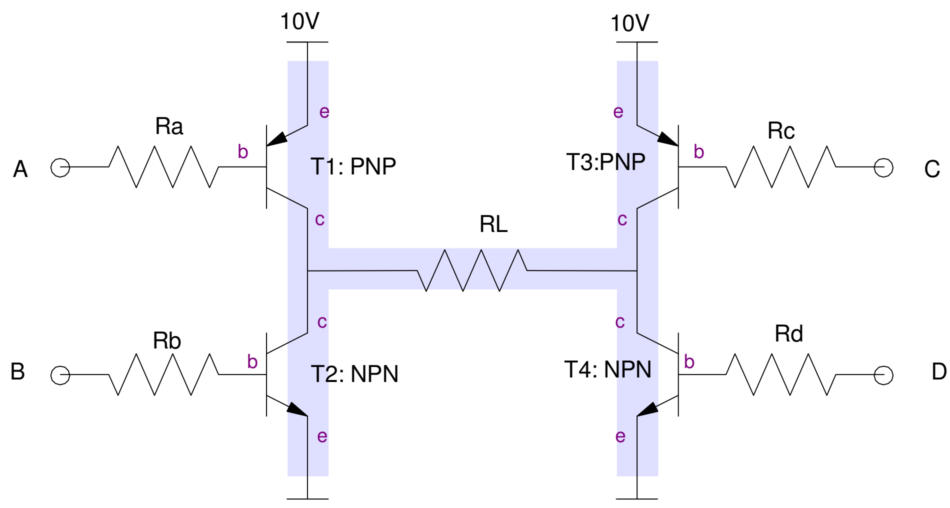
H-Bridges

With a single NPN transistor, you can turn a motor on and off. If the motor only spins in one direction, that's all you need. If you want to design a motor that can spin forward and backwards, you need an H-bridge.

To build an H-bridge, you need to NPN and two PNP transistors and four inputs. The connection to the load looks like the letter 'H' - hence the name H-bridge



H-Bridge

There are four modes of operation with an H-bridge:

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

There's actually a fifth mode:

- Smoke: All transistors on

When all transistors are on, you short power to ground. This tends to create lots of smoke and burns out components.

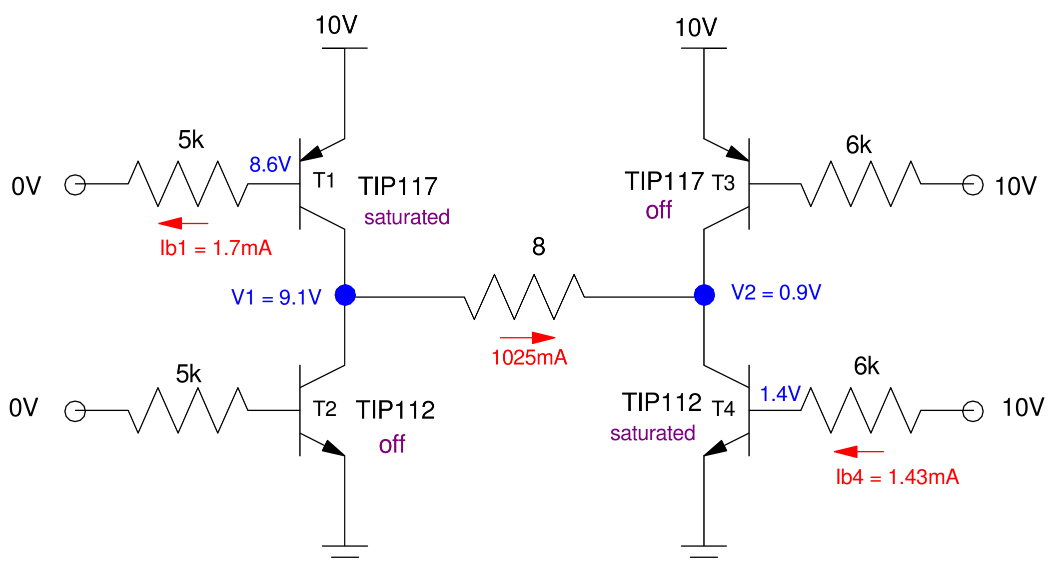
H-Bridge Analysis:

Given a circuit, determine the voltages and currents.

Assume TIP transistors

- $|V_{be}| = 1.4V$
- $\min(|V_{ce}|) = 0.9V$
- $\beta = 1000$

Forward: Determine the voltages and currents for the following H-bridge.



