H-Bridges

ECE 320 Electronics I

Jake Glower - Lecture #13

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

Transistor Switch (Review)

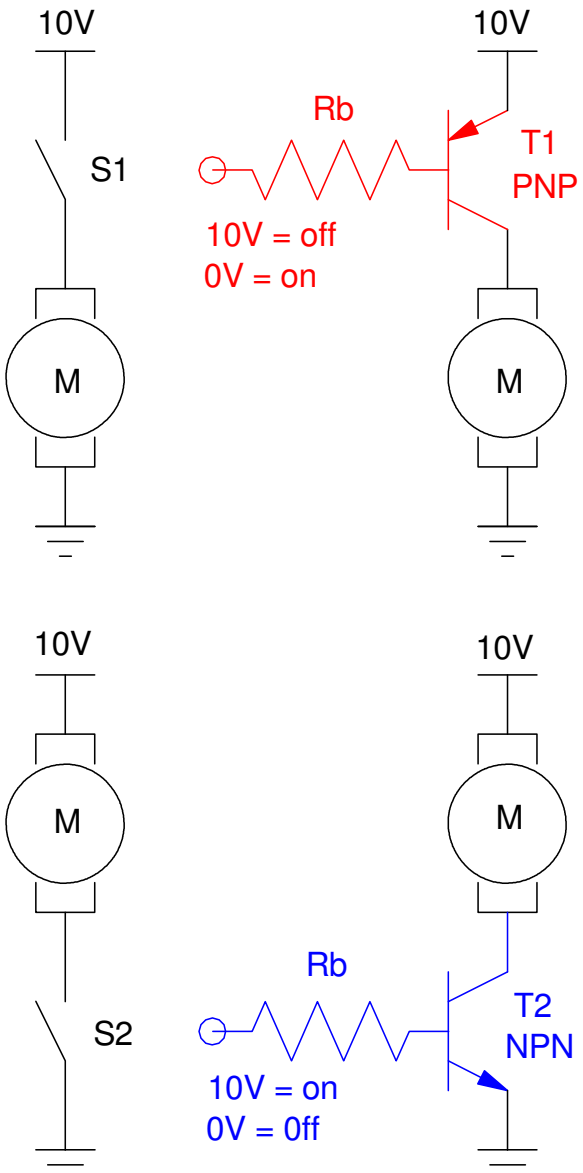
A transistor is an electronic switch

With it you can turn on and off

- Motors
- LEDs
- Speakers
- etc.

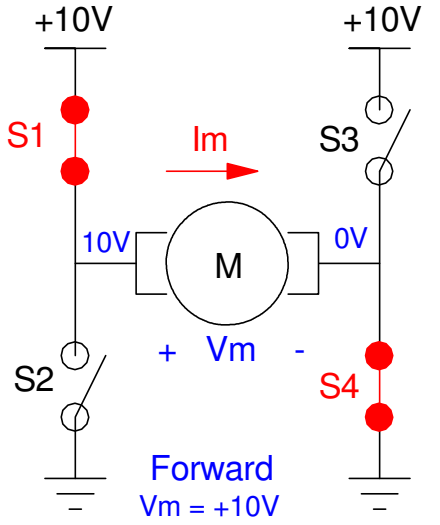
Two variations:

- PNP: Switch connected to power
- NPN: Switch connected to ground



Problem:

- How to you make a motor spin forward and reverse
- Using a single power supply?

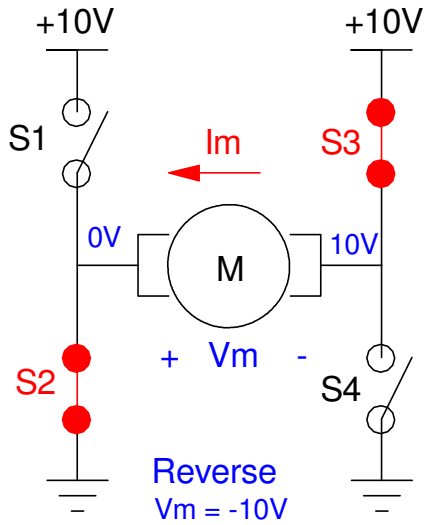


Solution: Use four switches

- Forward: Close S1 & S4
- Reverse: Close S2 & S3

Replace each switch with a transistor

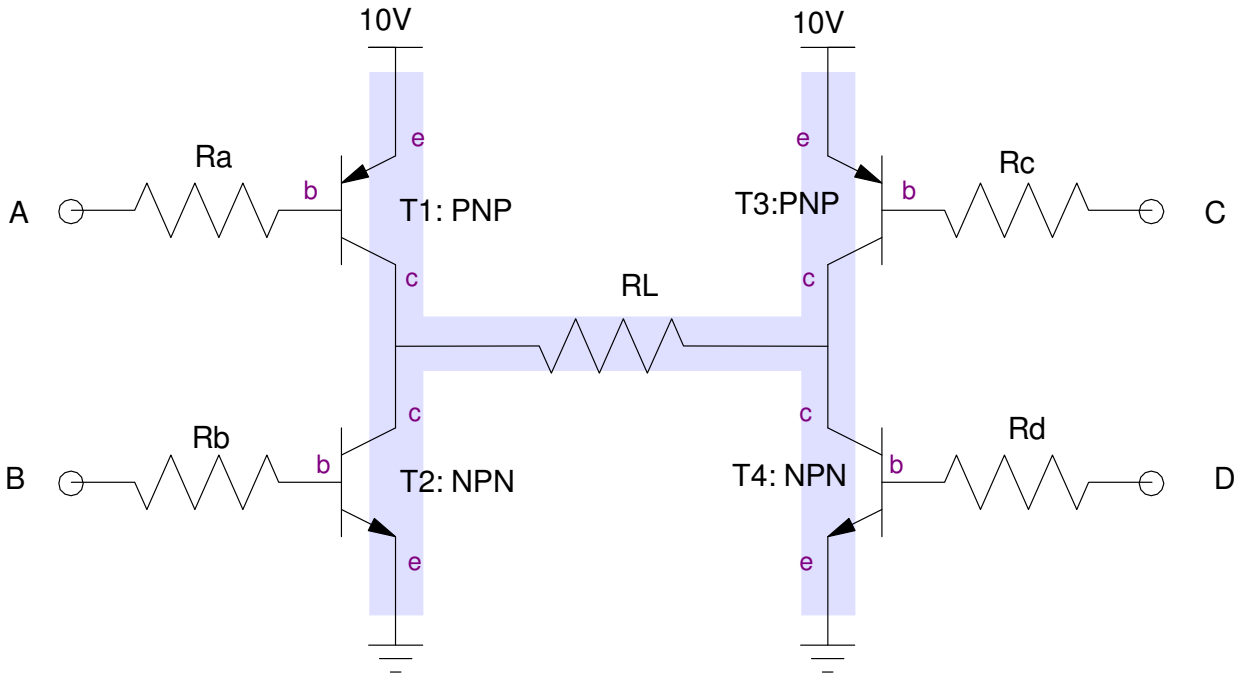
- PNP connected to power
- NPN connected to ground



