

Motor Control

Questions?

Direct Current (DC) Motors

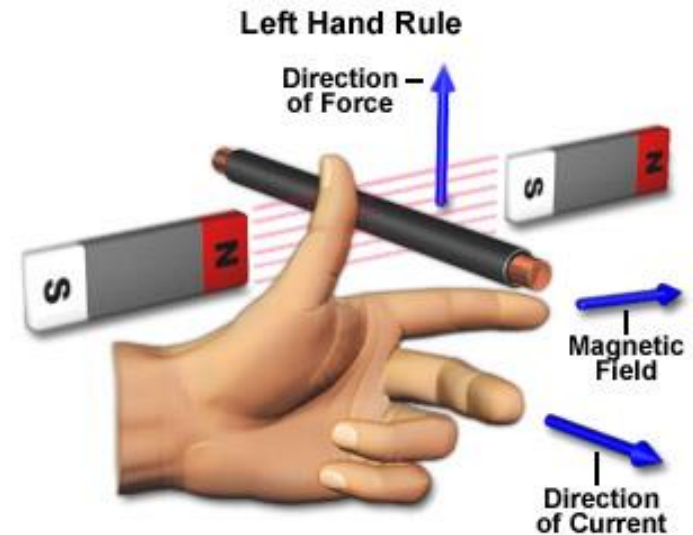
- Rotating shaft
- Fixed pair of magnets

www.pcgadgets.com



Direct Current (DC) Motors

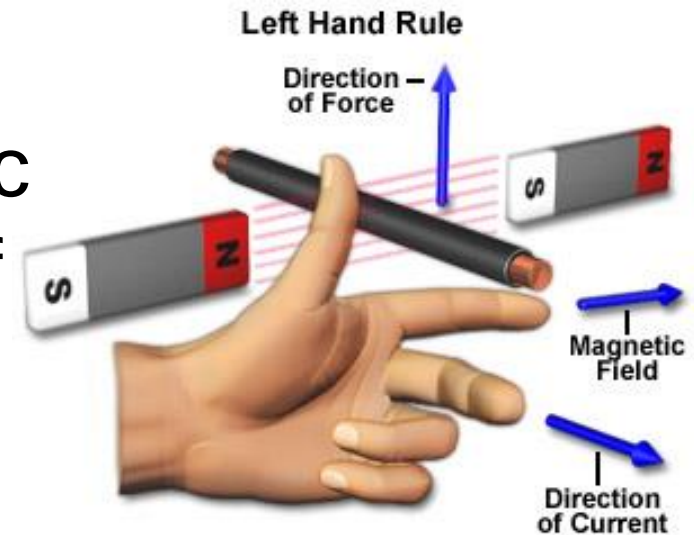
Wire placed within a magnetic field ...



Direct Current (DC) Motors

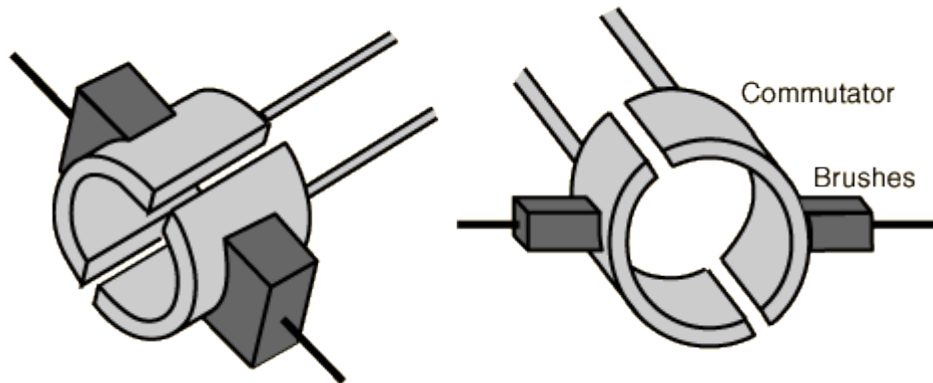
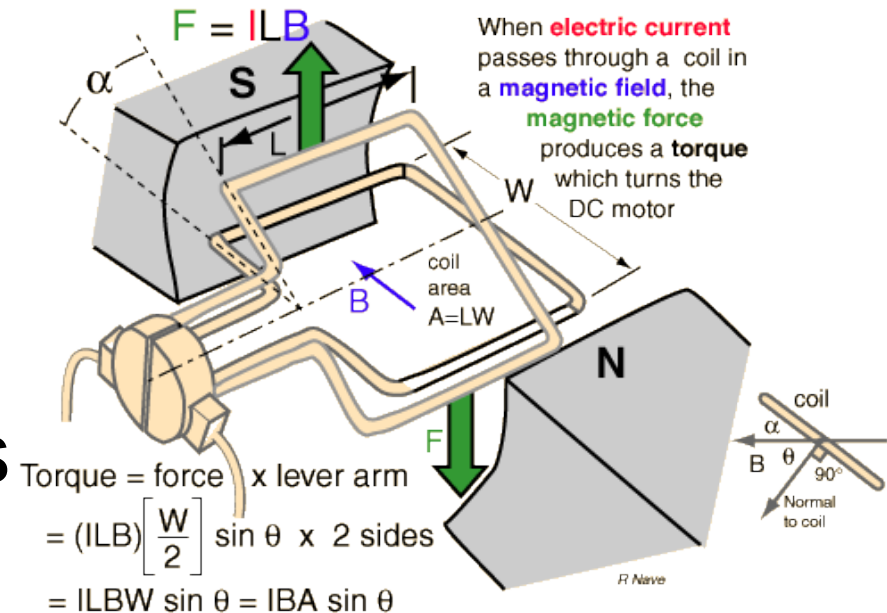
Wire placed within a magnetic field:

- Force on the wire is perpendicular the magnetic field and to the direction of current through the wire
- Direction of force: determined by the left-hand rule



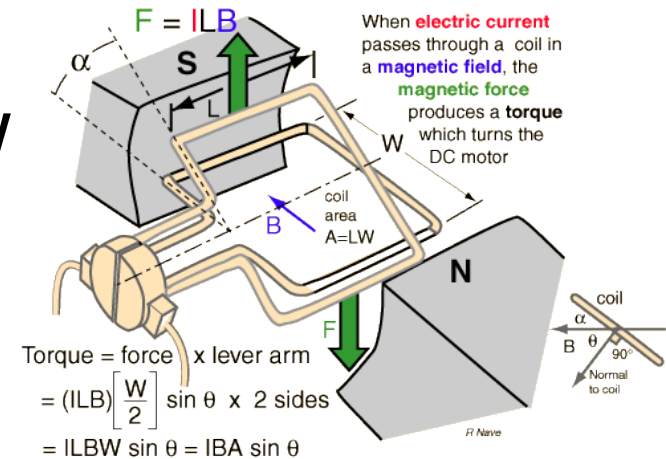
Direct Current (DC) Motors

- Force on the wire induces a torque about the motor shaft
- Commutator switches direction of current every half cycle
- Direction of torque remains the same throughout the cycle



DC Motors

- Average motor torque is proportional to current flow through the wire
 - Wire has some resistance
- Direction of current flow determines torque direction

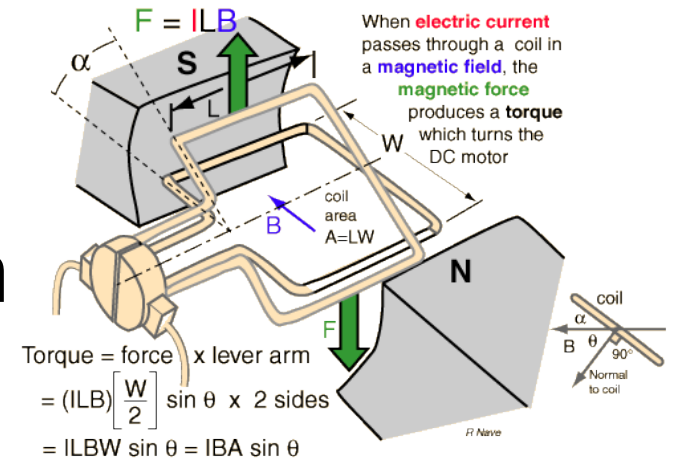


How can a digital input control torque magnitude?

DC Motors

How can a digital input control torque magnitude?

- Use Pulse Width Modulation (PWM)!

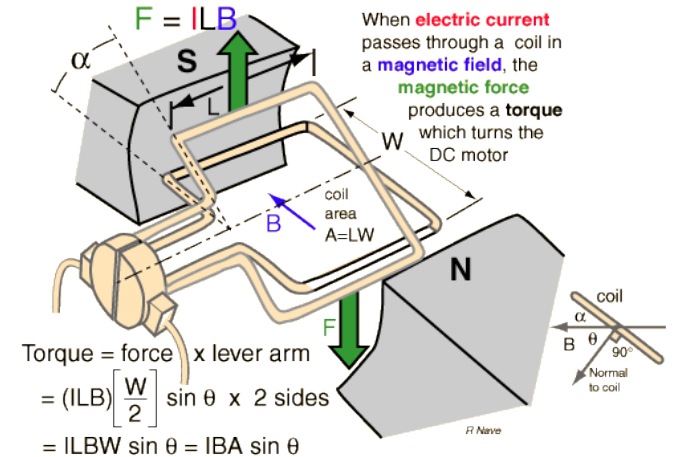


How do we handle torque direction?

DC Motors

How do we handle torque direction?

- +3.3V to north 0V to south
- 0V to north +3.3V to south



How would we implement this with our microcontroller?

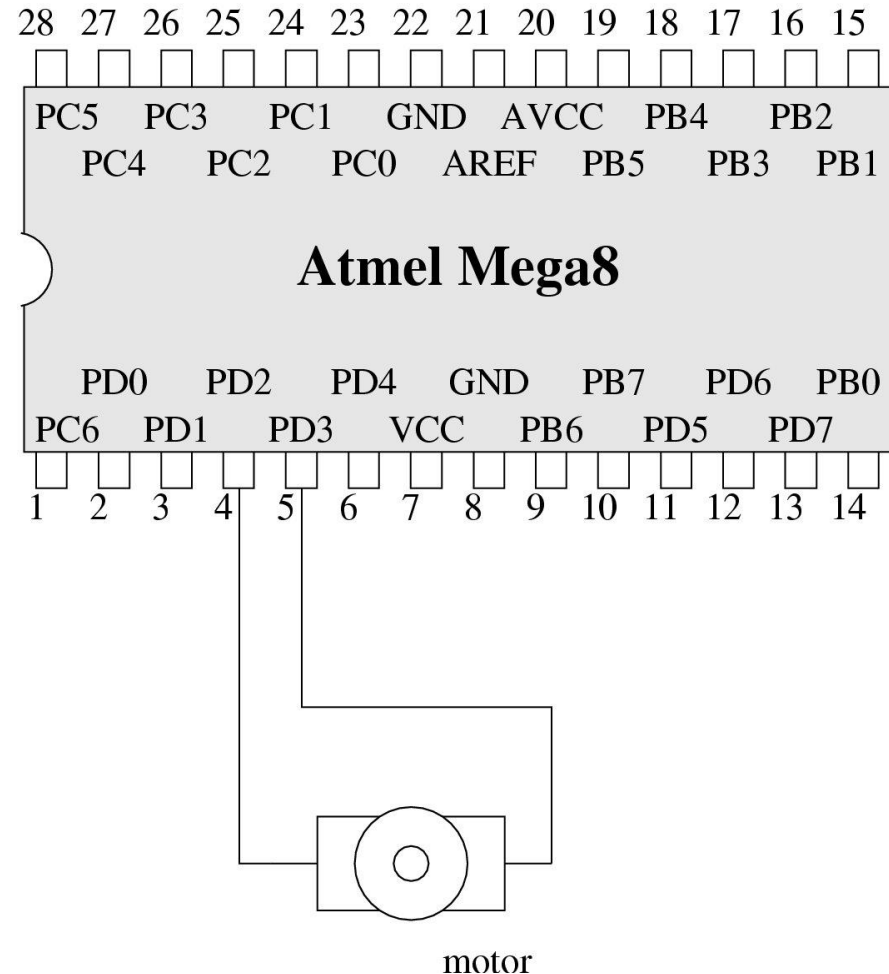
DC Motor Control

One possibility...

- Connect motor directly to the I/O pins

Two directions:

- PD2: 1; PD3: 0
- PD2: 0; PD3: 1

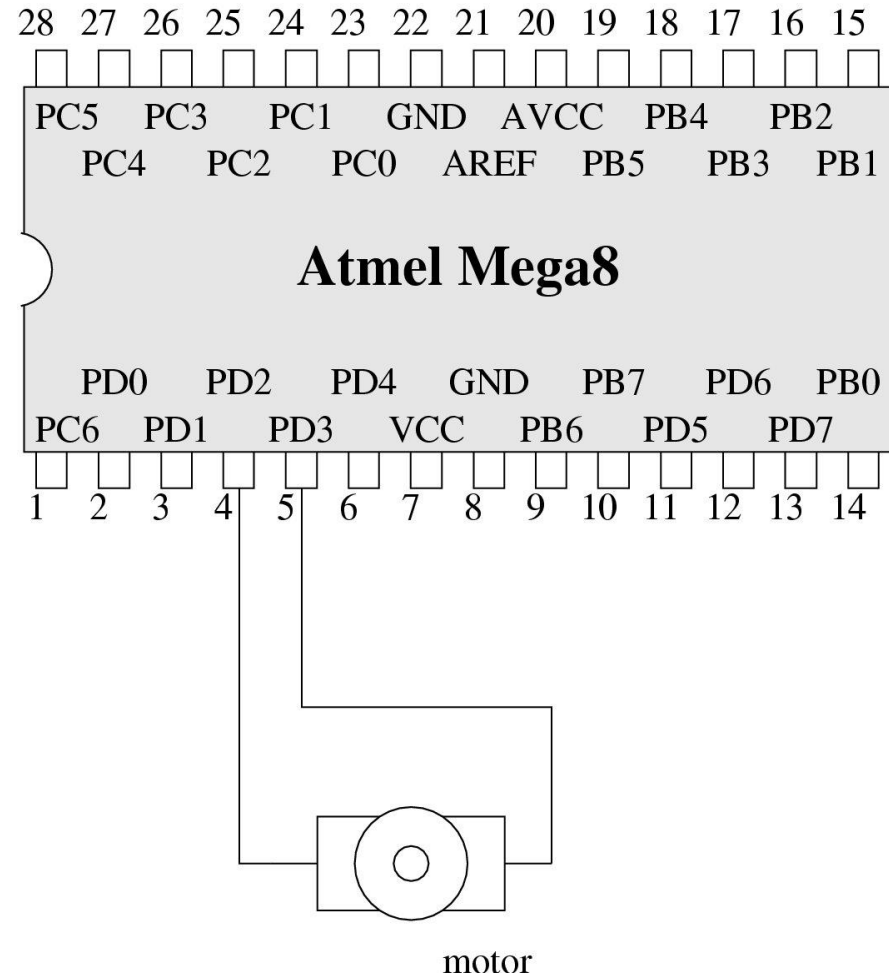


DC Motor Control

One possibility...

- Connect motor directly to the I/O pins

What is wrong with this implementation?

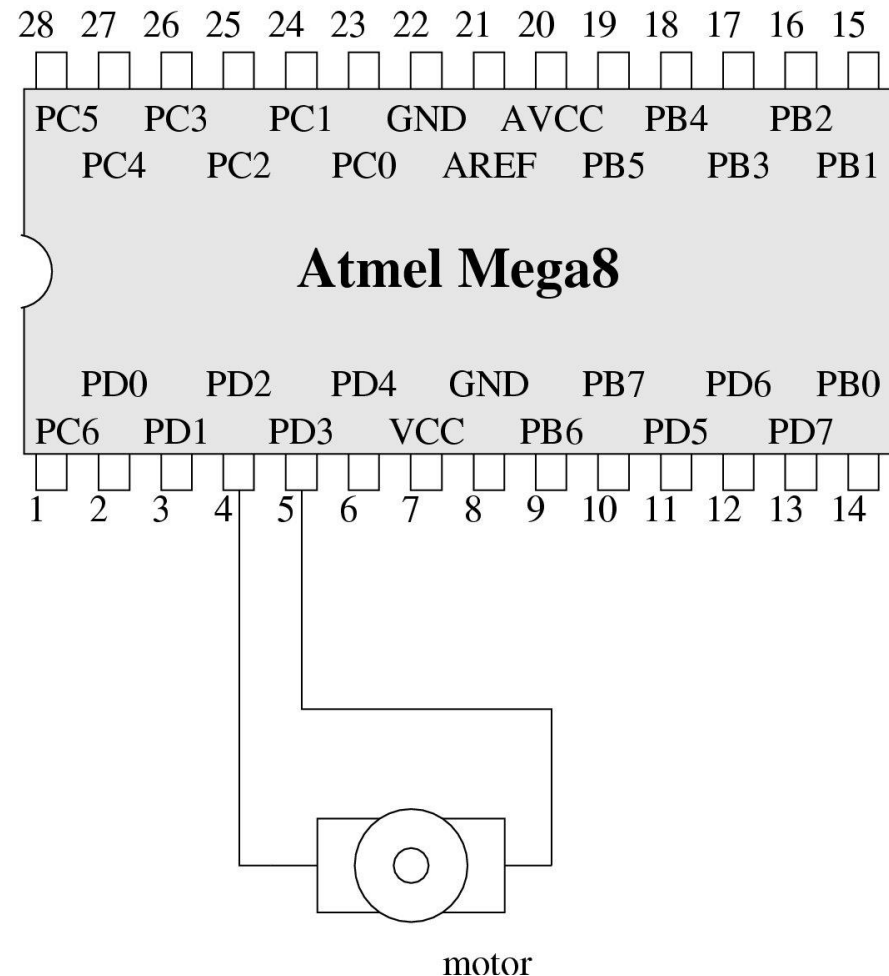


DC Motor Control

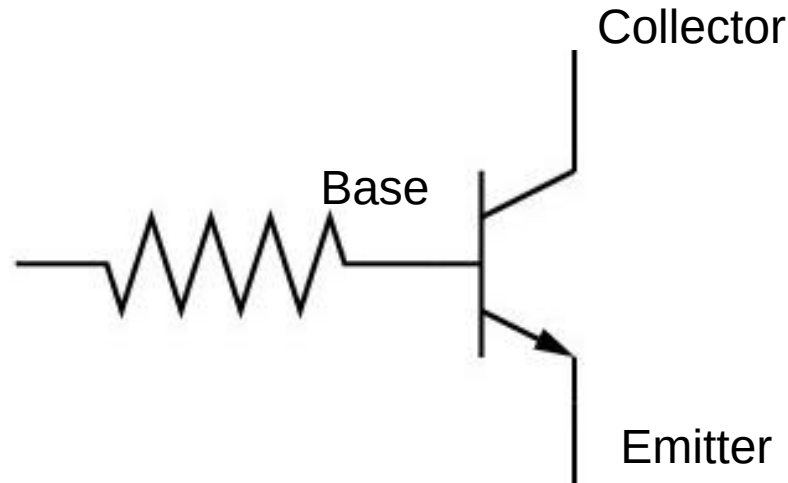
What is wrong with this implementation?

