Name: ______________________________ (please print)

Signature: ____________________________

# ECE 3455
## Exam 2
## November 17, 2007

exam duration: 90 minutes

- You may have one 8 ½ x 11 in. "crib" sheet, written on both sides, during the quiz. You may have any calculator you choose, but no computers. No other notes or materials will be allowed.
- Show all work necessary to complete the problem on these pages. A solution without the work shown will receive no credit.
- Show units in intermediate and final results, and in figures.
- If your work is sloppy or difficult to follow, points will be subtracted.

***This exam has 8 pages, including the cover sheet. Raise your hand if you are missing a page.***

1 _________________/35

2 _________________/35

3 _________________/30

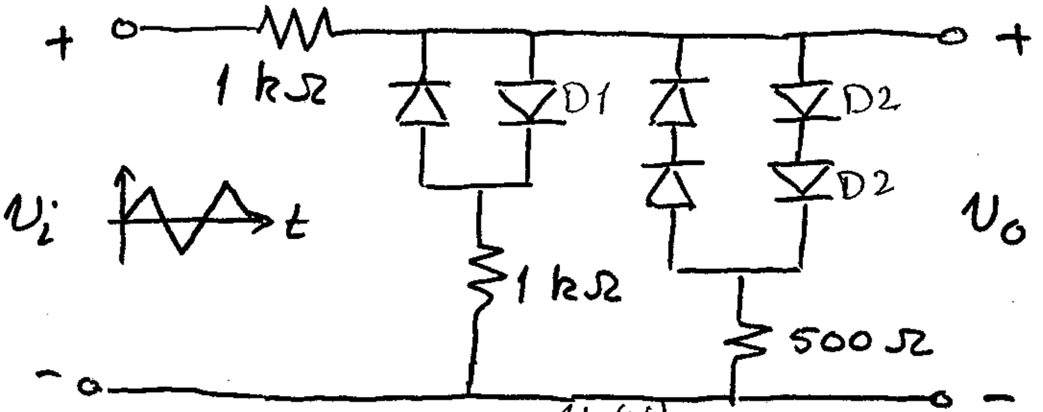
Total _________________/100

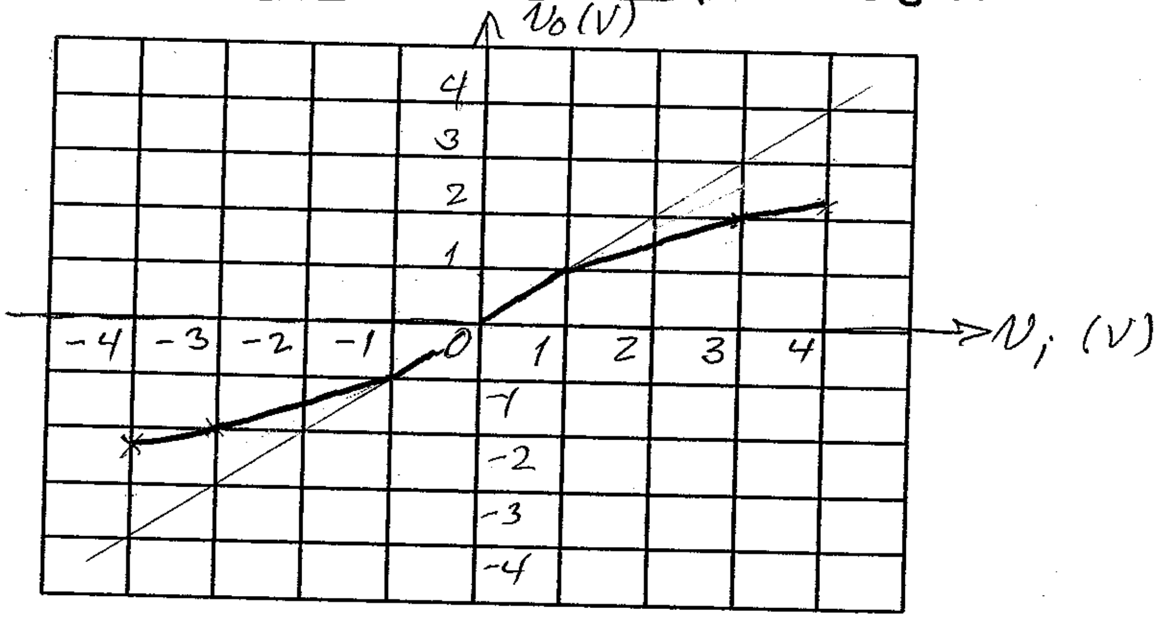
Room for Extra Work

1. **(35 points)** In the circuit below, all the diodes have $V_{th} = 1$ V, $r_D = 0$, and $I_S = 0$. The input voltage $v_i(t)$ is a triangle wave with period T = 2 ms and amplitude 4 V.

+30 a) Using the graph provided below, plot $v_o$ vs. $v_i$ (the transfer characteristic) for the full range of $v_i$.

+5 b) In a sentence or two, state what you think a circuit like this could be used for.





a)

