

ECE 320 - Final pt 1: Name _____

Semiconductors and Diodes. October 26, 2018

Semiconductors

- 1a) What is meant by a p-type semiconductor?

$$\# \text{ holes} \gg \# \text{ electrons}$$

- 1b) For metals, the resistance increases as temperature increases. For semiconductors, the resistance decreases as temperature increases. Why?

- as T goes up, the number of thermal electrons (+ holes) goes up
- more e^- and holes means more current (less R)

- 1c) Why can current flow p to n in a pn junction but not n to p?

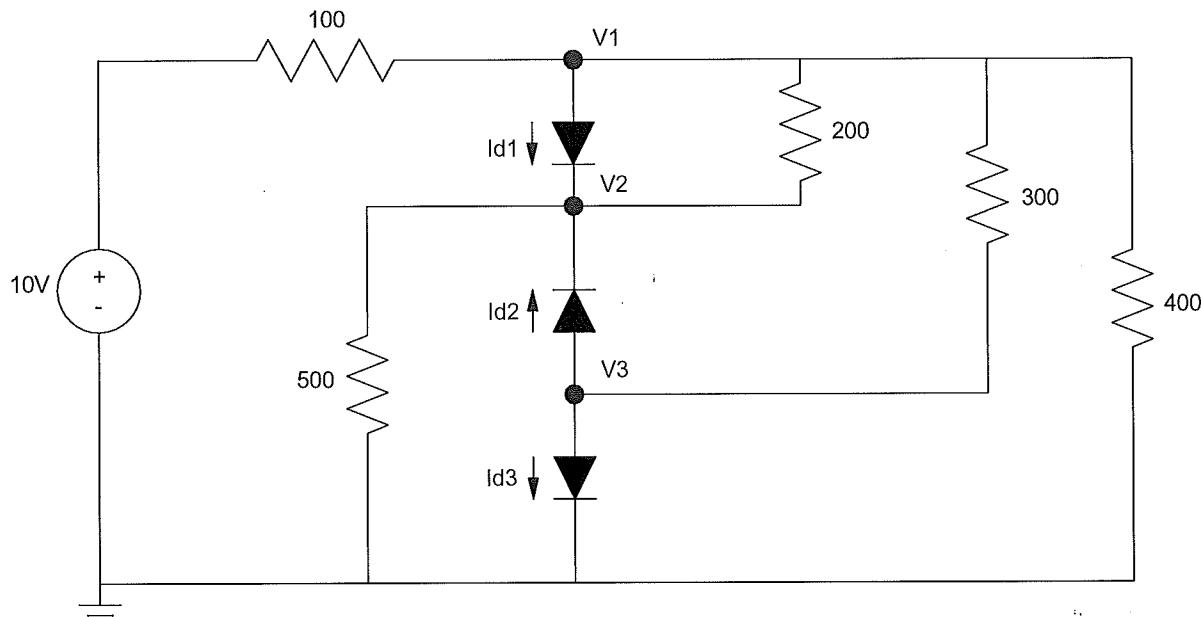
- P to n uses majority carriers (low R)
n to p uses minority carriers (high R)
- P to n reduces the depletion zone to zero (conduct)
n to p increases the depletion zone
- You need $> 0.7V$ to overcome the potential energy barrier

Diodes: Nonlinear Model

2) Assume the VI characteristics for a diode are

$$V_d = 0.052 \ln\left(\frac{I_d}{10^{-8}} + 1\right) \quad I_d = 10^{-8} \left(\exp\left(\frac{V_d}{0.052}\right) - 1 \right)$$

Write 6 equations for 6 unknowns ($V_1, V_2, V_3, Id_1, Id_2, Id_3$)



