Wheeled Locomotion

- Geared Drive Vs. Direct Drive
- Driving DC motors
- Stepper motors
- Open-loop and Closed-loop Control
- Feedback for Close-Loop Systems
- Drive Configurations

Geared Drive

- Usually a **DC motor** spinning at high speed, with little torque
- Convert speed to torque with gears (Speed and torque are inversely proportional)
- Gear ration by counting teeth
- Gears that touch one another spin opposite directions

How to Drive DC Motors

- You can use a transistor or relay as a switch
- H-bridge uses transistors like 4 switches
- Use a flyback diode
- **Tip:** MOSFETS can drive motors more efficiently than BJTs, so use them when possible

Image Links:
http://upload.wikimedia.org/wikipedia/commons/d/d4/H_bridge.svg
http://www.roko.ca/articles/hbridge/bridge1.gif
http://www.dprg.org/tutorials/1998-04a/hb6.png
http://modularcircuits.com/pic/simple_bridge.gif
Additional useful information:
http://en.wikipedia.org/wiki/H_bridge
http://en.wikipedia.org/wiki/Flyback_diode
(Good tutorial) http://roko.ca/robotics/h-bridge-fundamentals

Direct Drive (Focus on Steppers)

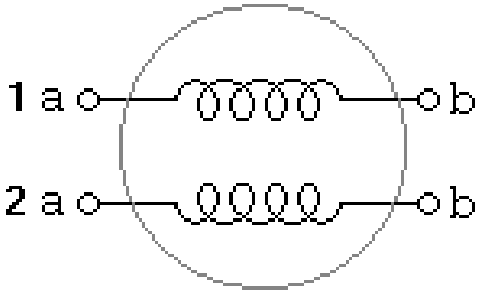
- Need to have a lot of torque, like a **stepper motor** which don't need gears to drive wheels
- Watch animation here:
  http://upload.wikimedia.org/wikipedia/commons/6/67/StepperMotor.gif
- "Degree per step" Common values: 7.5,1.8,and 0.9 degrees.
- They move to the next position and stop there. It is hard to move it from that position when the coils are energized.
  http://upload.wikimedia.org/wikipedia/commons/6/67/StepperMotor.gif

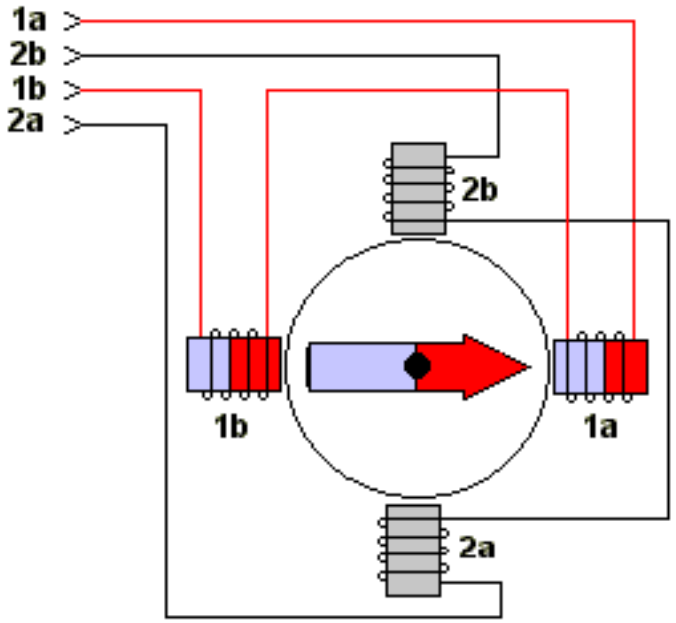
Direct Drive (Focus on Steppers)

- Come in a variety of numbers of wires: 4-wire, 5-wire, 6-wire, 8-wire.
- Coils draw a **LOT** of current, so you may need to use current-limiting resistor in series with each coil to prevent burning out your controller.
- There are two types of stepper motors, **unipolar and bipolar.**