Case 1: Forward (VL = +8.2V)

To analyze this, determine the current. It will be the minimum of

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

Transistor T1 limits the current to 1.72A (βI_b)

$$I_{b1} = \left(\frac{10 - 1.4}{5k}\right) = 1.72mA$$

Transistor T4 limits the current to 1.433A

$$I_{b4} = \left(\frac{10 - 1.4}{6k}\right) = 1.433mA$$

The 8-Ohm resistor limits the current to

$$I_{max} = \left(\frac{10-0.9-0.9}{8}\right) = 1.025A$$

The current is the minimum of these three

$$I = \min(\beta I_{b1}, \beta I_{b4}, I_{RL})$$

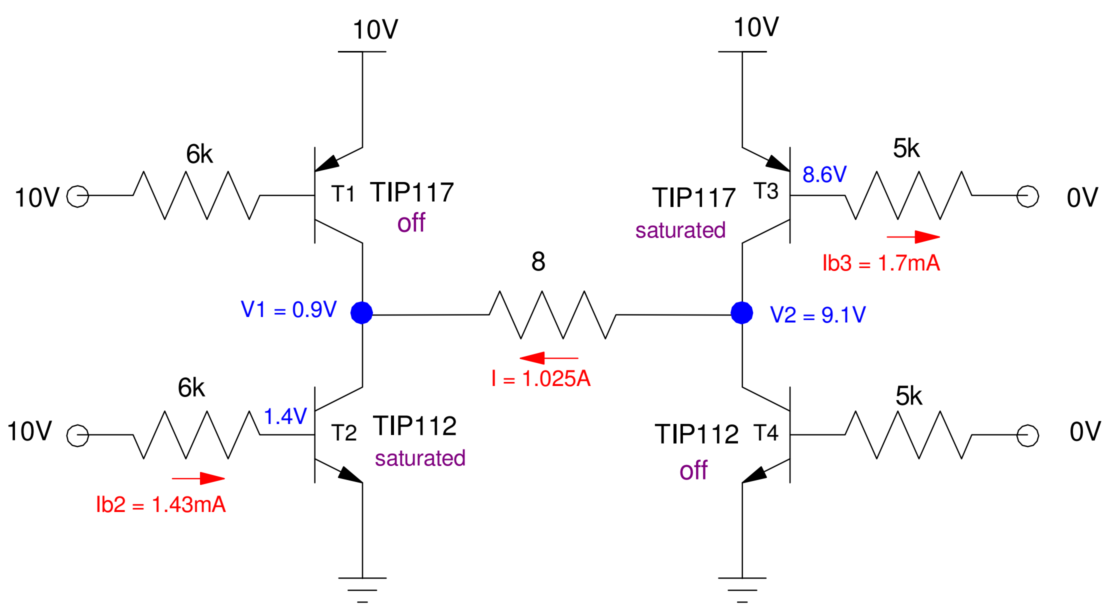
$$I = \min(1.72A, 1.433A, 1.025A)$$

Since RL limits the current, the transistors are saturated ($\beta I_b > I_c$) and

