EE 40/42/100, Spring 2007
Prof. Chang-Hasnain
Midterm #2

April 11, 2007
Total Time Allotted: 80 minutes
Total Points: 100

1. This is a closed book exam. However, you are allowed to bring two page (8.5" x 11"), single-sided notes.
2. No electronic devices, i.e. calculators, cell phones, computers, etc.
3. SHOW all the steps on the exam.
4. **Remember to put down units.** Points will be taken off for answers without units.

Last (Family) Name:____

First Name: ____

Student ID: ___________________________ Signature: ___________________________

Circle the class you are in:

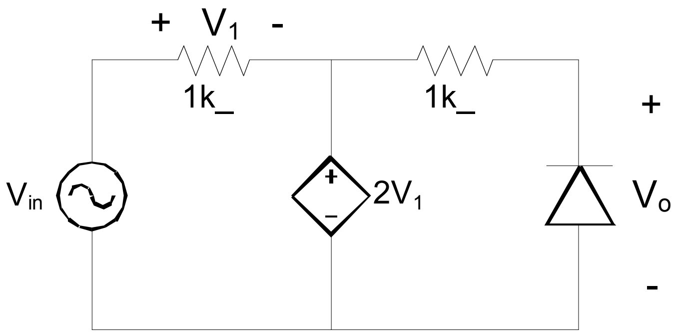
EE 40	EE 42	EE 100

Circle one discussion session you are in

	Monday		Tuesday		Wednesday		Thursday		Friday	
	Dis	TA	Dis	TA	Dis	TA	Dis	TA	Dis	TA
10:00	100(42)-101	Richard					40-105	Mike	100-107	Haibo
11:00	40-101	Mike	100-105	Haibo	100(42)-102	Tanya				
13:00	40-102	Jia	40-103	Isaac	100-104	Tanya				
15:00			100-106	Haibo						

Problem 1 (22 pts)	
Problem 2 (10 pts):	
Problem 3 (15 pts)	
Problem 4 (18 pts)	
Problem 5 (35 pts):	
Total	

1. (22 pts) Assume the diode in the circuit below using the **simple piecewise model with a threshold voltage of 0.6V** (also known as the **large signal model** in the text book).



(i) (4 pts) Re-draw the circuit assuming the diode is off. Express V_o as a function of V_{in}.

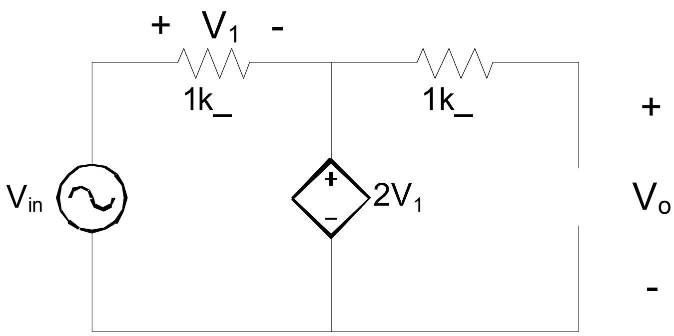


Figure 1 pt
Vin = V1+2V1 (1pts)
V1=Vin/3 (1pts)
V0=2V1=2Vin/3 (1pts)

(ii) (4 pts) Re-draw the circuit assuming the diode is on. Express V_o as a function of V_{in}.