$$Id_1 = 10^{-8} \left(\exp\left(\frac{V_1 - V_2}{0.052}\right) - 1 \right)$$

$$Id_2 = 10^{-8} \left(\exp\left(\frac{V_3 - V_2}{0.052}\right) - 1 \right)$$

$$Id_3 = 10^{-8} \left(\exp\left(\frac{V_3 - V_1}{0.052}\right) - 1 \right)$$

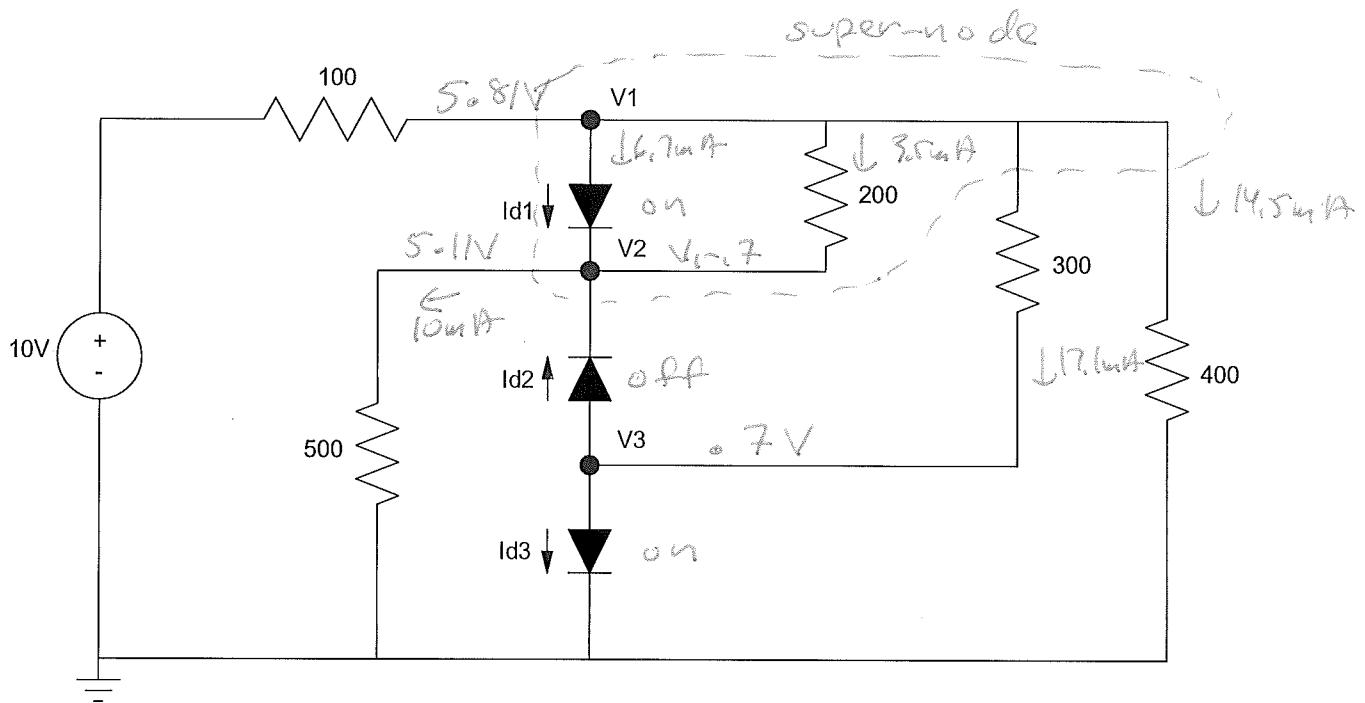
$$\frac{V_1 - 10}{100} + Id_1 + \frac{V_1 - V_2}{200} + \frac{V_1 - V_3}{300} + \frac{V_1}{400} = 0$$

$$-Id_1 - Id_2 + \frac{V_2 - V_1}{500} + \frac{V_2 - V_3}{200} = 0$$

$$Id_2 + Id_3 + \frac{V_3 - V_1}{300} = 0$$

3) Assume ideal silicon diodes ($V_f = 0.7V$). Determine the currents for the following diode circuit

V1	V2	V3	Id1	Id2	Id3
5.8168	5.1168	.7	6.7 mA	0	17.6 mA



$$\frac{V_1 - 10}{100} + \frac{V_1 - .7}{500} + \frac{V_1 - .7}{300} + \frac{V_1}{400} = 0$$

$$\left(\frac{1}{100} + \frac{1}{500} + \frac{1}{300} + \frac{1}{400} \right) V_1 = \frac{10}{100} + \frac{.7}{500} + \frac{.7}{300}$$

