ECE 320 - Homework #6

Transistors, Switches, and H-Bridges. Due Monday February 20th, 2017

1) The VI characteristics for an NPN transistor are shown below.

- Label the off / active / saturated regions
- From this plot, determine the current gain, β

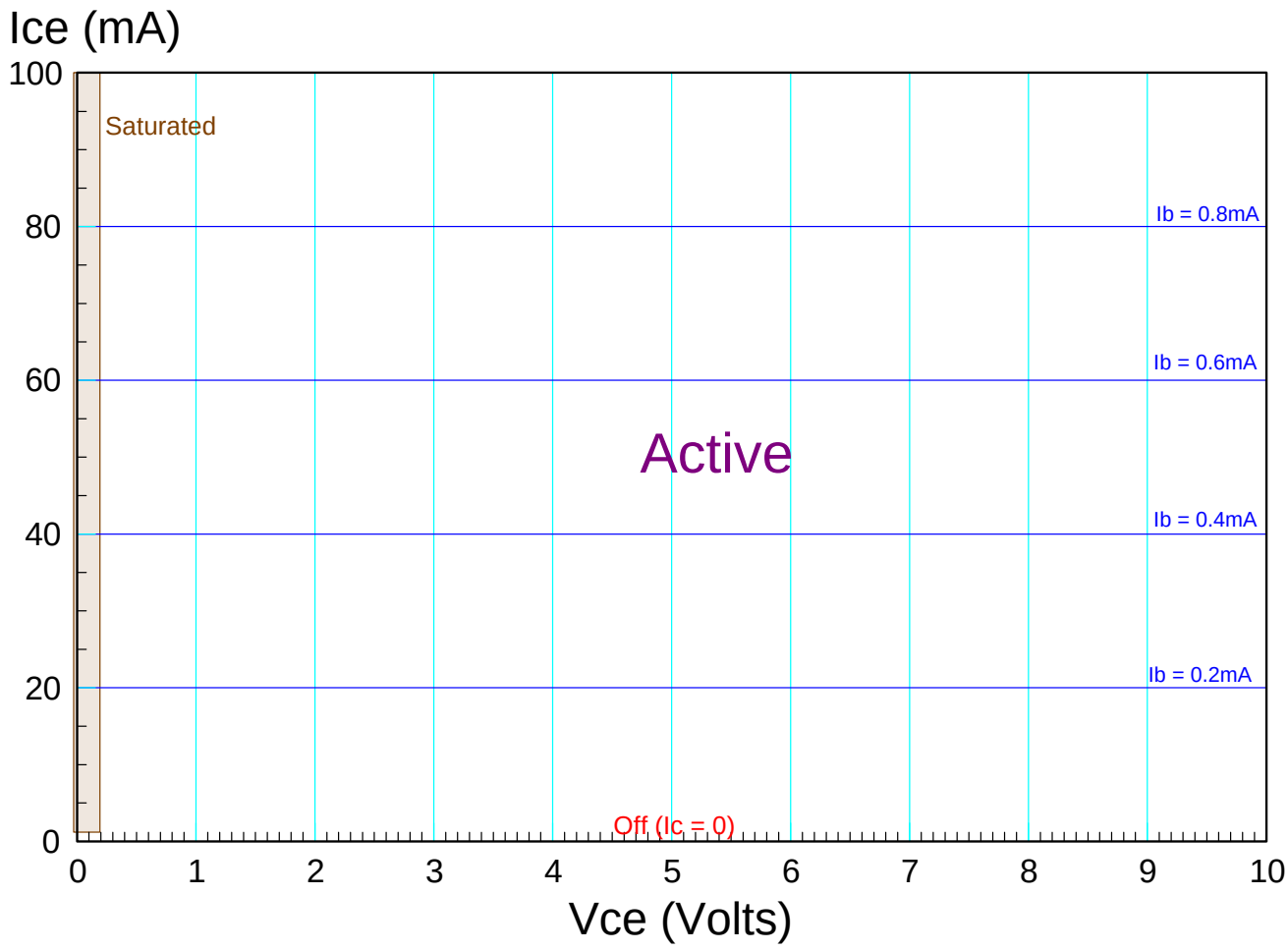
Pick a point in the active region

- Ic = 80mA
- Ib = 0.8mA

The ratio is the current gain