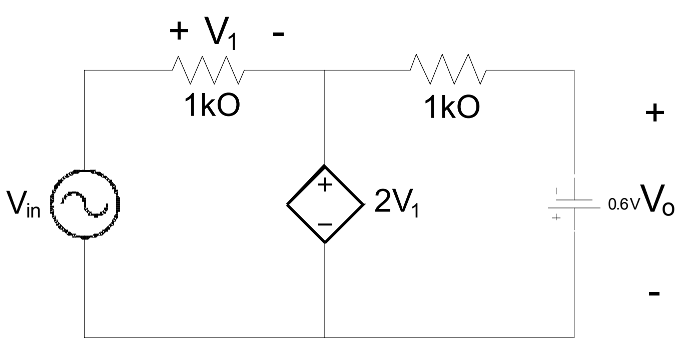


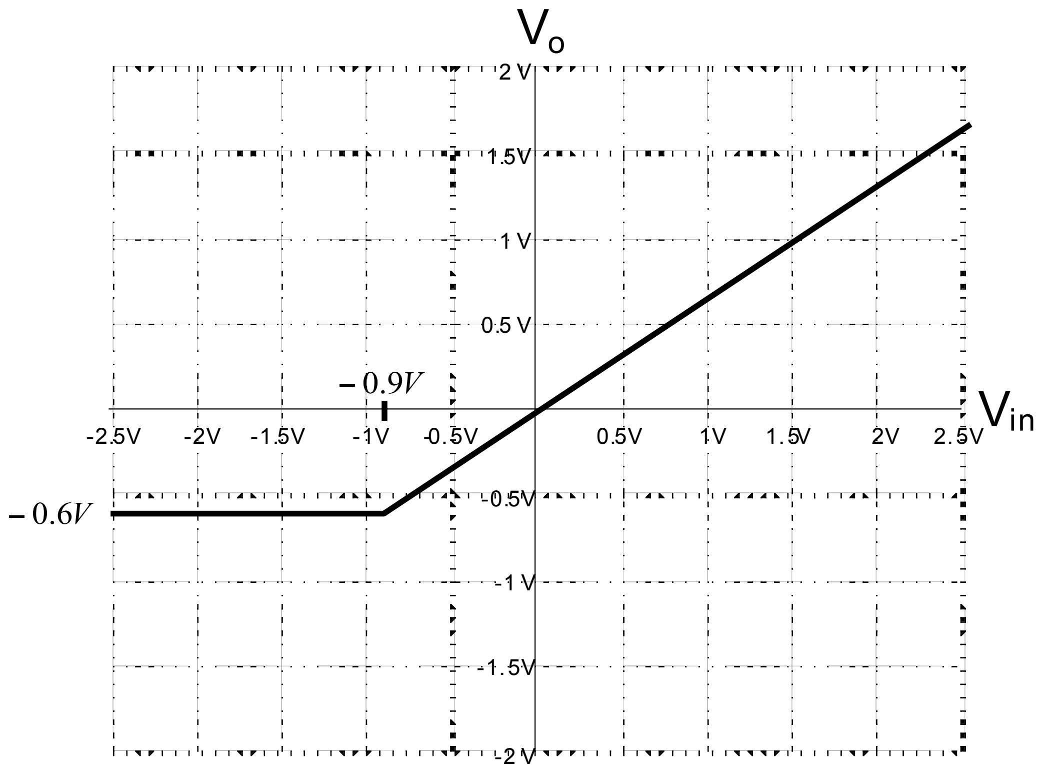
Figure 1 pt
V0=-0.6 V (3 pts)

(iii) (4 pts) For what values of V_{in} will the diode be on?

$2Vin/3 \leq -0.6V$ (2pts)

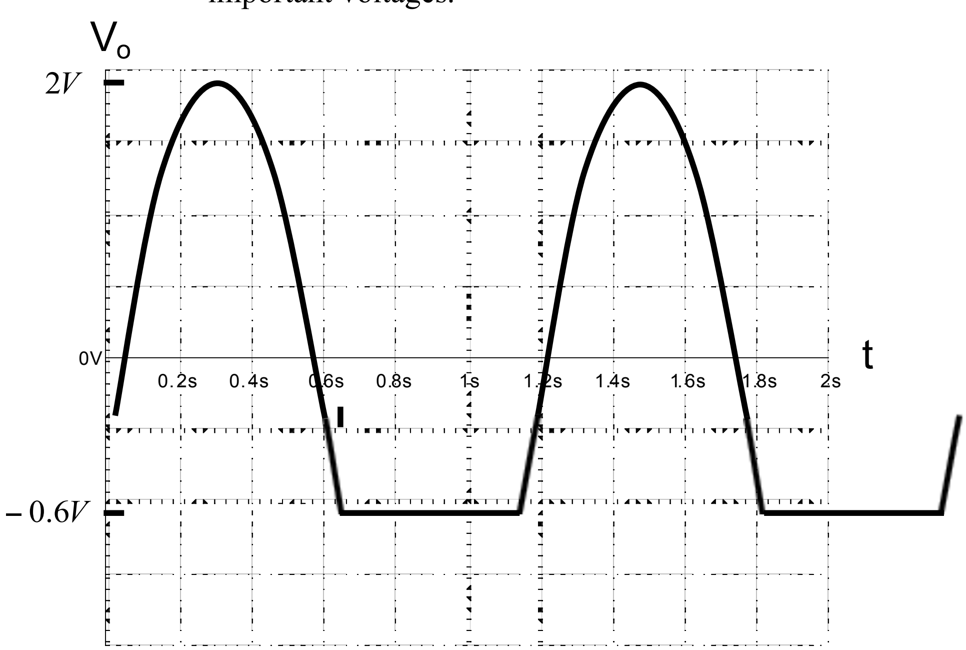
Vin ≤ -0.9V (2pts)

(iv) (4 pts) Plot V_o vs. V_{in}.