$$V_1 = 5.8168$$

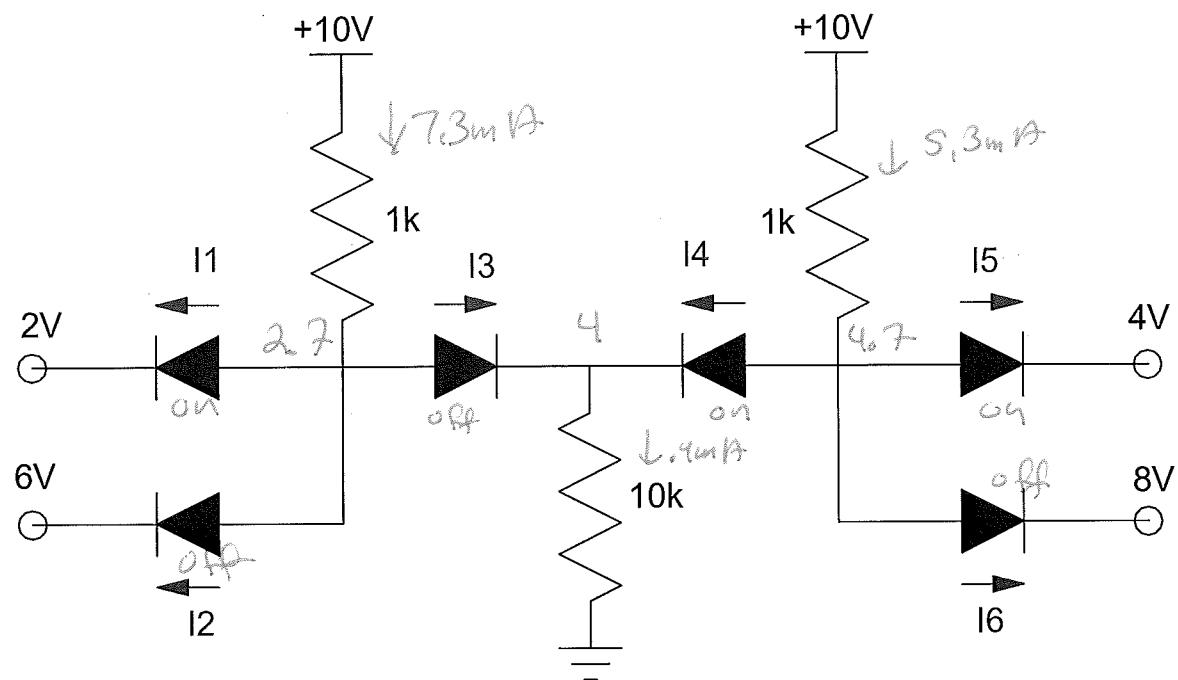
$$V_2 = V_1 - .7 = 5.1168$$

$$V_3 = .7$$

- 4) Determine the currents through the following min/max circuit. Assume ideal silicon diodes.

I1	I2	I3	I4	I5	I6
7.3mA	0	0	-4mA	4.9mA	0

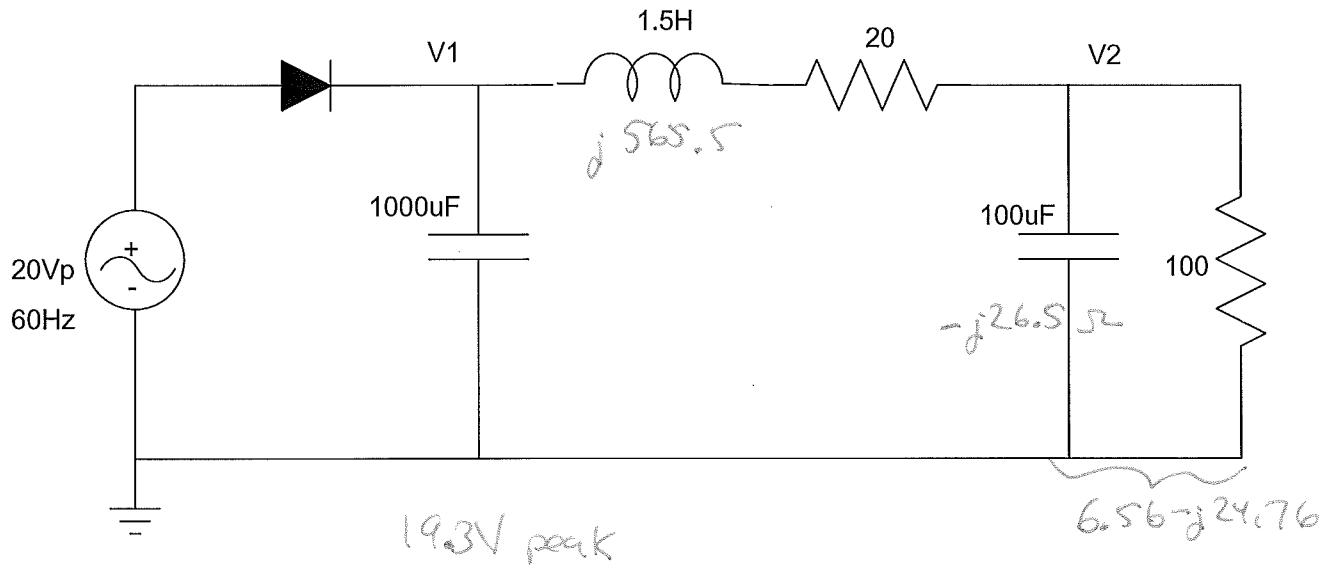
add up to 5.3



- 5) For the following AC to DC converter, determine the AC and DC voltages at V1 and V2

