ECE 320 - Homework #5

Transistors used as a Switch, H-Bridges. Due Wednesday, February 10th

Transistor Switch

Assume a TIP112 transistor (NPN) and TIP117 (PNP) ($0.34 each)

$$\beta = 1000 \qquad \min(|V_{ce}|) = 0.9V \qquad \max(I_c) = 4A$$

1) Design a circuit to meet the following requirements (i.e. a transistor used as a switch)

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

- Output: DC Motor which draws 200mA @ 10V

Relationship:

- When Vin = 0V, 0V is applied to the motor
- When Vin = 5V, 10V is applied to the motor +/- 1V

Model the Motor as a resistor:

$$R_{motor} \approx \left(\frac{10V}{200mA}\right) = 50\Omega$$

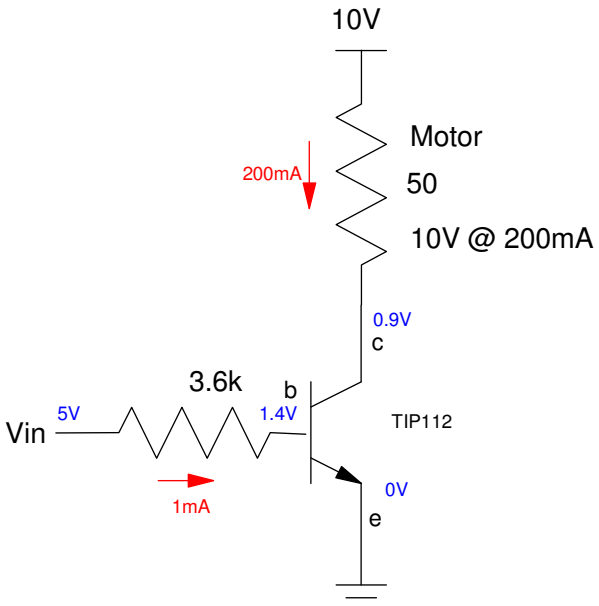
Pick Rb to saturate the transistor when Vin = 5V