-0.9V, -0.6V, positive side slope and shape (each 1pts)

(v) (6 pts) Now suppose $V_{in} = 3 \sin(2\pi\ t)$. Plot V_o versus time for $0 < t < 2s$. Label important voltages.

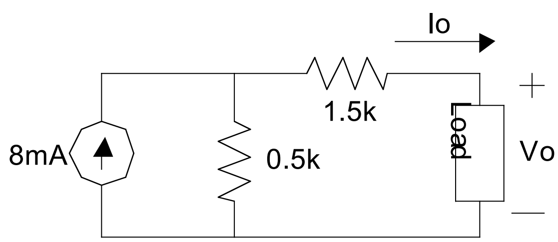


$$Vo = -0.6V = 2\sin(2\pi t)$$

$$t = \frac{\sin^{-1}(-0.3)}{2\pi}$$

2V, -0.6V, clamping on reverse side each are 2 pts.

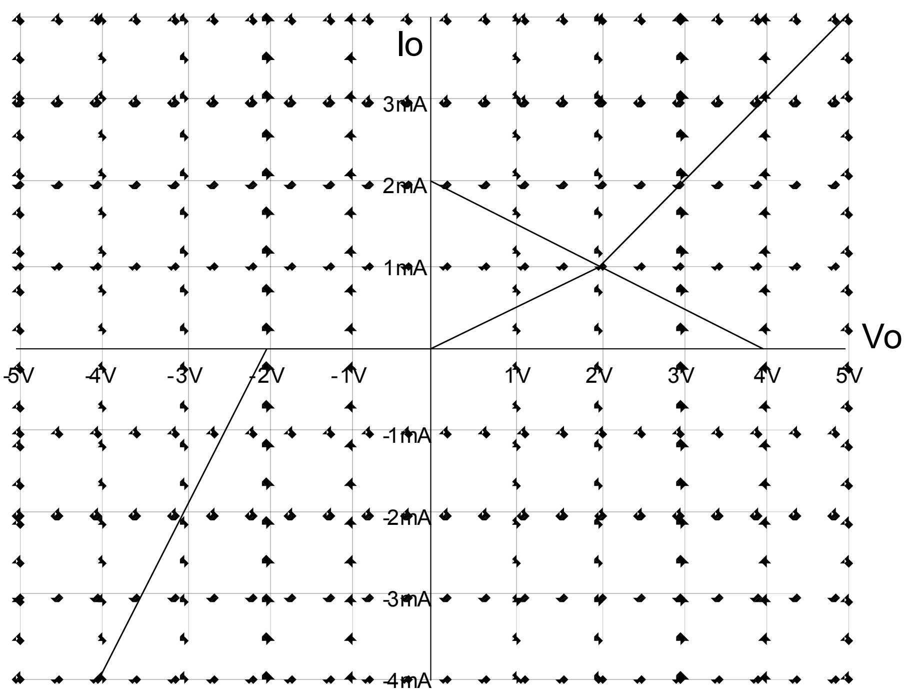
2 (10 pts) Consider the following circuit:



(i) (4 pts) Derive an expression relating Io to Vo.

