RWinton

**Cover Sheet** **Quiz #1b** **Ideal opamps, *pn* junctions and diode circuits**

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$$A_{non-invert} = \frac{1}{\beta} = \frac{R_2 + R_1}{R_1} \qquad A_{Invert} = -\frac{R_2}{R_1} = -\alpha$$

Instrumentation amplifier $A_{IA} = \alpha \times \left(1 + \frac{2R_4}{R_3}\right)$

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**Ideal diode equation:** $I = I_S\left[e^{V/nV_T} - 1\right]$

**Time averages of rectified sinusoidal waveforms (diode rectification)**

$$\langle V(HWR)\rangle = \frac{1}{\pi}Vp \qquad \langle V(FWR)\rangle = \frac{2}{\pi}Vp \qquad \langle V(3\phi R)\rangle = \frac{3}{\pi}Vp$$

**AC-DC converters:**

$V_{DC} = V_P - 0.5V_R$

half-wave $V_{ripple}$: $V_R = \frac{V_P}{fR_LC} = \frac{I_L}{fC}$

full-wave $V_{ripple}$: $V_R = \frac{V_P}{2fR_LC} = \frac{I_L}{2fC}$

three-phase $I_{ripple}$: $I_R = 0.134I_P$

or $V_{Ripple} = \frac{V_P}{6fR_LC}$ (with capacitance regulation)

**Level shifter** $\Delta V = \frac{\alpha - 1}{\alpha + 1} \times (V_P - V_D)$ where $\alpha = \frac{|V_1| - V_D}{|V_2| - V_D}$ and for which $2V_P = |V_1| + |V_2|$

If input = square wave then $\alpha = \frac{R_1}{R_2}$, if triangle wave then $\alpha = \left(\frac{R_1}{R_2}\right)^{1/2}$, if sine wave then $\alpha = \left(\frac{R_1}{R_2}\right)^{2/3}$,

**Charge pump/voltage multiplier:** $V_{out} = N \times V_C$ $\qquad V_C = 2(V_P - V_D)$

$w$(capacitance) $= \frac{1}{2}CV^2$ $\qquad T = \frac{C_Q}{C_P} \times \frac{N^2}{2f}$ $\qquad I_Q(\max) = 2fC_PV_C$

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**ECE3424** **Quiz #1: Opamps, pn junctions, and diode circuits** **6 Feb 2012**

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**Instrux:** Show work in space provided Be neat, concise, encircle answers Else –10 pts

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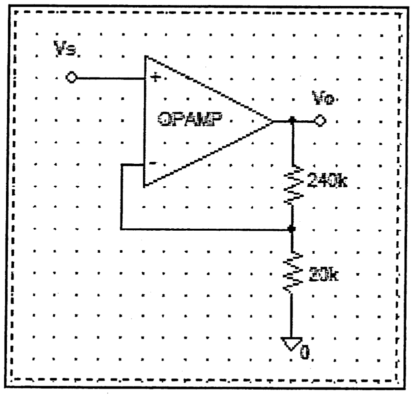
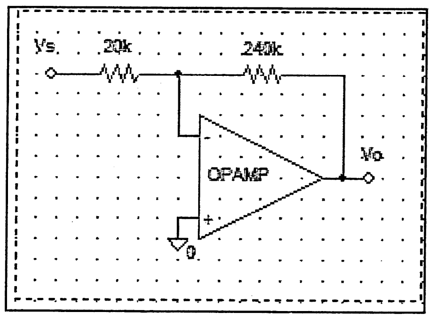
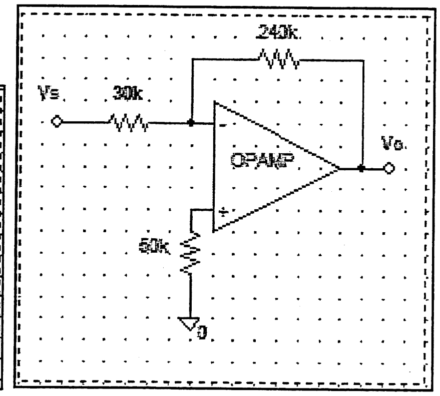
If you encounter a question for which you don't know how to resolve an answer, don't sit there and flounder. Go to the next question. There are excess pts.