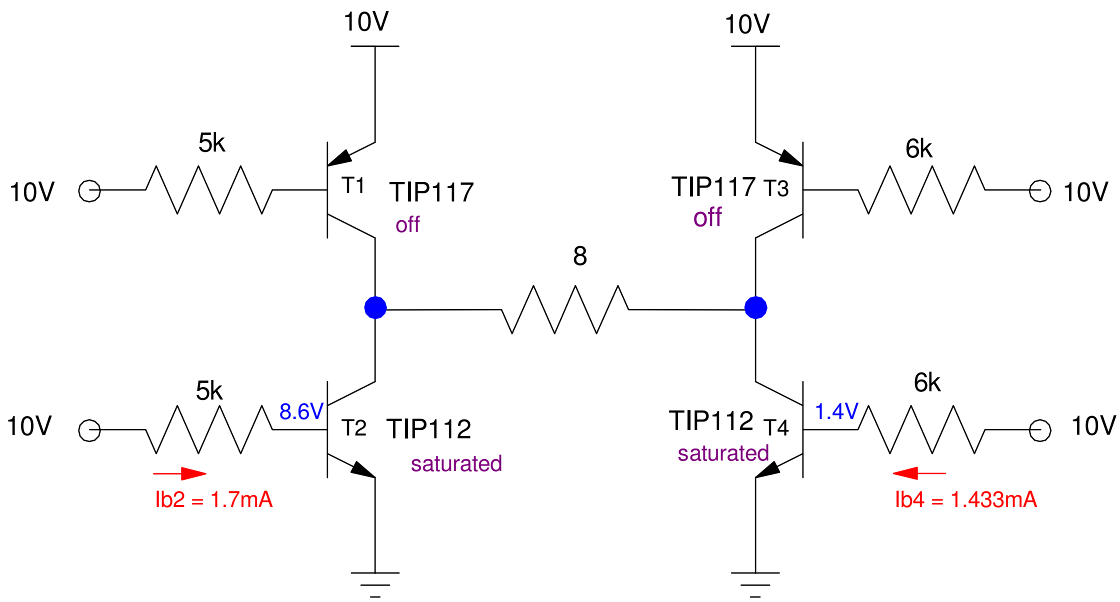
- V1 = 9.1V
- V2 = 0.9V
- I = 1.025A

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

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

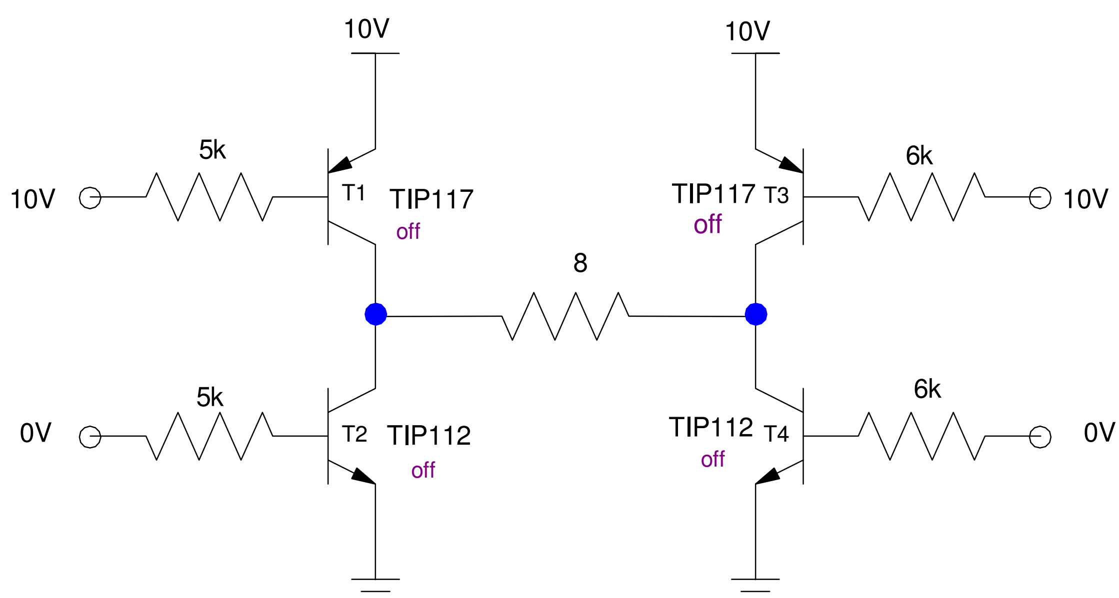


Braking: Turn on T2 and T4. This shorts the load out. If it's a motor, the motor acts as a generator, producing current which gets turned into heat as I^2R. This turns the kinetic energy into heat