(8mA –Io)*0.5k=Io*1.5k+Vo
4=2k*Io+Vo

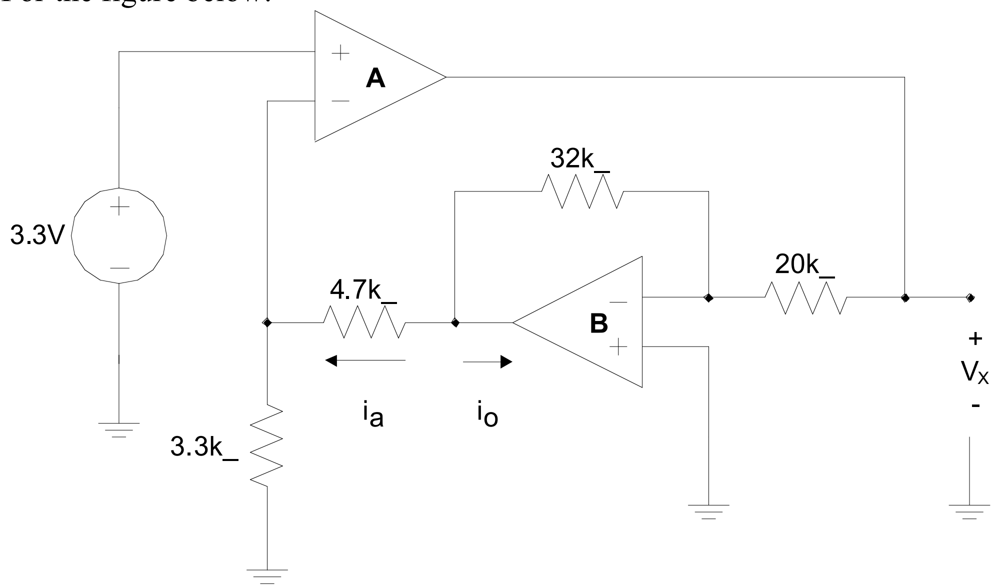
(ii) (6 pts) Now assume the load has the following I-V characteristic. Draw a **load line** and **find** the values of **Io and Vo**.



Io=1mA
Vo=2V

3. (15 pts)Op-amp circuit:

For the figure below:



Assume both are ideal op-amps:

1. Find i_a.

ia= 3.3V/3.3K=1mA

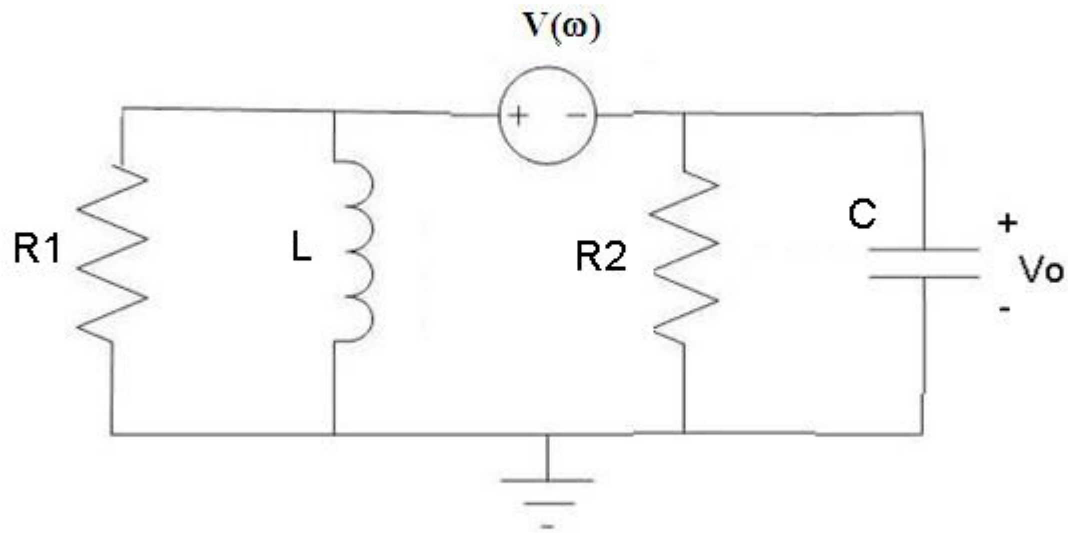
2. Find i_o.

io = -(3.3v+4.7K*1mA)/32K - ia= -1.25mA

3. Find V_x.

Vx= -0.25mA*20K=-5 V

4. (18 pts) Consider the following circuit: Find the transfer function $V_o/V_{in}(\omega)$



There are many different ways to solve this problem. I think voltage divider and KCL are the simplest.