$$\beta I_b > I_c$$

$$I_b > \frac{I_c}{\beta} = \frac{200mA}{1000} = 200\mu A$$

Let Ib = 1mA

$$R_b = \left(\frac{5V - 1.4V}{1mA}\right) = 3.6k\Omega$$

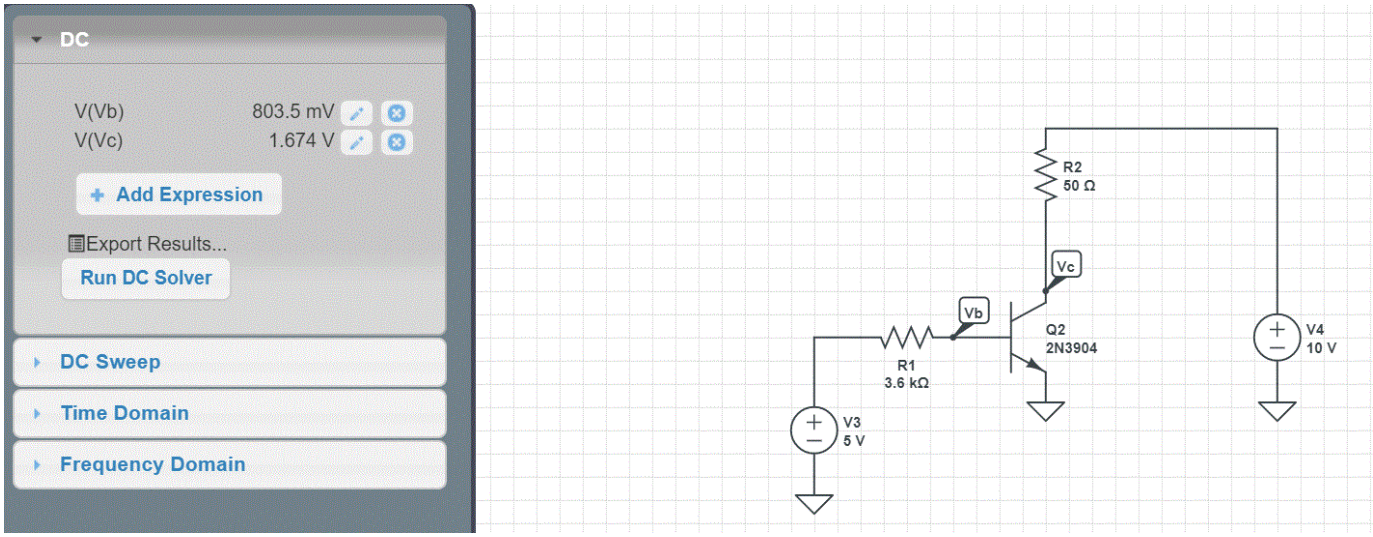


2) Check your design in PartSim

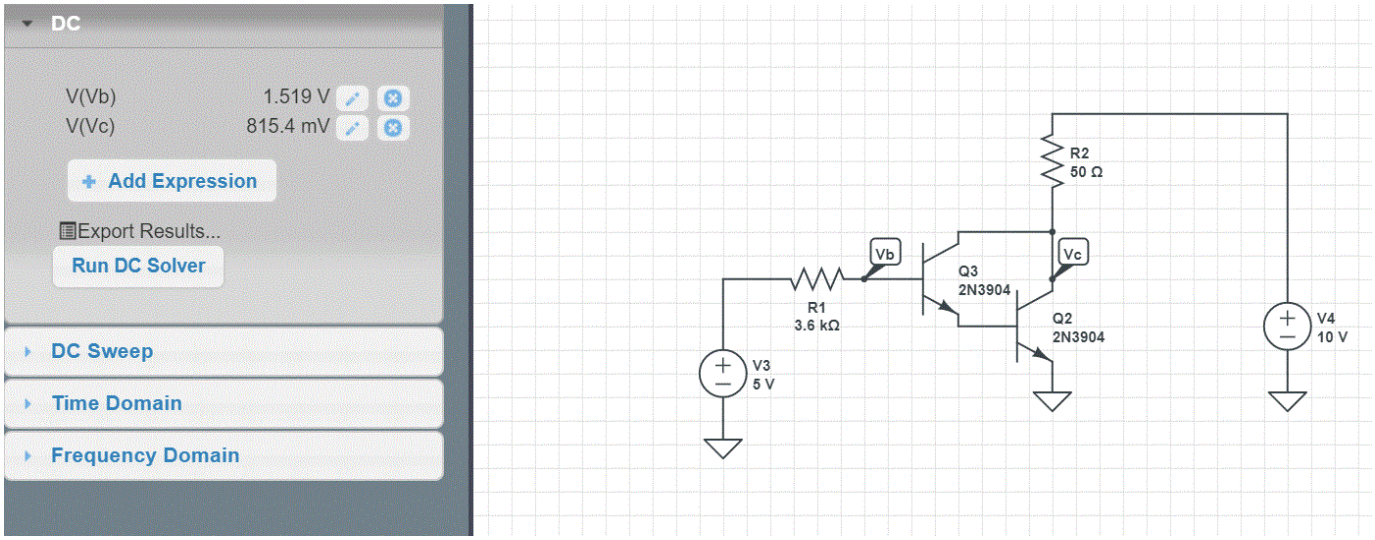
- Model the motor as a 20 Ohm resistor (200mA @ 10V)
- When Vin = 0V, is 0A flowing ni the motor?
- When Vin = 5V, is 200mA flowing through the motor (i.e. the 20 Ohm resistor)?

note:

- Use a 50 Ohm resistor to model the motor (200mA @ 10V)
- Use a 3904 transistor (Vendor Parts - Fairchild - NPN - 3904)



The gain of a 3904 transisor is only 200. This results in the transistor being in the active mode (Vce > 0.2V). If you use two transistors as a Darlington pair, the gain becomes 2002



3) Check your design in lab.

- When Vin = 0V, are the voltages and currents what you calculated and simulated?
- When Vin = 5V, are the voltages and currents what you simullated?