H-Bridges

4 modes of operation

- Forward: T1 & T4 on
- Reverse: T2 & T3 on
- Brake: T2 & T4 on
- Coast: all transistors off
- Smoke: All transistors on



H-Bridge Analysis: Forward

Assume TIP transistors (Vbe = 1.4V, Vce(sat) = 0.9V)

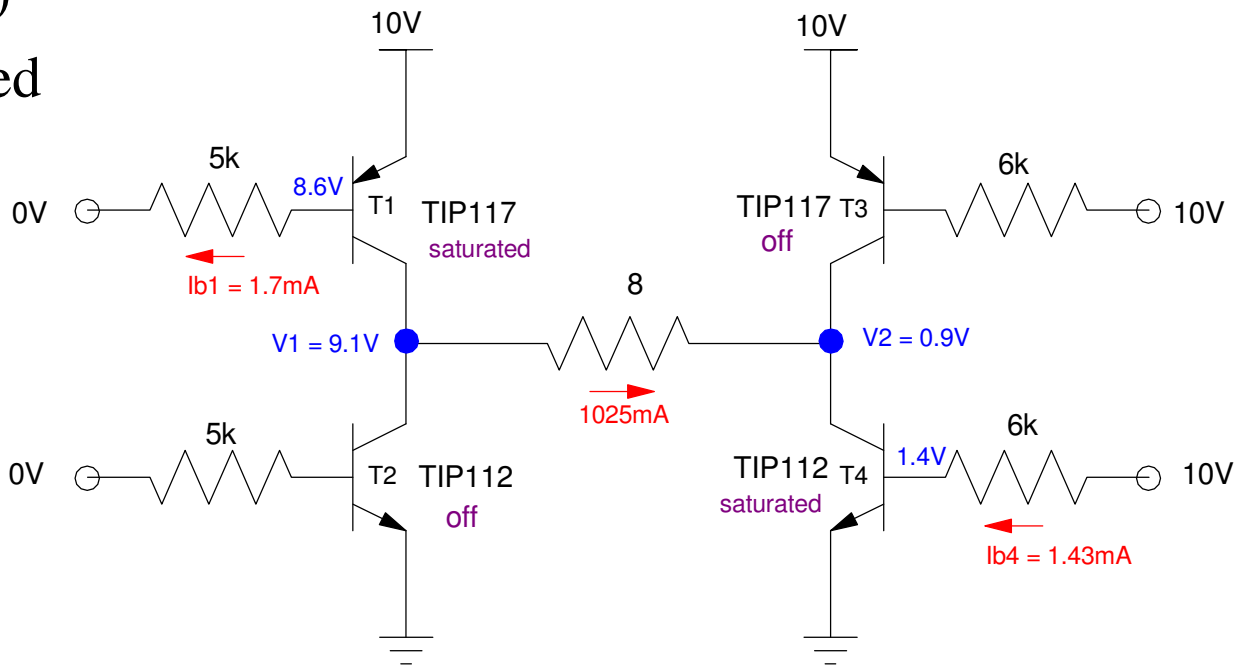
Transistors are current limiters

$$I = \min\left(\beta I_{b1}, \frac{10V - 0.9V - 0.9V}{8\Omega}, \beta I_{b4}\right)$$

$$I = \min(1.72A, 1.025A, 1.433A)$$

$\beta I_b > I_c$: Transistors are saturated

- V1 = 9.1V
- V2 = 0.9V
- I = 1.025A



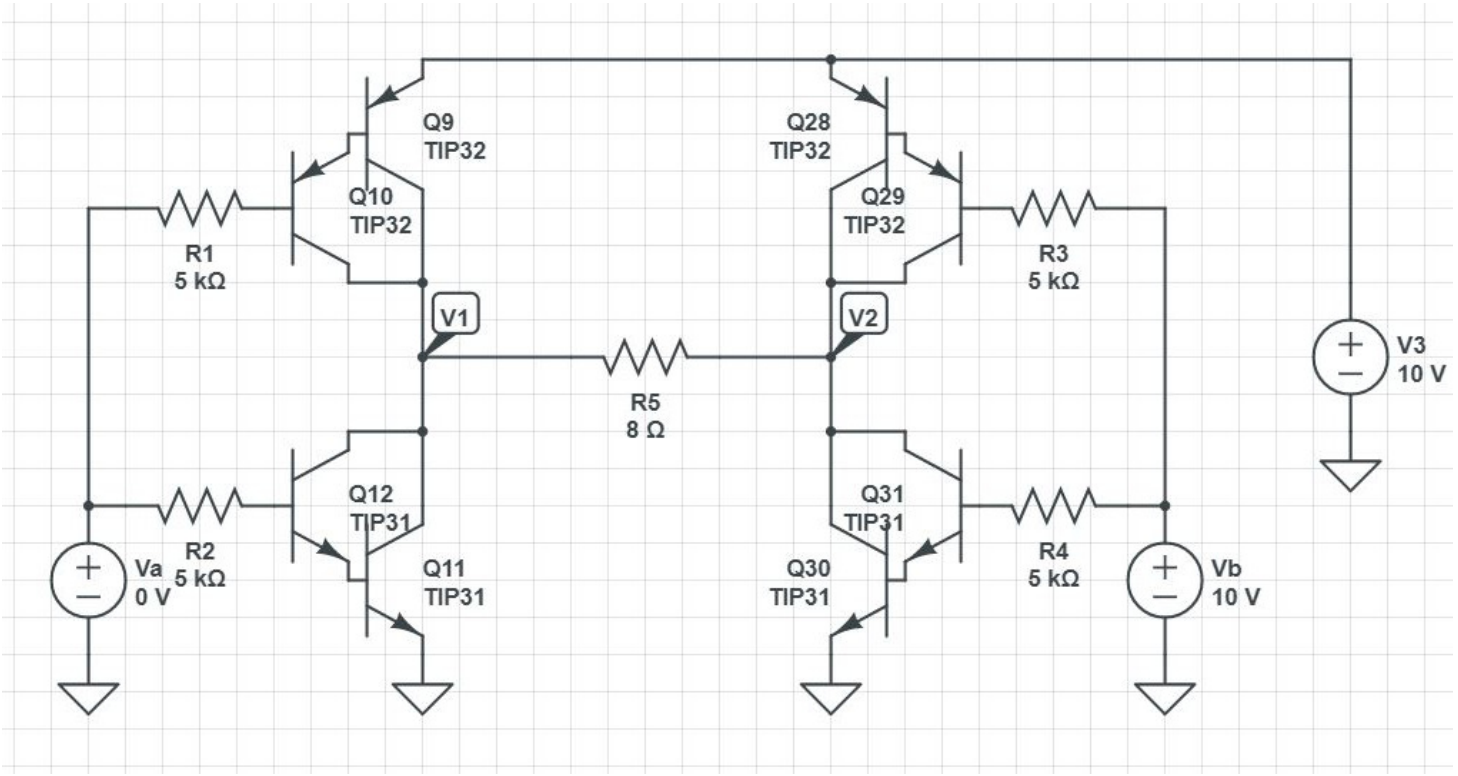
CircuitLab (take 1)