We note first the symmetry of the diodes, which suggests that if we know what happens for $v_i > 0$, we will have the output for $v_i < 0$ as just the negative of that for $v_i > 0$.

Room for Extra Work

We need 1 V to turn on any of the diodes so clearly we have

Plot +2
+3
+3

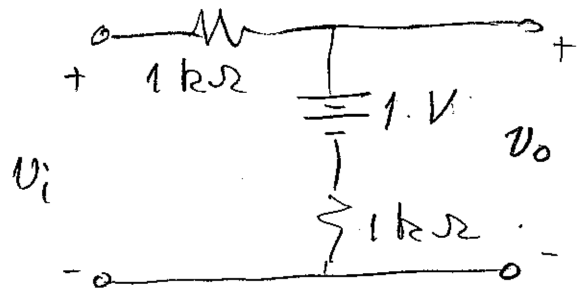
+3
+2

$$0 \leq v_i \leq 1\ \text{V} \Rightarrow v_o = v_i$$

since no diodes will be on.

For $v_i \geq 1$ V, D1 will go on, and we have

+5
+2
+3



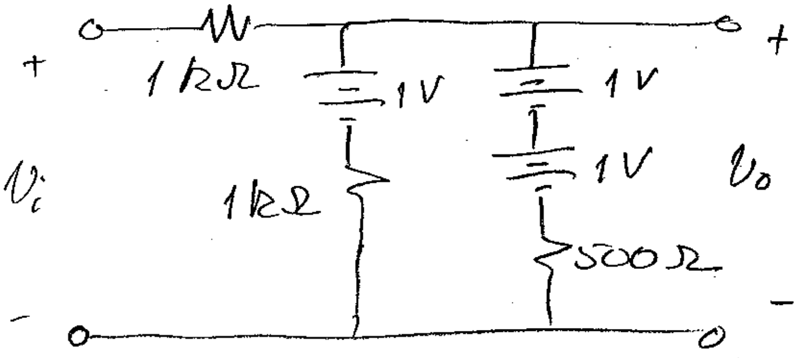
$$v_o = 1.0 + \frac{v_i - 1.0}{2000} \cdot 1000$$

$$v_o = \frac{1}{2} + \frac{1}{2} v_i \quad \text{V}$$

so the slope of $v_o$ vs. $v_i$ is ½ beginning at $v_i = 1$ V.

At some point diodes D2's turn on. Then we have

+9
+3
+3



$$\frac{v_o - v_i}{1000} + \frac{v_o - 1}{1000} + \frac{v_o - 2}{500} = 0$$

$$v_o - v_i + v_o - 1 + 2v_o - 4 = 0$$

$$4v_o = v_i + 5$$

$$\underline{v_o = \frac{1}{4} v_i + 1.25}$$

But where does this region start? The smallest $v_o$ at which this can happen is for $v_o = 2\,V$,

so $$2 = \frac{1}{4} v_i + 1.25$$

$$\Rightarrow \underline{v_i = 3\ V.}$$

At this point the slope of $v_o$ vs. $v_i$ drops to 1/4.
When $v_i = 4\,V$, $v_o = 2.25\ V$.

b) This is an example of a "wave-shaping" circuit. If we input a triangle wave, then over each segment of $v_i$, the input is proportional to time and so our $v_o - v_i$ plot looks qualitatively like $v_o - t$. So we could, with a proper choice of slopes, produce something like a sine wave from a triangle wave.

