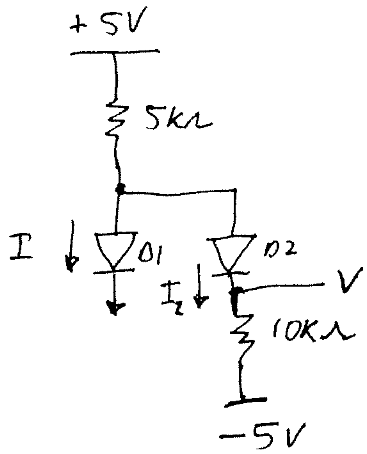
ECEN HW #4 Solutions – SAM PALERMO

1. a.



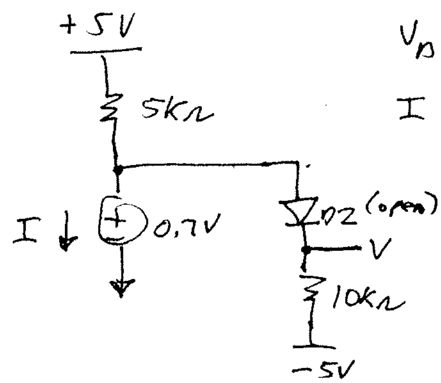
Case 00 ⇒ D1 & D2 "OFF"

$V_{D1} = 5V$, $V_{D2} = 10V$

$I = 0A$ $\quad I_2 = 0A$

⇒ Both Not consistent w/ diode model

Case 01 ⇒ D1 "ON" & D2 "OFF"



$V_{D1} = 0.7V$

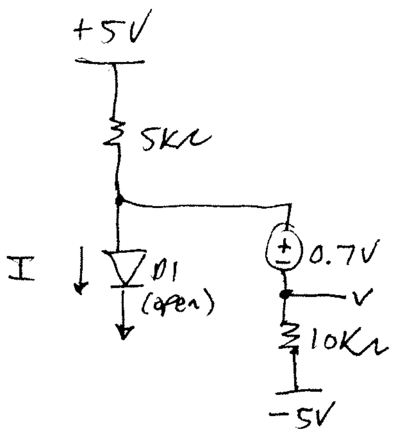
$I = \frac{5-0.7}{5k\Omega} = 0.86mA$

$V_{D2} = 5.7V$

$I_2 = 0$

D2 not consistent w/ diode model

Case 10 ⇒ D1 "OFF" & D2 "ON"



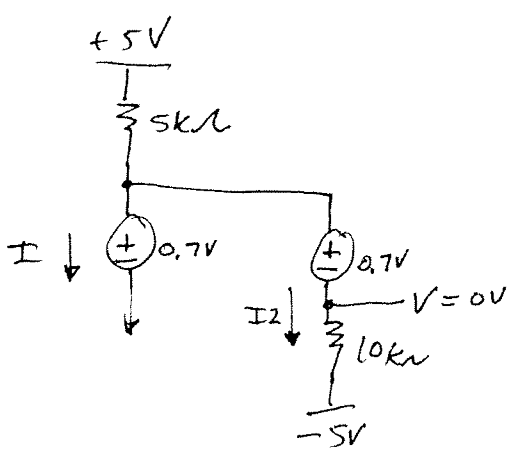
$$\frac{V+0.7-5}{5K} + \frac{V+5}{10K} = 0 \implies V = 1.2V$$

$V_{D1} = 1.9V$ $\quad V_{D2} = 0.7V$

$I = 0A$ $\quad I = 0.62\,mA$

D1 not consistent w/ diode model

Case 11 ⇒ D1 & D2 "ON"



$$I = 0.36mA$$
$$V = 0V$$

$V_{D1} = V_{D2} = 0.7V$

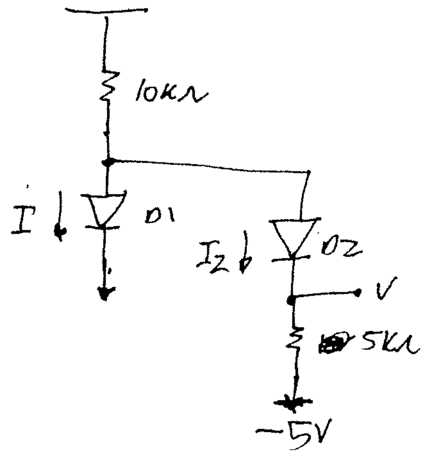
$$\frac{0.7-5}{5K} + I + \frac{0+5}{10K} = 0$$

$I = 0.36mA$

$I_2 = 0.5mA$

⇒ Both consistent w/ diode model (Done)

1.b.