Build a Darlington pair using two transistors

- Similar to TIP112 & TIP117
- Use TIP31/32 to handle the current

Results:

- V1 = 9.265V
  9.1V calculated
- V2 = 0.860V
  0.9V calculated
- Q31.b = 1.314V
  1.4V calculated
- Q10.b = 8.498V
  | Vbe | = 1.502V (1.4V)
- **V12 = +8.405V**
  I6 =+1.051A



CircuitLab (take 2)

Use a single transistor

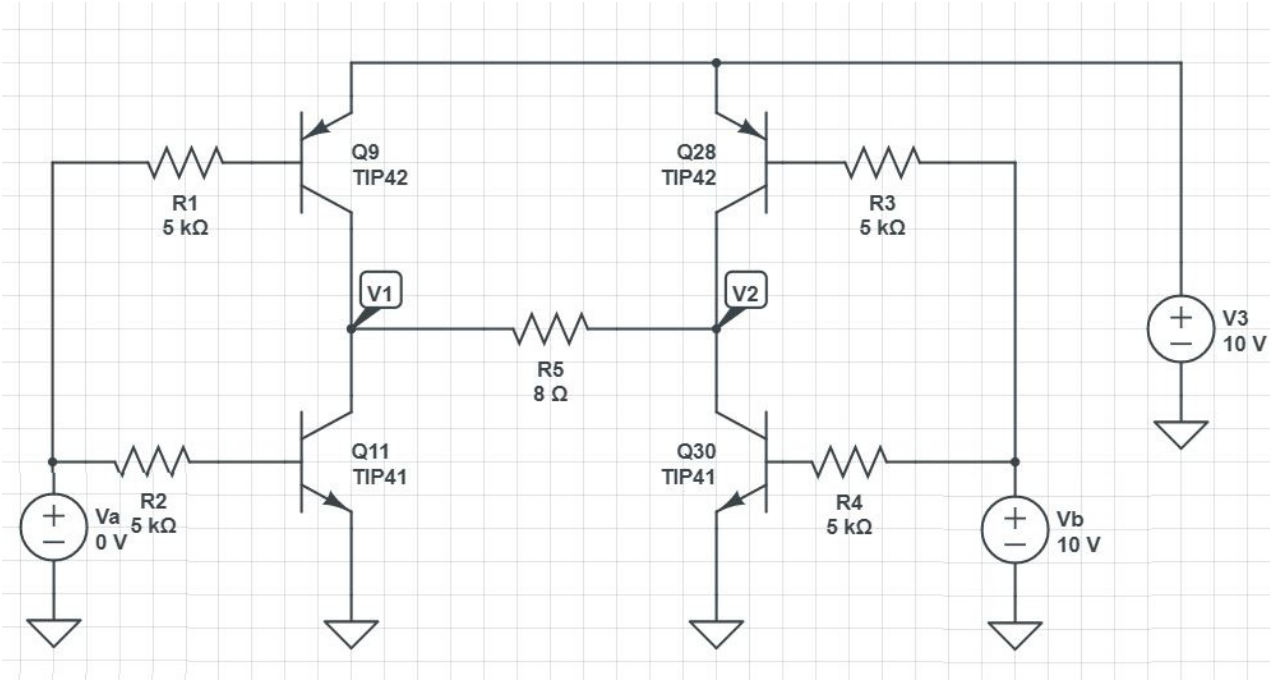
- TIP41/TIP42
- Adjust gain to be 1000

Similar to a Zetex 1051a

- $1 each

Result

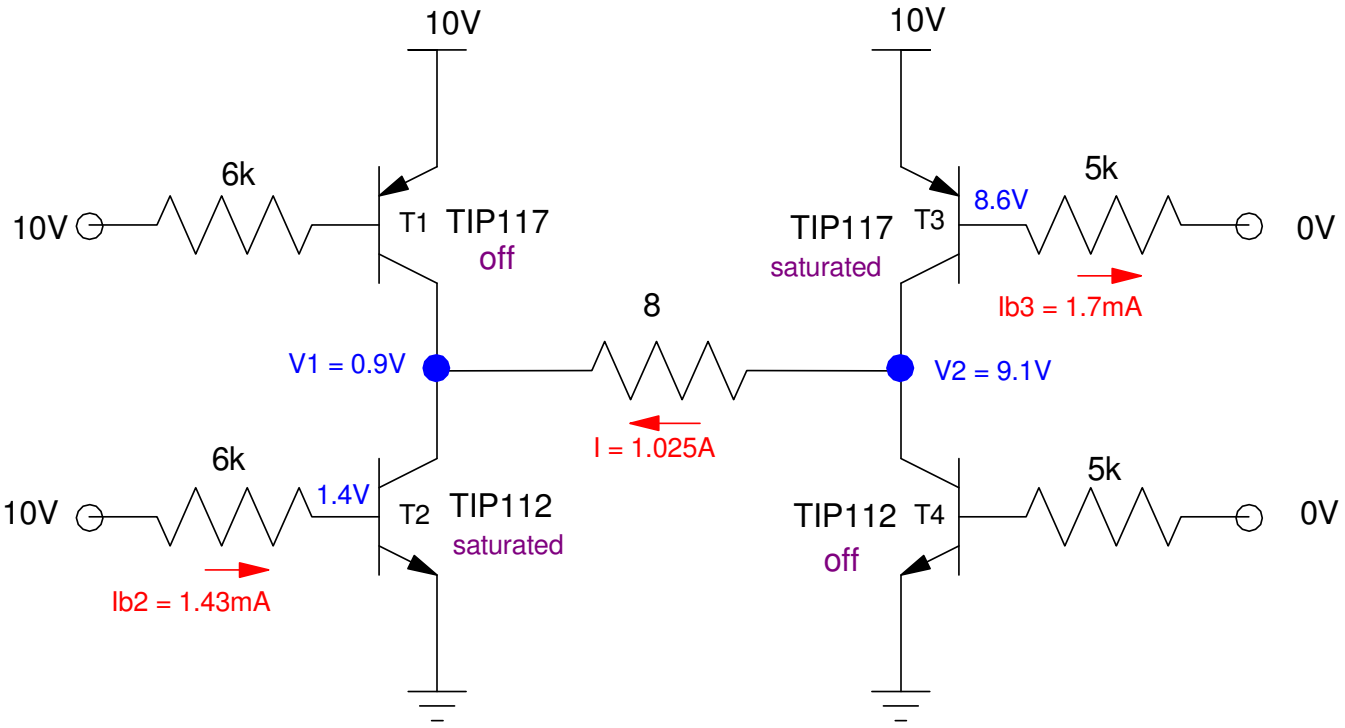
- V1 = 9.842V
  0.158V drop means Q9 is saturated
- V2 = 0.252V
  Q30 is saturated
- Q30.b = 0.746V
  0.7V calculated
- Q9.b = 9.264V
  | Vbe | = 0.736V (0.7V)
- **V12 = +9.590V**
  I5 = 1.199A