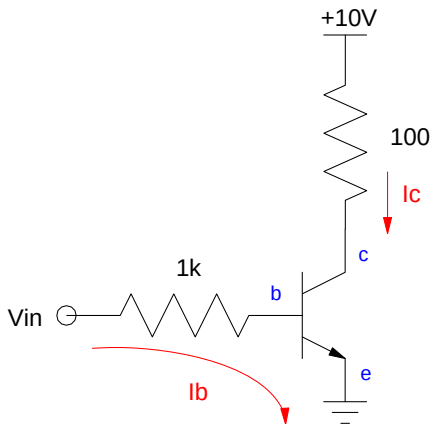
$$100 I_b = I_c$$

$$\beta = 100$$



2a) Draw the load-line for the following circuit on the above VI plot.

2b) Determine the operating point (Q-point) when



Vin = 0V

- Ib = 0
- Ic = 0
- Vce = 10V

Vin = 1V

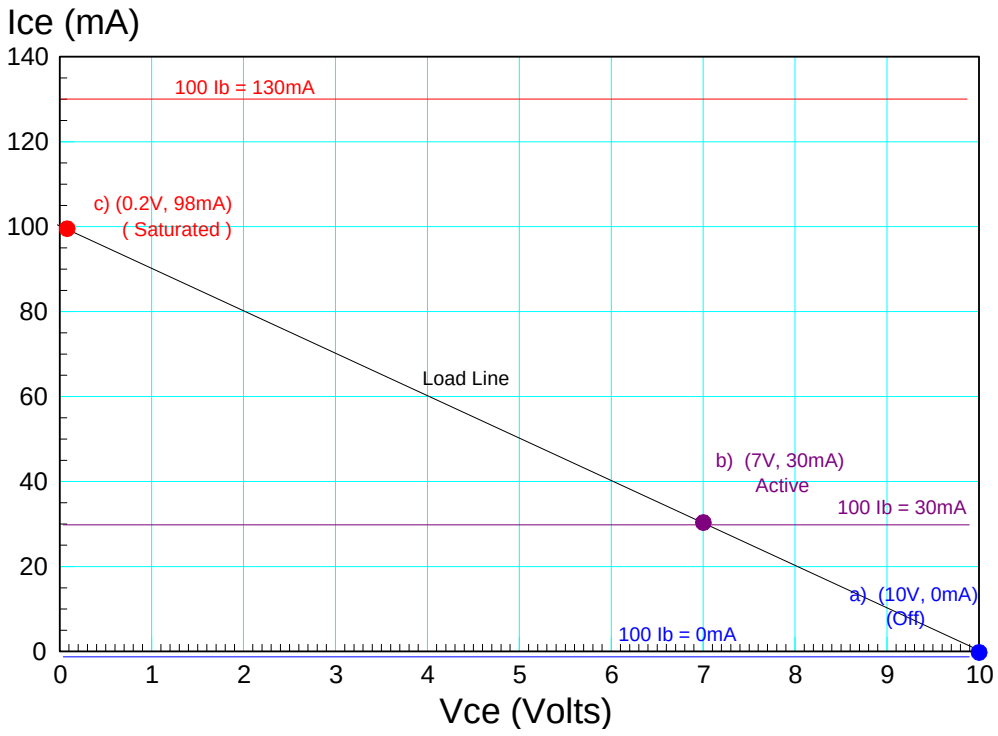
- $I_b = \left(\frac{1-0.7}{1k}\right) = 300\mu A$
- $I_c = \beta I_b = 30mA$
- $V_{ce} = 10 - 100I_c = 7V$