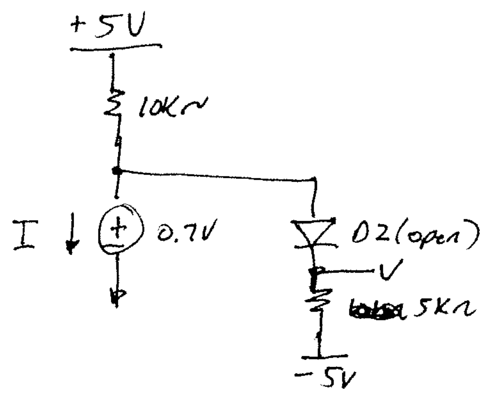
Case 00 ⇒ D1 & D2 "OFF"

$V_{D1} = 5V$, $V_{D2} = 10V$

$I = 0A$ $\quad I_2 = 0A$

⇒ Both not consistent w/diode model

Case 01 ⇒ D1 "ON" & D2 "OFF"



$V_{D1} = 0.7V$

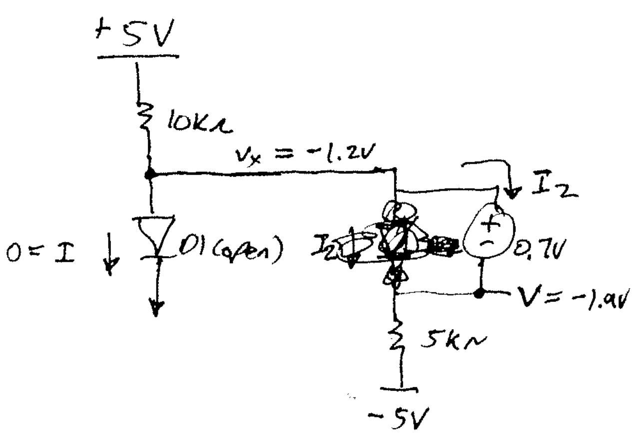
$I = \frac{5-0.7}{10k} = 0.43mA$

$V_{D2} = 5.7V$

$I_2 = 0$

D2 not consistent w/ diode model

Case 10 ⇒ D1 "OFF" & D2 "ON"



$$\frac{V+0.7-5}{10k} + \frac{V+5}{5K} = 0 \Rightarrow V = -1.9V$$

$$I_2 = \frac{5+1.2}{10k} = 0.62mA$$

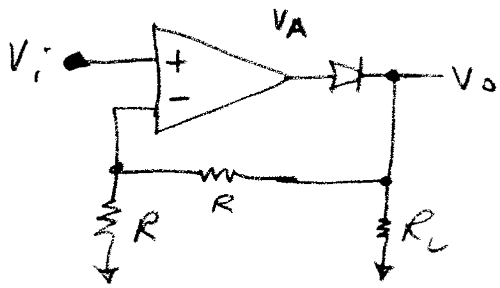
$V_{D1} = -1.2V$ $\quad V_{D2} = 0.7V$

$I = 0$ $\quad I_2 = 0.62mA$ ⇒ Both consistent w/diode model (Done)

No need to compute Case 11

$$I = 0mA$$
$$V = -1.9V$$

2.



