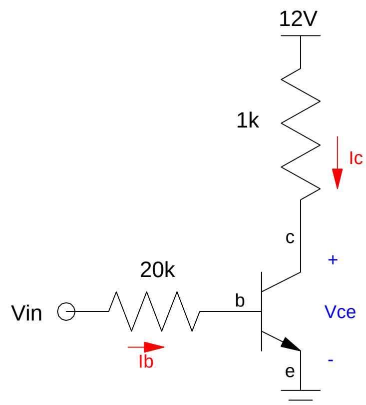
ECE 320 - Homework #5

Transistor Theory, Transistor as a Switch, H-Bridge. Due Monday, September 26th

Assume

- NPN: 3904 Transistor, $\beta = 100$, max(Ic) = 200mA, max(Vce) = 40V, \$0.06 ea.
- PNP: 3907 Transistor, $\beta = 100$, max(Ic) = 200mA, max(Vec) = 40V), \$0.07 ea.

Transistors:



1) The VI characterstics for a transistor are given in the following graph.

Label the Off - Saturated - and Active regions on this graph.

Determine the current gain, β, from this graph.

20uA at Ib produces 2mA at Ic.

$\beta = 100$

2) For the circuit to the right, draw the load line

shown on graph

3) Determine the Q-point (Vc, Ic) when

Vin = 0.5V: This isn't enough to turn on the diode, so

Ib = 0

Ic = 0

Vce = 12V

Vin = 3V: This is enough to turn on the diode from base to emitter. Assuming active:

$$I_b = \left(\frac{3V-0.7V}{20k}\right) = 115\mu A$$

$$I_c = \beta I_b = 11.5mA$$

$$V_c = 12V - 1k \cdot I_c$$

$$V_c = 0.5V$$

The Q-point is

Vce = 0.5V

Ic = 11.5mA

Vin = 5V: This is enough to turn on the diode from base to emitter. Assuming active:

$$I_b = \left(\frac{5V-0.7V}{20k}\right) = 215\mu A$$

$$I_c = \beta I_b = 21.5mA$$

$$V_c = 12V - 1k \cdot I_c$$

$$V_c = -9.50V$$

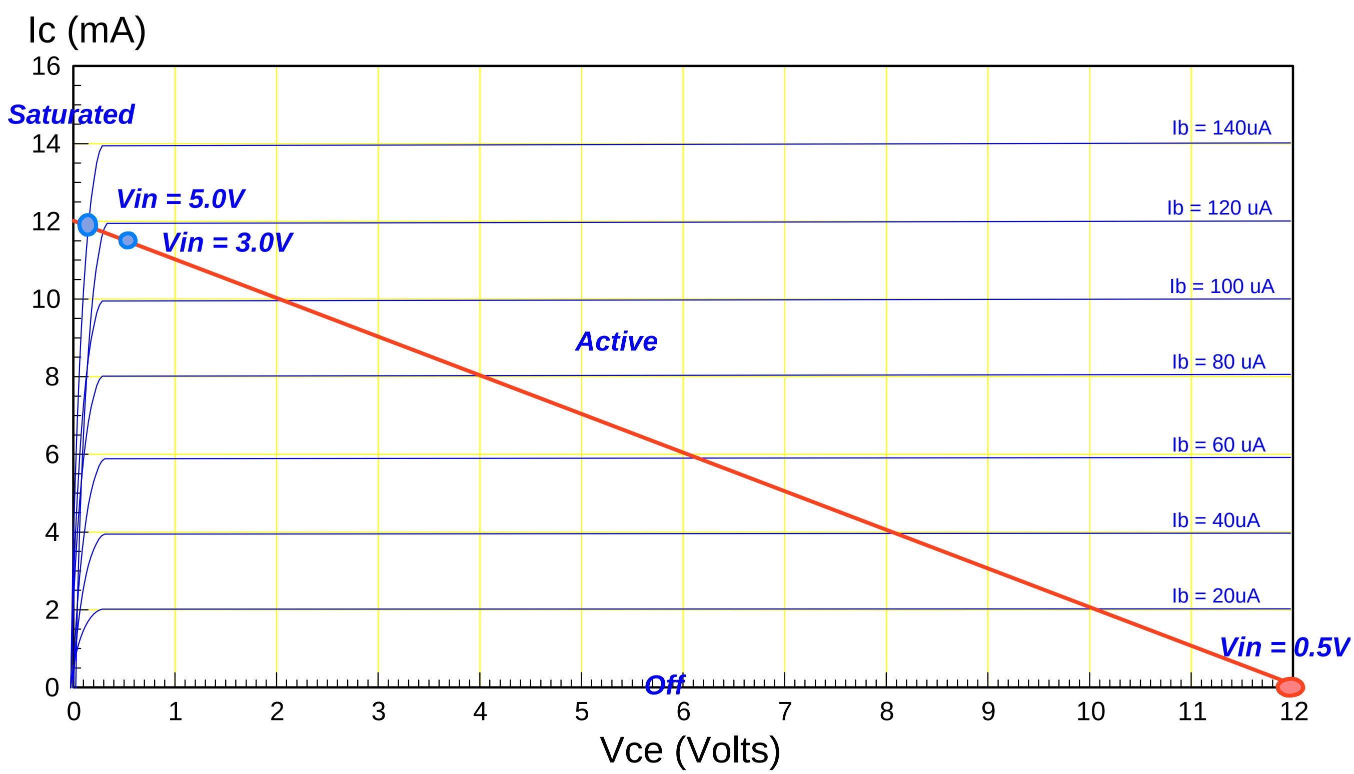
Vc can't go negative, so it clips at 0.2V (saturated). Then