**OA-1** (20 pts) Assume ideal opamps and find information as indicated (by inspection, if possible).




vo/vs = + 13 V/V

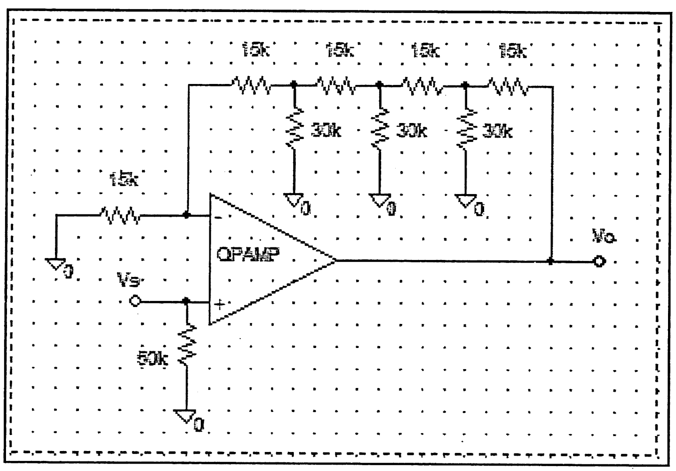
$R_{in}$ = ∞

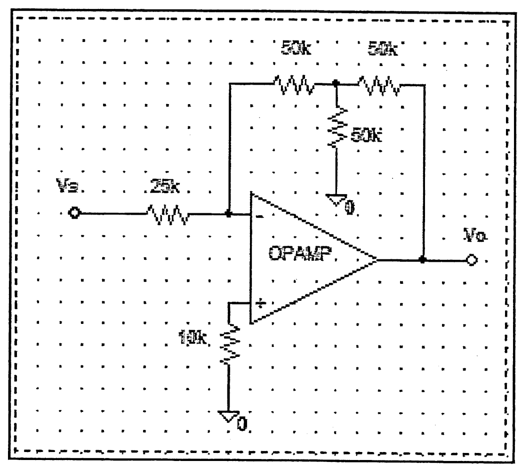
vo/vs = − 12 V/V

$R_{in}$ = 20 kΩ

vo/vs = − 8 V/V

$R_{in}$ = 30 kΩ




vo/vs = + 16 V/V

$R_{in}$ = 50 kΩ

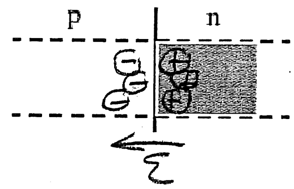
vo/vs = − 6 V/V

$R_{in}$ = 25 kΩ

**D-1.** (6 pts)

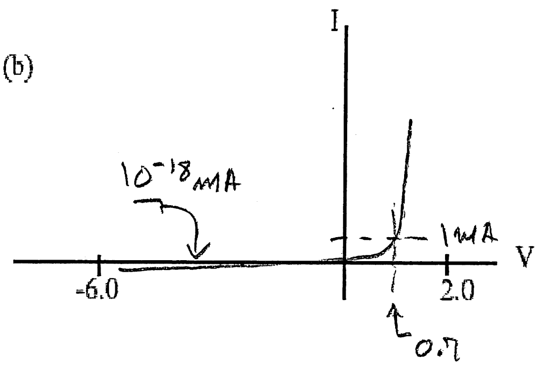
Indicate on the *pn* junction figure (1) the polarity of charges (+, -) that are uncovered by the diffusion in the vicinity of the junction and (2) the direction (arrow) of the built-in E-field. Assume $V_{bias} = 0$.

(a)



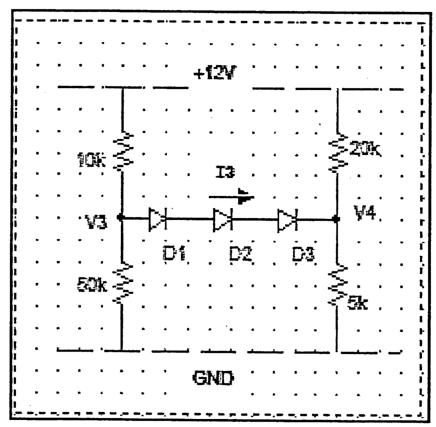

**D-2.** (6 pts)

(b)




Sketch a representative plot of $I$ vs $V$ characteristics for the *pn* junction for bias over the range –6.0V to +2.0V and identify typical magnitudes of current levels $I$ at forward and reverse biases.