Vin = 2V

- $I_c = \left(\frac{2-0.7}{1k}\right) = 1.3mA$
- $I_c = \beta I_b = 130mA$
- $V_{ce} = 10 - 100I_c = -3V$

Vce can't be negative. Instead, it clips at 0.2V (saturated)

- $V_{ce} = 0.2V$
- $I_c = \left(\frac{10-0.2}{100}\right) = 98mA$



Note: The transistors we have in lab are

	Part	Beta	max(Ic)	Vce(sat)
NPN	3904	100	200mA	0.2V
	TIP112	1,000	2A	0.9V
PNP	3907	100	200mA	0.2V
	TIP117	1,000	2A	0.9V

Transistor Switch

3) Design a circuit so that your cell-phone (or a signal generator) can drive an 8-Ohm speaker

Input: 0V / 3V square wave, capable of driving 10mA

Output: 8 Ohm speaker

Relationship:

- When Vin = 0V, 0mA flows through the speaker
- When Vin = +3V, +XmA flows through the speaker

where

- X = 100mA (if you're using a 3904 transistor)
- X = 500mA (if you're using a TIP112 transistor)

Assume a 3904 transistor operating at 200mA

Rc: Choose to limit the current to 200mA

$$R_{total} = \frac{3V - 0.2V}{200mA} = 14\Omega$$

8 Ohms comes from the speaker. Add another 6 Ohms to make the total 14 Ohms.

Rb: Choose so that

$$\beta I_b > I_c$$

$$I_b > 2mA \quad \text{(and less than 10mA)}$$

Let

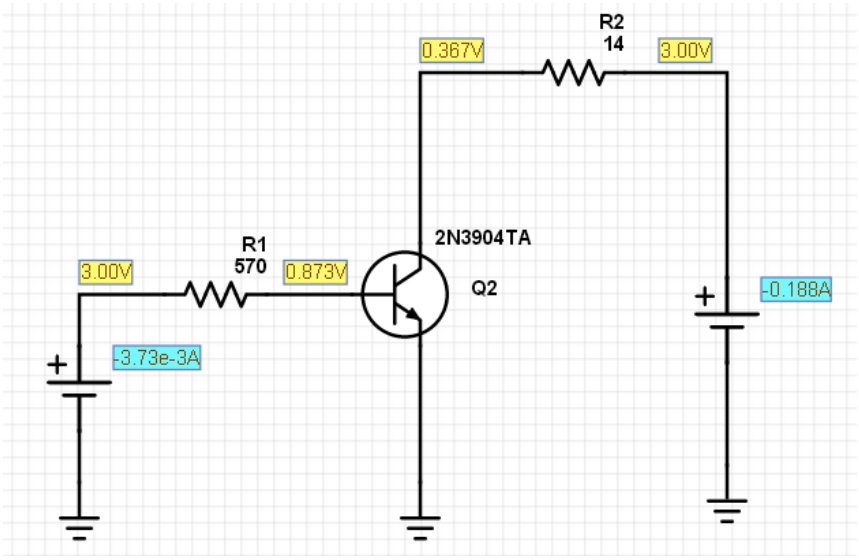
$$I_b = 4mA$$

$$R_b = \frac{3V - 0.7V}{4mA} = 575\Omega$$

Give or take. Something close to 575 Ohms will work.