H-Bridge: Reverse

Flip the voltages to turn on T2 and T3. This results in

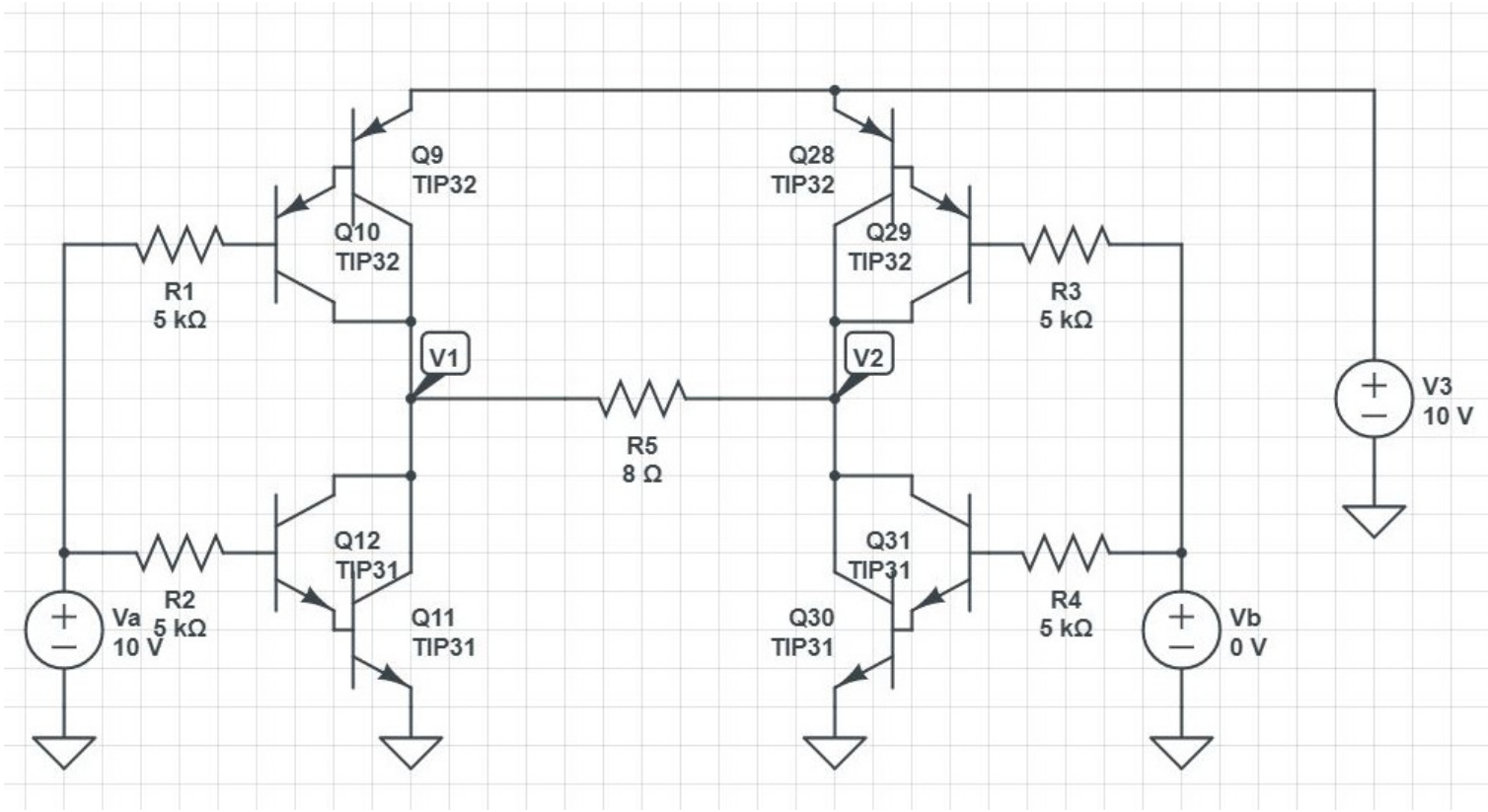
- V1 = 0.9V
- V2 = 9.1
- V12 = -8.20V
- I = -1.025A



CircuitLab

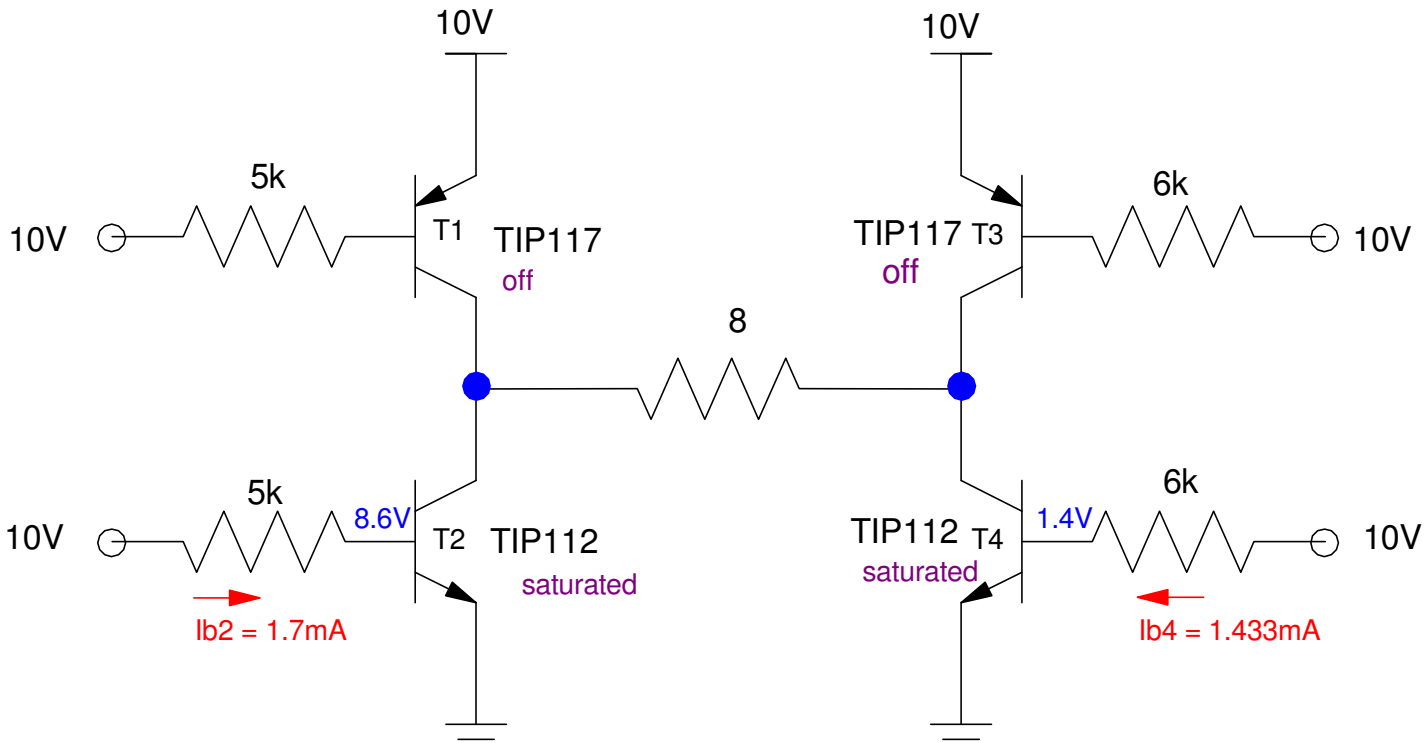
- V1 = 0.860V
- V2 = 9.266V
- **V12 = -8.406V**