**D-3.** (9 pts) For the diode circuit shown find the values of voltages $V_3$, $V_4$ and current $I_3$, using the constant voltage drop (CVD) model of the diode.




*Hint:* Apply nodal analysis at nodes $V_3$ and $V_4$.

($V_3$) $\quad V_3(0.1 + .02) - 0.1 \times 12 + I_D = 0$ $\quad$ ($V_3 \rightarrow V_4 + 2.1$)

$V_4(.05 + 0.2) - .05 \times 12 - I_D = 0$

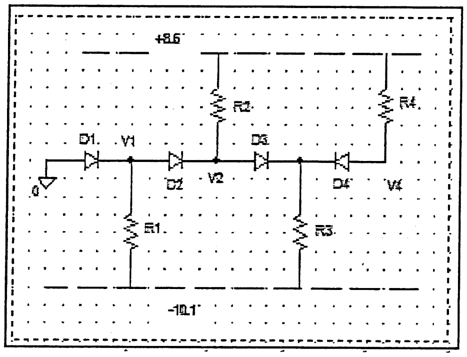
$V_4(0.12 + 0.25) + 2.1 \times 0.12 - 1.8 + 0 = 0$ $\quad$ ($2.1 \times 0.12 = 0.252$)

$$\therefore V_4 = \frac{1.8 - 0.252}{0.37} \cong \boxed{4.18\ V}$$

$$V_3 \doteq V_4 + 2.1 \simeq \boxed{6.28\ V}$$

$$I_D = I_3 = V_4 \times (0.25) - 0.6 = \boxed{0.446\ mA} \quad (V_4 = 4.18)$$

**D-4** (12 pts) Identify all possible active operating states for the diode circuit string as shown by their 'state tables'. Use "1" to indicate that a diode is conducting and "0" to indicate that a diode is non-conducting




| D1 | D2 | D3 | D4 |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 |
| ~~1~~ | | ~~1~~ | ~~1~~ |
| ~~1~~ | | ~~1~~ | ~~1~~ |
| ~~1~~ | ~~1~~ | ~~1~~ | ~~1~~ |
| | | | |
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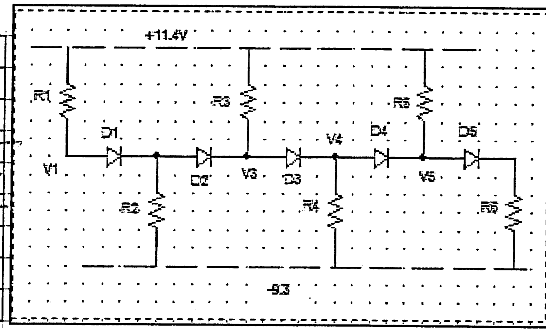
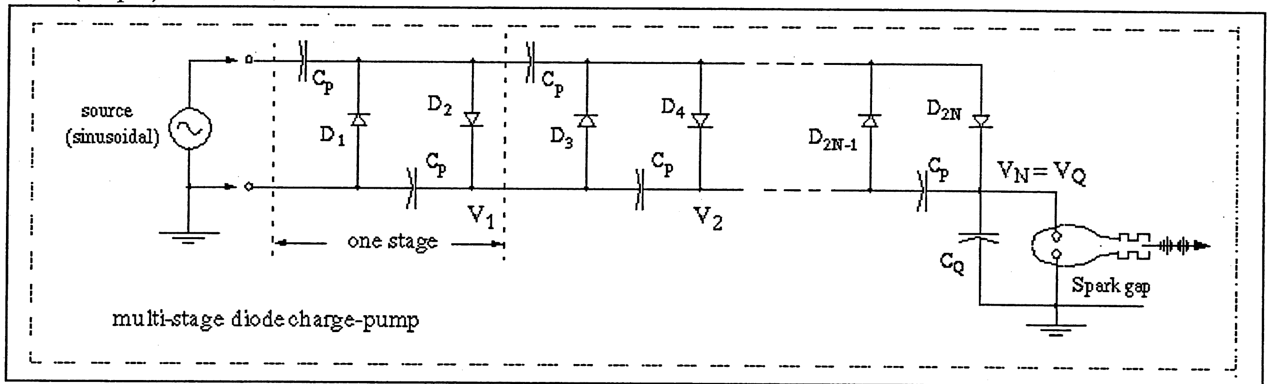



| D1 | D2 | D3 | D4 | D5 |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 | 1 |
| ~~1~~ | | ~~1~~ | | ~~1~~ |
| ~~1~~ | | ~~1~~ | | ~~1~~ |
| | | | | |
| | | | | |

**D-5.** (16 pts)




The circuit shown is to be used to ignite the plasma chamber for plasma pulse weapons located around the perimeter of a high-security residence. The charge pump capacitances $C_p$ are all of value 250pF except for the storage capacitance $C_Q$, which is of value 0.1uF. The electrodes are 0.4mm apart and the breakdown field is 10,000V/cm. There are 100 stages. Find

(If you can determine any of the answers by inspection that would be OK.)