$$I_c = \left(\frac{12V - 0.2V}{1k}\right) = 11.8mA$$

The Q-point is

Vce = 0.2V

Ic = 11.8mA



Transistor Switches:

4) Design a circuit which allows you to turn on and off a 3W LED with the function generator:

Input: 0V / 5V signal capable of driving 20mA

Output: 3W LED. Vf = 3V @ 1A

Relationship:

- 0V in = 0mA to the LED
- 5V in = 100mA to the LED (something the 3904 transistor is capable of)

First, design a circuit to drive 100mA through the LED. Assume a 5V power supply

$$R_c = \left(\frac{5V - 3V - 0.2V}{100mA}\right) = 18\Omega$$

Next, choose Rb so that

- Ib < 20mA (input limit), and
- 100Ib > Ic

To saturate the transistor

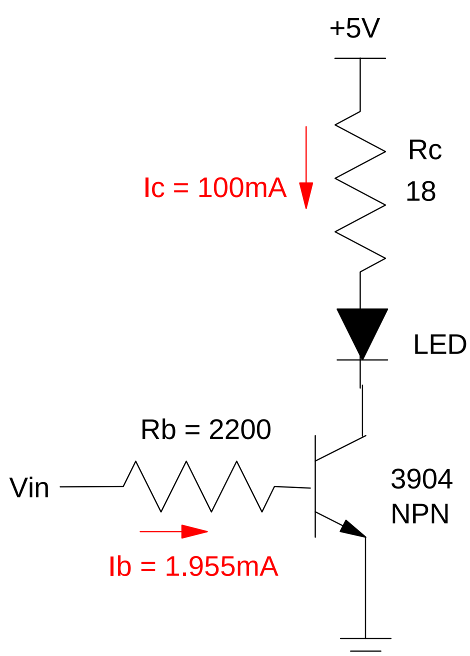
$$\beta I_b > I_c$$

$$I_b > \frac{100mA}{100} = 1mA$$

Let Ib = 2mA

$$R_b = \left(\frac{5V - 0.7V}{2mA}\right) = 2150\Omega$$

The exact value of Rb isn't critical: anything close works. Let Rb = 2200.