  -8.2V calculated



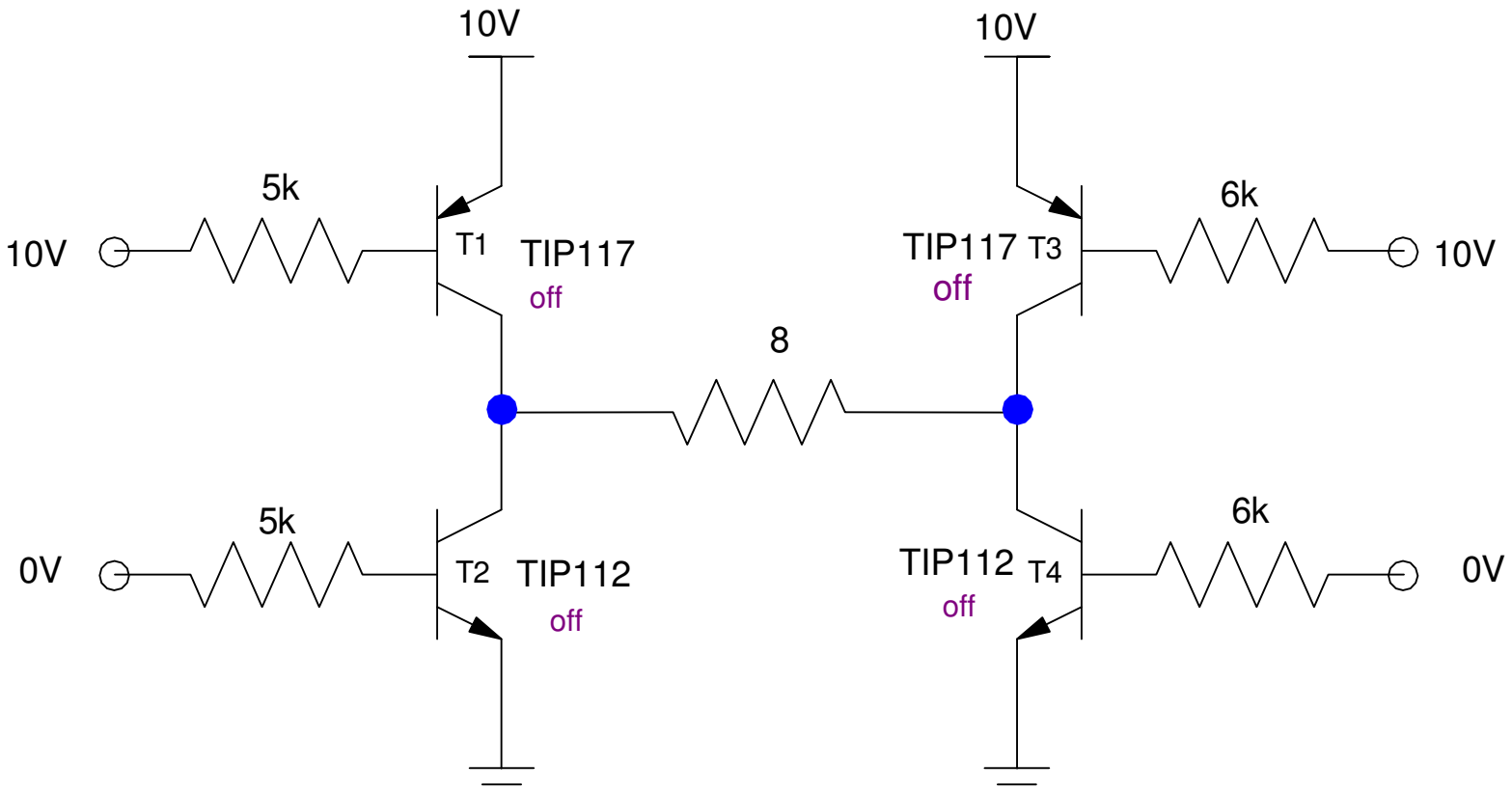
H-Bridge: Brake

- T2 and T4 on
- Motor acts as a geneator (kinetic energy converted to heat)



H-Bridge: Coast

- All transistors off
- Motor spins freely



H-Bridge Analysis (take 2)

If you do it wrong, a transistor will be in the active region.