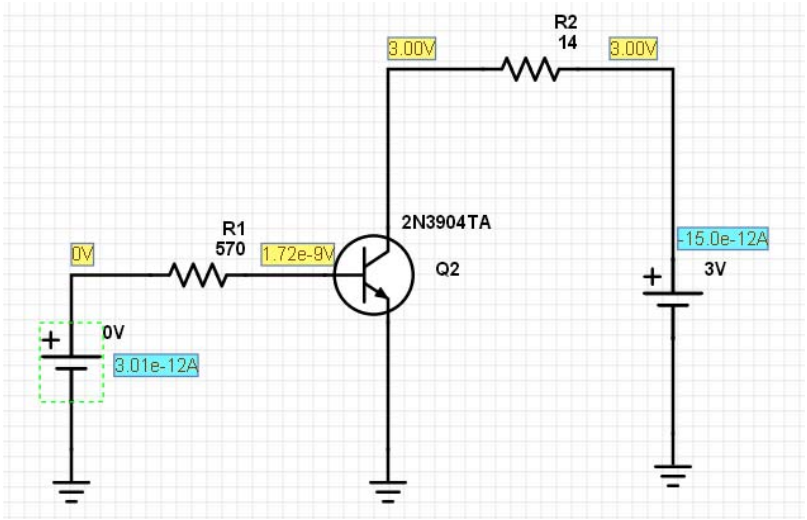
4) Simulate your design in PartSim and verify its operation at 0mA and XmA. (note: if the transistors are saturated, Vce = Vce(sat))

On State



	Vb	Ib	Vc	Ic
Calculated	0.7V	4mA	0.2V	200mA
Simulated	0.873V	3.73mA	0.367V	188mA

Off State



	Vb	Ib	Vc	Ic
Calculated	0.0V	0mA	3.0V	0mA
Simulated	0.0V	-3.01pA	3.00V	15.0pA

H-Bridge

5) Design a circuit so that your cell-phone (or a signal generator) can drive an 8-Ohm speaker

Input: 0V / 3V square wave, capable of driving 10mA

Output: 8 Ohm speaker

Relationship:

- When Vin = 0V, -200mA flows through the speaker
- When Vin = +3V, +200mA flows through the speaker

Rload: Assume 3904 / 3907 transistors. Assuming 0.2V drop across each of two transistors when saturated, the resistance you need is

$$R = \frac{3V - 0.2V - 0.2V}{200mA} = 13\Omega$$

Add 5 Ohms in series with the 8 Ohm speaker.