- Our I/O pins can source/sink at most 10 mA of current
- This is not very much when it comes to motors...

How do we fix this?



NPN Transistors

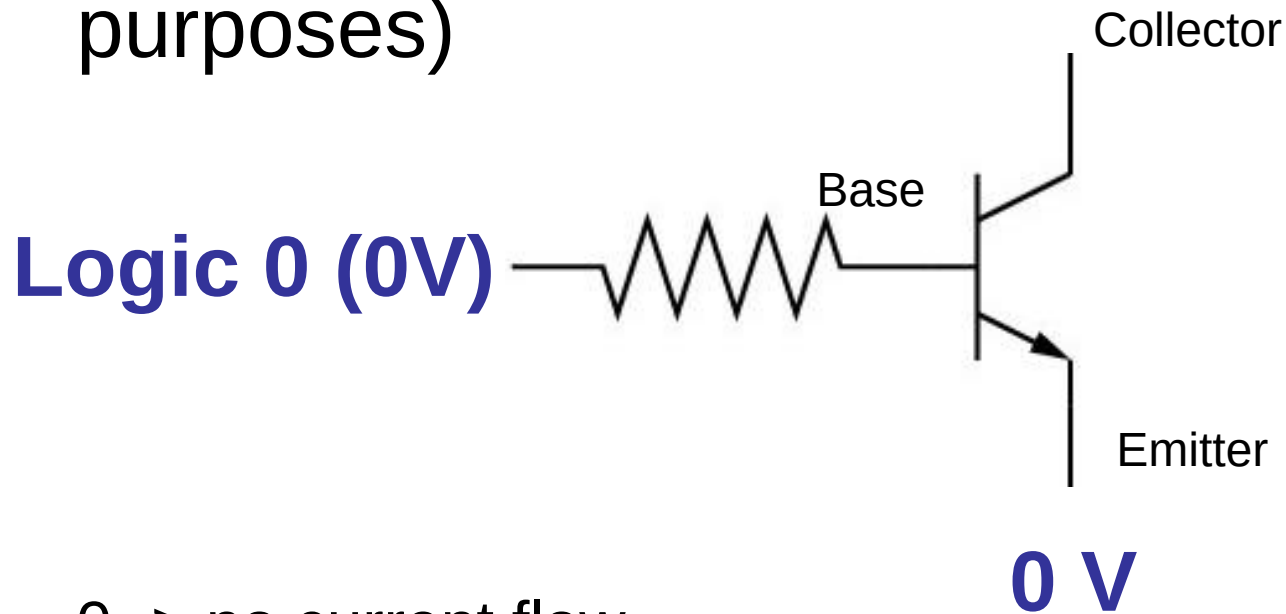


Base to emitter is a diode!

- Current from base to emitter is non-negative
- Small B- $\rightarrow$ E current opens a “valve” that allows large C- $\rightarrow$ E current

Transistors as Switches

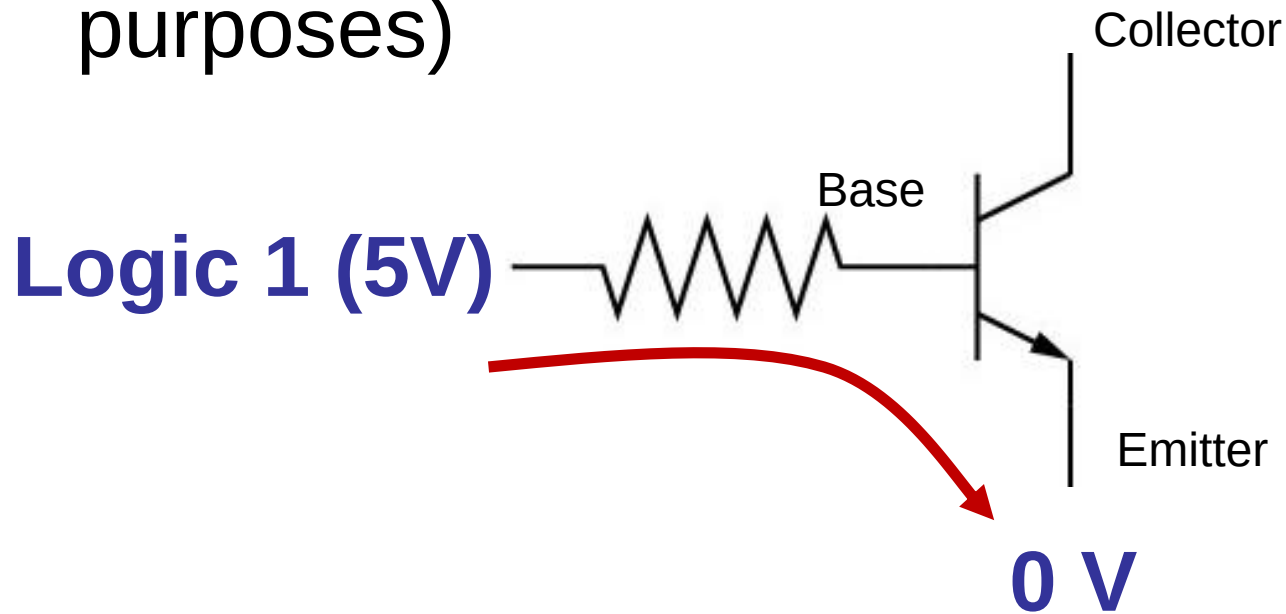
(what we need to understand for our purposes)



0 -> no current flow

Transistors as Switches

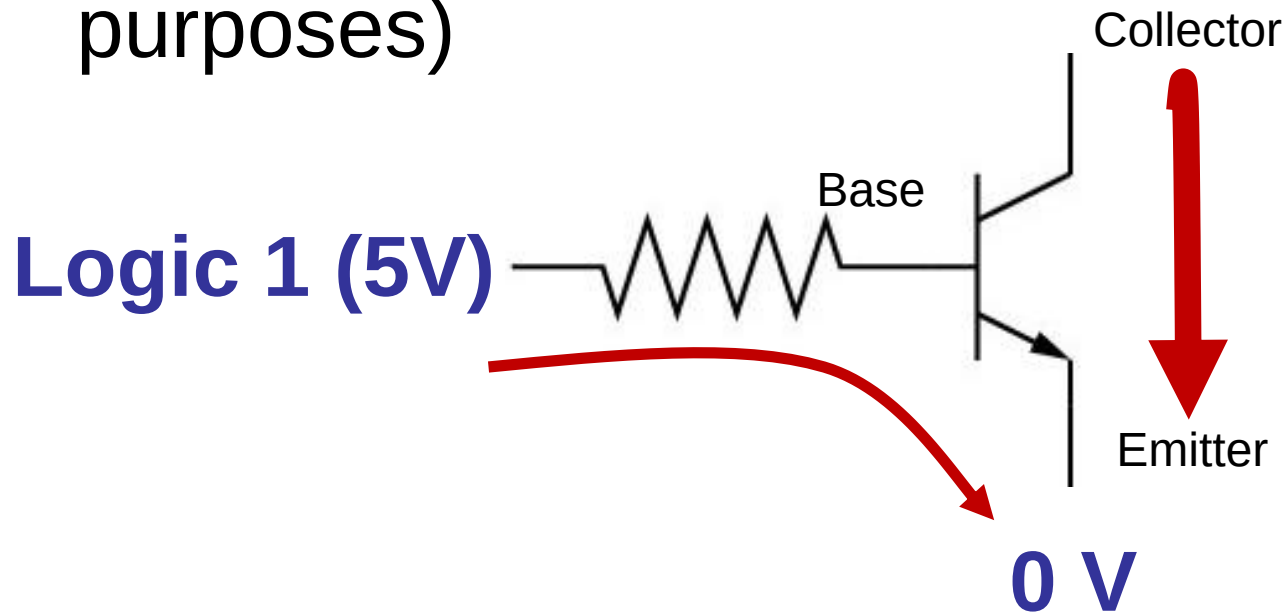
(what we need to understand for our purposes)



1 -> small amount of current flow from base to emitter

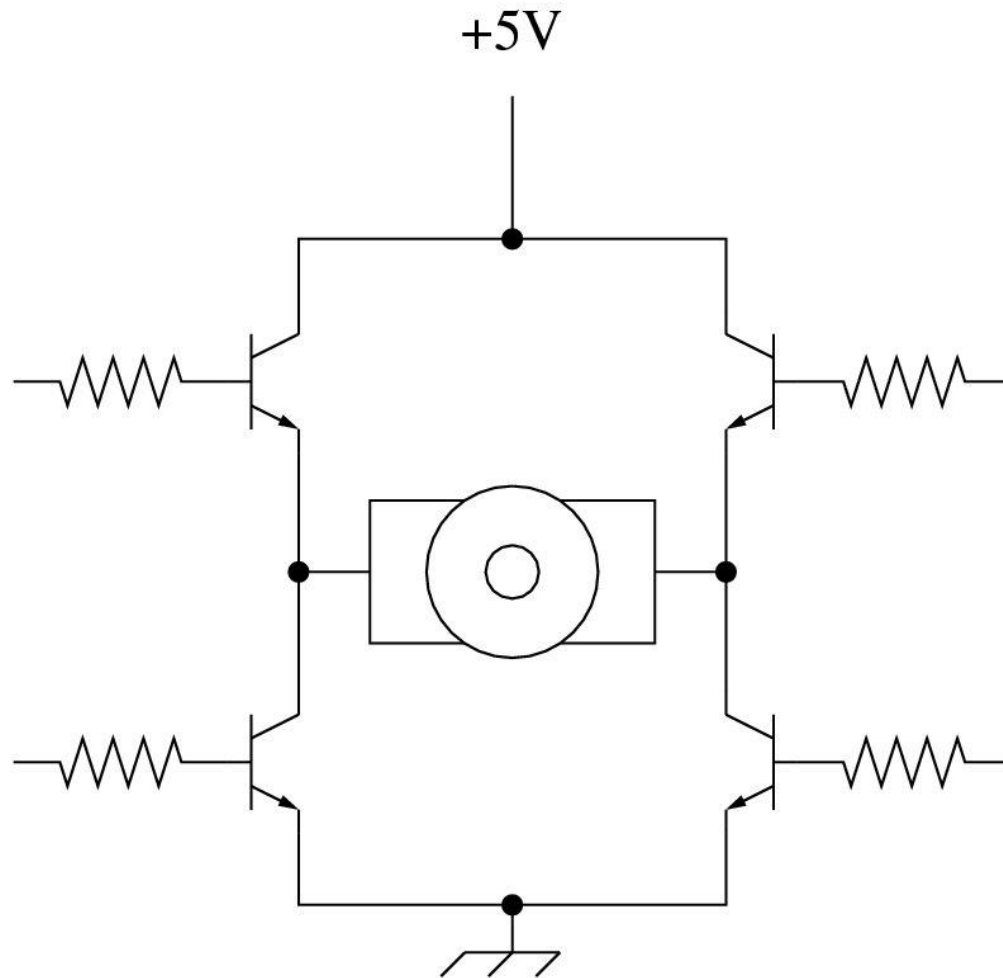
Transistors as Switches

(what we need to understand for our purposes)



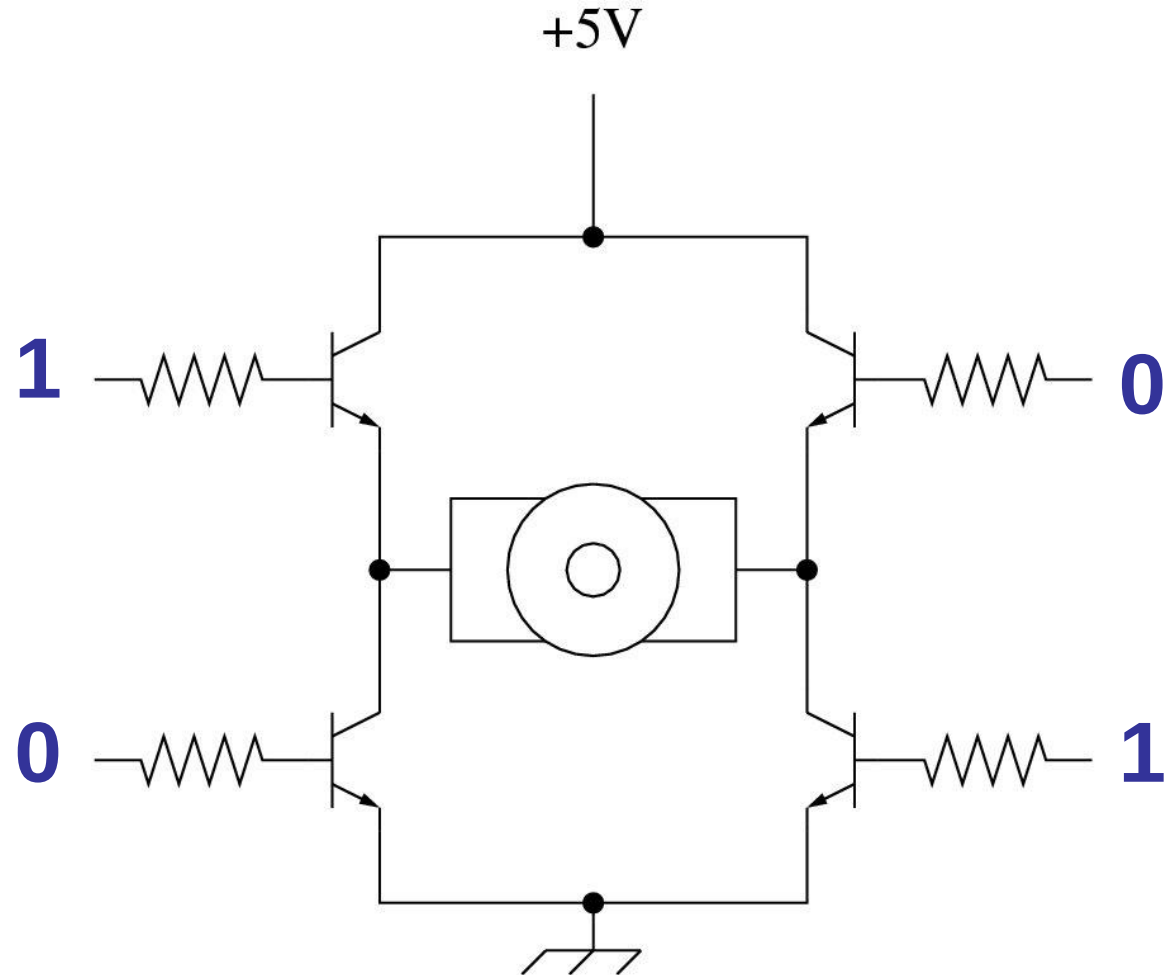
1 -> small amount of current flow from base to emitter
also allows (possibly large) current to flow from
collector to emitter

Simple H-Bridge



Simple H-Bridge

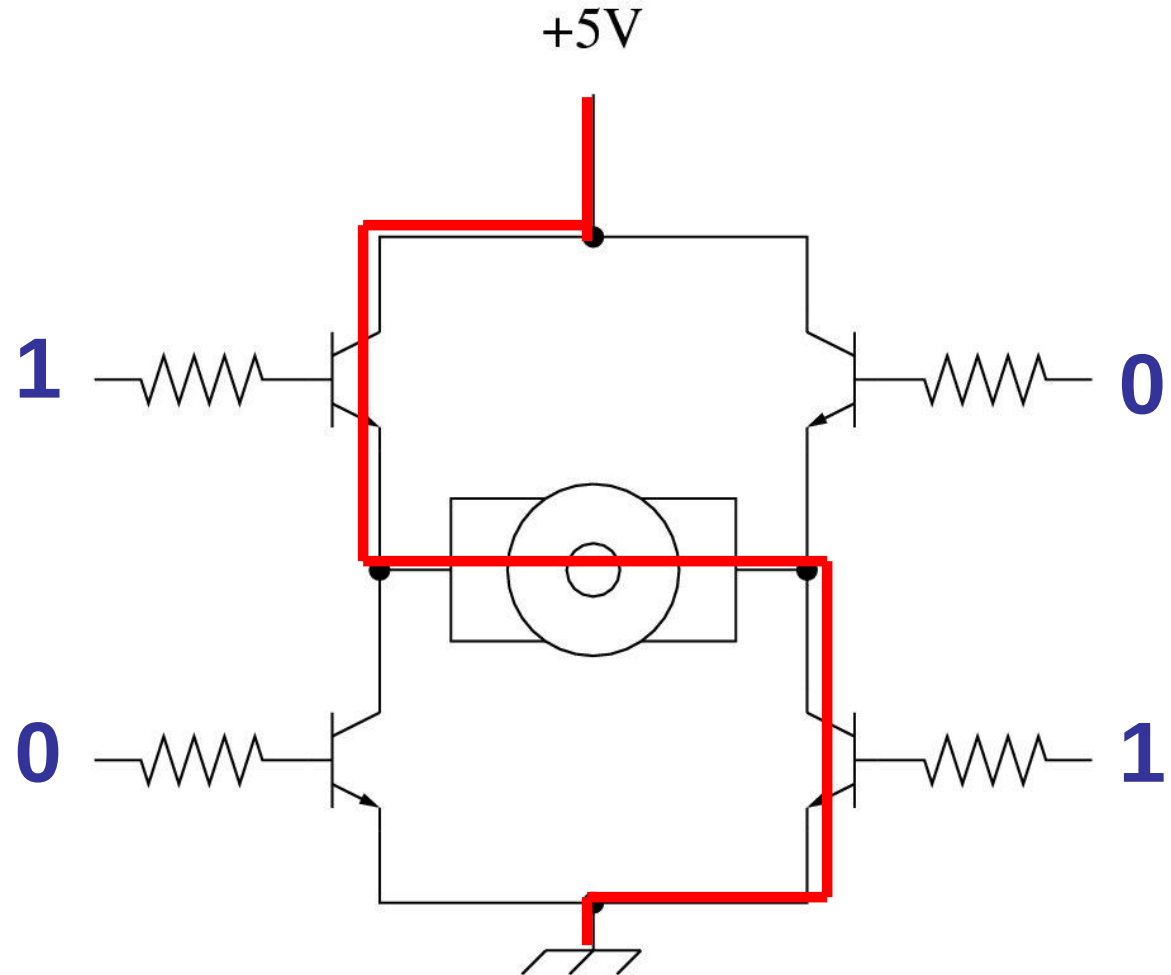
What
happens
with these
inputs?



