillator start?
   (2) (5%) Under such R_f, what is the oscillation frequency?
   (3) (5%) Derive the peak-to-peak value of V_{out1} if $R_3 = 2R_4$ and diode turn-on voltage is V_D.
   (4) (5%) What is the amplitude ratio between V_{out1} and V_{out2}?

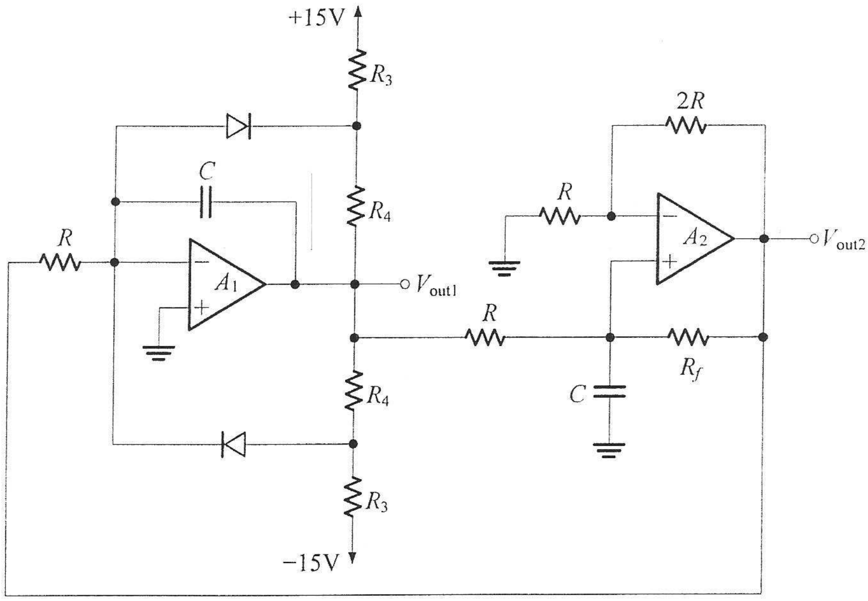

Fig. 3

4. (20%) Design a 100kHz, 50% duty-cycle oscillator. You have the following components to use: one 555 timer, resistors, capacitors, inductors, and diodes. (All passive devices are ideal.)
   (1) (14%) Explain your design with circuits and mathematical expressions, and
   (2) (6%) determine the values of the passive devices.

5. (20%) For the circuit shown in Fig. 5,
   (1) (5%) Show that the output voltage of the circuit in Fig. 5(a) is given by

$$v_O = -nV_T \ln\left(\frac{v_I}{I_S R}\right), \quad v_I > 0$$

   where I_S and n are the diode parameters and V_T is the thermal voltage.
   (2) (7%) Verify that the circuit in Fig. 5(b) implements the transfer characteristic $v_O = -v_1 v_2$ for v_1, $v_2 > 0$. Assume all diodes to be identical.
   (3) (8%) Check the circuit's performance (Fig. 5(b)) for v_1 = 2V and v_2 = 3V. Assume all diodes to be identical, with 700-mV drop at 1mA current and n = 2.

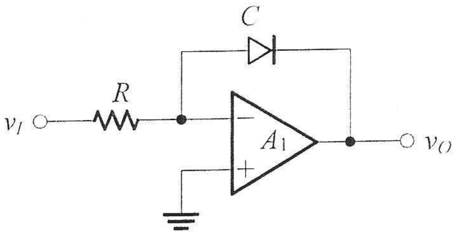
C
R
v_I
A_1
v_O
−
+

Fig. 5(a)

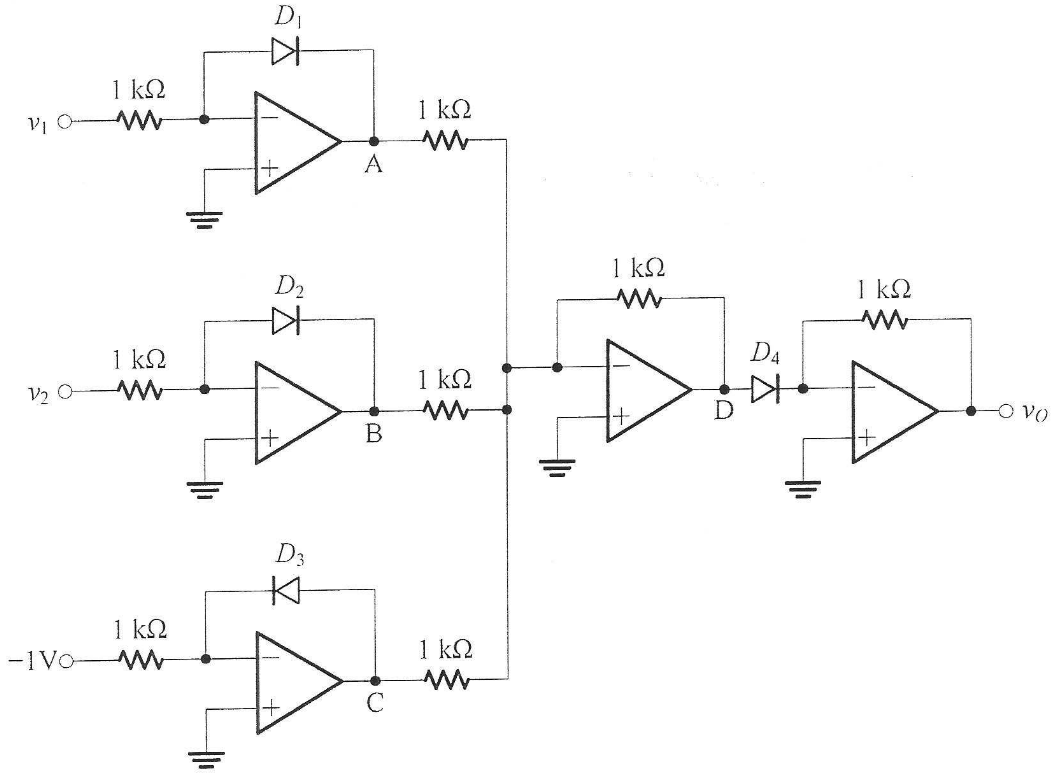
D_1
1 kΩ
v_1
1 kΩ
A
D_2
1 kΩ
v_2
1 kΩ
B
D_3
1 kΩ
−1V
1 kΩ
C
1 kΩ
D
D_4
1 kΩ
v_O

Fig. 5(b)