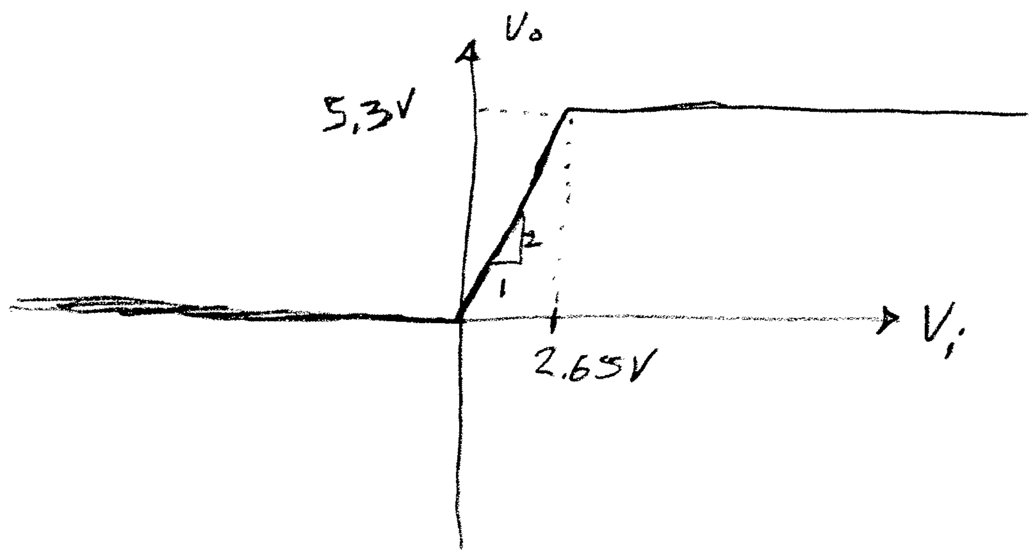
w/o diode

$$V_o = \left(1 + \frac{R}{R}\right)V_i = 2V_i$$

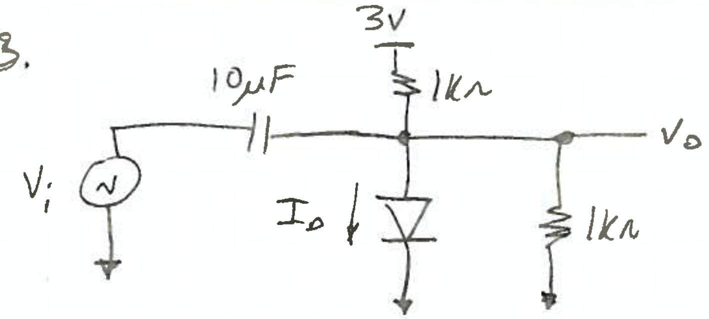
* If $V_i < 0V$, normal non-inverting amp would force a negative V_o, which implies current flowing into the opamp. However, the diode blocks this current and the opamp is in "open-loop" with V_A saturating at $-6V$ and $V_o = 0V$.

* If $V_i > 0V$, if the diode is "off" then the "open-loop" opamp will saturate $\Rightarrow V_A = 6V$. However, this voltage allows the diode to be forward-biased up until $V_o = 5.3V$, which corresponds to $V_i = \frac{5.3V}{2}$.

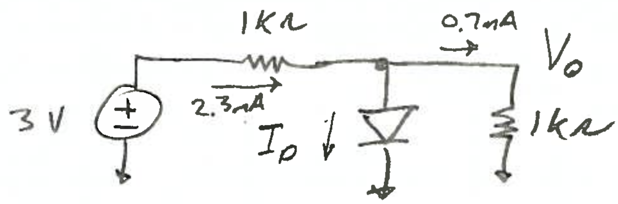
Thus, from $0 \leq V_o \leq 2.65V$ the circuit operate with a linear gain of 2 V/V. For $V_i \geq 2.65V$, V_o saturates at 5.3V.



3.



a. "DC" schematic

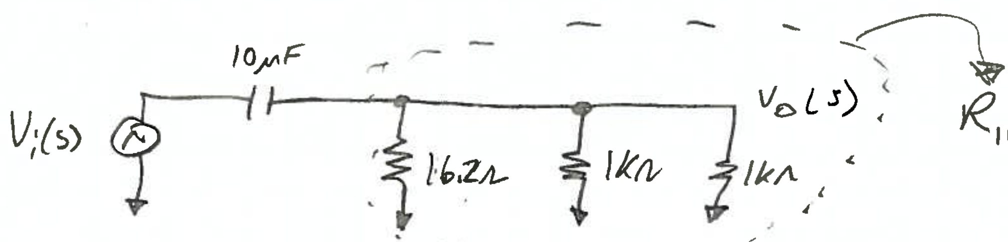


$V_o = 0.7V$

$I_D = 1.6mA$

b. Diode $r_d = \frac{n V_{th}}{I_D} = \frac{25.9mV}{1.6mA} = 16.2\Omega$

"AC" schematic



$R_{||} = 15.7\Omega$

$$\frac{V_o(s)}{V_i(s)} = \frac{R_{||}}{\frac{1}{sC} + R_{||}} = \frac{s}{s + \frac{1}{R_{||}C}} = \frac{s}{s + 6.37\times10^3}$$