Simple H-Bridge

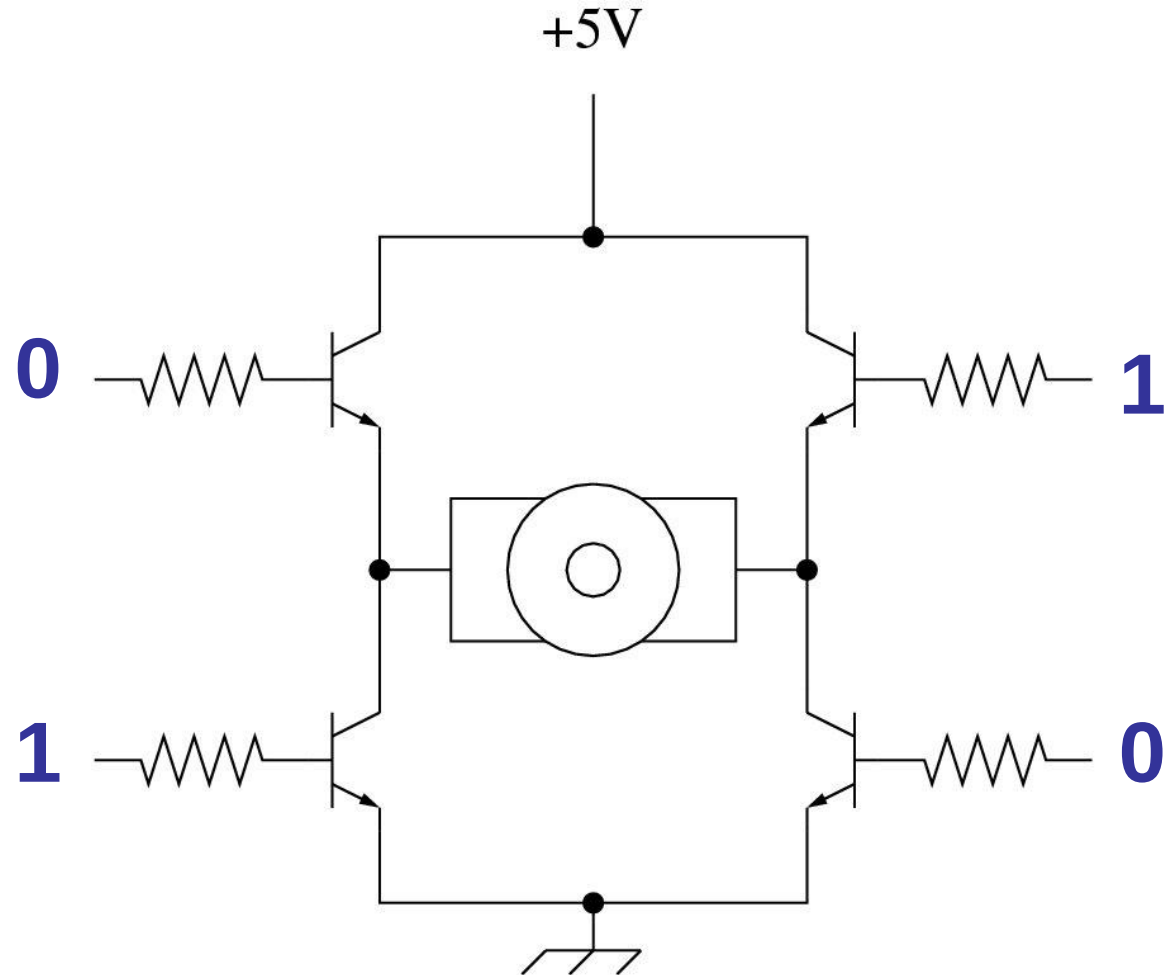
What happens with these inputs?

- Motor turns in one direction



Simple H-Bridge

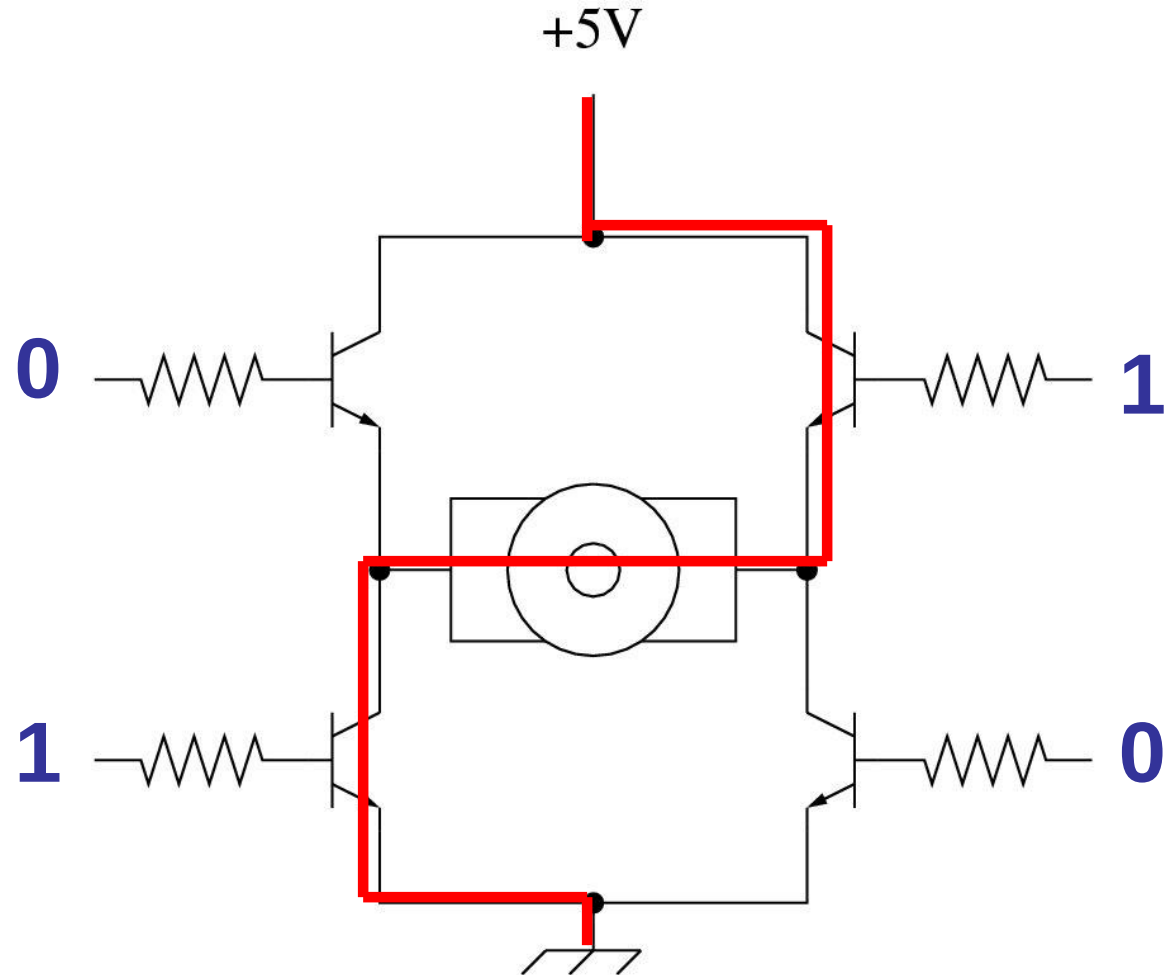
How about
these
inputs?



Simple H-Bridge

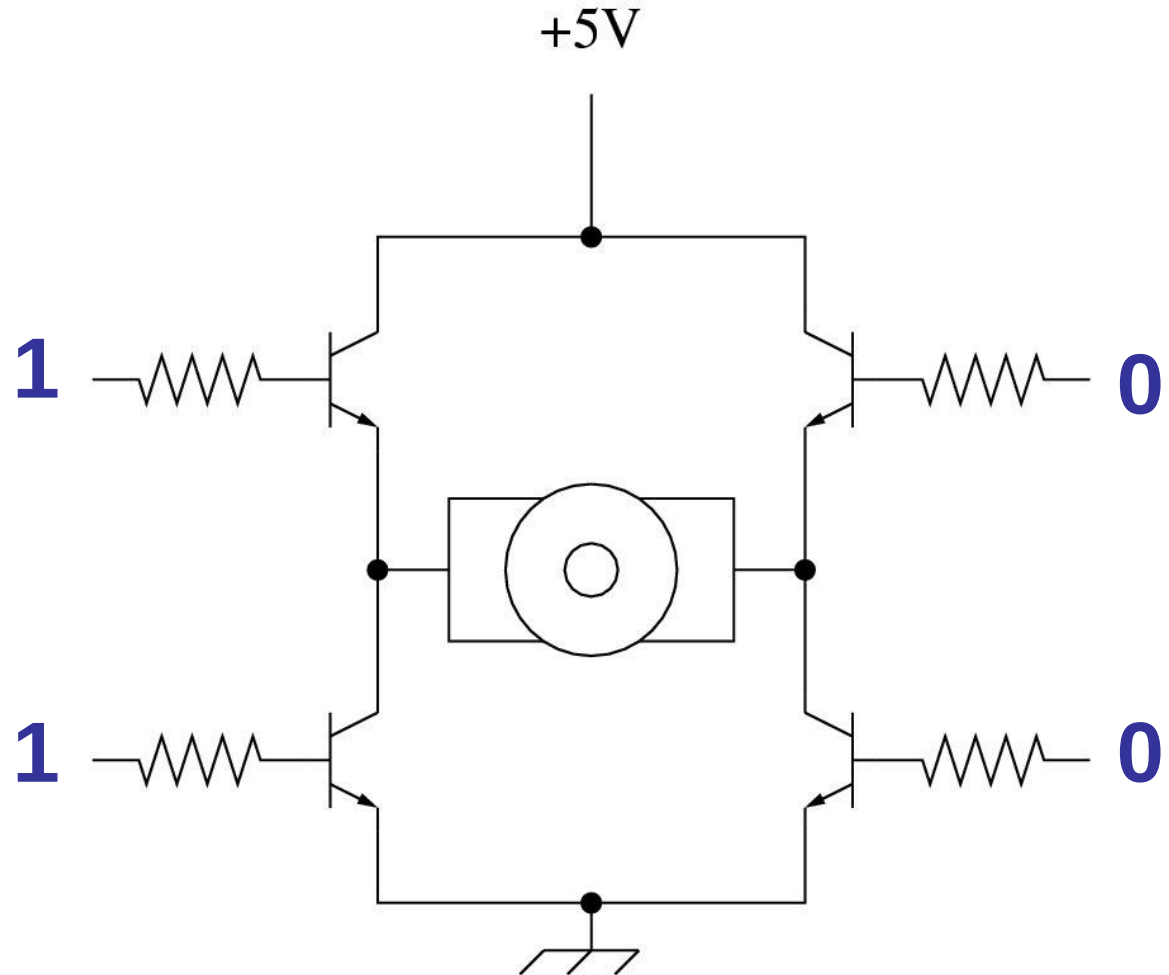
What happens with these inputs?

- Motor turns in the other direction!



Simple H-Bridge

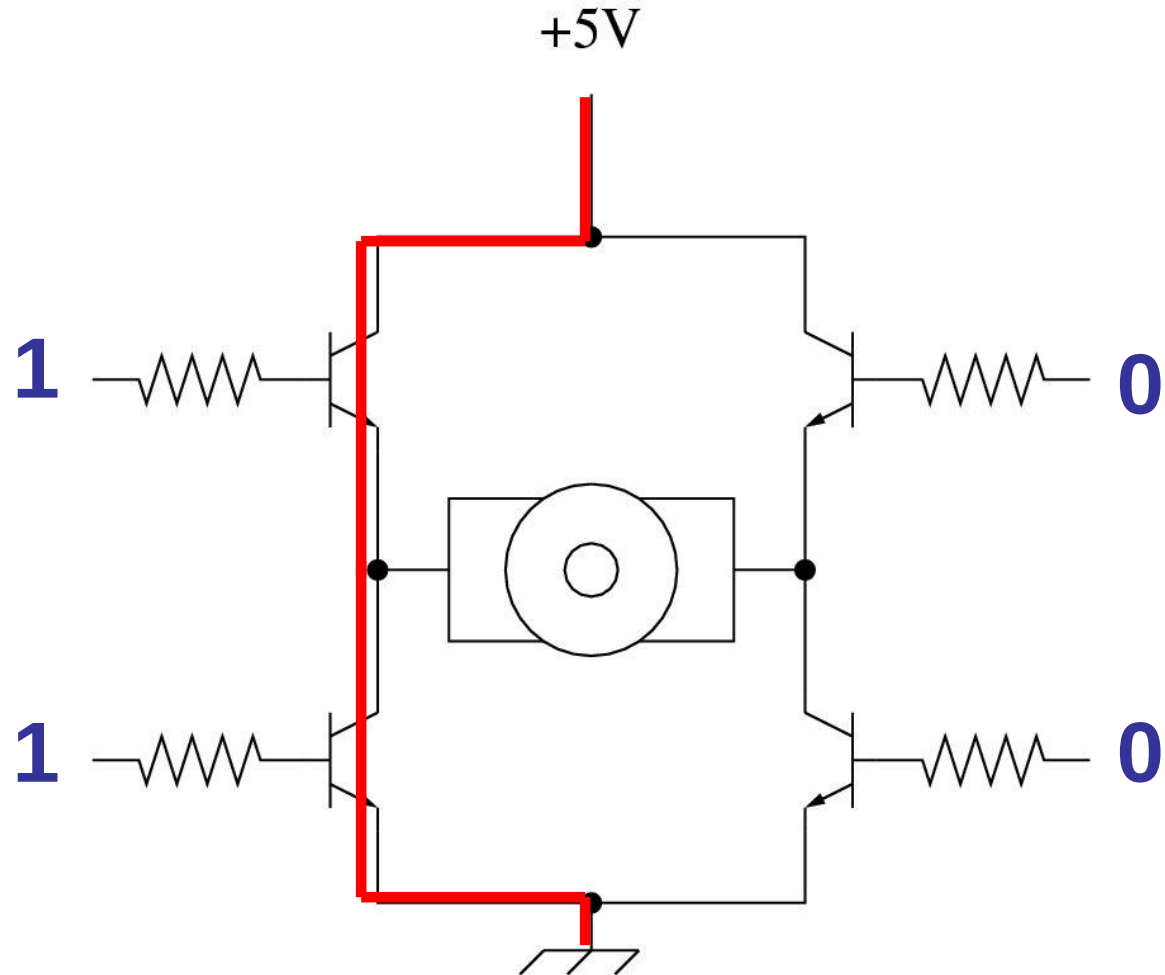
How about
these
inputs?



Simple H-Bridge

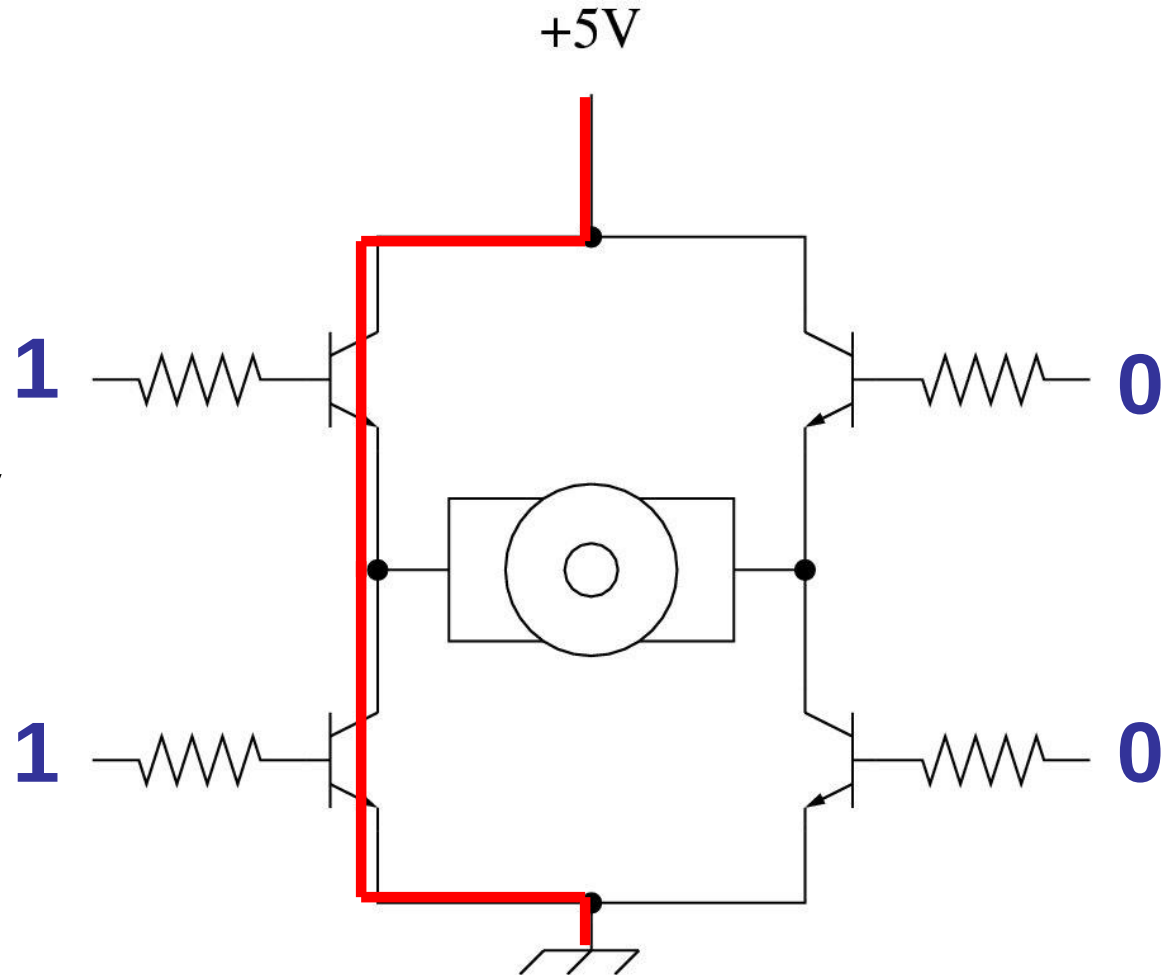
What happens with these inputs?