Voltage divider method:

$$\frac{Vo}{Vin} = -\frac{R_2 // \frac{1}{j\varpi C}}{R_1 //(j\varpi L) + R_2 // \frac{1}{j\varpi C}} = -\frac{\frac{R_2}{1 + j\varpi R_2 C}}{\frac{j\varpi R_1 L}{R_1 + j\varpi L} + \frac{R_2}{1 + j\varpi R_2 C}}$$

You **DON'T** have to simplify that to get full credit. However, in case you do simplify it, you should be able to get something similar to the following:

$$\frac{Vo}{Vin} = -\frac{\frac{R_2}{1 + j\varpi R_2 C}}{\frac{j\varpi R_1 L * (1 + j\varpi R_2 C) + R_2 * (R_1 + j\varpi L)}{(1 + j\varpi R_2 C) * (R_1 + j\varpi L)}} = -\frac{R_2 * (R_1 + j\varpi L)}{j\varpi R_1 L * (1 + j\varpi R_2 C) + R_2 * (R_1 + j\varpi L)}$$

$$= -\frac{R_1 R_2 + j\varpi R_2 L}{R_1 R_2 - \varpi^2 R_1 R_2 C L + j\varpi L(R_1 + R_2)}$$

KCL @ ground method:

$$\frac{V_1}{R_1}+\frac{V_1}{j\varpi L}+\frac{Vo}{R_2}+Voj\varpi C=0 \quad where \quad V_1=Vo+Vin$$

$$\frac{Vo+Vin}{R_1}+\frac{Vo+Vin}{j\varpi L}+\frac{Vo}{R_2}+Voj\varpi C=0$$

$$\frac{Vo}{Vin}=-\frac{\frac{1}{R_1}+\frac{1}{j\varpi L}}{\frac{1}{R_1}+\frac{1}{j\varpi L}+\frac{1}{R_2}+j\varpi C}$$

It can be further simplified to the result in voltage divider.

5. (35 pts) Consider the following transfer function of a circuit.

$$H(f) = \frac{V_{out}}{V_{in}} = \frac{a}{1 + jf / f_B} \qquad \text{Let a = 10, } f_B = 1 \text{ kHz.}$$

(a) (5 pts) Write an expression for |H(f)| in dB.

$|H(f)| = 10/\text{sqrt}(1+(f/f_B)^2)$

$20\lg|H(f)| = 20 - 10 \lg(1+(f/f_B)^2)$

(b) (4 pts) Evaluate (approximate) this expression for $f << f_B$. Find |H(f)| and the slope in the region.

|H(f)| = 20loga = 20 Slope: 0dB/decade

(c) (3 pts) Evaluate (approximate) this expression for $f >> f_B$. What is the slope?

$20 - 20\log(f/ f_B)$ Slope: -20dB/decade

(d) (2 pts) Evaluate this expression for $f = f_B$ (What is $\left|H(f_B)\right|_{dB}$ exactly?).

20-10log2

(e) (5 pts) Write an expression for $\angle H(f)$.

$-\arctan(f/f_B)$

(f) (3 pts) Evaluate this expression for $f << f_B$. Find $\angle H(f)$.

0^o

(g) (3 pts) Evaluate this expression for $f >> f_B$. Find $\angle H(f)$.

-90^o

(h) (3 pts) Evaluate this expression for $f = f_B$. Find $\angle H(f_B)$.

- 45^o

(i) (2 pts) What type of filter is this?

Low pass filter

(j) (5 pts) Suppose the input signal is given by:

$v_{in}(t) = 5 + 10\cos(10^3 * 2\pi * t) + 10\cos(10^4 * 2\pi * t - 50°)$

Find an expression for the output $v_{out}(t)$

(Hint: $\frac{1}{\sqrt{1.01}} \approx 0.995$, $\frac{1}{\sqrt{2}} \approx 0.7071$, $\frac{1}{\sqrt{101}} \approx 0.0995$,

$\arctan 0.1 \approx 5.71°$, $\arctan 10 \approx 84.29°$) These may not all be needed.

$5 \rightarrow 50$

$10\cos(10^3*2\pi*t) \rightarrow 100 * 0.7071\cos(10^3*2\pi*t - 45^o)$

$10\cos(10^4*2\pi*t-50^o) \rightarrow 100 * 0.0995\cos(10^4*2\pi*t - 50^o-84.29^o)$

Vout(t) $= 50 + 100 * 0.7071\cos(10^3*2\pi*t - 45^o) + 100 * 0.0995\cos(10^4*2\pi*t - 50^o-84.29^o)$