Braking Mode: Short out the load

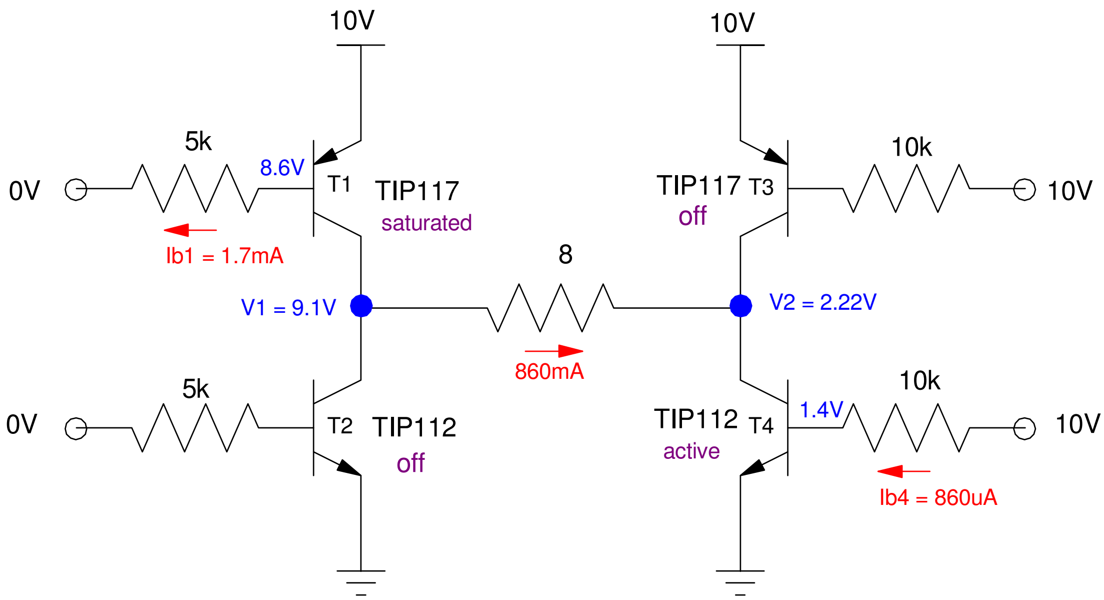
Coast: All transistors off.



Coast: All transistors off

H-Bridge Analysis (take 2)

If you do it wrong, a transistor will be in the active region. For example, find the voltages and currents



Solution: First find the base currents

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

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

The currents is then

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

$$I_L = \min(1.73A, 1.025A, 860mA)$$

Since transistor 4 wins, it limits the current and is operating in the active region.

T1 is saturated

- $\beta I_b = 1.74A > 860mA$
- $V_{ec} = 0.9V$
- $V_1 = 9.1V$

V2 is harder to find since T4 is in the active region. This tells you that 0.9V < Vce < 12V (i.e. dosn't help). To find V2, back into it

$$V_L = 8\Omega \cdot 860mA = 6.88V$$

$$V_2 = V_1 - 6.88V = 2.22V$$

This is actually a bad design: you want the transistors to saturate. 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

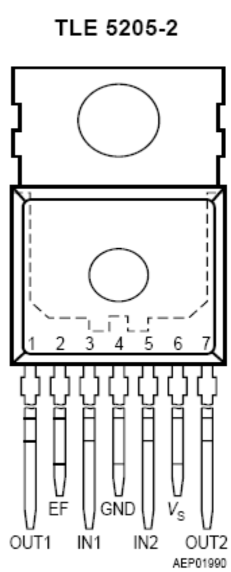
$$R_b = \left(\frac{10V - 1.4V}{2mA}\right) = 4300\Omega$$

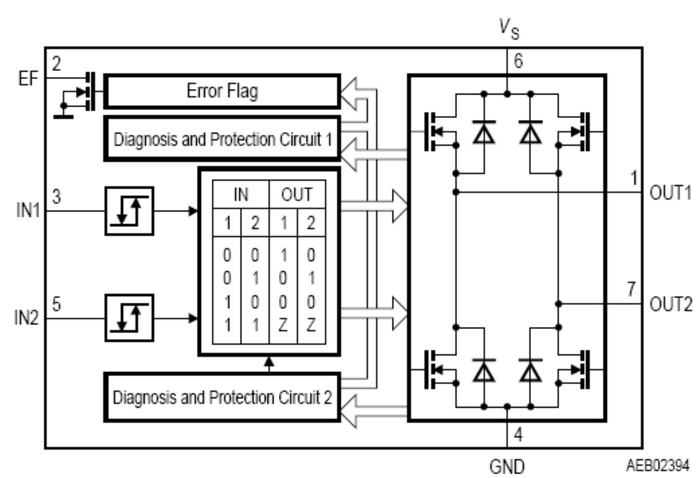
Make all four resistors 4.3k (give or take) and this H-bridge will be able to drive the load at

- +8.2V T1 and T4 on
- -8.2V T2 and T3 on
- 0V all transistors off

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

H-Bridges are kind of useful. Not surprisingly, there are H-bridges on a chip.