- We short power to ground ... very bad



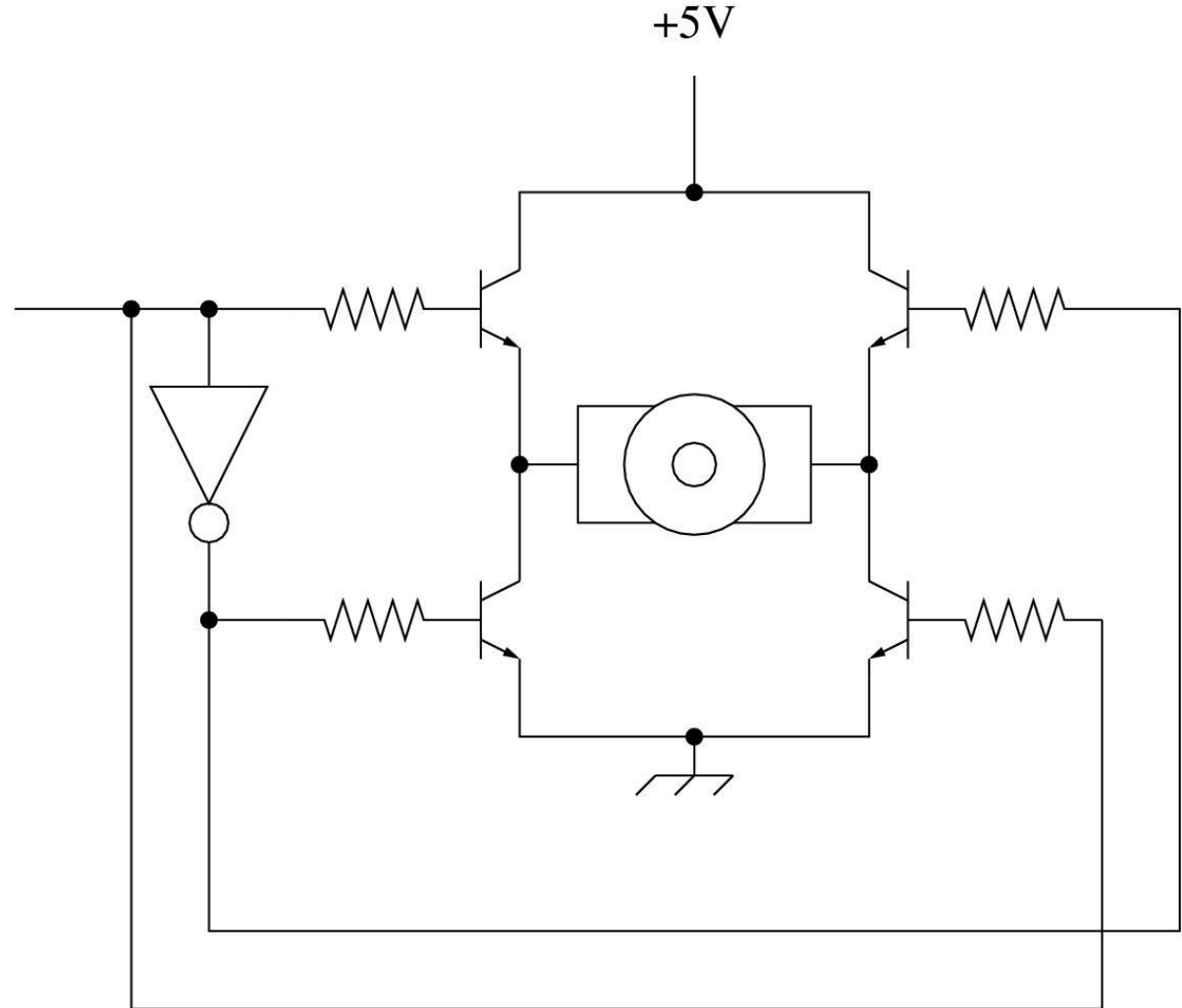
Simple H-Bridge

How can we prevent a processor from accidentally producing this case?



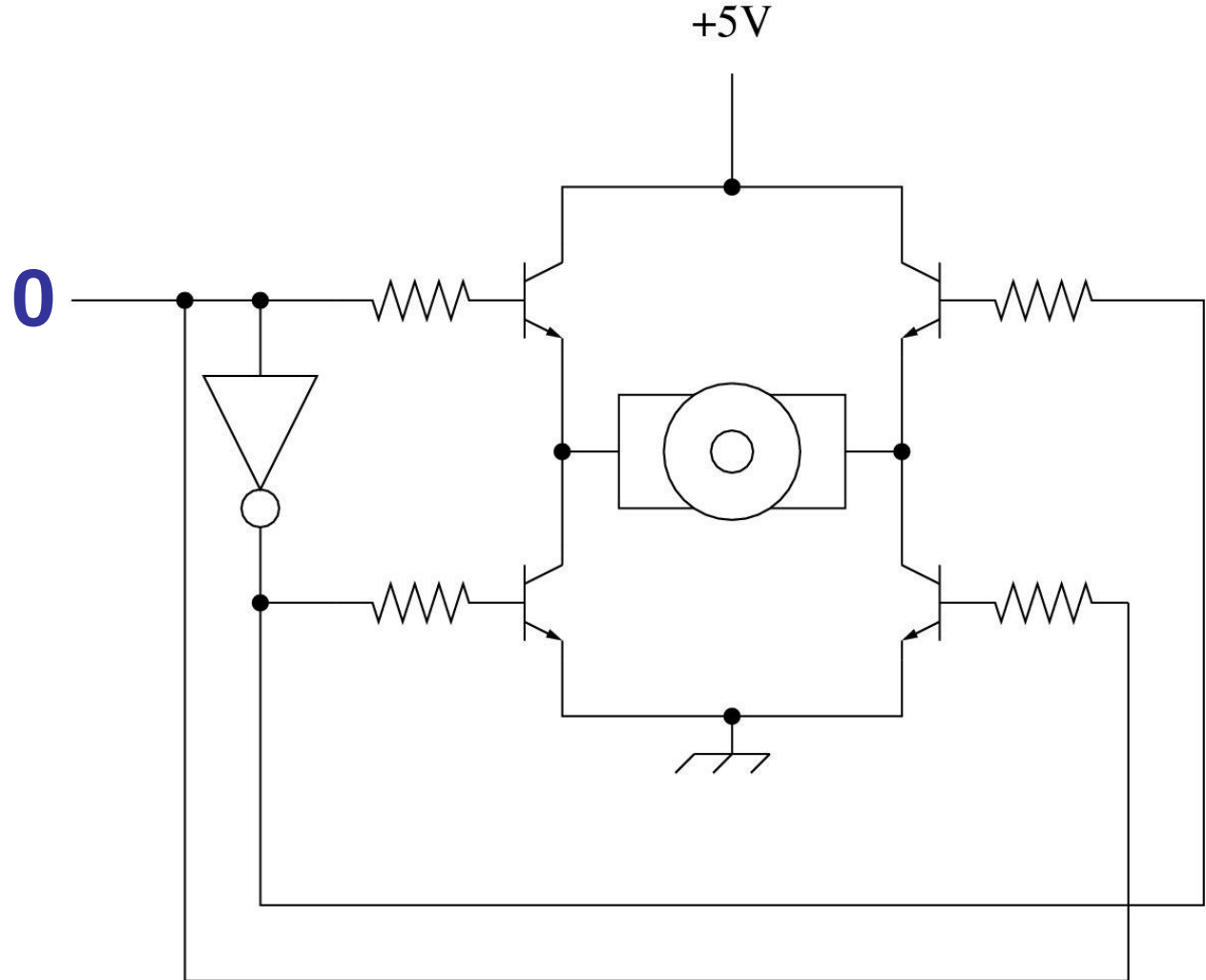
Modified H-Bridge

We introduce a little logic to ensure the short never occurs



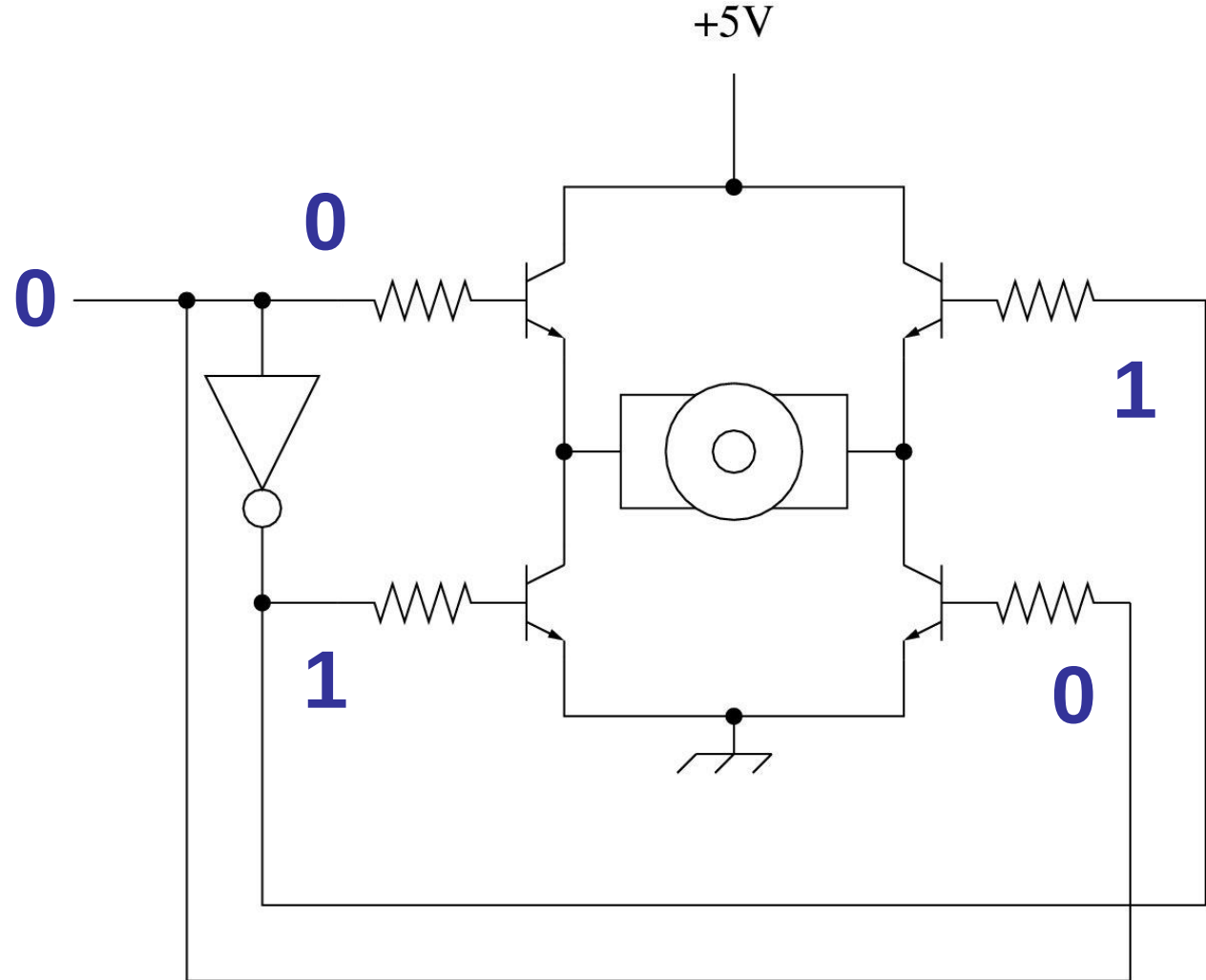
Modified H-Bridge

What happens
with this
input?



Modified H-Bridge

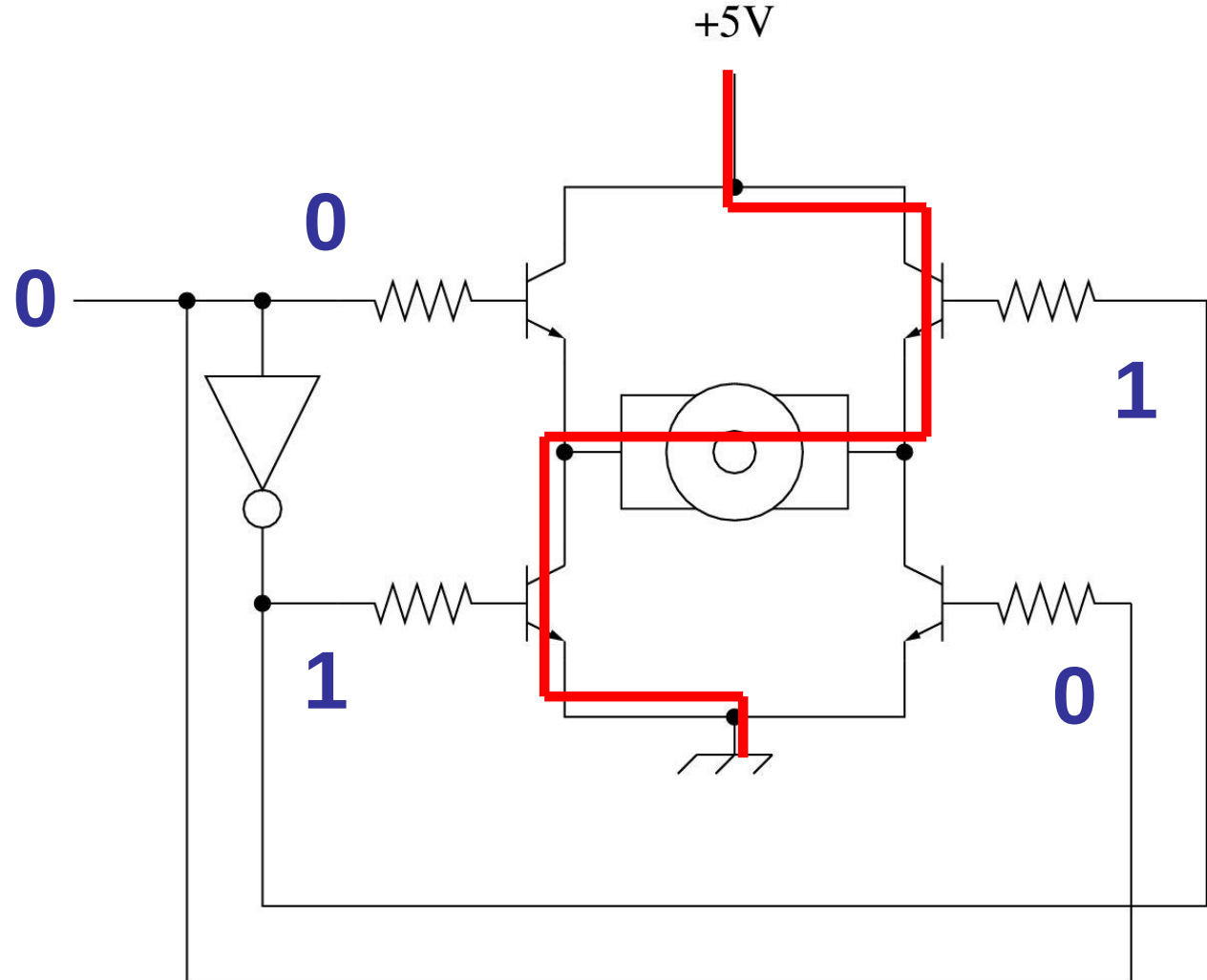
What happens
with this
input?



Modified H-Bridge

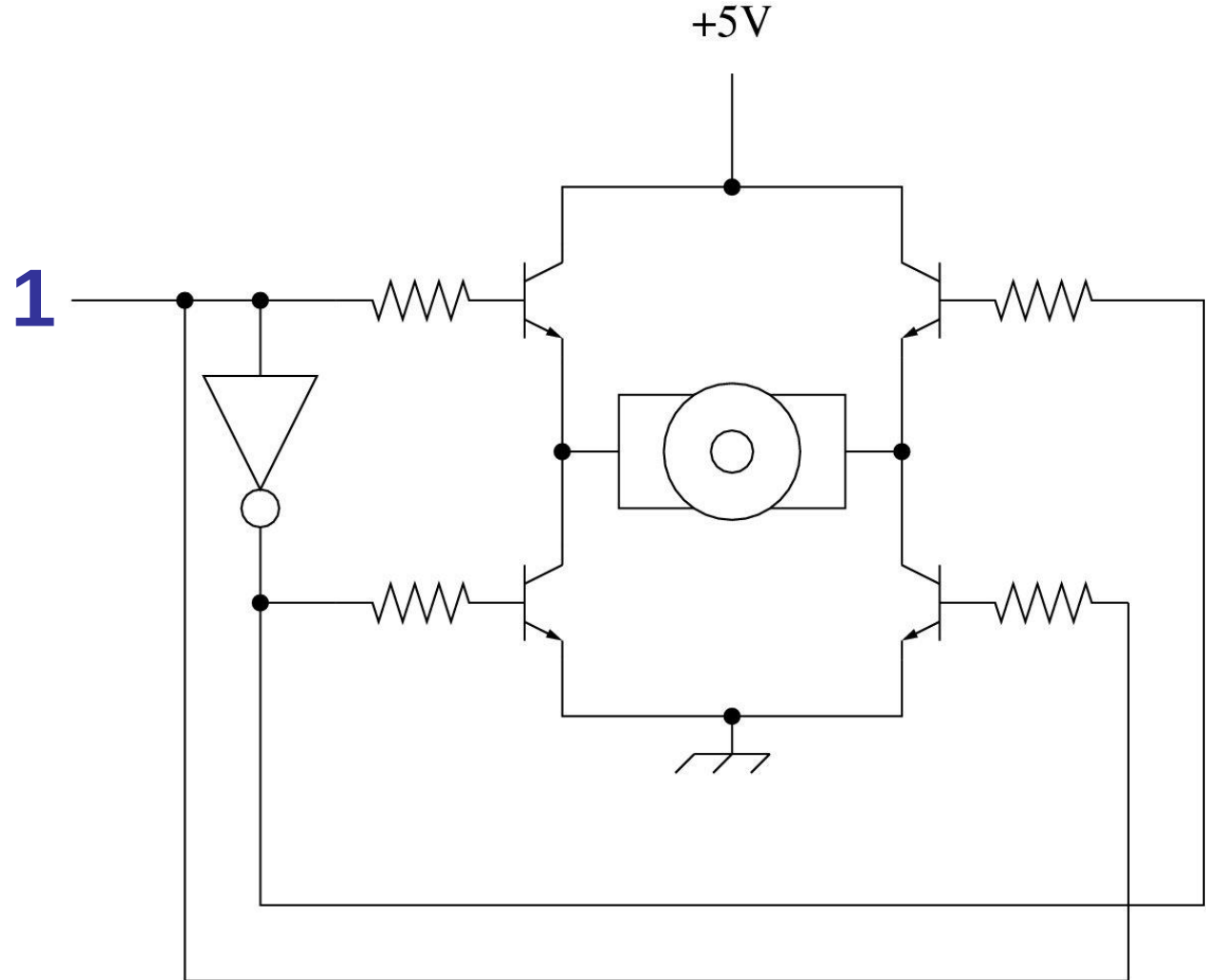
What happens with this input?