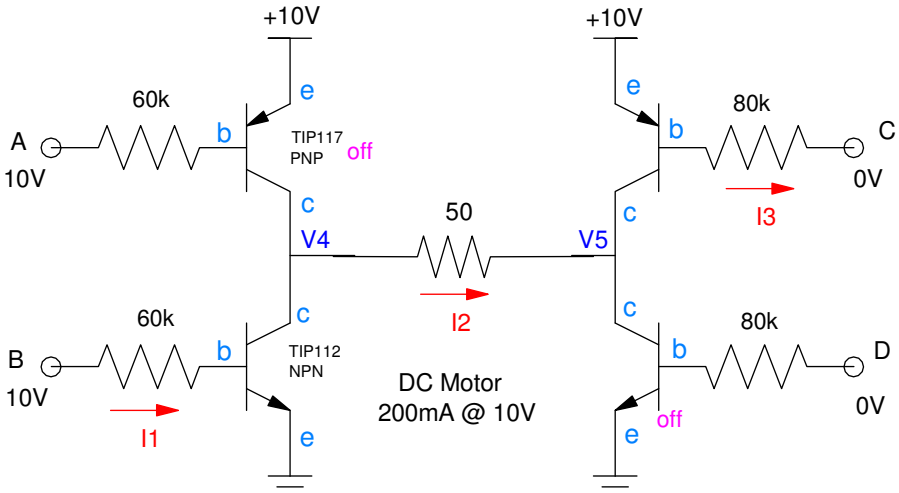
Vin = 0V (off)	Calculated porblem 1	Simulated problem 2	Measured problem 3
Vin	0.0V	0.0V	0.0V
Vbe	0.0V	0.0V	0.0V
Vce	10.0V	10.0V	10.0V
Ic	0.0 mA	0.0 mA	0.0 mA (calculated from Vin and Vc)

Vin = 5V (on)	Calculated porblem 1	Simulated problem 2	Measured problem 3
Vin	5.0V	5.00 V	5.00 V
Vbe	1.40 V	1.519 V	1.39 V
Vce	0.90 V	0.815 V	0.68 V
Ic	182 mA	184 mA	1A (stalled) 43mA (no load)

H-Bridges

4) Determine the voltages and currents for the following H-bridge. Assume TIP transistors

- | Vbe | = 1.4V
- β = 1000
- $V_{ce(sat)} = 0.9V$



$$I_1 = \left(\frac{10V - 1.4V}{60k}\right) = 143.3\mu A \qquad I_3 = \left(\frac{10V - 1.4V}{80k}\right) = 107.5\mu A$$

$$\beta I_1 = 143.3mA \qquad \beta I_3 = 107.5mA$$

I2 is at most

$$\max(I_2) = \left(\frac{10V - 0.9V - 0.9V}{50\Omega}\right) = 164mA$$

The current is then

$$I_2 = \min(143.3mA, 164mA, 107.5mA) = 107.5mA$$

This means

$V_4 = 0.9V$ *transistor 1 is saturated: Vce = 0.9V*

$V_5 = V_4 + 50I_2 = 6.275V$ *transistor 3 is active: 0.2V < Vce < 10V*

5) Design an H-Bridge cable of running a DC servo motor forward (+10V), reverse (-10V) and stop (0V). Assume the DC servo motor draws 200mA @ 10V.