$$\frac{V_o(s)}{V_i(s)} = \frac{s}{s + 6.37\times10^3}$$

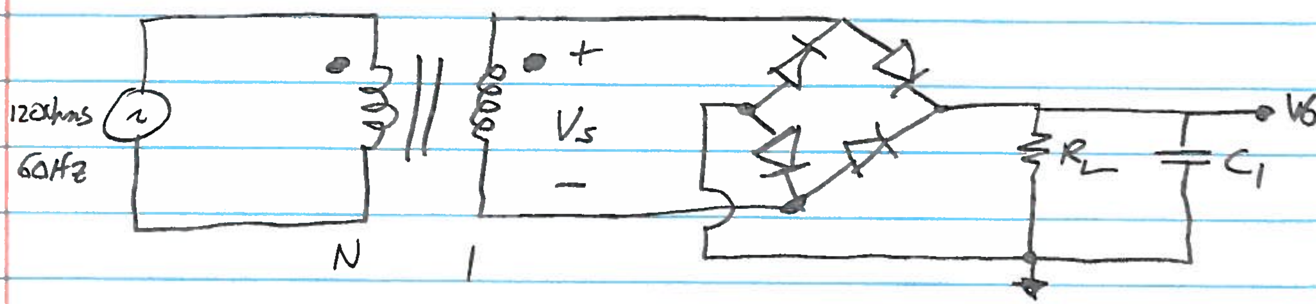
c. At $\omega = 2\pi 10^5$

$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{j\,2\pi10^5}{j\,2\pi10^5 + 6.37\times10^3} \Rightarrow \left|\frac{V_o(j2\pi10^5)}{V_i(j2\pi10^5)}\right| = 0.999 \simeq 1$$

$$\measuredangle \frac{V_o(j2\pi10^5)}{V_i(j2\pi10^5)} = 0.581^\circ \simeq 0^\circ$$

Thus, $V_{O,total} \cong 0.7V + 0.001 \sin(2\pi10^5 t)$

4. To minimize capacitance w/ a single-ended transformer use a Bridge Rectifier.



To get output voltage = 5 V

$$V_{o,peak} = V_{s,peak} - 1.4V = 5V$$
$$V_{s,peak} = 6.4V$$

Requires transformer ratio

$$\frac{120\sqrt{2}}{N} = \frac{6.4}{1} \Rightarrow N = 26.5$$

Load Current Range requires R_L

$$R_L = \frac{V_{max}}{I_{max}} = \frac{5V}{500mA} = 10\Omega$$

$$V_R = 5\% \text{ of } 5V = 0.25V$$

$$C_1 = \frac{V_{s,peak} - 2V_{D,ON}}{2 R_L f_{in} V_R} = \frac{6.4V - 1.4V}{2(10\Omega)(60Hz)(0.25V)}$$

$$C_1 = 16.7mF$$

Diode Maximum Reverse Voltage $= V_p - V_{D,ON} = 6.4V - 0.7V$
$= 5.7V$

Diode Peak Current

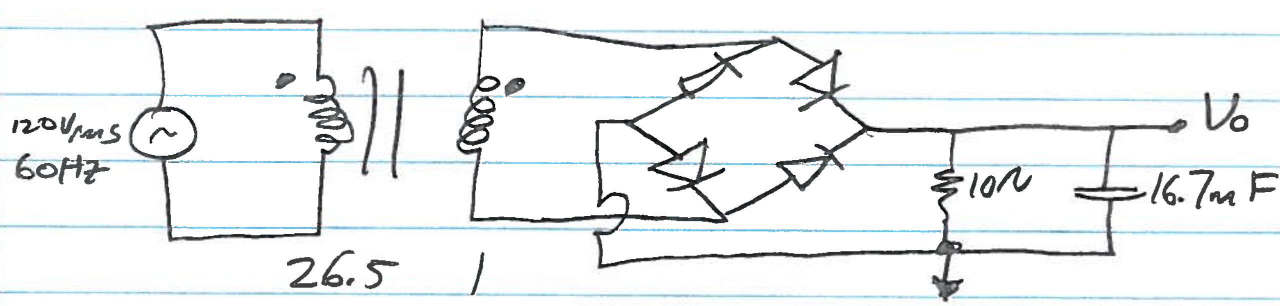
$$I_p = \frac{V_p}{R_L}\left(R_L C_1 \omega_{in} \sqrt{\frac{2V_R}{V_p}} + 1\right)$$

Here it is more accurate to use $V_p = 5V$

$$I_p = \frac{5V}{10\Omega}\left((10\Omega)(16.7mF)(2\pi \cdot 60Hz)\sqrt{\frac{2(0.25V)}{5V}} + 1\right)$$

$I_p = 10.5A$, but will also accept $I_p = 11.9A$ if you use $V_p = 6.4V$

Summary



|Diode Breakdown Voltage| > 5.7V

$I_p = 10.5A$ (or 11.9A)