- Motor turns in one direction



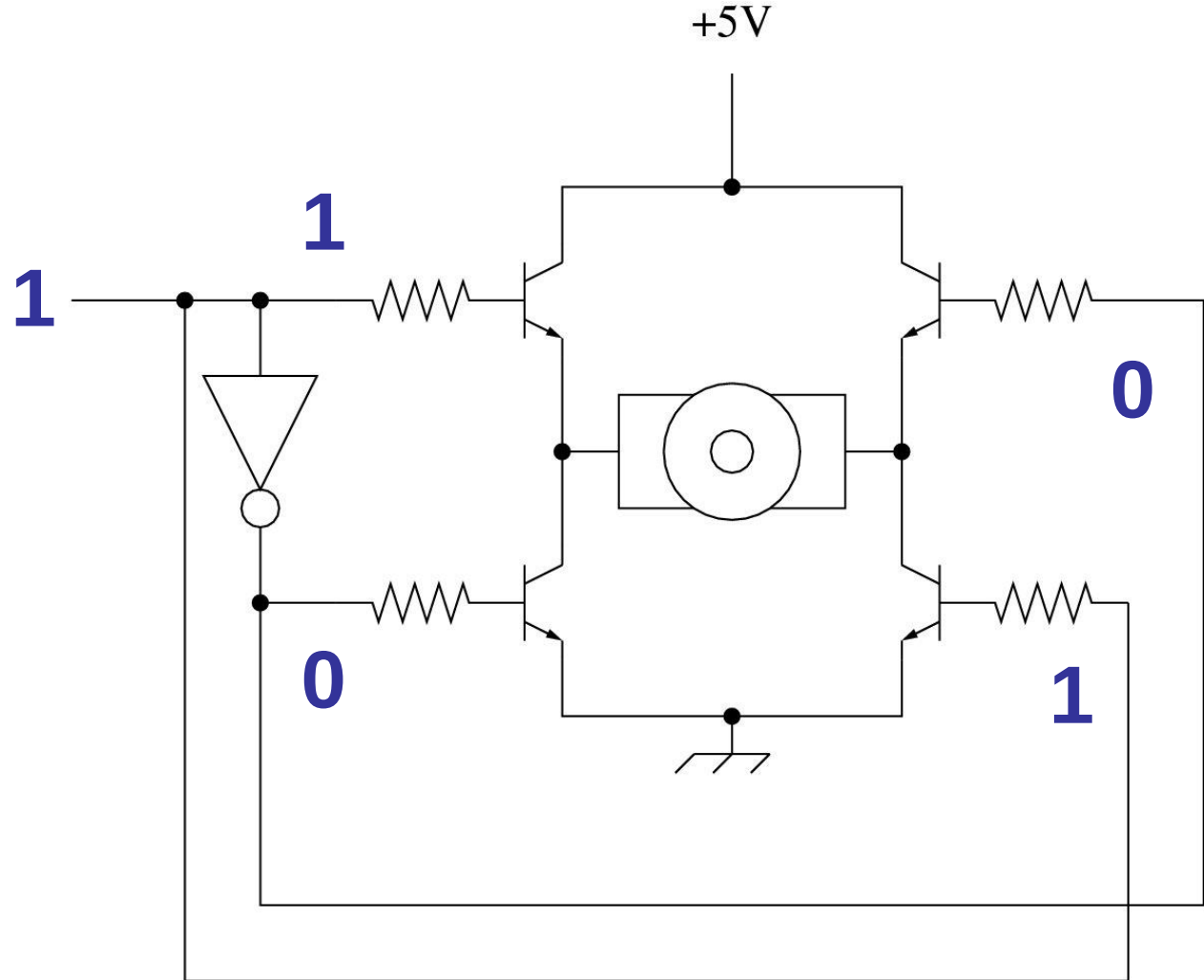
Modified H-Bridge

How about this
input?



Modified H-Bridge

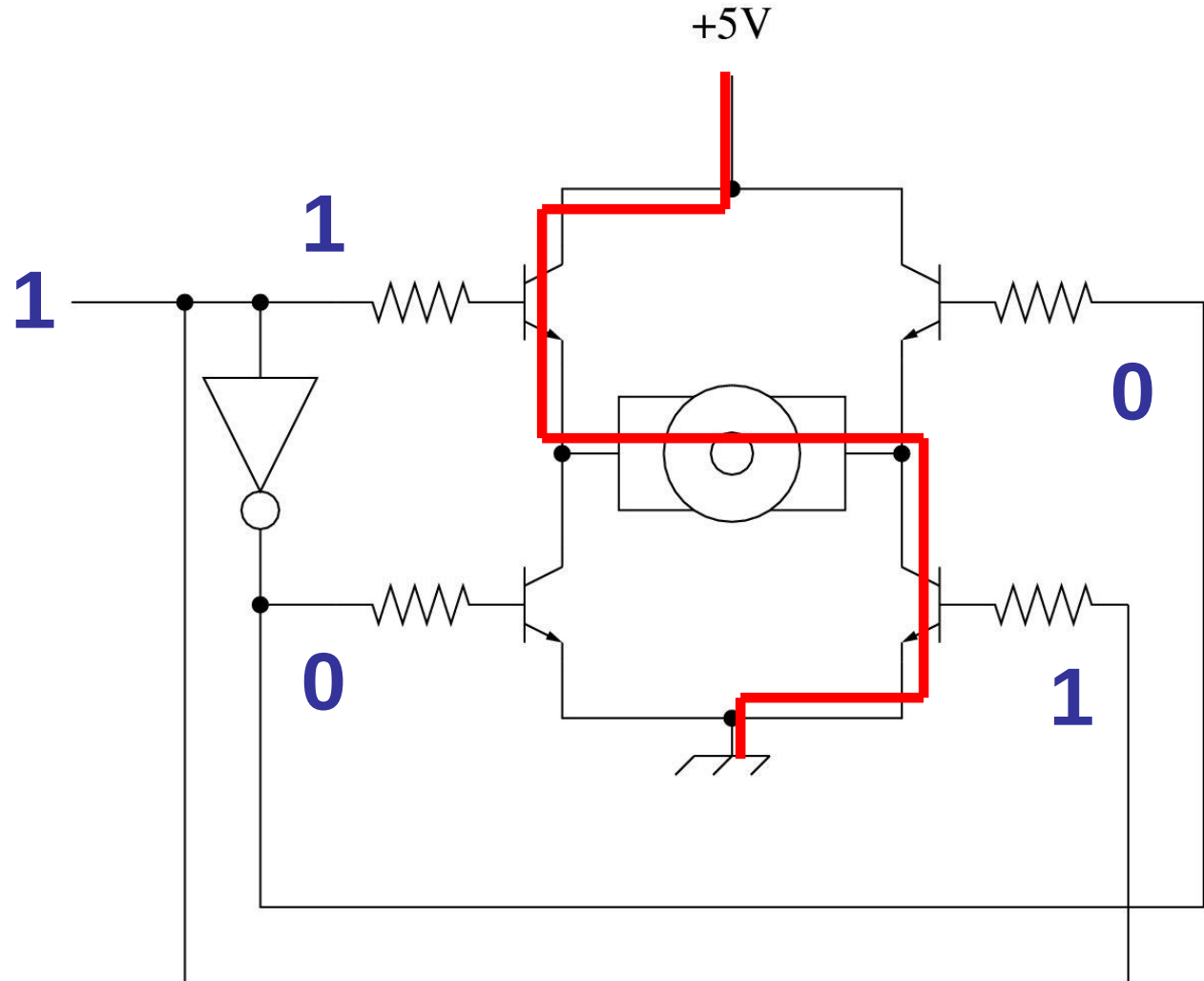
What happens
with this
input?



Modified H-Bridge

How about this input?

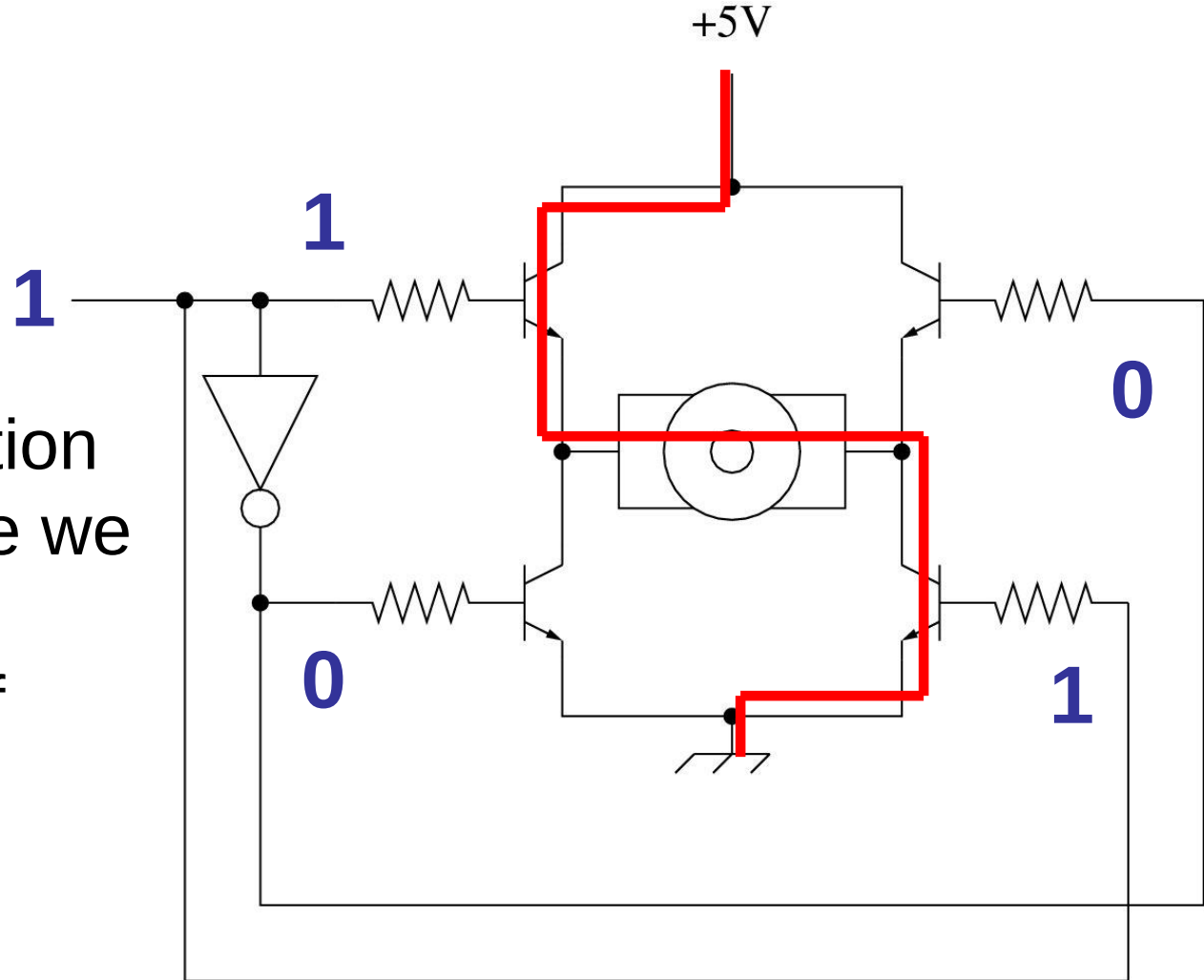
- Motor turns in the other direction



Modified H-Bridge

This implementation is nice because we only need one **direction** bit of control

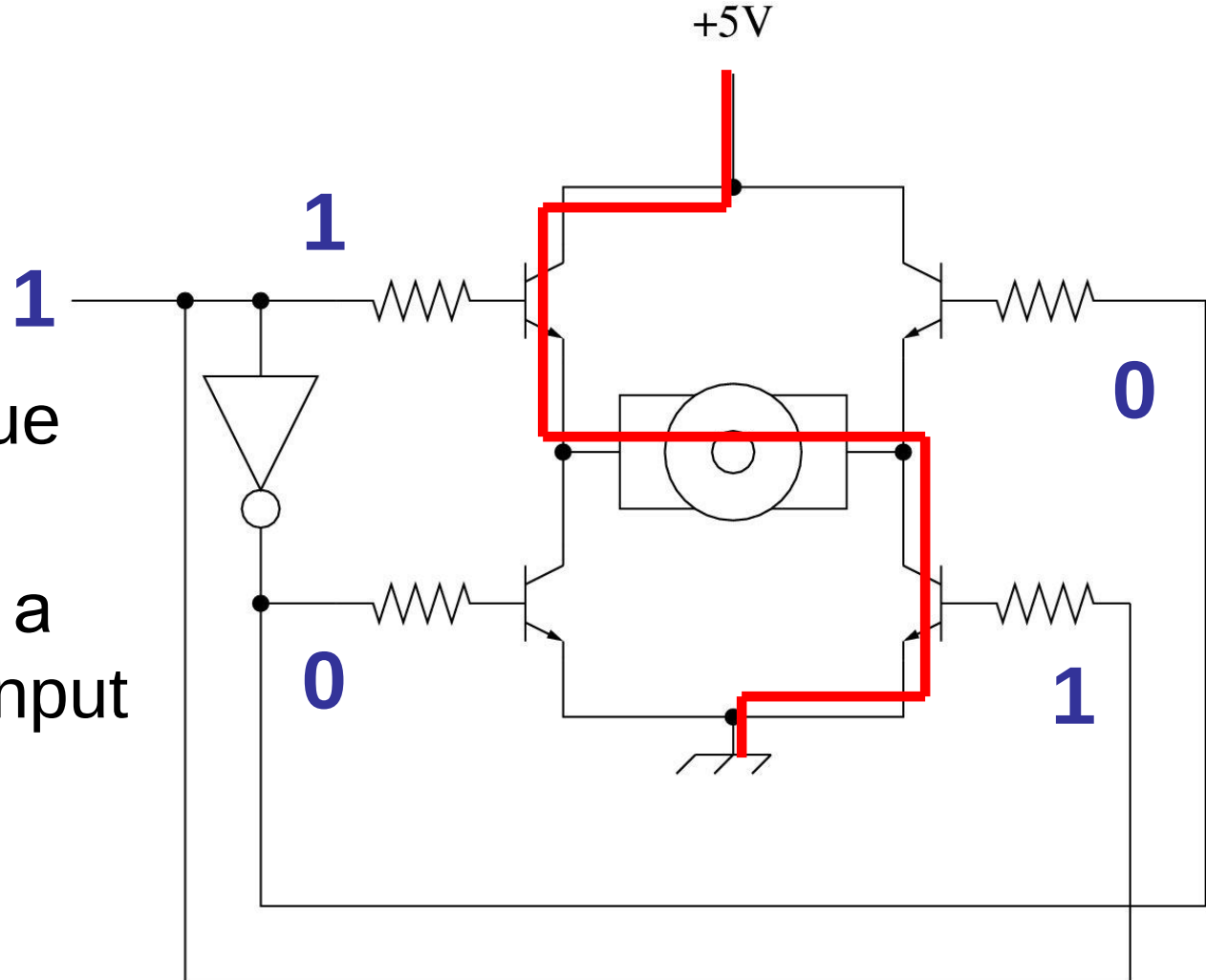
- What are we missing?



Modified H-Bridge

What are we missing?