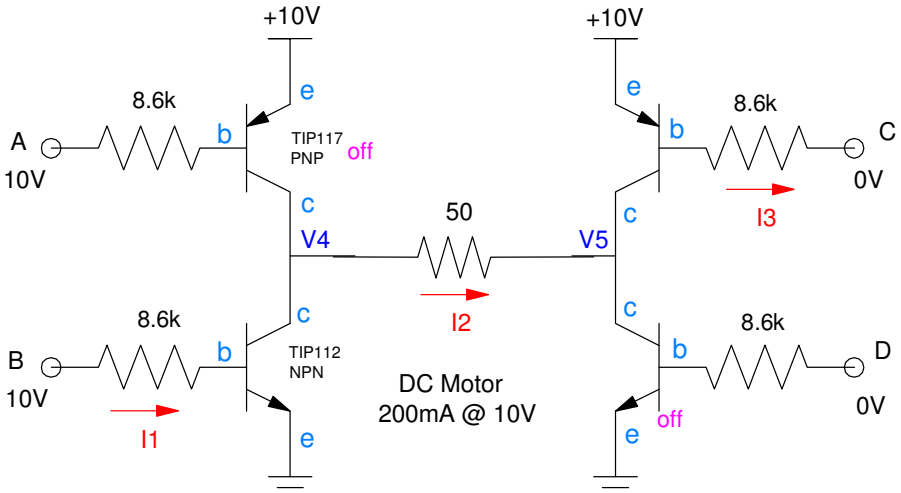
Drop the base resistors so that

$$\beta I_b > I_c = 164mA$$

$$I_b > 164\mu A$$

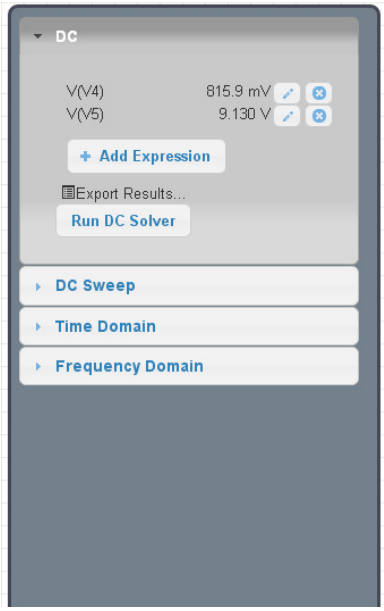
Let Ib = 1mA

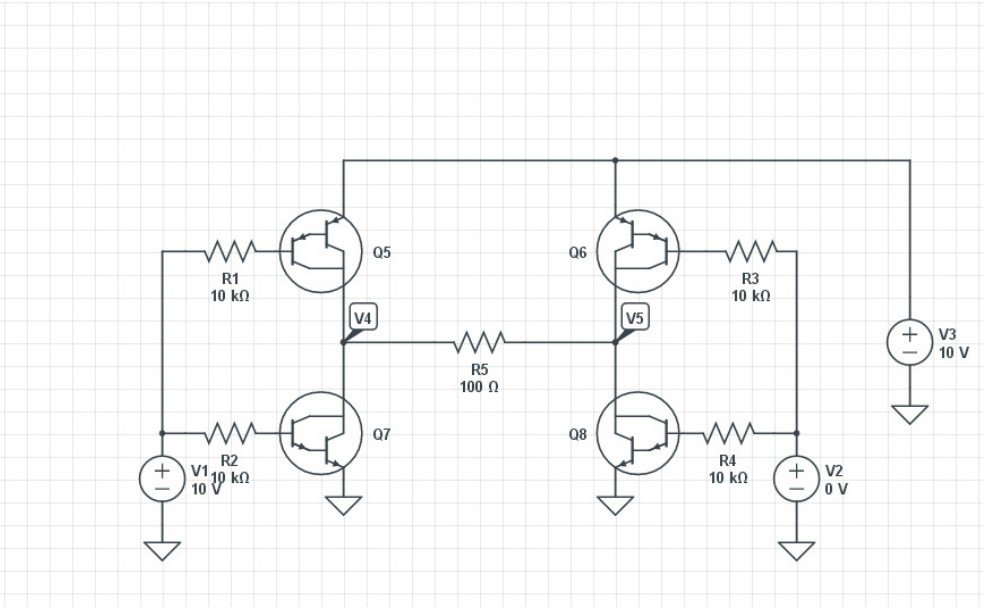
$$R_b = \left(\frac{10V - 1.4V}{1mA}\right) = 8.6k\Omega$$



6) Check your design for problem #2 in PartSim (or similar program)

	V4	V5
Calculated	9.1 V	0.9 V
Simulated	9.130 V	0.8159 V





7) **Lab:** Build your circuit in lab and verify it works for all three states (forward, reverse, stop).

- note: Check Vce. If it's 0.9V, the transistor is saturated (on)