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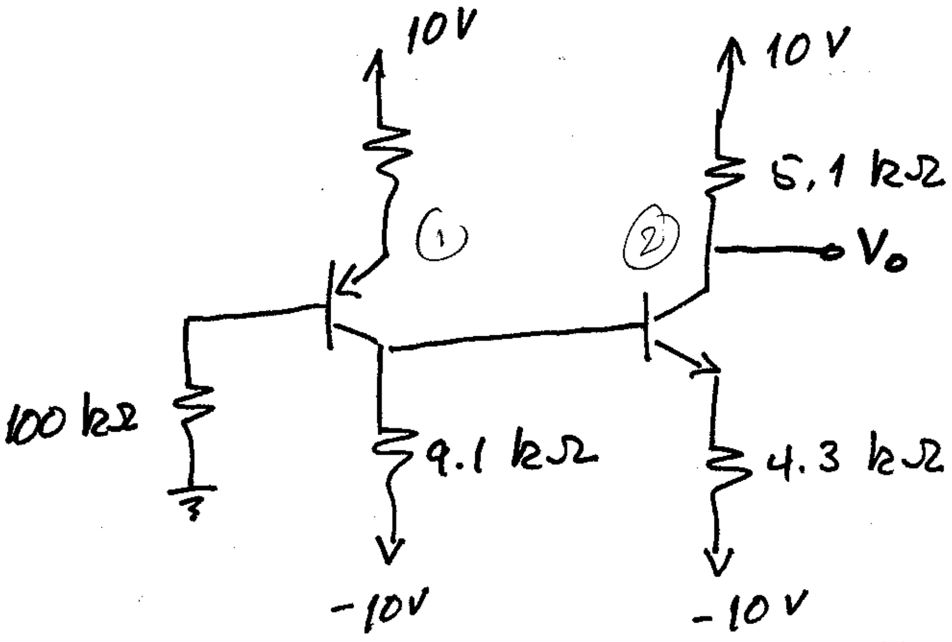
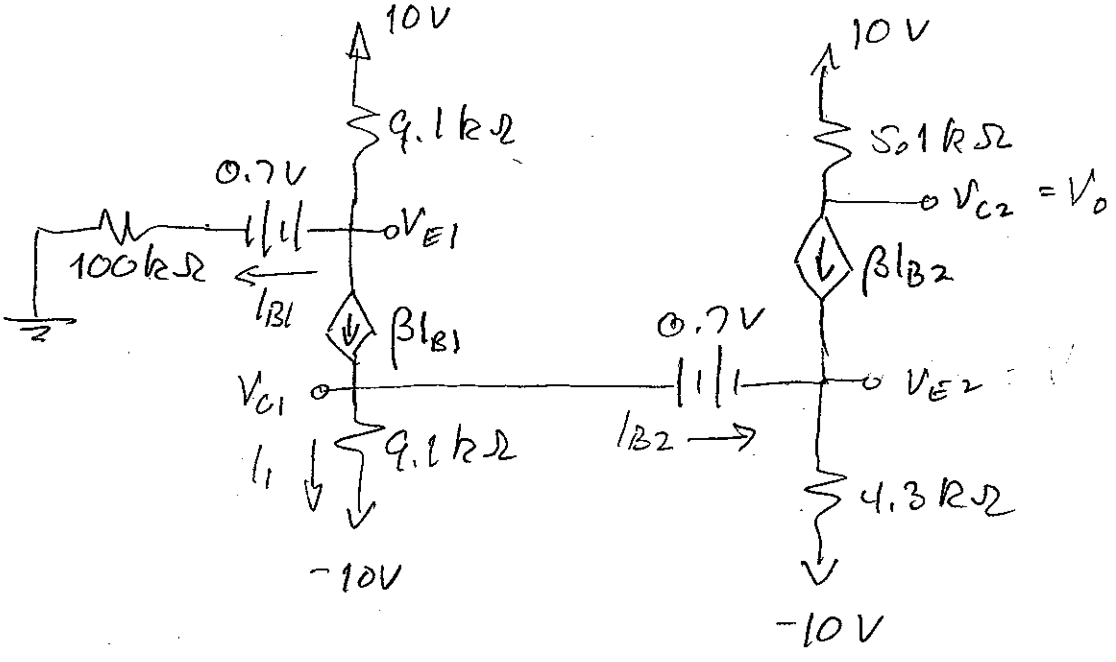
wrong range in $v_i$ -3 ea.
inconsistent plot : -2 ea.
(wrong slopes)