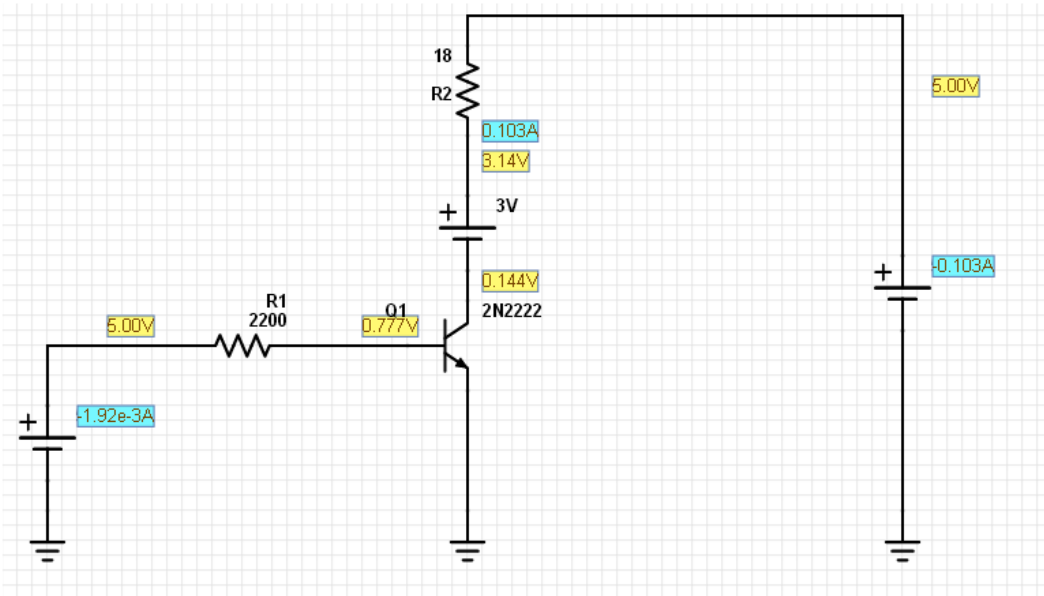


PartSim Simulation:

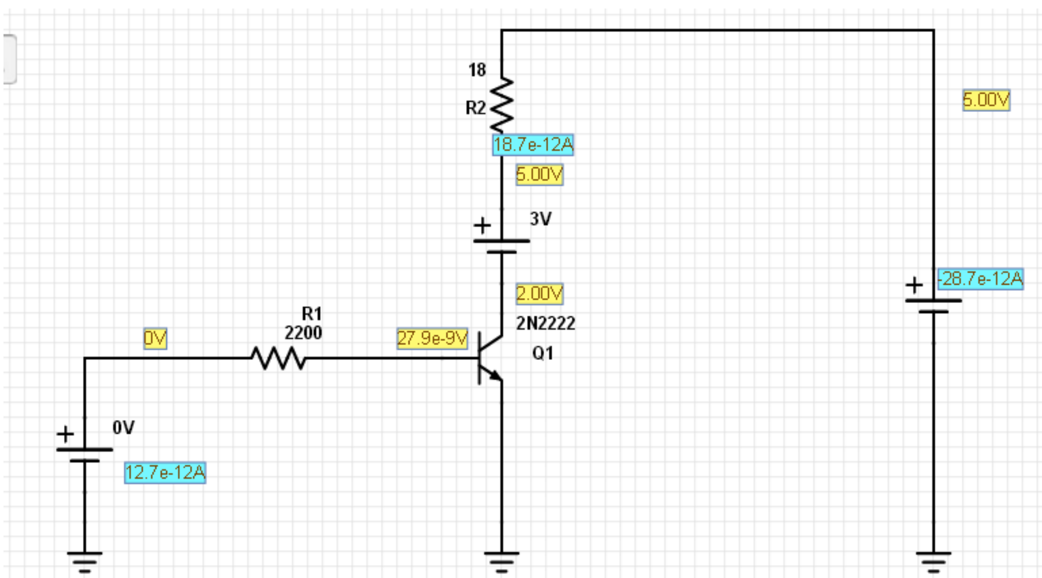
Diode is on: A white LED isn't in PartSim, so use a 3V source to simulate the voltage drop through the diode.

This results in

- Ic = 103mA (vs. 100mA computed)
- Ib = 1.92mA (vs. 1.955 computed)



0V in turns off the diode



H-Bridge

5) Design an H-bridge to drive +/- 100mA through an 8-Ohm speaker

Input: Four signals (A,B,C,D), each 0/5V capable of 20mA

Output: 8 Ohm Speaker

Relationship:

- Setting (A, B, C, D) to different voltages allows you to drive the speaker at +100mA, 0mA, or -100mA
- Tolerance: 10%

Assume +5V power.

Add a resistance to limit the current to the 8-Ohm speaker to 100mA

$$R_{total} = \left(\frac{4.8V - 0.2V}{100mA}\right) = 46\Omega$$

The 8-Ohm speaker contributes 8 Ohms (duh), so you need to add 38 Ohms to get to 46 Ohms.