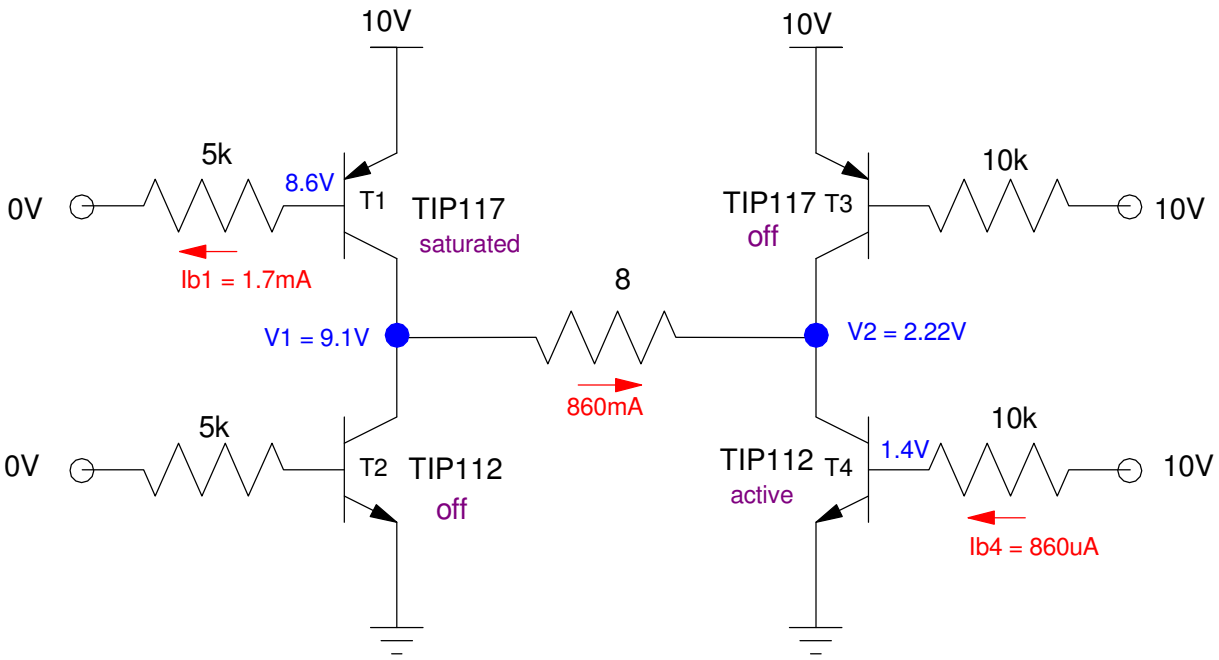
$$I_{b1} = \left(\frac{10-1.4}{5k}\right) = 1.720mA$$

$$I_{b4} = \left(\frac{10-1.4}{10k}\right) = 860\mu A$$

I is:

$$I = \min\left(\beta I_{b1}, \left(\frac{10-1.8}{8}\right), \beta I_{b4}\right)$$

$$I = \min\left(1.73A, 1.025A, 860mA\right)$$



T4 is in the active region (bad)

Fix: Make sure transistors are saturated

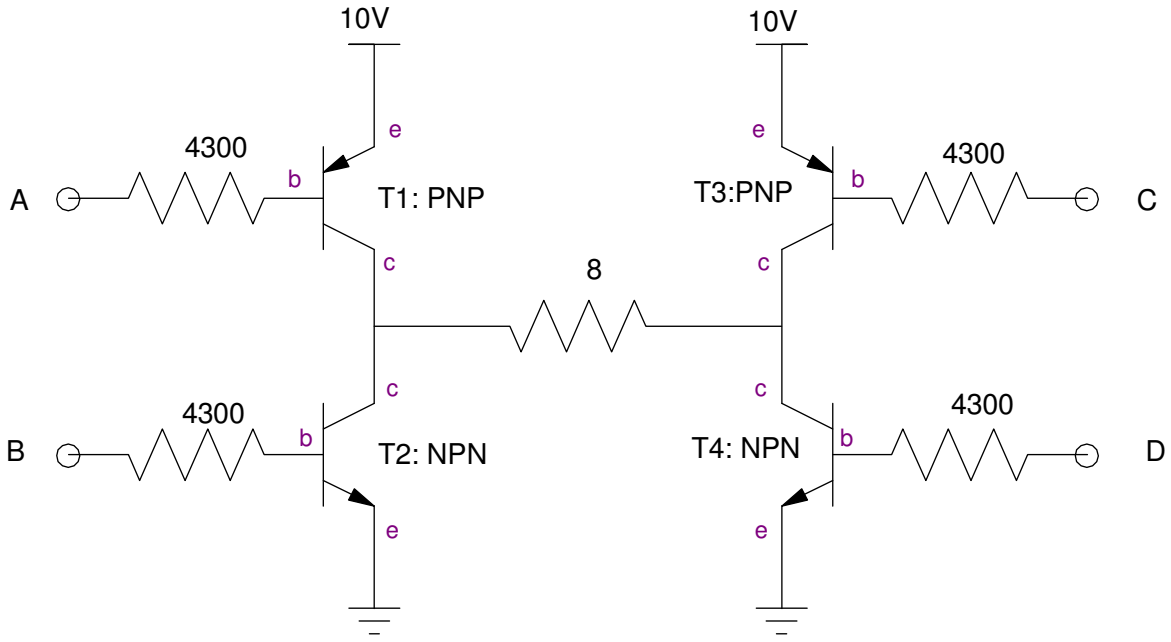
Since you're trying to push 1.025A through the 8 Ohm load, Ib should be