2. **(35 points)** In the circuit below, find the voltage $V_O$. Both BJTs have $\beta = 100$ and $V_{CE,SAT} = 0.3$ V.



The BE junctions of both BJTs look like they will be ON so let's try ACTIVE REGION for both



Model

+10

Room for extra work

KVL

$$-10 + 9100(101) I_{B1} + 0{,}7 + 100000\, I_{B1} = 0$$

(+4) $$I_{B1} = 9.12\ \mu A$$

KVL

$$\cancel{10} - 9100\,\underbrace{(\beta I_{B1} - I_{B2})}_{\simeq\ \beta I_{B1}} + 0{,}7 + 101\, I_{B2} \times 4300 \cancel{-10} = 0$$

(+6)

$$\Rightarrow I_{B2} = \frac{9100\beta I_{B1} - 0{,}7}{101 \times 4300}$$

Analysis +20

$$= 17{,}5\ \mu A$$

$$V_{CE1} = \left[(\beta I_{B1} - I_{B2})9100 - 10\right] - \left[10 - (\beta+1) I_{B1} \times 9100\right]$$

(+5) $$= -1{,}86 - 1{,}62 = -3{,}48\ V \quad \leq -0{,}5\ V$$ ✓

$$V_{CE2} = \left[10 - 5100 \times \beta I_{B2}\right] - \left[(\beta+1) I_{B2} \times 4300 - 10\right]$$

(+5) $$= 1{,}08 - (-2.40) = 3{,}47\ V \geq 0{,}5\ V$$ ✓

So both are ACTIVE (LINEAR) region.