V1		V2	
DC (mean(V1))	AC (V1pp)	DC (mean(V2))	AC (V2pp)
17.96V	2.68V _{pp}	14.97	127V _{pp}

$$19.3 - \frac{1}{2}V_{pp}$$



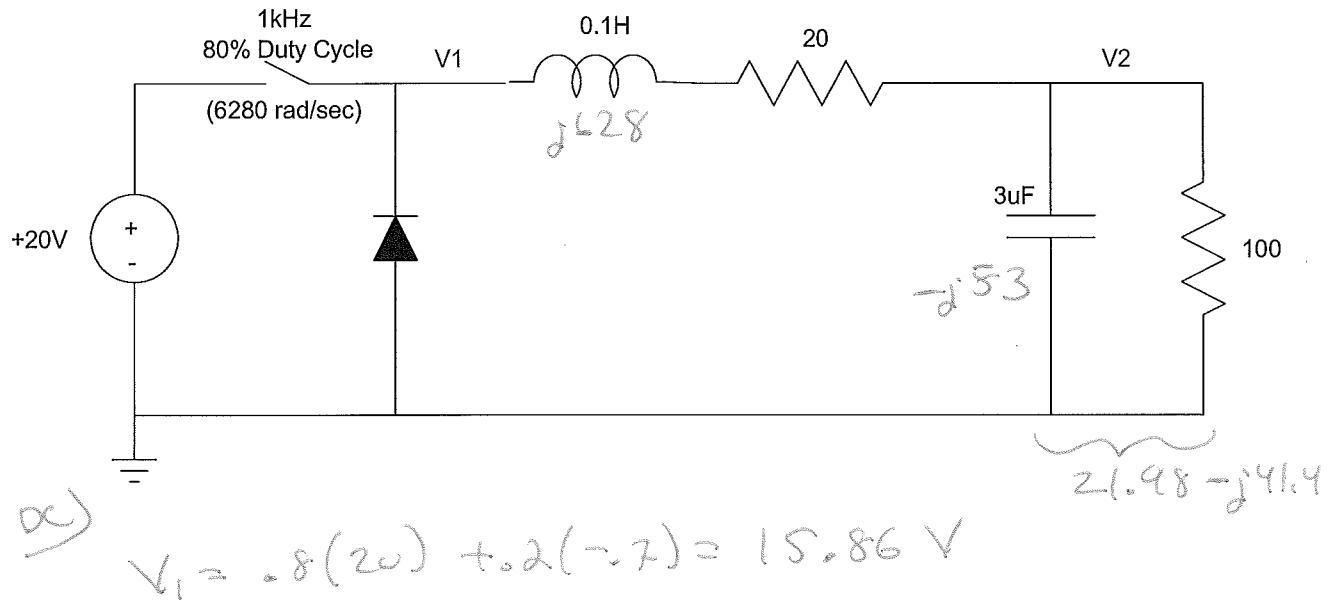
$$I \approx \frac{19.3}{120\Omega} = 160\text{mA} = C \frac{dV}{dt}$$

$$dV \approx 2.68\text{V}_{pp}$$

$$V_2 = \left(\frac{6.56 - j24.76}{(6.56 - j24.76) + (20 + j565)} \right) 2.68\text{V}_{pp}$$

- 6) For the following DC to DC converter, determine the AC and DC voltages at V1 and V2

V1		V2	
DC (mean(V1))	AC (V1pp)	DC (mean(V2))	AC (V2pp)
15.86	20.7V _{pp}	13.21	1.65V _{pp}



$$V_2 = \frac{21.98 - j41.4}{(21.98 - j41.4) + (20 + j628)} \cdot 20.7 \text{ V}_{pp}$$