Bipolar Stepper Motors

- Simple motor driver uses an H-Bridge on each coil
- Usually have 4 or 8 wires





Conceptual Model of Bipolar Stepper Motor

Additional Information:

http://arduino.cc/en/Reference/StepperBipolarCircuit

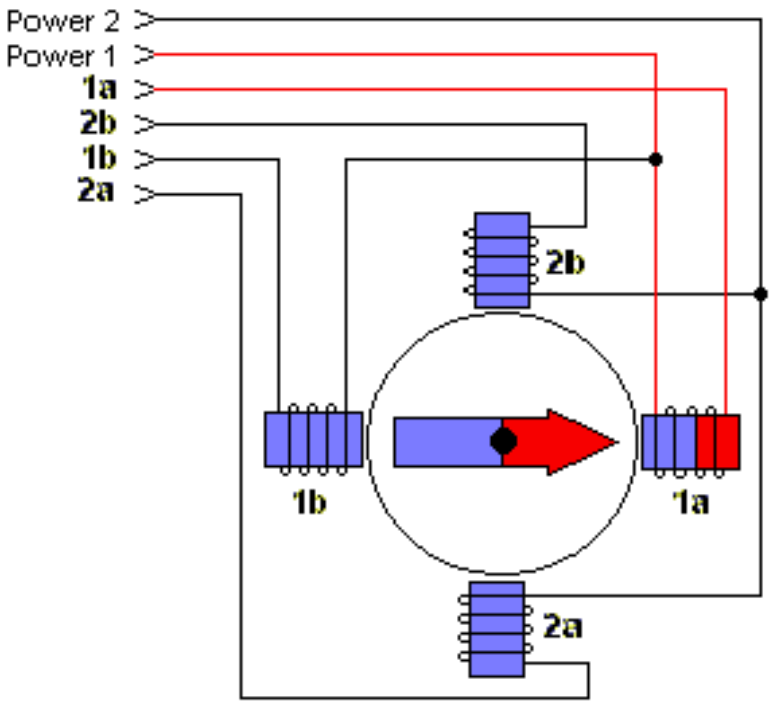
http://en.wikibooks.org/wiki/Practical_Electronics/Stepper_Motors

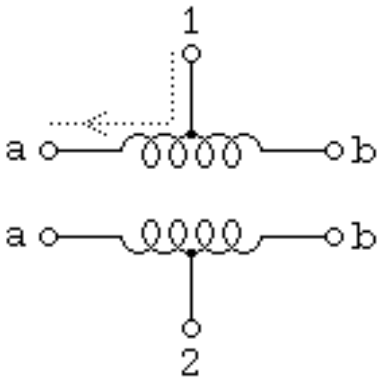
http://www.stepperworld.com/Tutorials/pgBipolarTutorial.htm

http://www.divms.uiowa.edu/~jones/step/index.html (<--Best)

Unipolar Stepper Motors

- Has 5 or more wires. Similar to Bipolar, except each coil has a center tap which is the common (or power) node.





Conceptual Model of Unipolar Stepper Motor

Image: http://www.stepperworld.com/Tutorials/model.gif

Unipolar Stepper Motors

- Simple motor driver uses Darlington transistors to energize each coil in the correct sequence.
- Can be used as Bipolar.
- 8-wire is the most versatile as it can be converted to a 6-wire, 5-wire, or a 4-wire motor.

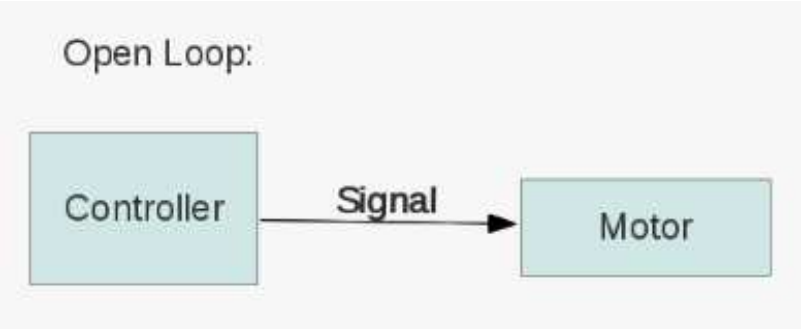
Additional Information:
http://arduino.cc/en/Reference/StepperUnipolarCircuit
http://en.wikibooks.org/wiki/Practical_Electronics/Stepper_Motors
http://www.stepperworld.com/Tutorials/pgUnipolarTutorial.htm
http://www.motionking.com/support/unipolar_bipolar.htm
http://www.divms.uiowa.edu/~jones/step/index.html (<--Best)