- Control of torque magnitude
- Let's introduce a second PWM input that turns the motor on/off

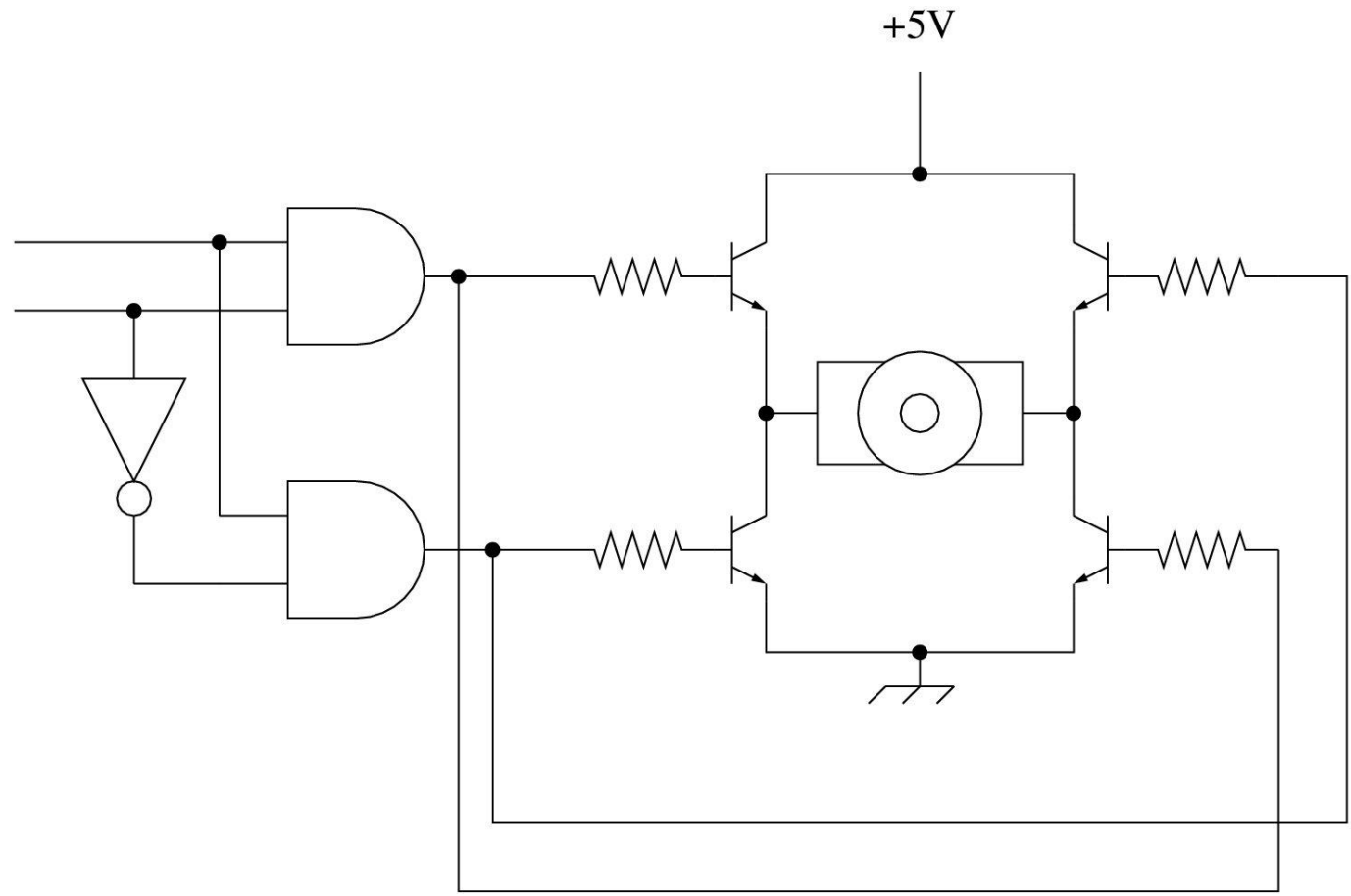


Pulse Width Modulation for Motor Control

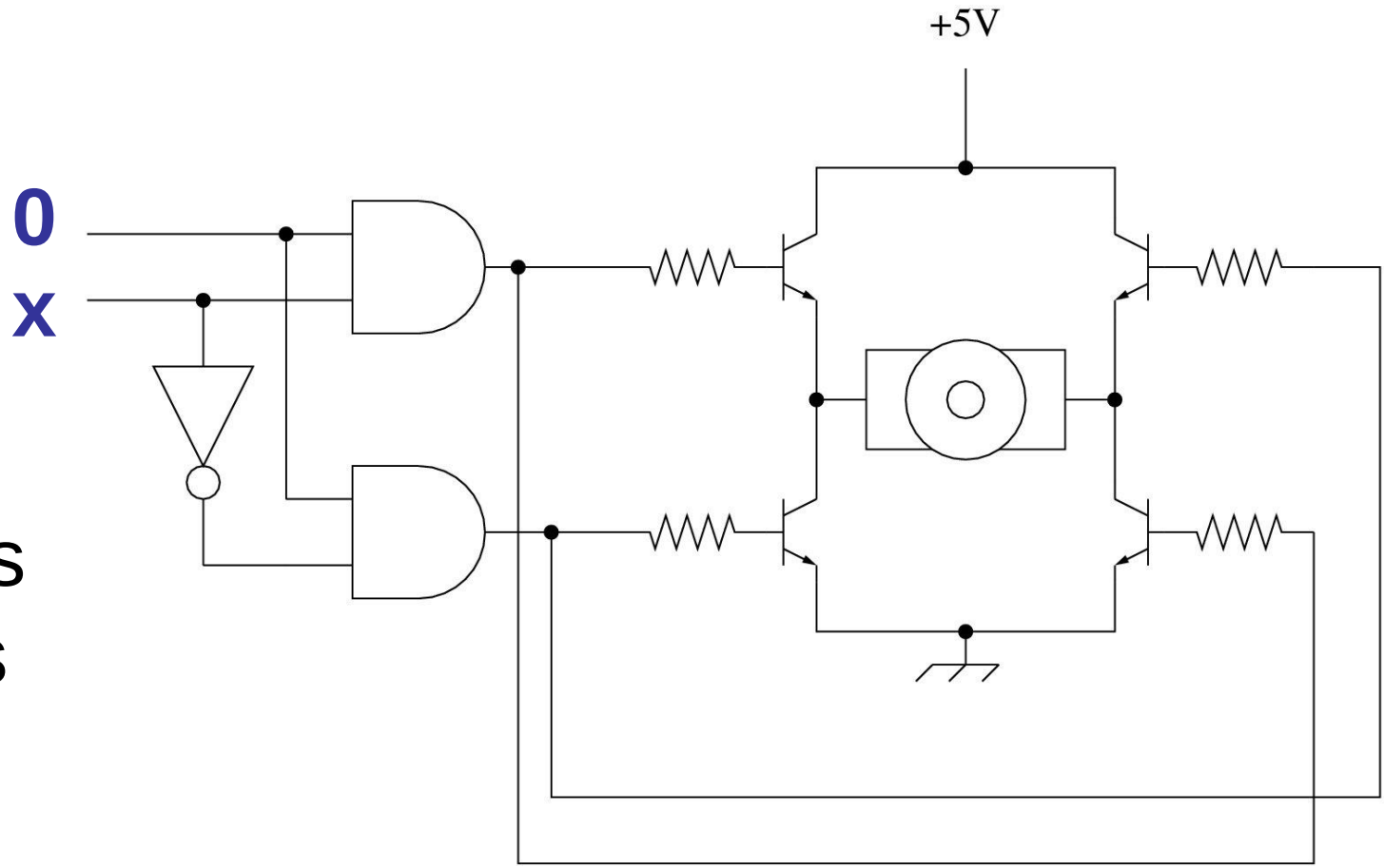
Goal: given on/off input, we want to specify the motor torque

- With PWM, we turn the motor on/off very fast
- We can control **average** motor torque with duty cycle
- With a high frequency signal, the inertia of the motor smooths out the sharp on/off transitions

PWM and Direction Control



PWM and Direction Control

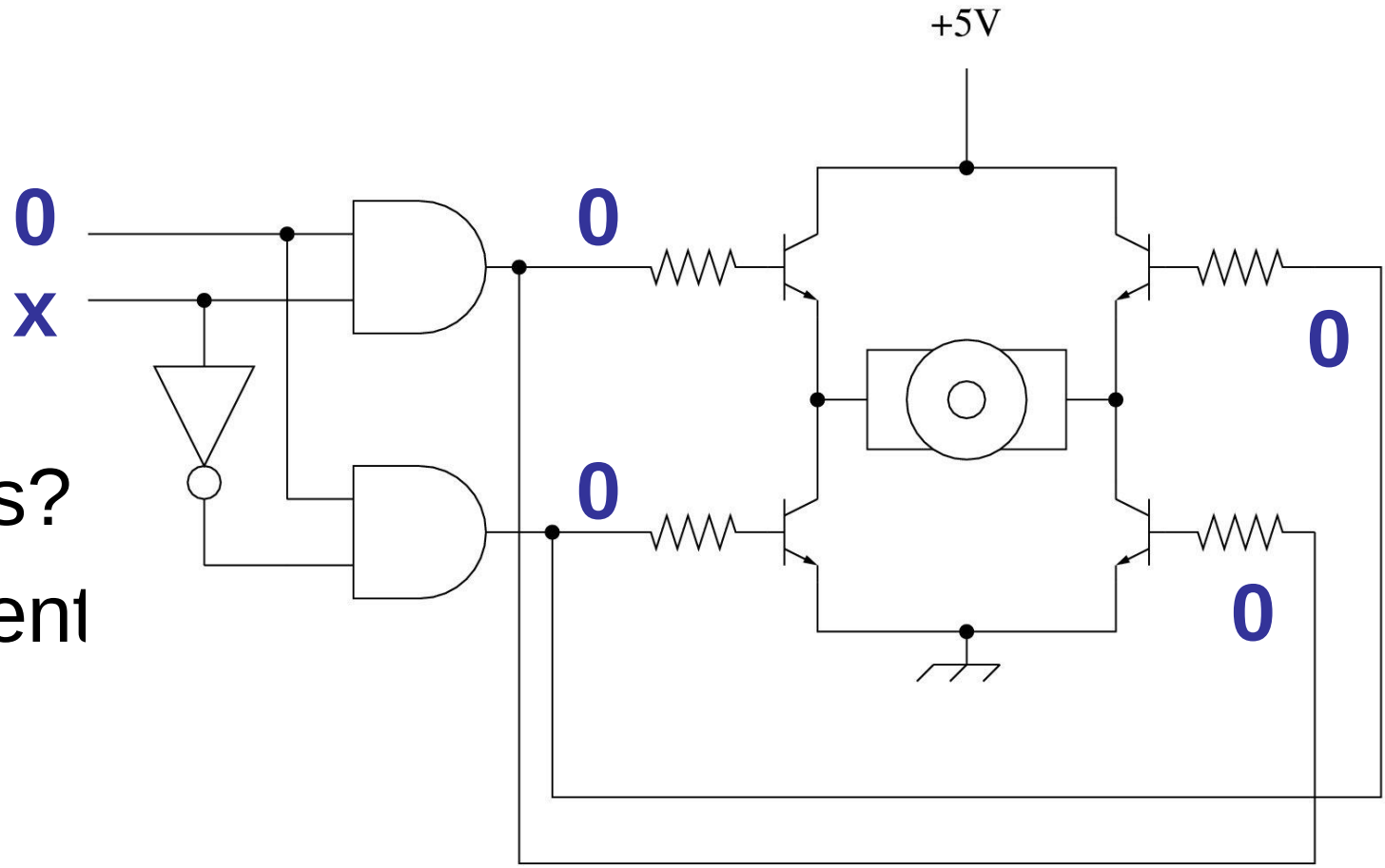


What
happens
with this
input?

PWM and Direction Control

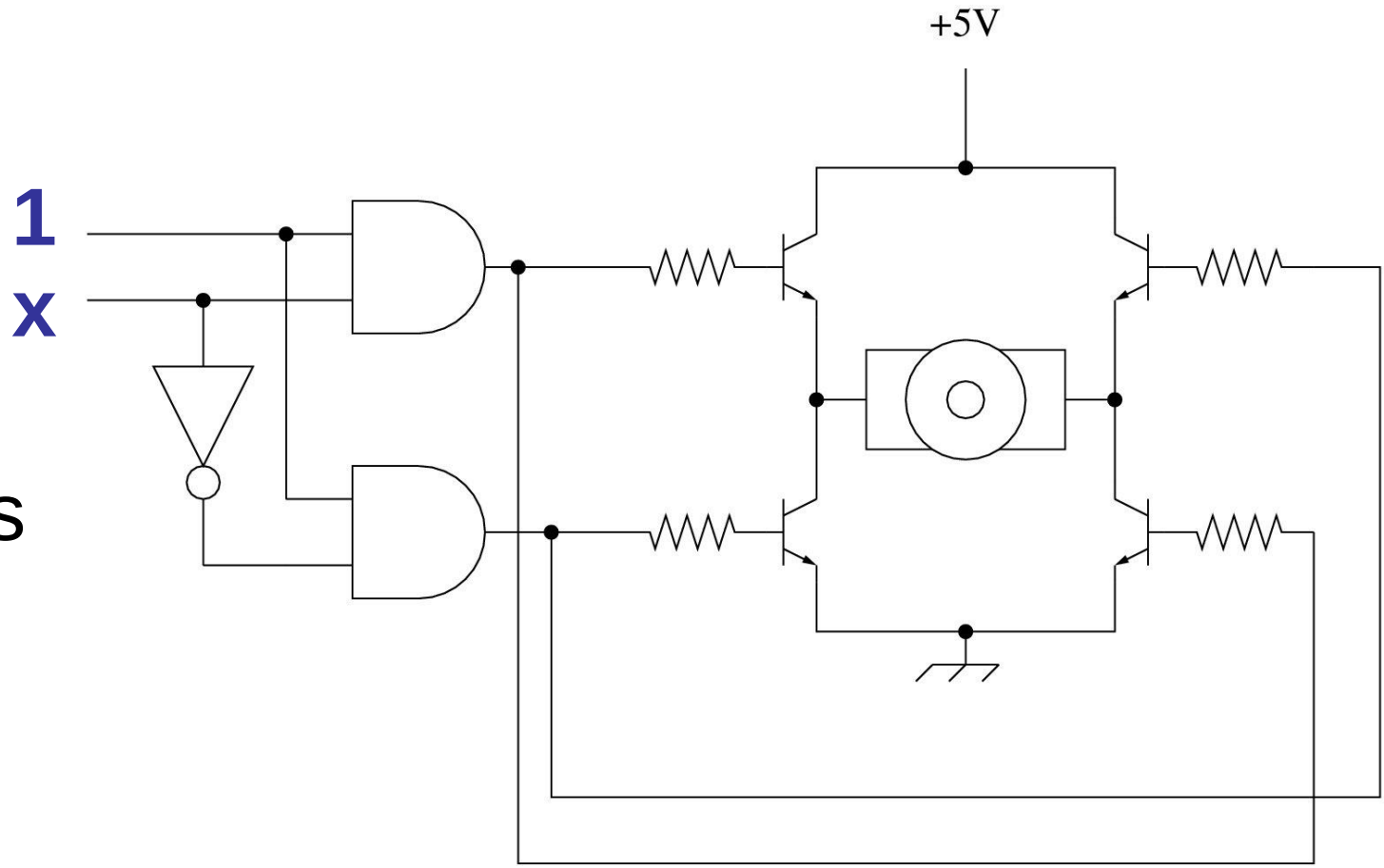
What happens?

- No current flow



PWM and Direction Control

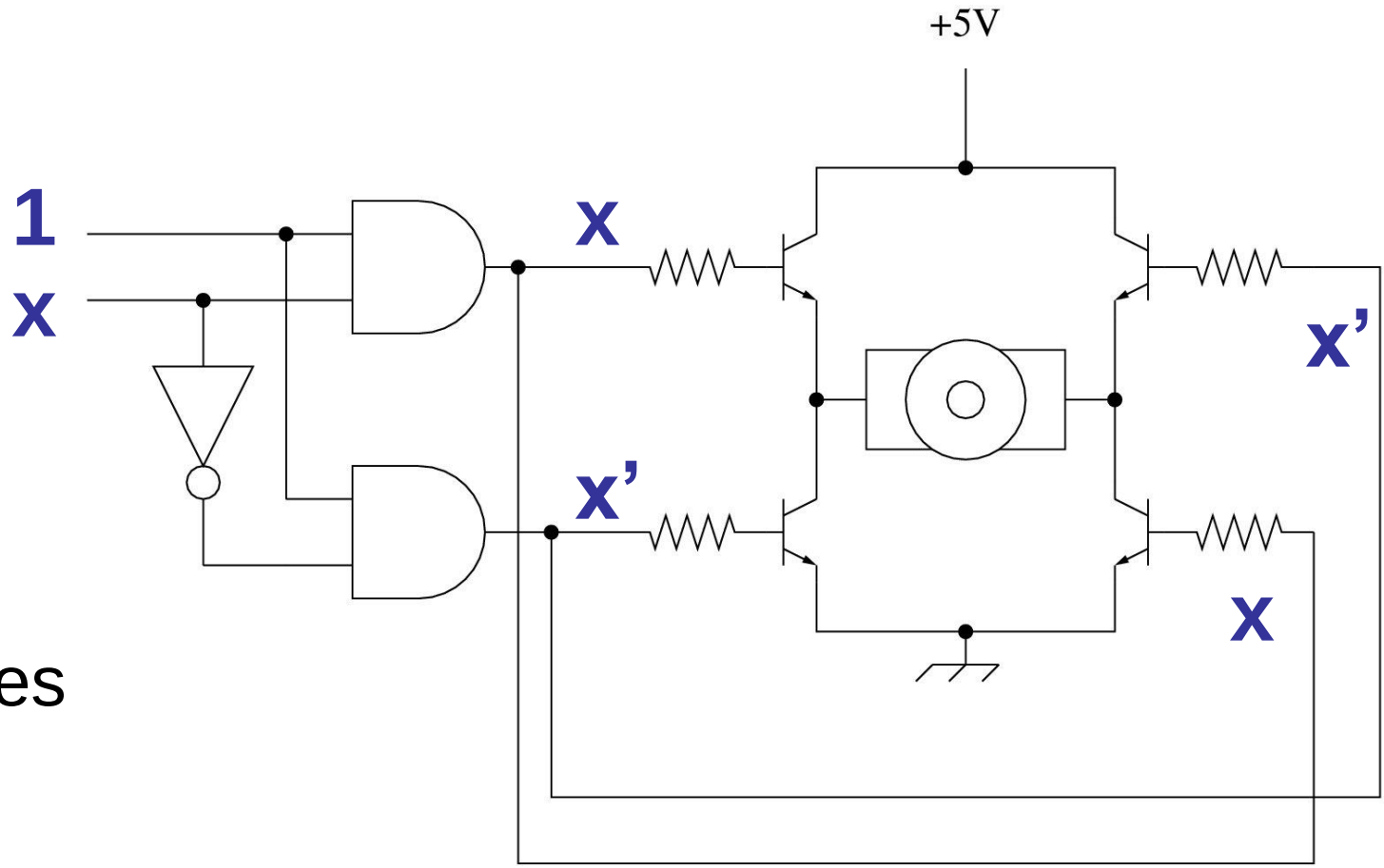
What
happens
now?



PWM and Direction Control

What happens now?