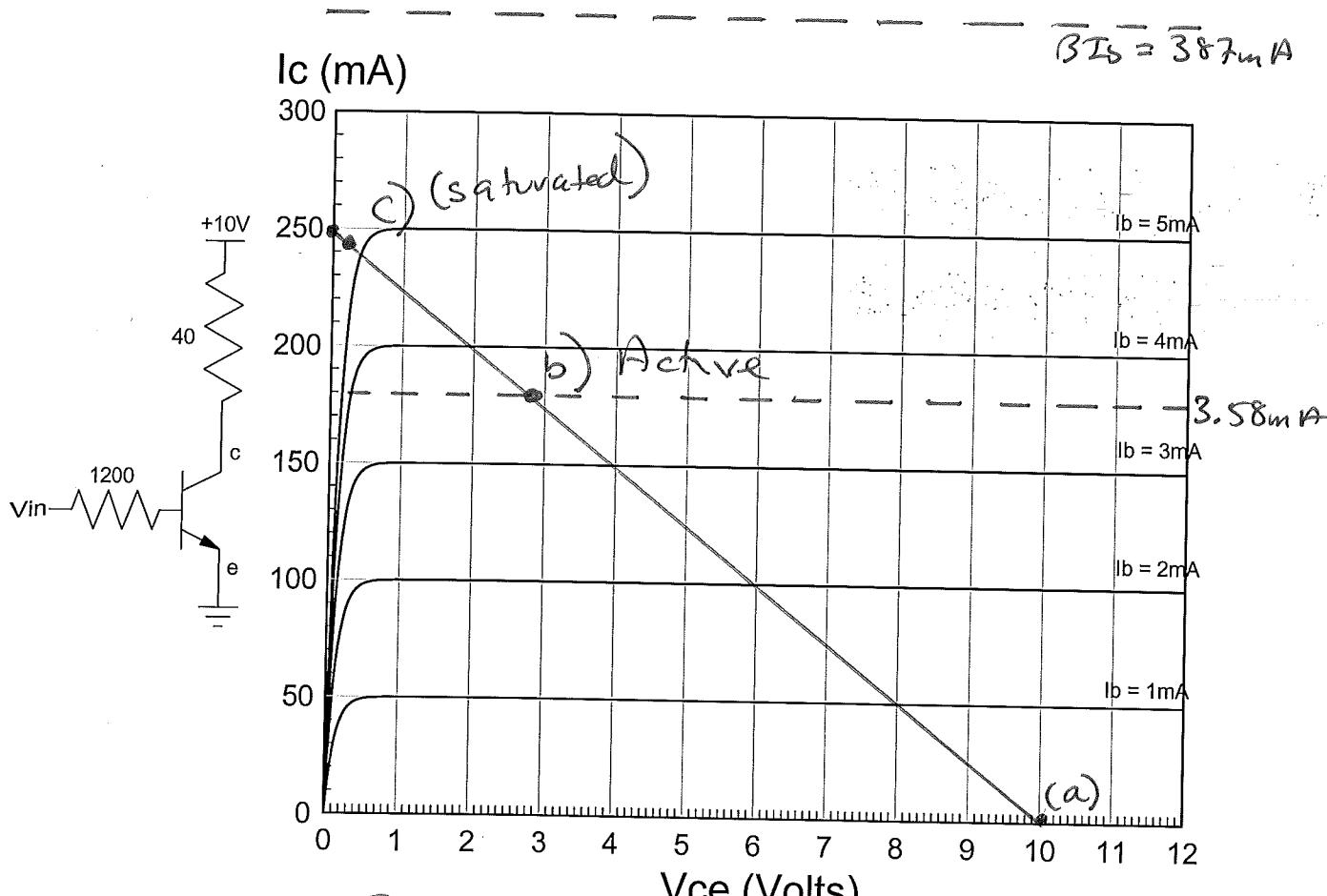
$$= 1.65 \text{ V}_{pp}$$

ECE 320 - Final pt 2: Name _____

Transistors and Op-Amps. October 29, 2018

- 1) **Transistor Theory.** The VI characteristics for an NPN transistor are shown below. Draw the load-line for the circuit below and determine the Q-point (V_{ce} , I_c) for $V_{in} = 0V$, $5V$, and $10V$.

Load Line	(a) Q-Point for $V_{in} = 0$	(b) Q-Point for $V_{in} = 5V$	(c) Q-Point for $V_{in} = 10V$
show on graph	show on graph	show on graph	show on graph



b) $I_b = \frac{5 - .7}{1200} = 3.58\text{ mA}$ $\beta = 50$

$I_c = 50 \cdot I_b = 179\text{ mA}$

c) $I_b = \frac{10 - .7}{1200} = 7.75\text{ mA}$

$B \cdot I_b = 387\text{ mA}$

2) Transistor Switch: An NPN transistor is to turn on and off a 5W LED with a 0V / 5V input:

Input: 0V / 5V DC source capable of driving up to 20mA

$$\beta = 100$$

Output: 5W white LED

Relationship:

- $V_{in} = 0V$: $I_d = 0mA$
- $V_{in} = 5V$: $I_d = 1.5A$

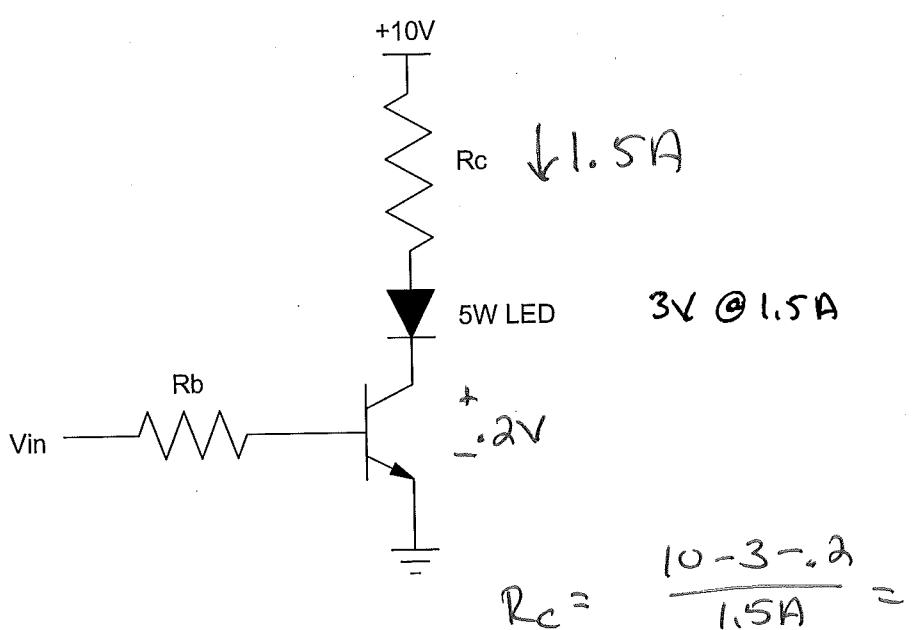
Determine the resistors for the following circuit. Assume an ideal silicon transistor with $\beta = 100$

min value of R_b	max value of R_b	R_c
215 Ω	286 Ω	4.53 Ω

1.80

$$V_{be} = 0.7V$$

240



$$R_c = \frac{10 - 3 - 2}{1.5A} =$$

$$20mA > I_b > 15mA$$

$$@ 15mA \quad R_b = \frac{5 - .7}{15mA} = 286 \Omega$$

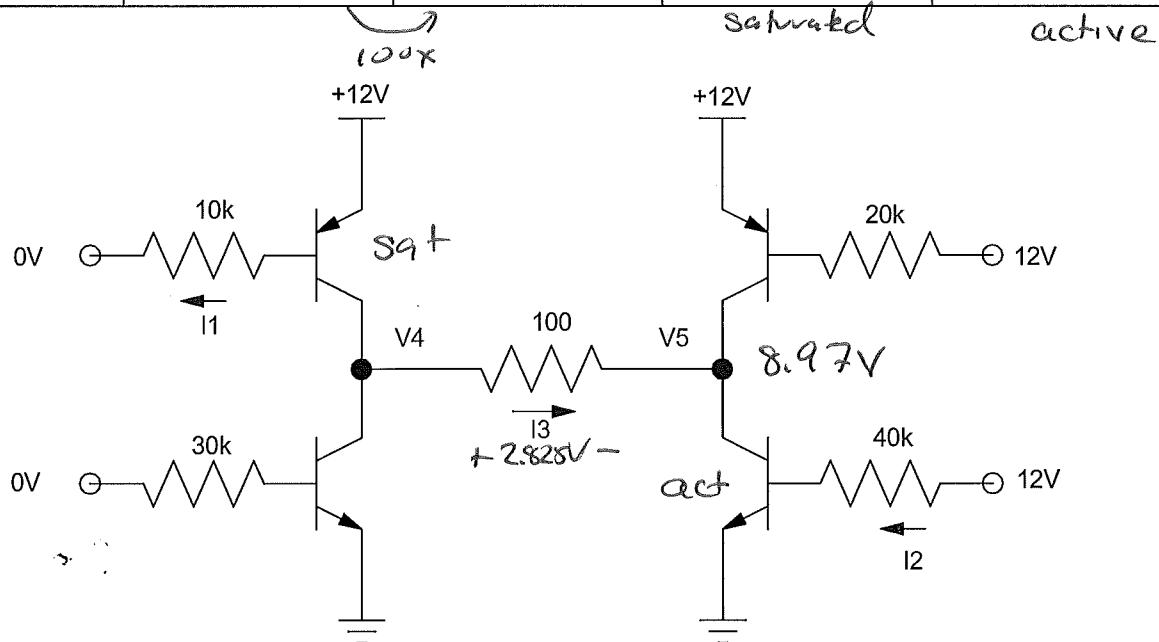
$$@ 20mA$$

$$R_b = \frac{5 - .7}{20mA} = 215 \Omega$$

3) H-bridge. Determine the voltages and currents for the following H-bridge. Assume all transistors have

- $|V_{be}| = 0.7V$
- $\beta = 100$
- $\min(|V_{ce}|) = 0.2V$

I1	I2	I3	V4	V5
1.13mA	2.82mA	28.2mA	11.8V	8.97V



$$I_1 = \frac{12 - 7}{10k} = 1.13mA$$

$$I_2 = \frac{12 - 7}{40k} = 2.82mA$$

$$I_3 = \min(113mA, 116mA)$$

(28.2mA)

$$I_3 = 28.2mA$$

4) Schmitt Trigger. Design a circuit to turn on or off a DC servo motor based upon temperature:

- The motor turns on when $T > 30^\circ\text{C}$ (303K) 805Ω 2.23V
- The motor turns off when $T < 25^\circ\text{C}$ (298K) 100Ω 2.5V

Assume a thermistor with the characteristics of

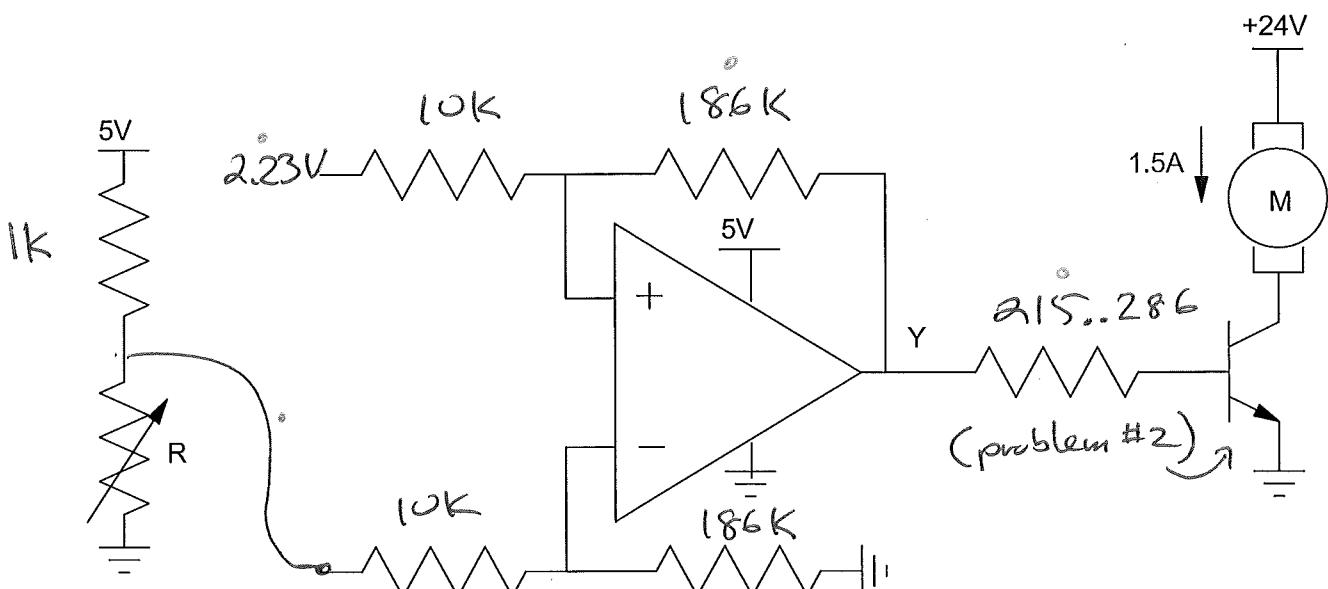
$$R = 1000 \cdot \exp\left(\frac{3905}{T} - \frac{3905}{298}\right) \Omega$$

where T is the temperature in degrees Kelvin. Assume

Transistor:

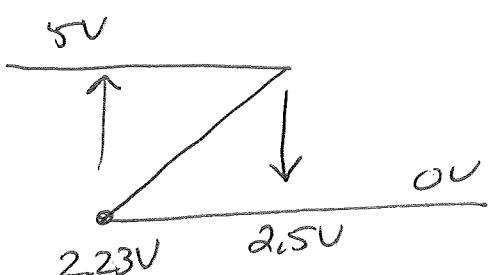
Op-Amp

- | | |
|-------------------------------|--|
| • $V_{be} = 0.7\text{V}$ | - rail to rail (output goes 0V to 5V) |
| • $V_{ce(sat)} = 0.2\text{V}$ | - max output = 20mA |
| • $\beta = 100$ | |



