Direct Current (DC) Motors

- Rotating shaft
- Fixed pair of magnets
Direct Current (DC) Motors

Wire placed within a magnetic field:

- Force on the wire is perpendicular to 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

When electric current passes through a coil in a magnetic field, the magnetic force produces a torque which turns the DC motor.

Torque = force \times \text{lever arm} = (ILB) \left( \frac{W}{2} \right) \sin \theta \times 2 \text{ sides} = ILBW \sin \theta = IBA \sin \theta

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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?

- +5V to north 0V to south
- 0V to north +5V 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 20 mA of current
• This is not very much when it comes to motors…

How do we fix this?
If there is current flow:
• Base to emitter, and
• (possibly) collector to emitter
Transistors as Switches

(what we need to understand for our purposes)

Logic 0 (0V)

0 -> no current flow
Transistors as Switches

(what we need to understand for our purposes)

Logic 1 (5V)

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

(what we need to understand for our purposes)

Logic 1 (5V)

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

+5V
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?

+5V

0 1
1 0
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
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

What would this look like?
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

With the PWM input, we can control the magnitude of torque.
Dual H-Bridge for Project 3

Note: Input1 to input5 should be connected to 5 output pins on Atmega8 and these are the control signals. Particularly, sending a PWM signal to input1 controls the rotational speed of the right fan; sending a PWM signal to input2 controls the rotational speed of the left fan; sending a PWM signal to input3 controls the rotational speed of the middle fan; input4 and input5 control the rotation direction of the middle fan. Specifically, input4=1 & input5=0, one rotation direction; input4=0 & input5=1, the other rotation direction.