- 'x' determines motor direction

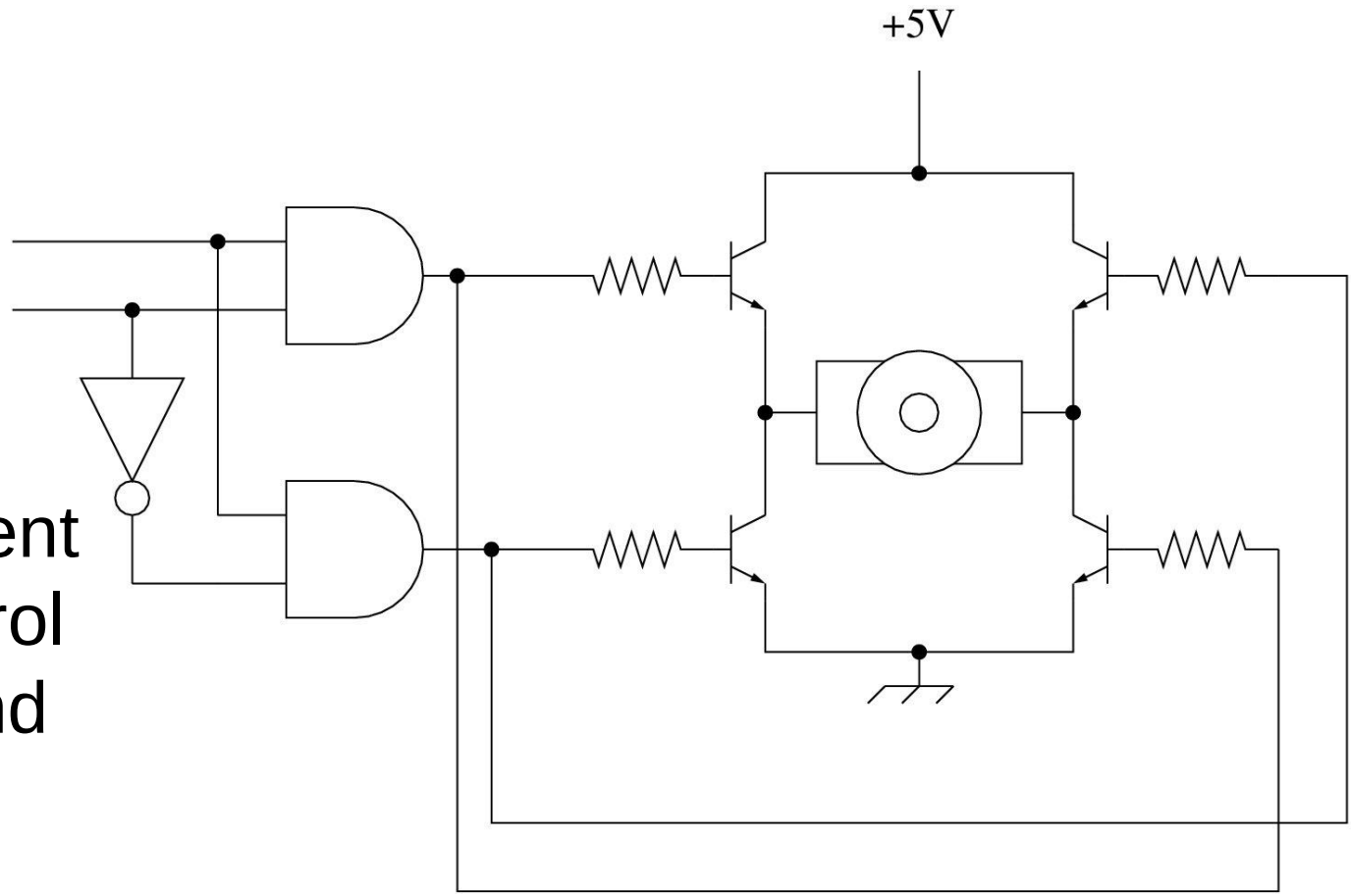


PWM and Direction Control



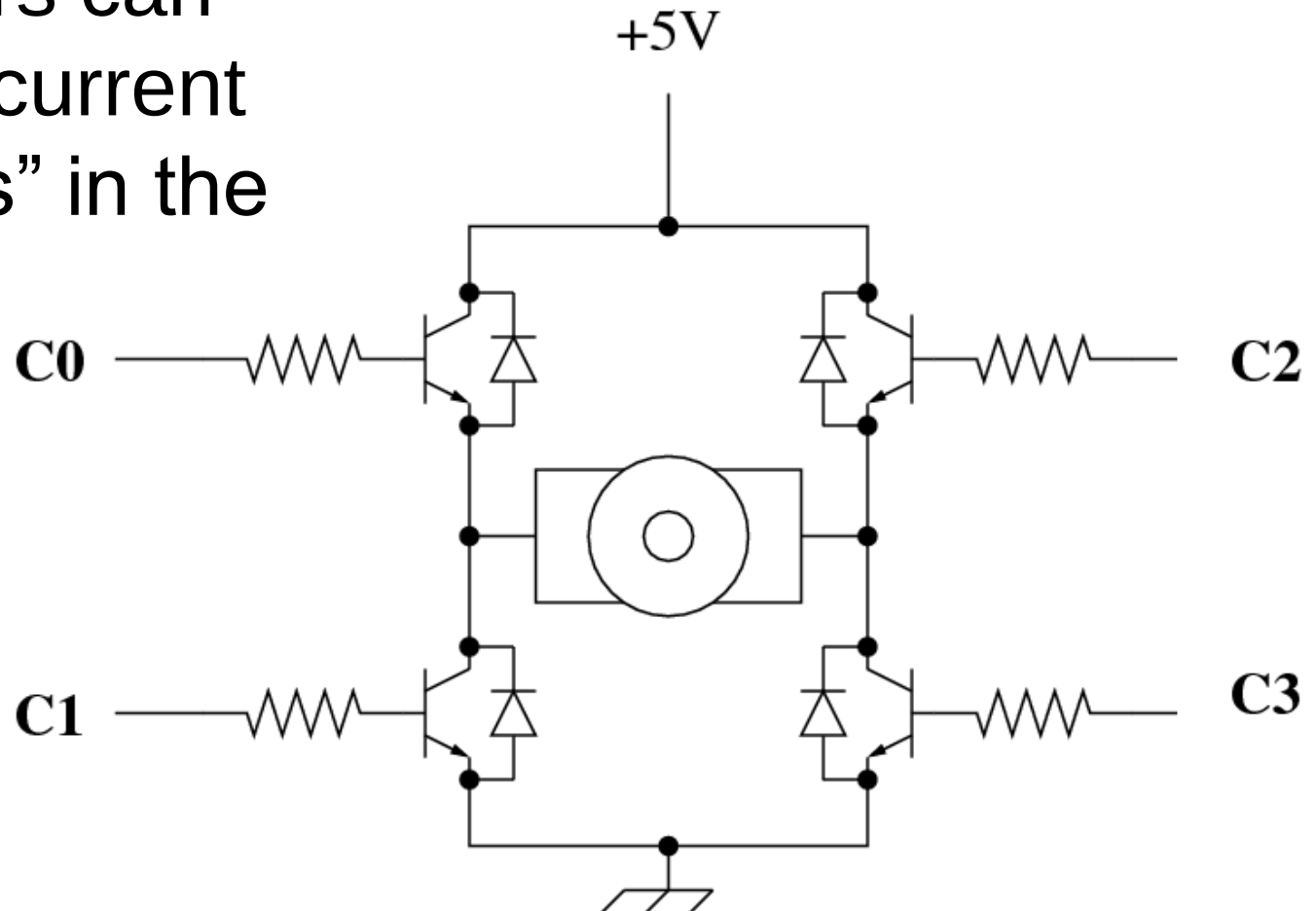
Direction

Two low-current
inputs control
direction and
torque
magnitude



H-Bridge: More Detail

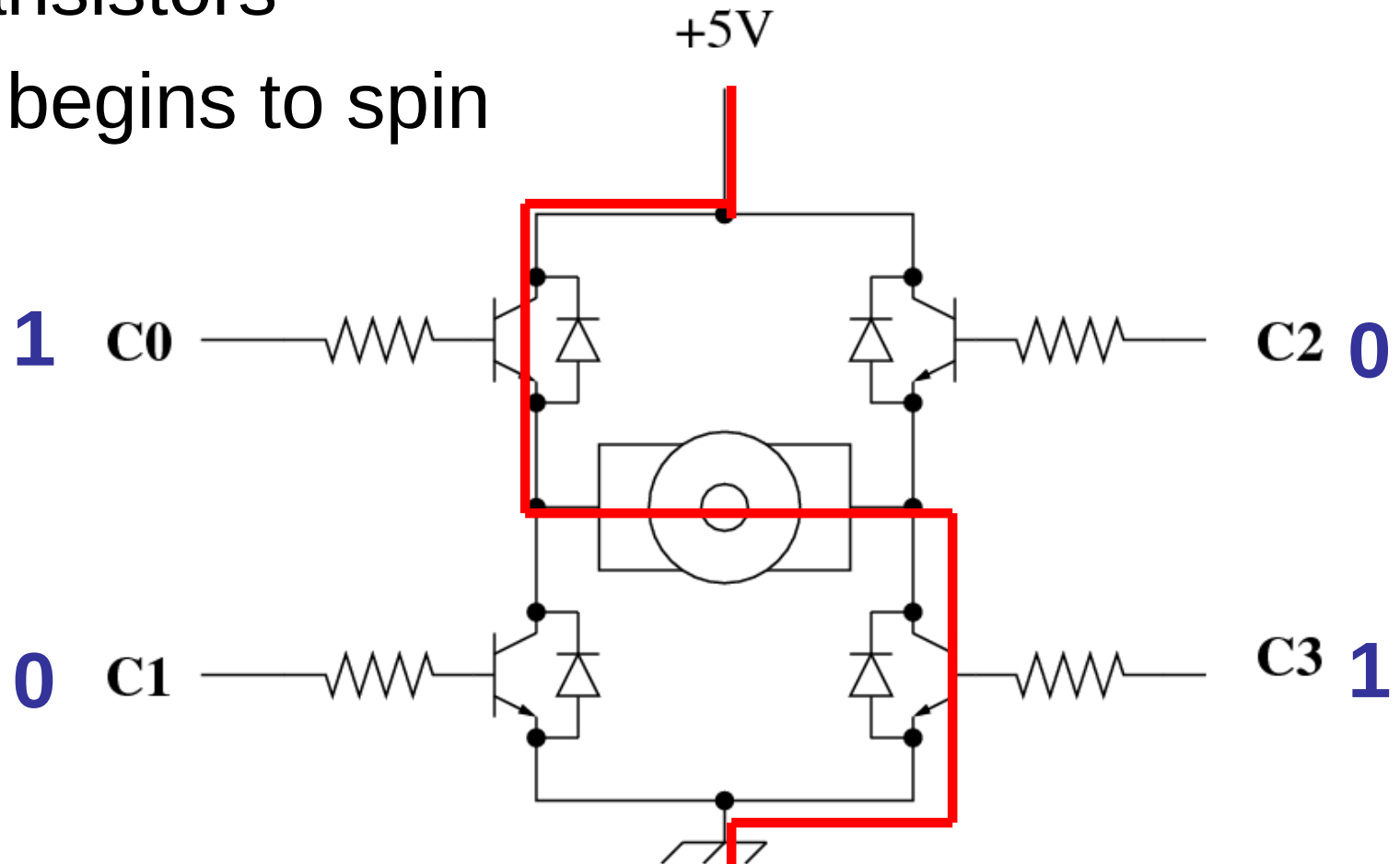
Diodes across the transistors can conduct current “upwards” in the circuit



H-Bridge: More Detail

Current flow through the transistors

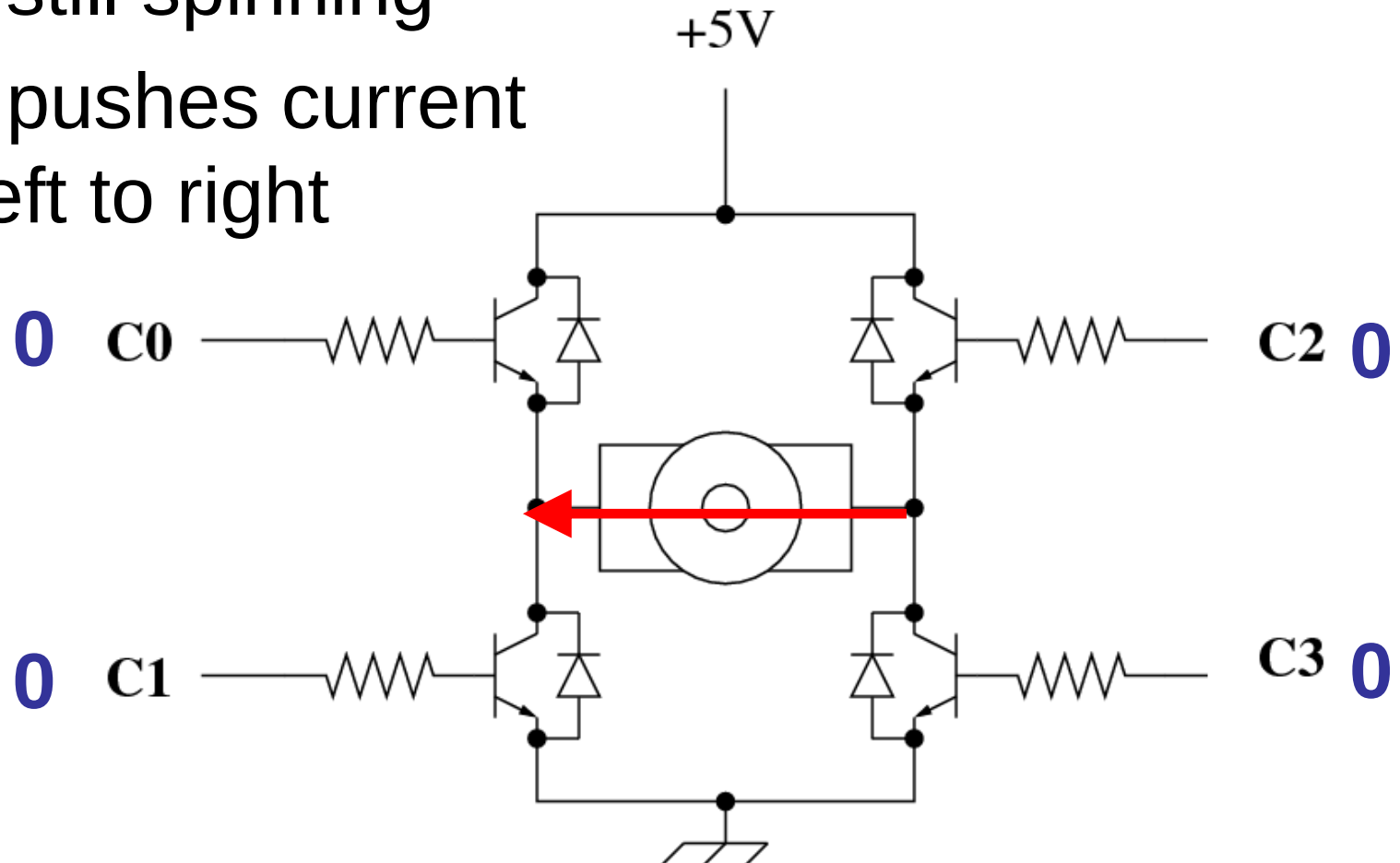
- Motor begins to spin



H-Bridge: More Detail

All transistors off, but:
motor still spinning

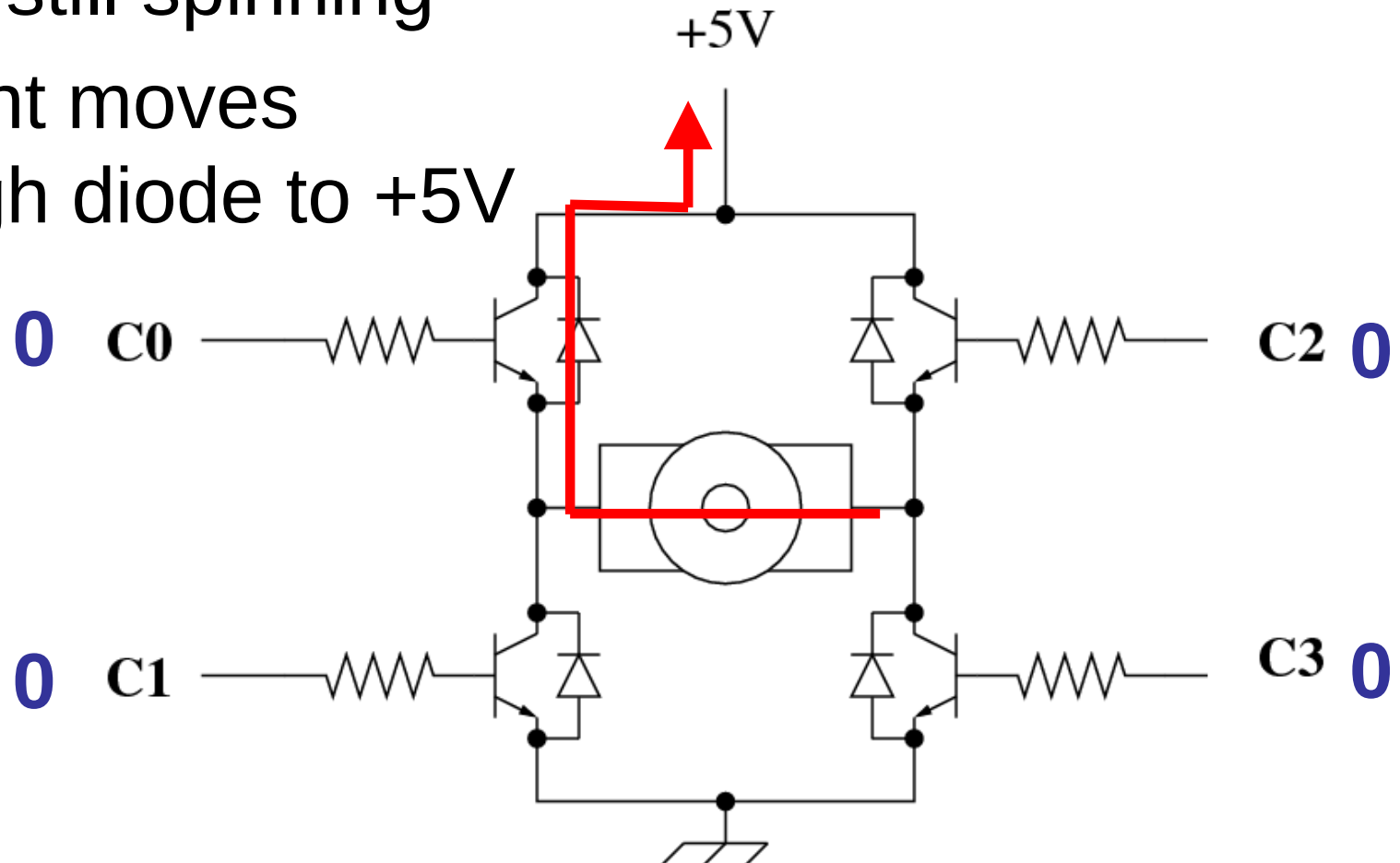
- Motor pushes current from left to right