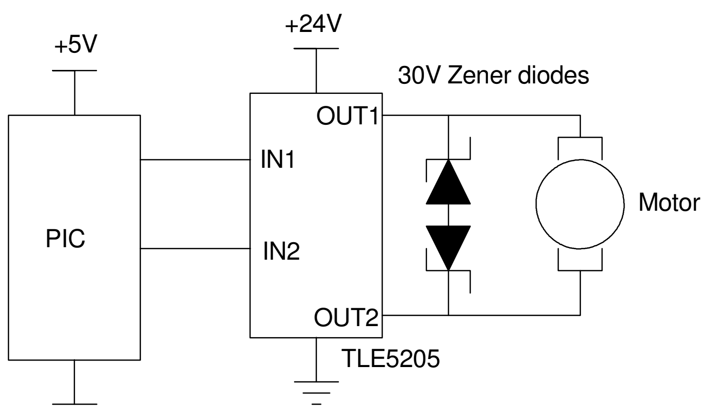


TLE5205 ($7.16 from Digikey)

This chip lets a PIC drive a motor at up to +40VDC, +5A using TTL levels. The logic from the PIC is:

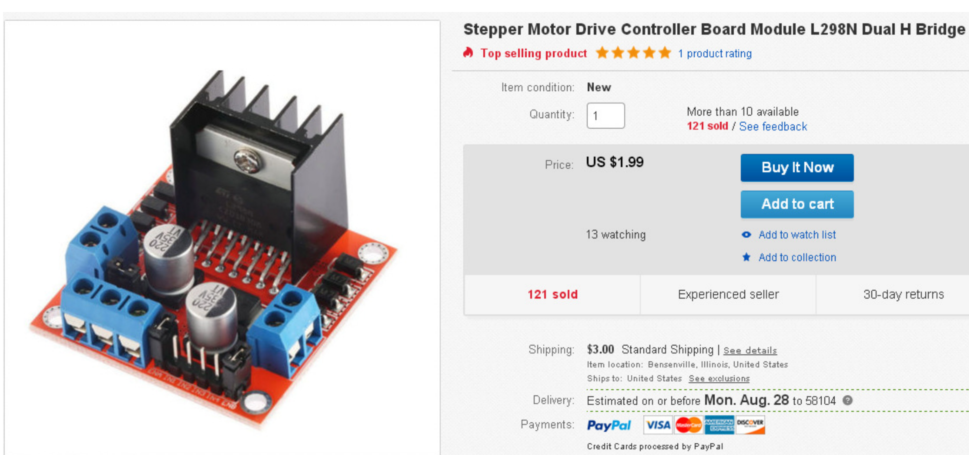
Functional Truth Table				
IN1	IN2	OUT1	OUT2	Comments
L	L	H	L	Motor turns clockwise
L	H	L	H	Motor turns counterclockwise
H	L	L	L	Brake; both low side transistors turned-ON
H	H	Z	Z	Coast: no current through the motor

note: You need to use zener diodes to protect the chip at the output. Use zener diodes slightly larger than the voltage driving the motor.



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, each capable of

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

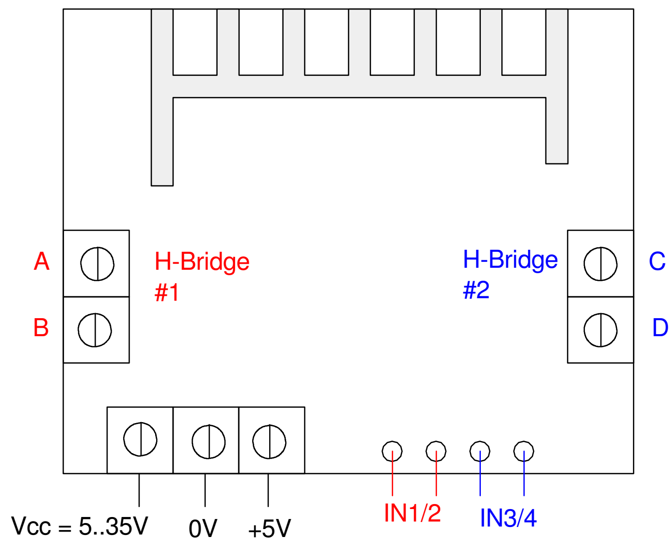
The board contains two H-bridges

- { IN-1, IN-2 } control voltage Vab
- { IN-3, IN-4 } control voltage Vcd

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

If you're trying to demonstrate knowledge of electronics and H-bridges, I'd build an H-bridge at the transistor level. If you're trying to demonstrate something else, I'd use an L298N board. They're inexpensive, they're easy to use, and they work.



Wiring for a L298N board IN1 and IN2 control the voltage V_{AB}. IN3 and IN4 control the voltage V_{CD}.