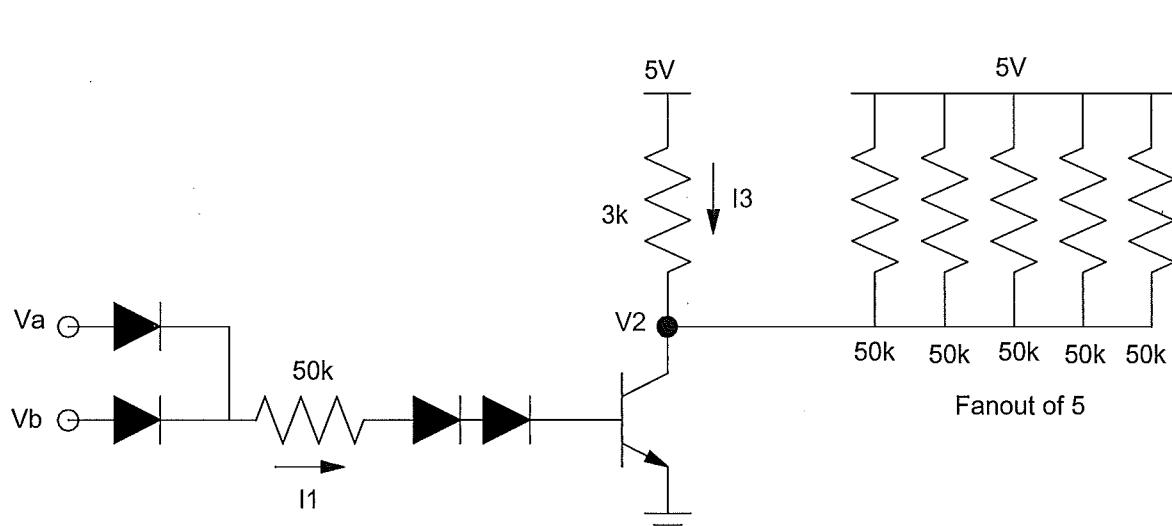
$$\text{gain} = \frac{5\text{V} - 0\text{V}}{2.5\text{V} - 2.23\text{V}}$$

$$= 18.6$$



5) DTL OR Gate: A DTL NOR gate is connected to five other gates (modeled as five 50k resistors at the output). Determine the logic levels for this gate

<u>Logic Level 0</u>	<u>Logic Level 1</u>
Range of Va and Vb that result in the transistor being off	Range of Va and Vb that result in the transistor begin saturated.



4 diodes in series = 2.8V

off for $V_{in} < 2.8V$

$$I_C = \frac{5 - 2}{3k} + 5 \cdot \frac{5 - 2}{50k} = 2.08 \mu A$$

$$\beta I_B \geq I_C$$

$$I_B = 20.8 \mu A \quad (\text{edge discharge})$$

$$V_a = 2.8 + 50k \cdot I_B = 3.84V$$

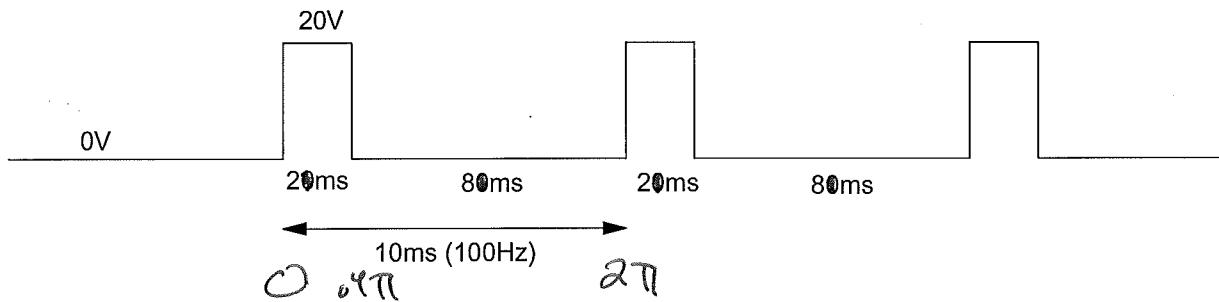
6) Fourier Transforms: A 20% duty cycle, 20Vp, 100Hz square wave drives a circuit. Determine the DC and AC terms (1st harmonic) for this waveform.

$$\text{DC: } X_0 = \frac{1}{T} \int_0^T x(t) \cdot dt$$

$$\text{AC: } X_1 = \frac{2}{T} \int_0^T x(t) \cdot e^{-j\omega_0 t} \cdot dt$$

$$\omega_0 = \frac{2\pi}{T}$$

DC Term X ₀ (Volts)	AC Term (100Hz component) 2 X ₁ (Vpp)
4V	14.96 V _{pp}



$$\text{DC} = (0.2)(20) = 4V$$

$$\text{AC: } X_1 = \frac{2}{2\pi} \int_0^{4\pi} 20 e^{-j\omega t} dt$$

$$X_1 = \frac{20}{\pi j} \left(-\frac{1}{j} \right) \left(e^{-j\omega t} \right)_0^{4\pi}$$

$$X_1 = \left(-\frac{20}{\pi j} \right) \left(-1 + e^{-j \cdot 4\pi} \right) = 605 j^{4.39}$$

$$2|X_1| = 14.96$$