H-Bridge: More Detail

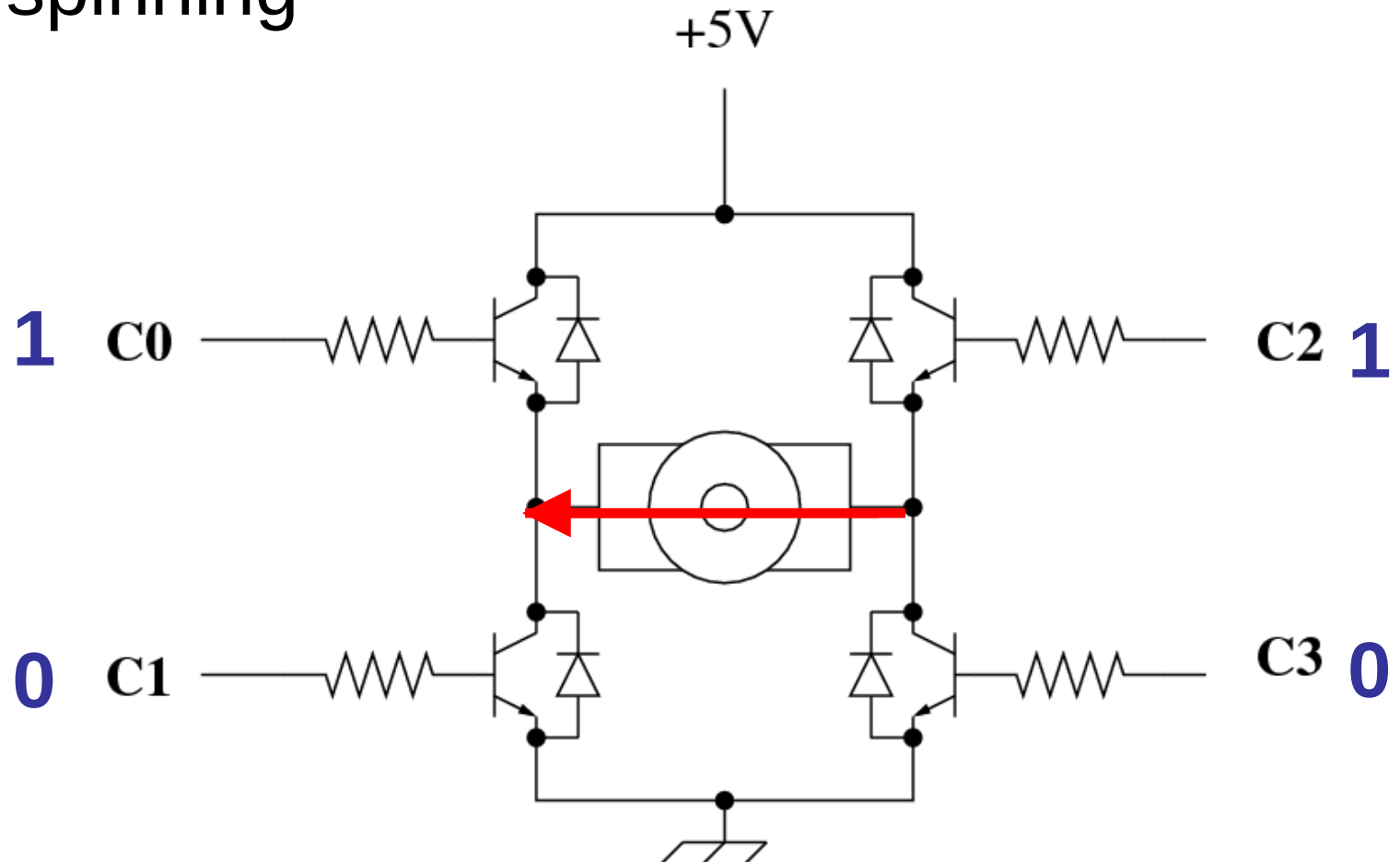
All transistors off, but:
motor still spinning

- Current moves through diode to +5V



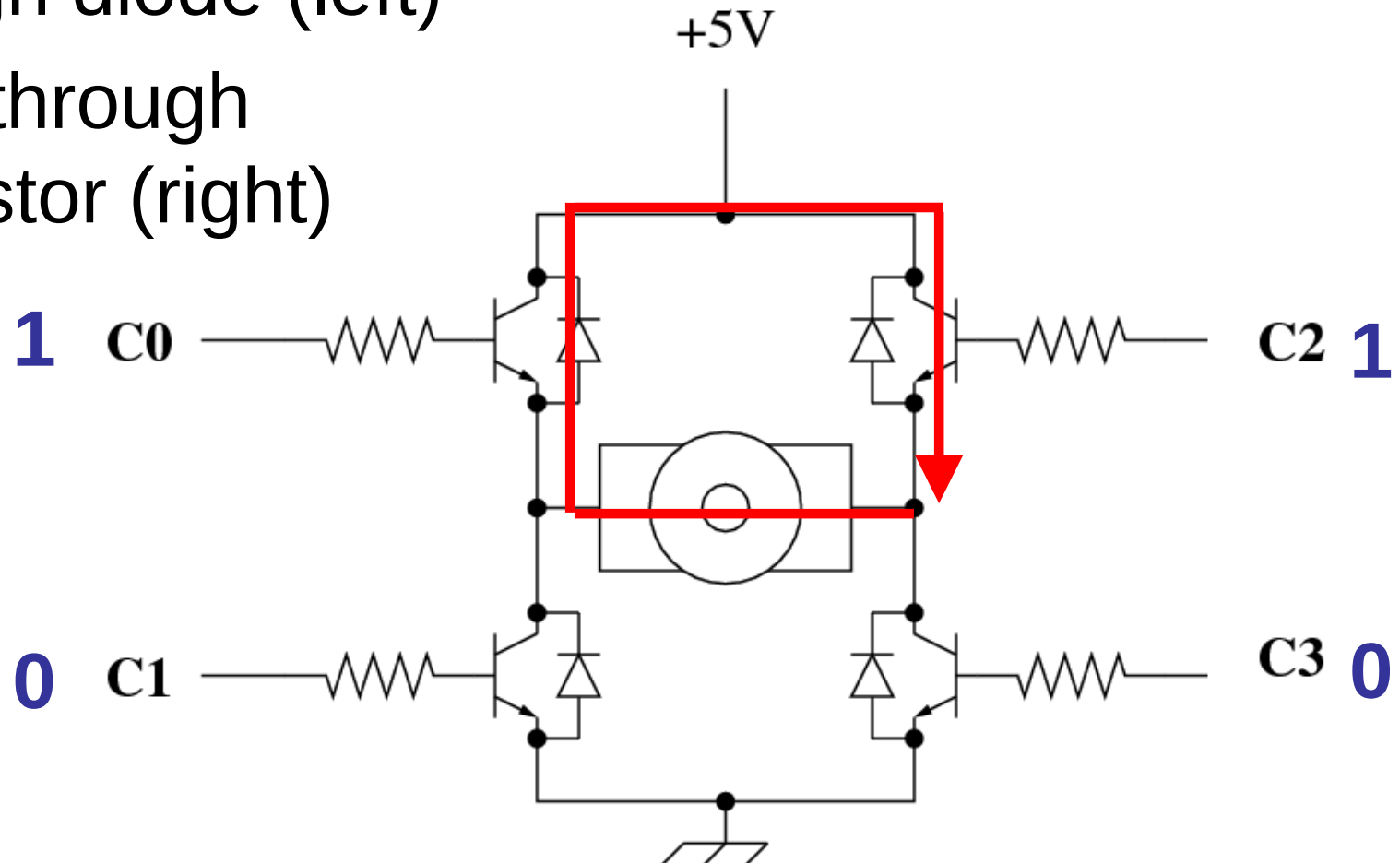
H-Bridge: Dynamic Braking

Top transistors on;
motor spinning



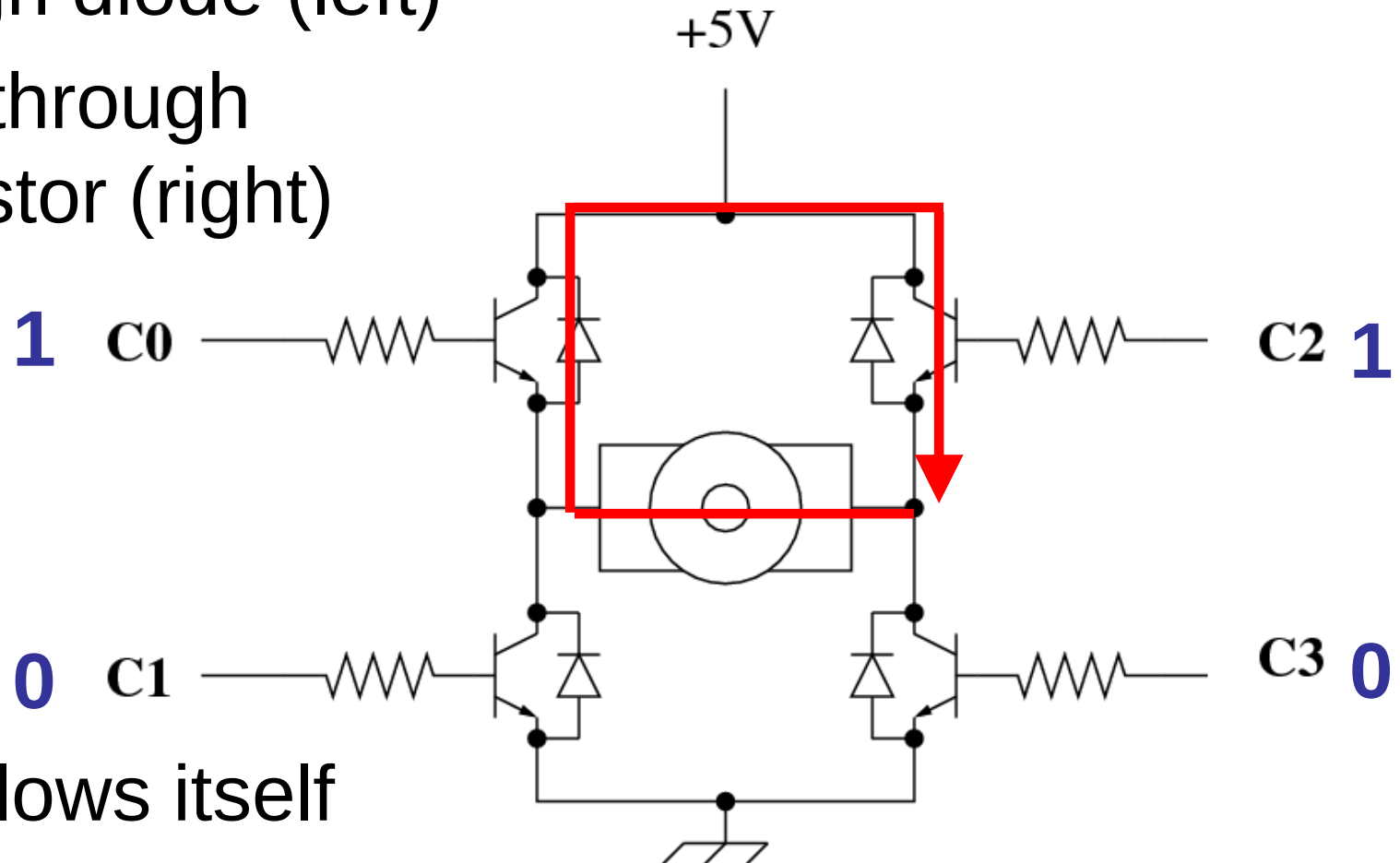
H-Bridge: Dynamic Braking

- Current moves through diode (left)
- Then through transistor (right)



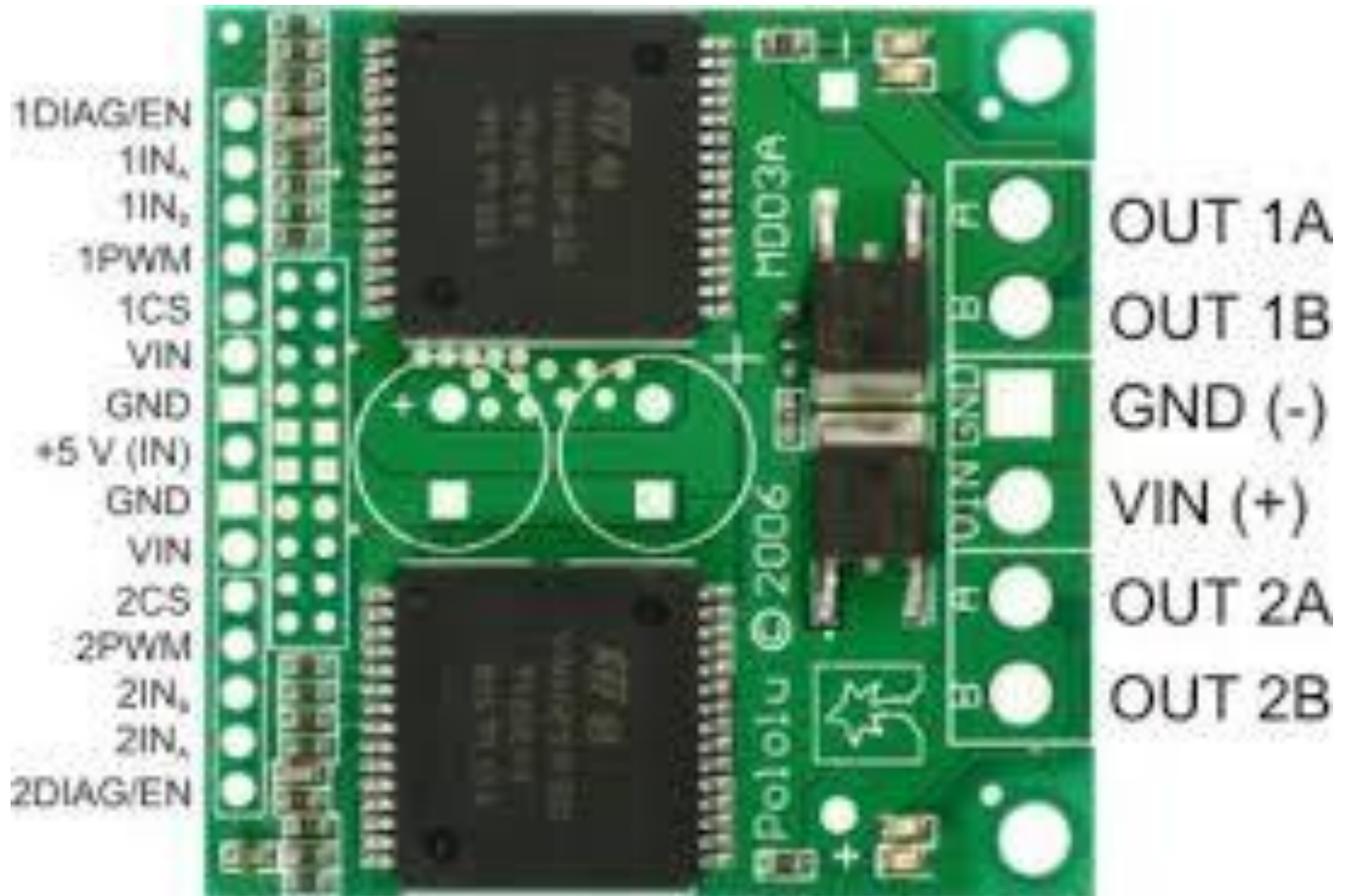
H-Bridge: Dynamic Braking

- Current moves through diode (left)
- Then through transistor (right)



Motor slows itself down!

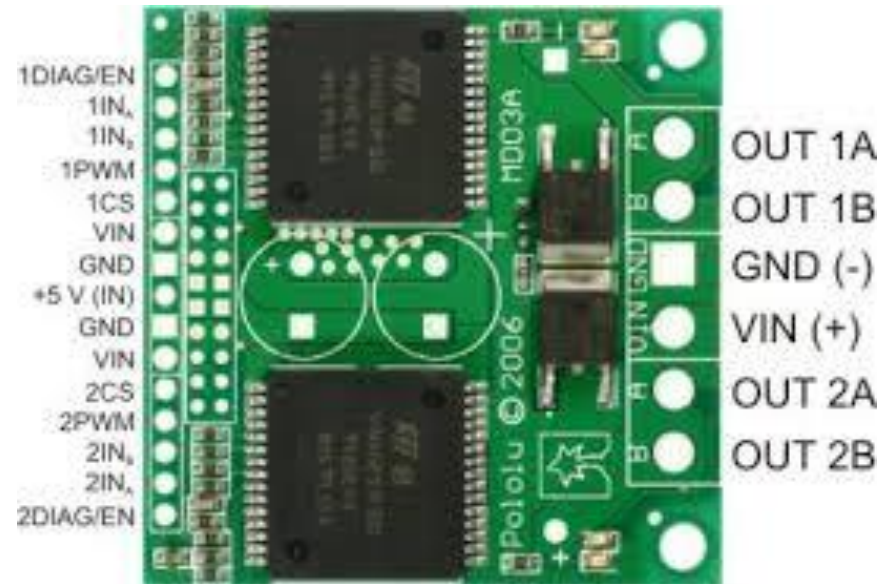
Dual H-Bridge for Project 4



Dual H-Bridge

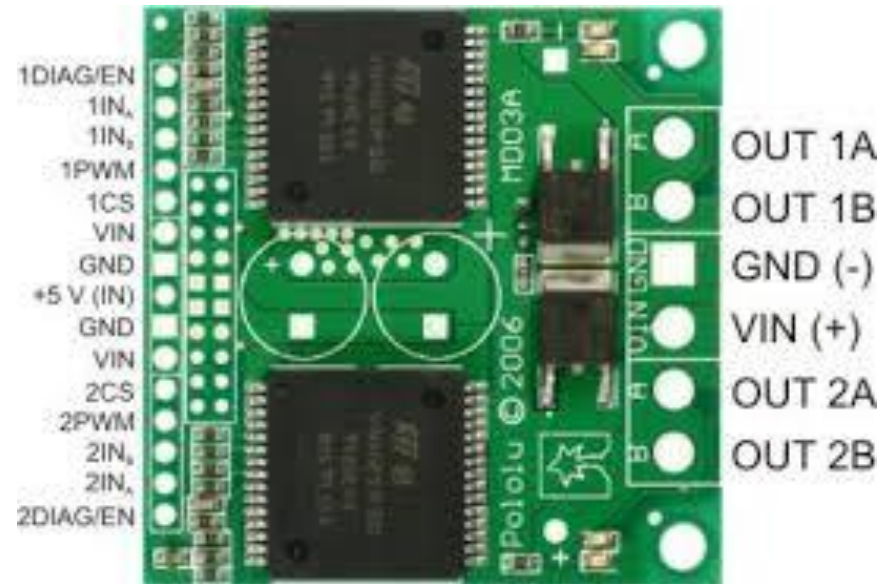
- Left side: Teensy interface
- Right side: Motor interface

Do not mix these two!



Dual H-Bridge: Motor Side

- GND: battery negative
- VIN: battery positive
 - These are the thick power cables coming up to the circuit deck
- OUT-A / OUT-B
 - Connections to motor



Dual H-Bridge: Teensy Side

- GND: Teensy ground
- +5V: from supply (same as for cameras)
- PWM: current magnitude
- IN-A / IN-B:
 - 0/0: dynamic braking
 - 1/0: current flows in one direction
 - 0/1: current flows in other
 - 1/1: dynamic braking