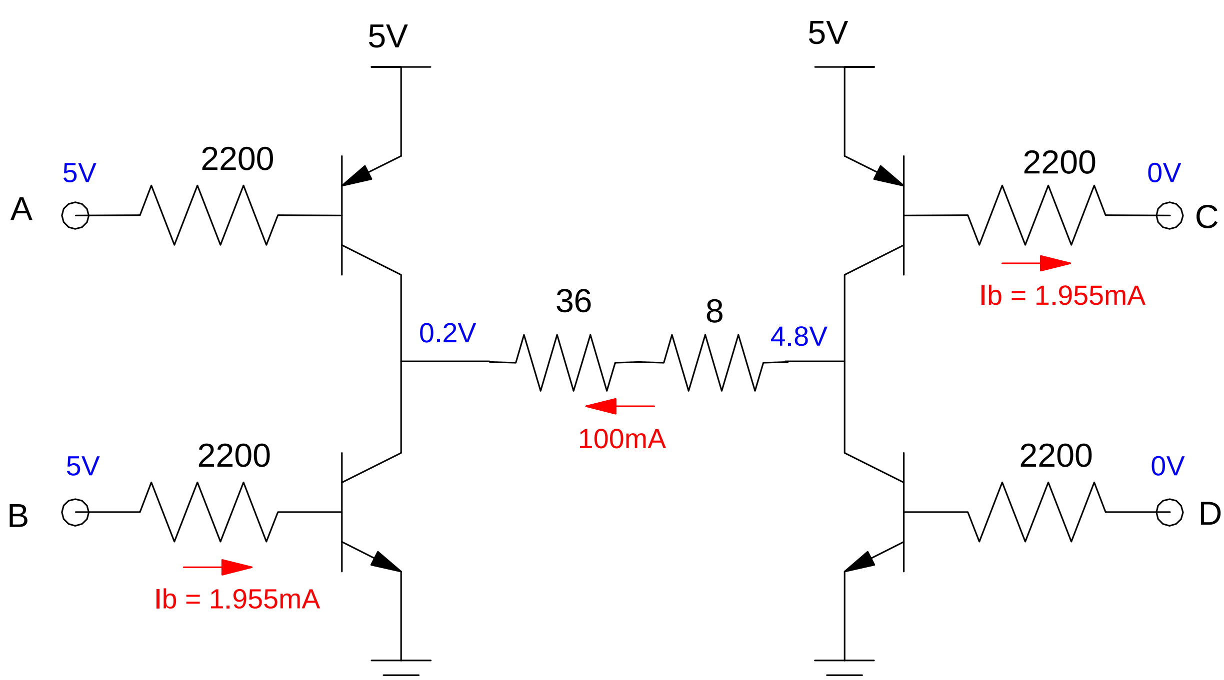
To saturate the transistors, pick Rb so that 100Ib > Ic. For the PNP transistors (When Vc = 0V)

$$R_b = \left(\frac{5V - 0.7V}{20mA}\right) = 2150\Omega$$

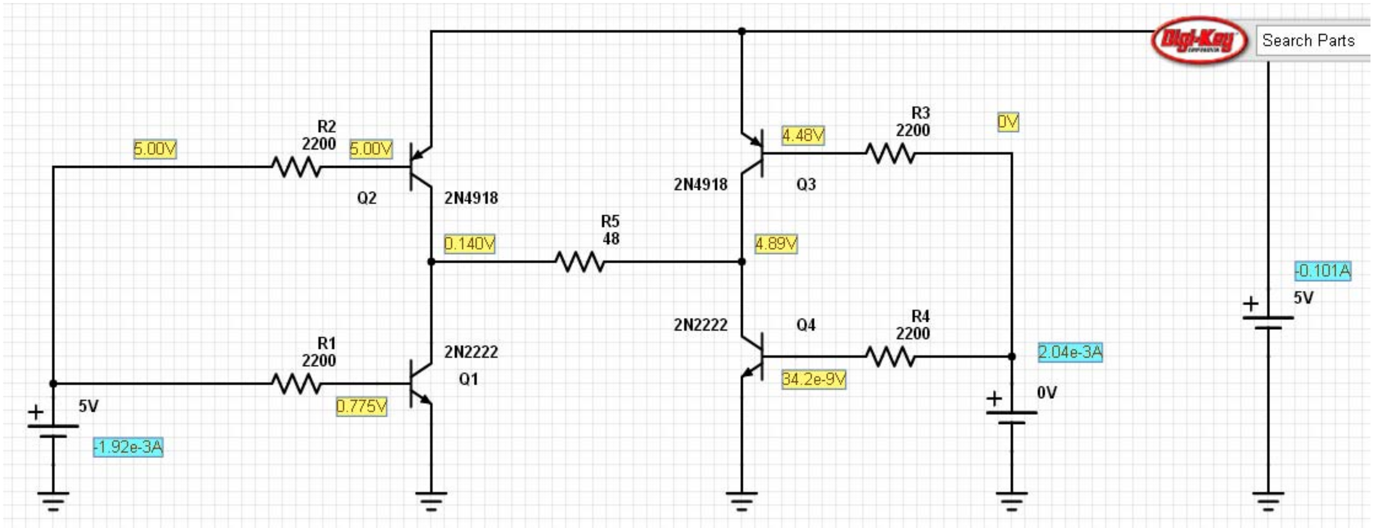
For the NPN transistors (when Vb = 5V)