Rb: To saturate the transistors

$$\beta I_b > I_c$$

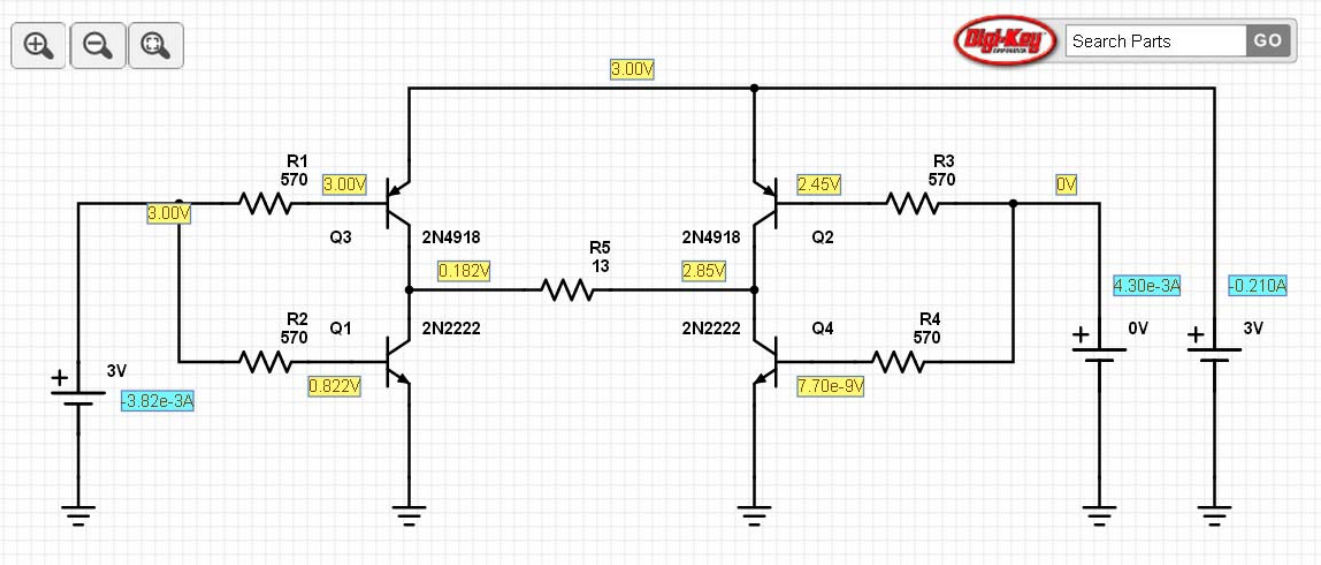
$$I_b > 2mA$$

Let Ib = 4mA

$$R_b = \left(\frac{3 - 0.7}{4mA}\right) = 575\Omega$$

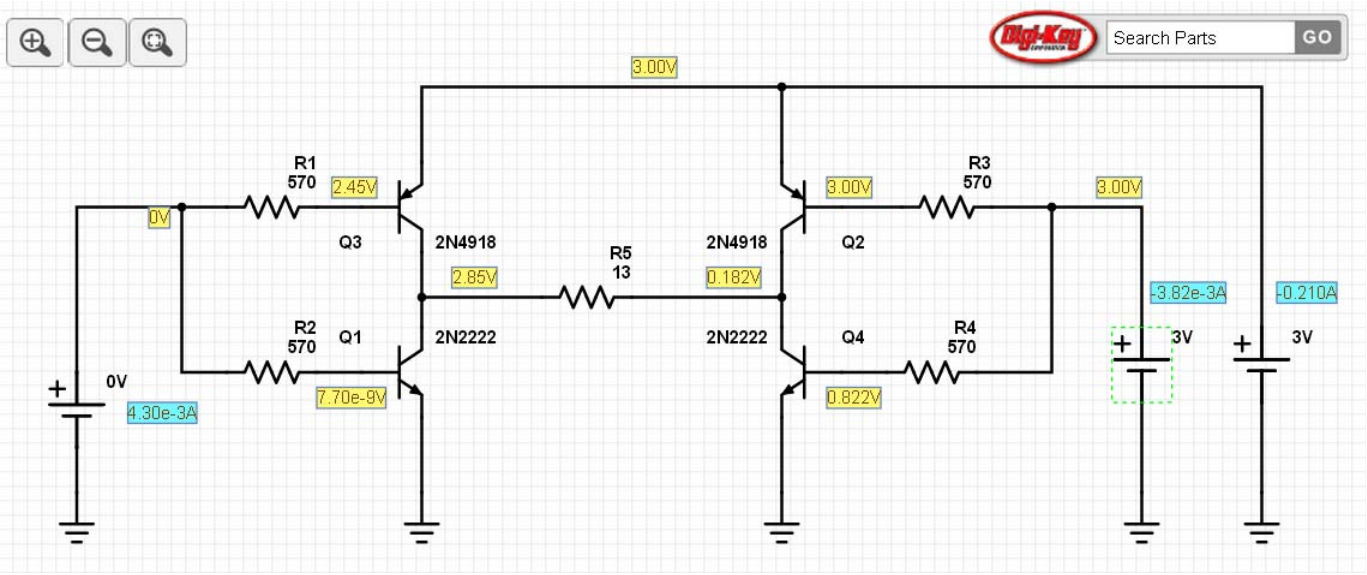
6) Simulate your design in PartSim and verify its operation at +100mA and -100mA. (note: if the transistors are saturated, Vce = 0.2V)

Reverse:



	Va (left)	Vb (right)	I (load)
Calculated	0.2V	2.8V	-200mA
Simluated	0.182V	2.85V	-205mA

Forward



	Va (left)	Vb (right)	I (load)
Calculated	2.8V	0.2V	+200mA
Simluated	2.85V	0.182V	+205mA

Lab)

7) Build one of these two circuits and verify their operation with a signal generator (or your cell phone with a function generator app).