(a) What amplitude input signal is required to ignite the plasma, assuming CVD model for the diodes?

$V_Q = 10000 \times .04 = 400V = N \times V_C \rightarrow = 2(V_s - V_D)$ (100; 0.7)

$V_s =$ 2.7 V

(b) How much energy (Joules) is released in each plasma pulse?

$w_Q =$ energy = 8 mJ

$w_Q = \frac{1}{2} \times 0.1\mu F \times (400)^2 = \frac{1}{2}(0.1) \times 160{,}000\ \mu J$

(c) At what frequency does the signal generator need to operate in order to charge the plasma spark capacitance ($C_Q$) at a rate (frequency) of 50Hz? Assume each stage requires one cycle to recharge.

$T = \frac{1}{f_Q} = \frac{C_Q}{C_p} \times \frac{N^2}{2f}$ ∴ $f = \frac{C_Q}{C_p} \times \frac{N^2}{2} \times f_Q$ (0.1μF / 0.25nF; $100^2$; 50)

$400 \times 5000 \times 50$

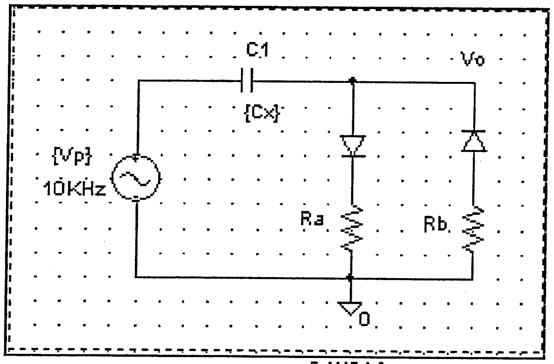
$f =$ freq = 100 MHz

(d) Using the freq determined by part (c) what is the maximum current that flows forward courtesy of the charge pump action?

$I_Q = 2f \times C_p V_c = 2 \times 100MHz \times 0.25nF \times (2 \times (2.7 - 0.7))$ $I_Q =$ 200 mA

$= 2 \times 100M \times 0.25 \times 4$

**D-6** (8 pts) Level shifter



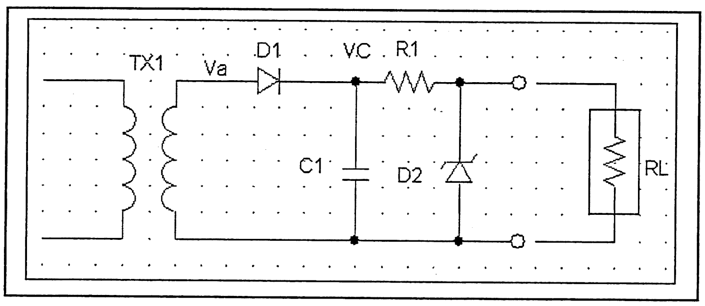

The circuit shown to the left is a level-shifter for which the input is sinusoidal $= V_p \sin(\omega t)$ where $V_p = 6.0V$. For the resistance $Ra = 300k\Omega$ and $Rb = 100k\Omega$, by how much $\Delta V$ is the shift in level at equilibrium, assuming the formula on the cover sheet? Assume $V_{diode} = V_D = 0.5V$.

$$\alpha_{12} = \left(\frac{300}{100}\right)^{2/3} = 2.08$$

$\Delta V =$ 1.93 V

$$\Delta V = (6.0 - 0.5) \times \left(\frac{2.08 - 1}{2.08 + 1}\right) = 5.5 \times 0.35 \cong +1.93\ V$$

**D-7** (15 pts) For the HWR (half-wave rectifier) `knob' shown, for which we desire to choose component values that will support a regulated 0.4W, 4.0V application from a 120V 60Hz source. A zener diode with Vz = 4.0V in emplaced in the circuit as shown Assume that transformer turns ratio $n$ is chosen so that the peak voltage $V_P$ across the capacitance is 10V.