$$R_b = \left(\frac{5V - 0.7V}{20mA}\right) = 2150\Omega$$

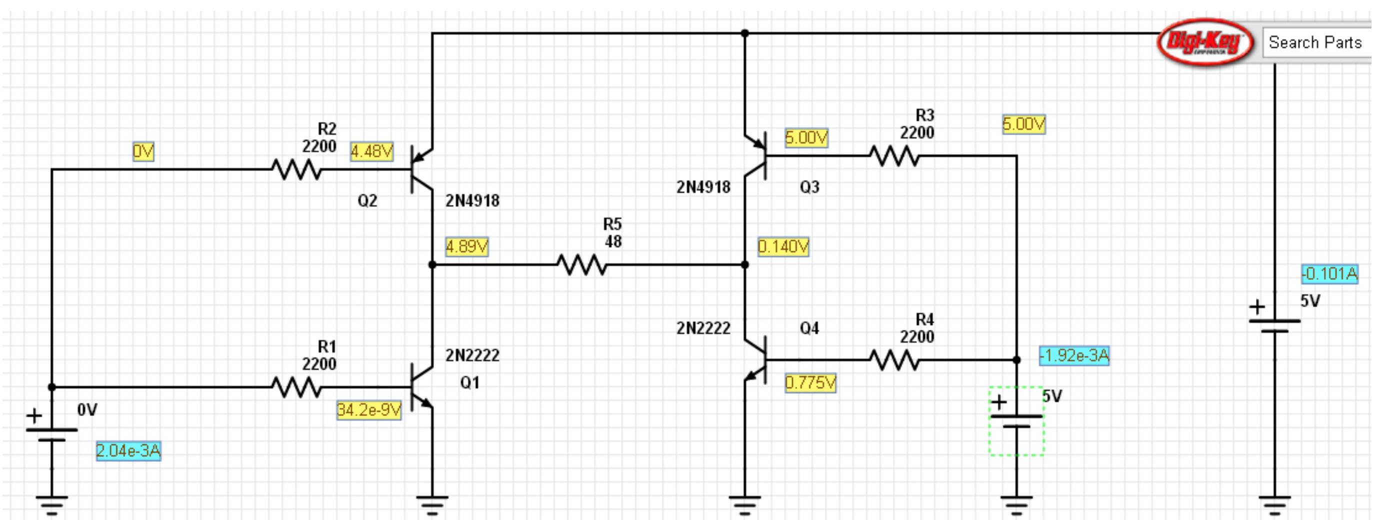
Round each to 2200 Ohms (resulting in Ib = 1.955mA). This H-brige will work for loads up to 195.5mA.



Simulating in PartSim:



	Calculated	Simulated	Measured (lab)
Vleft	0.2V	0.140V	-
Vright	4.8V	4.89V	-
Vb1	0.7V	0.775V	-
Vb3	4.3V	4.48V	-



	Calculated	Simulated	Measured (lab)
Vleft	4.8V	4.89V	-
Vright	0.2V	0.140V	-
Vb4	0.7V	0.775V	-
Vb2	4.3V	4.40V	-

Lab:

6) Simulate in PartSim (or similar program) problem 3, 4, or 5

7) Build in lab either problem 3, 4, or 5.