$$\beta I_b > I_c$$

$$I_b > \frac{I_c}{\beta} = \frac{1.025A}{1000} = 1.025mA$$

Let Ib = 2mA. Then

$$R_b = \left(\frac{10V - 1.4V}{2mA}\right) = 4300\Omega$$

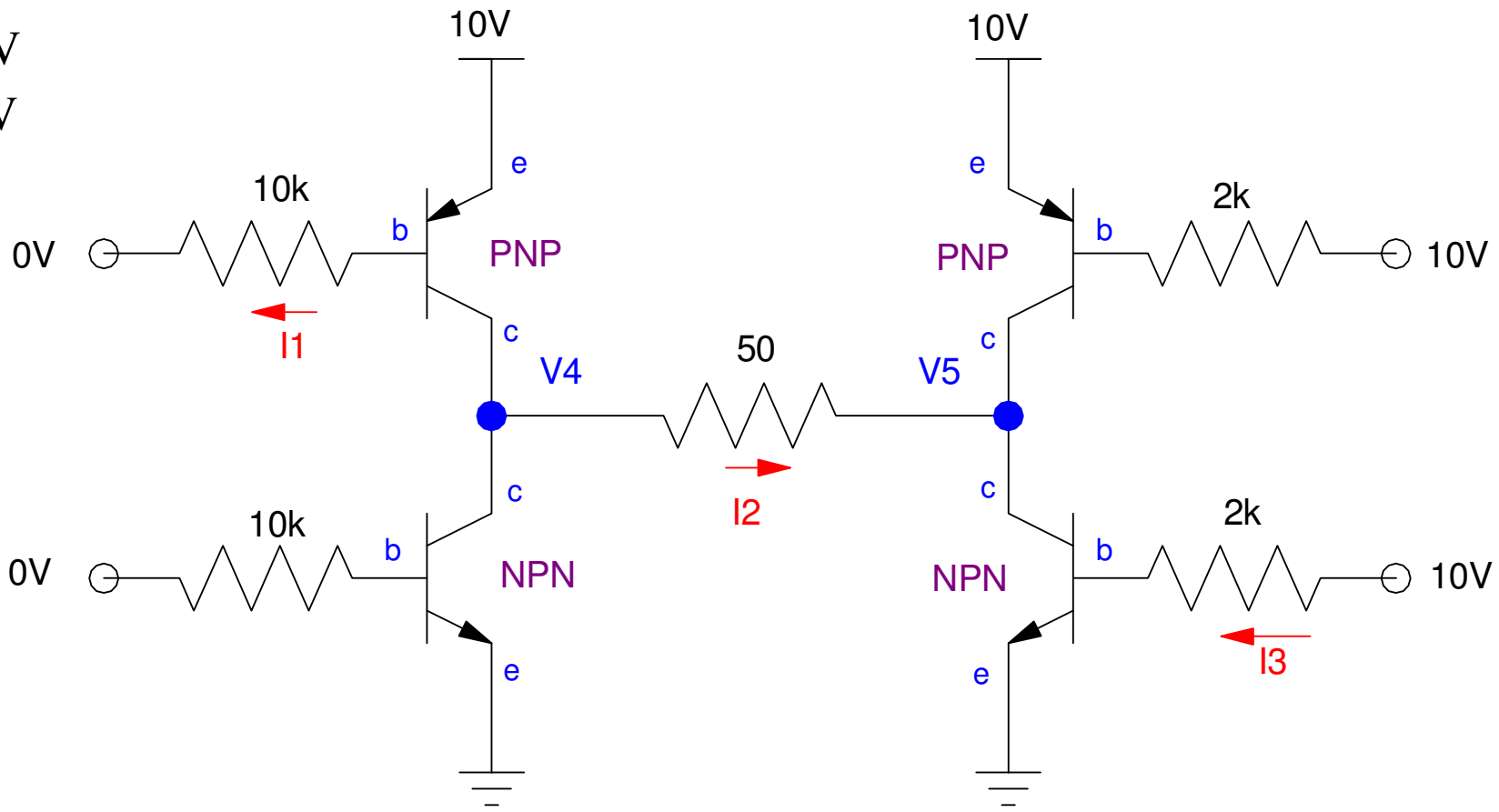


Handout

Find the voltages and currents.

Assume

- | Vbe | = 0.7V
- | Vce | > 0.2V
- β = 100

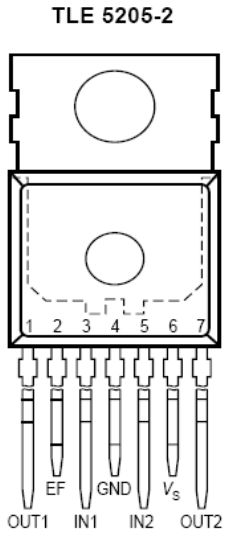


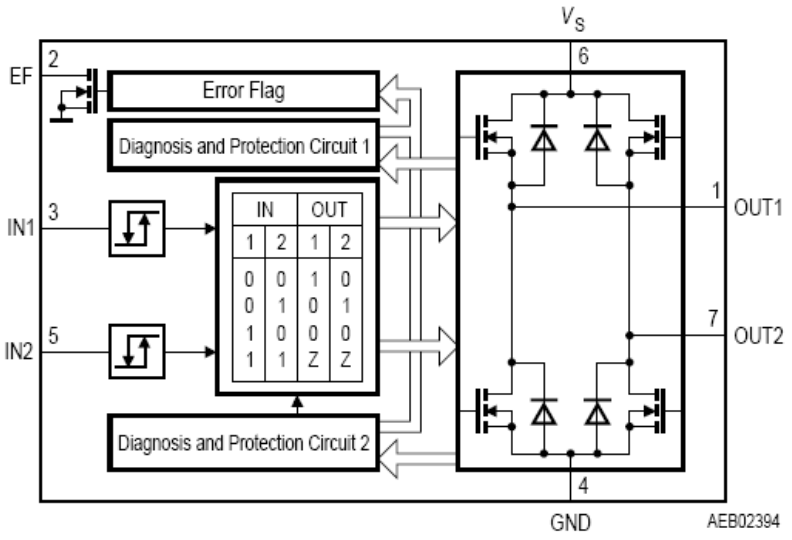
1/2 H-Bridge on a Chip: TLE5205:

H-Bridges are kind of useful.

- Available from Digikey ($7.16 each)

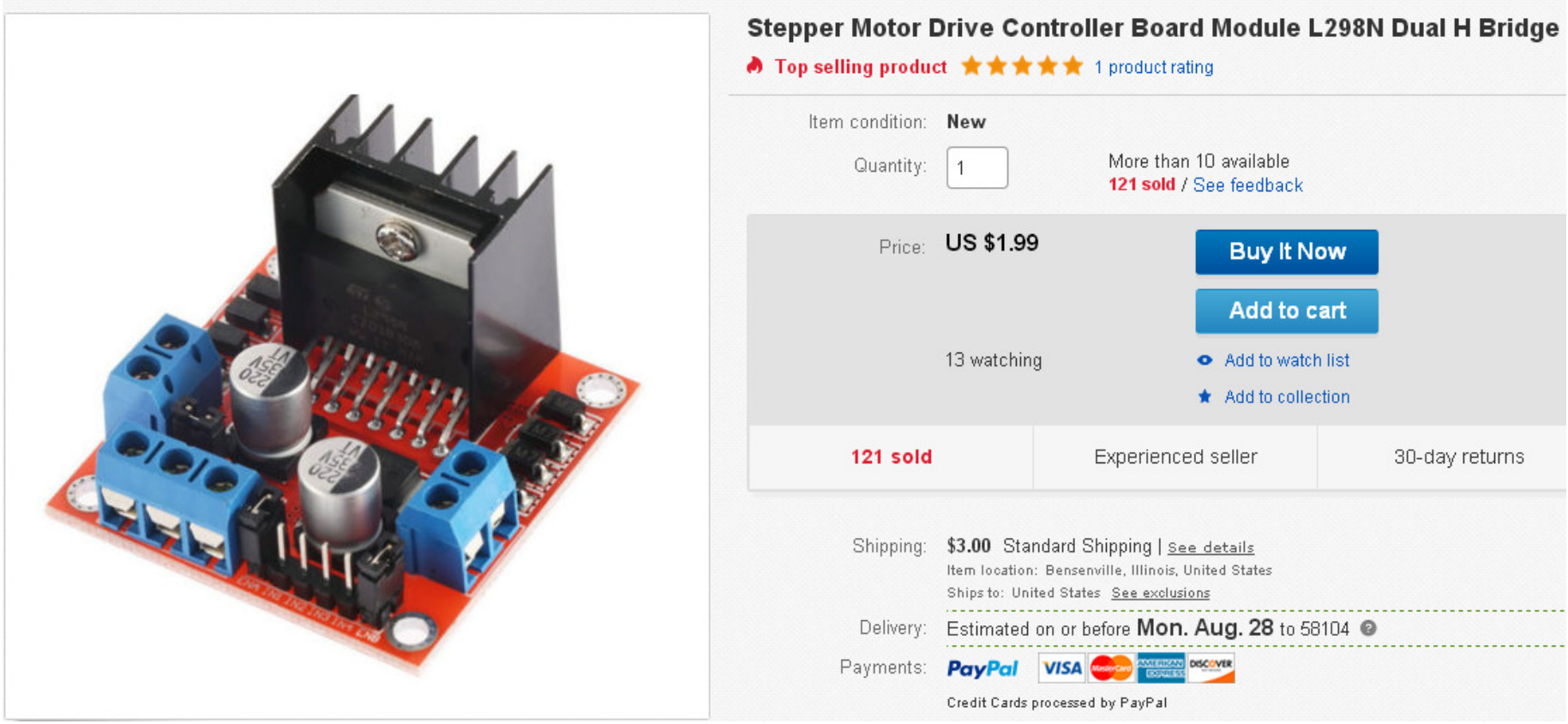
Functional Truth Table				
IN1	IN2	OUT1	OUT2	Comments
L	L	H	L	Motor turns clockwise
L	H	L	H	Motor turns counterclockwise
H	L	L	L	Brake:
H	H	Z	Z	Coast:





Dual H-Bridges: L298N

A third option is to use a ready-built H-bridge like the one shown below.



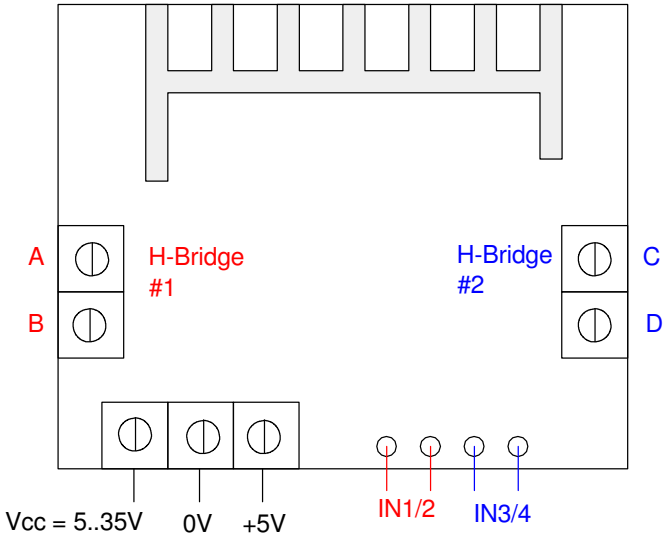
Dual H-Bridge from ebay (search: Arduino H Bridge)

This chip actually contains two H-bridges

- Voltage Range: 5V .. 35V
- Current Range: Up to 2A per channel
- Max Power: 25W:

IN-1	IN-2	Vab
0V	0V	0 V
0V	5V	+ Vcc
5V	0V	- Vcc
5V	5V	0 V

IN-3	IN-4	Vcd
0V	0V	0 V
0V	5V	+ Vcc
5V	0V	- Vcc
5V	5V	0 V



Goal: Demonstrate knowledge of H-bridges

- Build an H-bridge at the transistor level

Goal: Anything else

- Use an L298N board

H-Bridge Demo

With a single +5V power supply,

Drive a DC motor

- Forward
- Stop
- Reverse

Drive a speaker

- Forward
- 0V
- Reverse

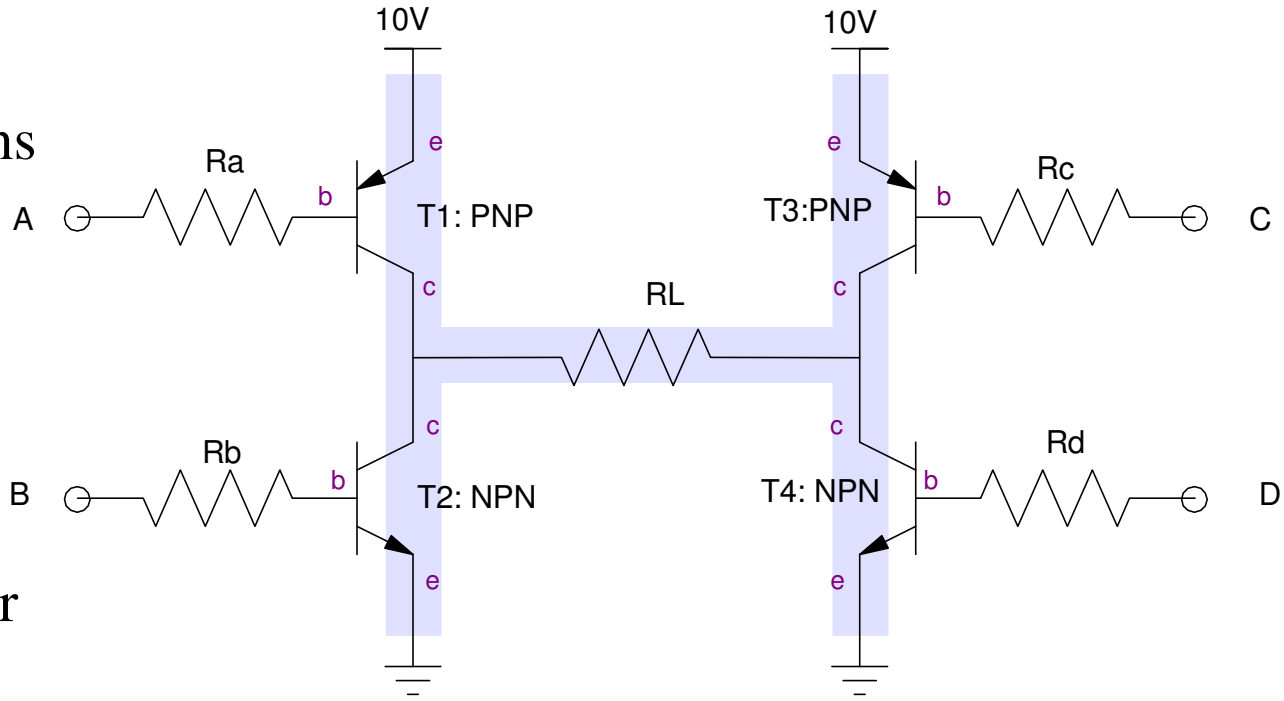
Summary

A transistor allows you turn turn a device

- On and
- Off

An H-bridge gives more options

- Forward
- Reverse
- Coast
- Brake



Ideally, all transistors are either

- Off, or
- Saturated