(a) If $V_C(min) = 8V$ with the load connected, what value of $R_1$ and of $C_1$ is required assuming that the current through the zener diode approaches zero when $V_C$ approaches $V_C(min)$.
(Note that Vripple $V_R = V_P - V_C(min)$ ).

(b) What average power must the zener diode dissipate when the load is not connected?

a) $\left.\begin{array}{l} V_C(MAX) = 10V \\ V_C(MIN) = 8V \end{array}\right\} V_R = 2.0V = V_P/(fRC) \qquad V_P = V_C(MAX) = 10V$

$$I_L = P_L/V_Z = 0.4W/4V = 0.1A, \quad R_L = 4V/0.1 = 40\Omega$$

$$\therefore R_1 = (V_C(MIN) - V_Z)/I_L = (8-4)/0.1 = 40\Omega$$

$$C = V_P/(V_R \times f \times (R_1 + R_L)) = 10/9600 = 1042\ \mu F$$

(10, 2, 60, 40+40)

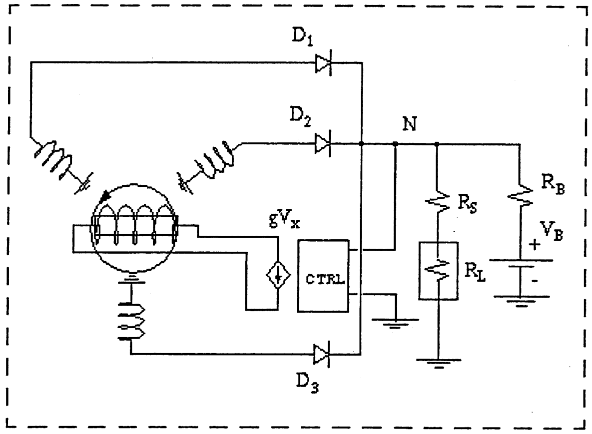
b) $I_Z(MIN) = I_L = 0.1A = 100mA$

$$I_Z(MAX) = I_1(MAX) = \frac{V_C(MAX) - V_Z}{R_1} = \frac{10-4}{40} = 150mA$$

$$\therefore P_Z = \frac{1}{2}(100mA + 150mA) \times V_Z = 500mW$$

(4)

**A-1** (10pts) The alternator of an automobile can be represented by the circuit shown. The alternator consists of three coils, energized sequentially at phase angles that are 120° with respect to each other by the rotating electromagnet. The three phases are rectified by diodes D1, D2, and D3. The charging voltage applied to the battery is sampled by a control circuit which adjusts the strength of the electromagnet rotor by means of a dependent source.




The resistance $R_B$ = battery resistance = 0.15Ω

(a) For $V_B$ = 12V determine $V_N$ (max) at charging current 50 A and the percentage ripple in $V_N$ that results.

(b) What drop-down resistance $R_S$ is required for an application (shown as $R_L$) that uses 0.45W of power at 9.0V, and what voltage ripple $V_R$ would occur across the application?

a) $V_N = 12 + 50 \times 0.15 = 19.5$

$V_P = \pi/3 \times 19.5 = \boxed{20.4V}$ $\quad \Delta V = V_R = 0.134 \times V_P = 2.74V$

Ripple $= V_R/V_P = \boxed{13.4\%}$

b) $V_N(MIN) = 20.4 - 2.74 = 17.66V$ $\quad I_L = 0.45W/9 = .05A$

$\therefore R_S = (17.66 - 9.0)/.05 \cong \boxed{173\ \Omega}$

$V_R = 0.134 \times 9.0 = \boxed{1.21V}$

**A-2.** (4pts) For the three-phase rectified output (cover sheet) the ripple $V_R/V_P = 0.134$ without capacitance and $V_R/V_P = 1/(6fR_LC)$ with (large) capacitance across the load $R_L$.

Why is there a 6 in the denominator? ____________________

**E-1 (only if you have time):** Bonus questions

(2 pts) What day of the week is today's date one year from today? Thu

(3 pts) How many complete ceiling tiles are in the ECE3424 lab? 298

(2 pts) How many vertices does a regular convex icosahedron have? 12

(2 pts) How many edges does a regular convex icosahedron have? 30

12+20 -2