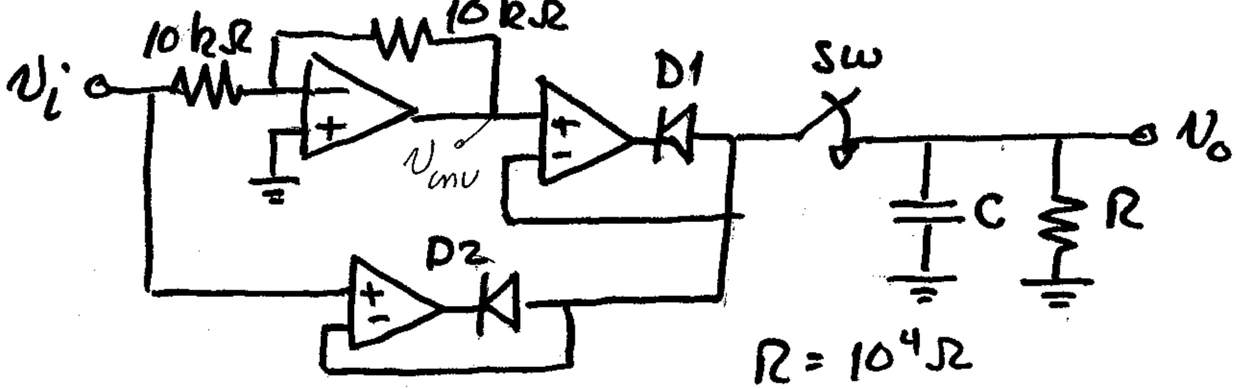
$$\therefore V_o = V_{C2} = 1{,}08\ V$$

Conclusion +5

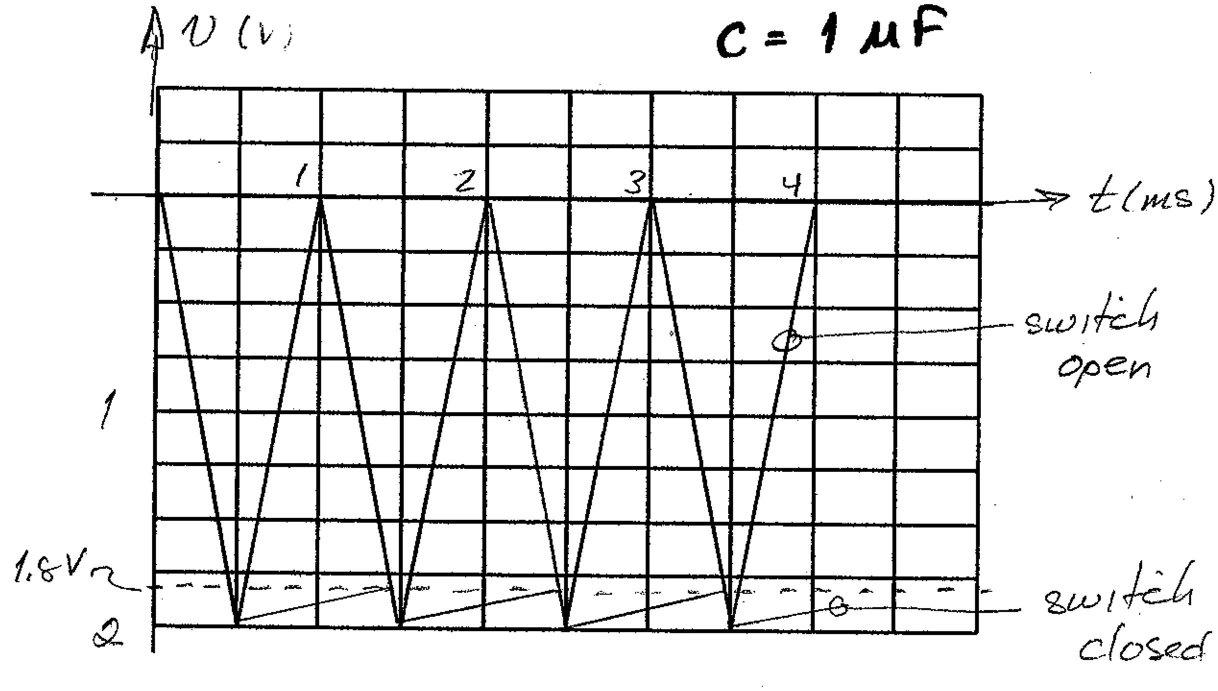
$$\beta I_{B1} - I_{B2} = I_1 = 0{,}894\ mA$$

3. **(30 points)** In the circuit below, the input voltage is a triangle wave with period T = 2 ms and amplitude 2 V. The diodes can be modeled using a constant voltage drop model with $V_{th} = 0.7$ V.

On the graph provided, make a plot of the output $v_O$ as a function of ***time*** with the switch open, and again with the switch closed. Assume steady state in both cases. Do this for two cycles of the input voltage. Put both output voltages on the same plot, and clearly indicate the amplitude of each waveform.



$R = 10^4\,\Omega$
$C = 1\,\mu F$



With the switch open, we look at $v_{open}$.
For $v_i > 0$, $v_{inv}$ will be negative which will turn D2 OFF. However, D1 will go ON ⇒ $v_{open} = -v_i$.
For $v_i < 0$, D2 is ON and D1 is OFF so now $v_{open} = v_i$. But in both 7 cases $v_{open}$ is negative →

Room for extra work

so we have a full-wave rectifier as indicated in the figure.

With the switch closed, $V_{open}$ is the same as $v_o$. The CR network is a power supply configuration and we expect a ripple voltage:

$$V_r = \frac{V_p}{2fCR}$$

$$= \frac{2(2\times10^{-3})}{2(10^{-6})(10^{4})} = 0.2\,V$$

We have indicated an approximately linear response on the figure.

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+20 Analysis / Plot

+ 10 Analysis / Plot