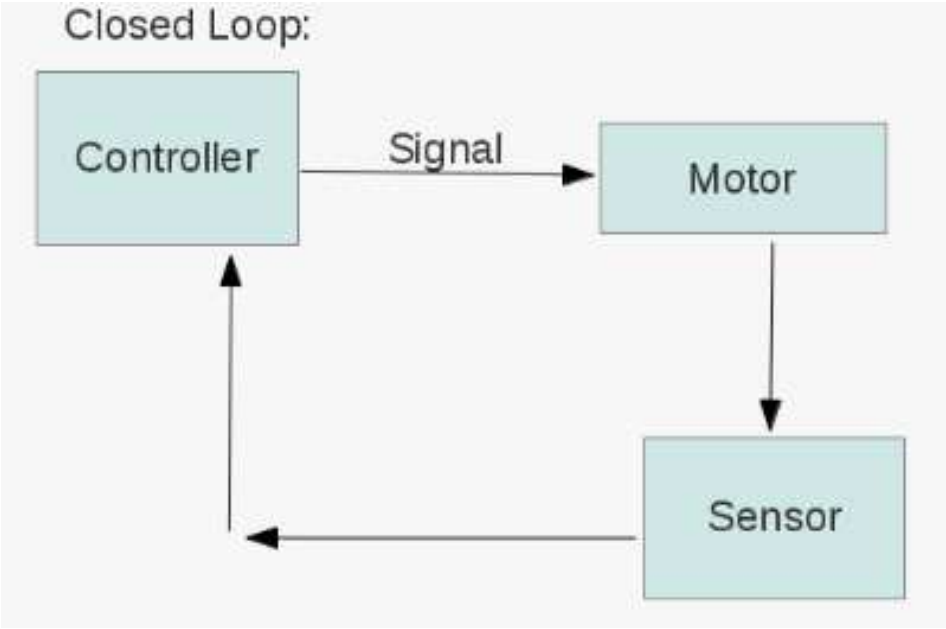
Stepper Motor Driver Interfacing:

- Unless you design it yourself, stepper motor drivers are usually designed to accept two inputs:

- Step and Direction. This simplifies the driver schematic and the driver can be treated as a black box.
  - "Direction" is binary (0 for one direction, 1 for the other)
  - "Step" line is pulsed once for each time you wish the motor to step in that particular direction.

Control:


Open Loop:
Controller
Signal
Motor


Closed Loop:
Controller
Signal
Motor
Sensor

Motor Encoders

- Encoders track the position of a motor.
  - **Magnetic encoder:** Like a bicycle speedometer. Magnets are placed on the wheel and a magnetic sensor can detect this as the wheel turns. Multiple magnets with alternating poles can improve the accuracy of the reading.

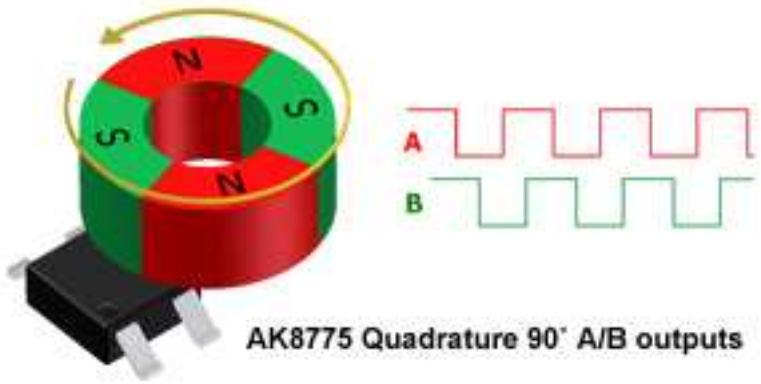
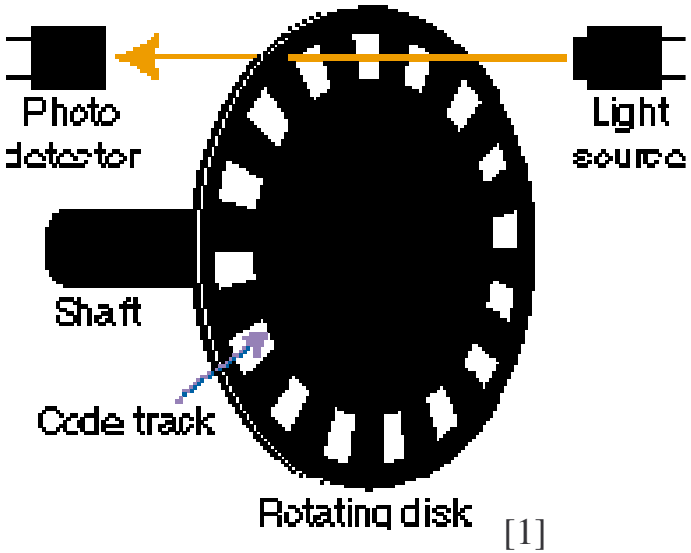


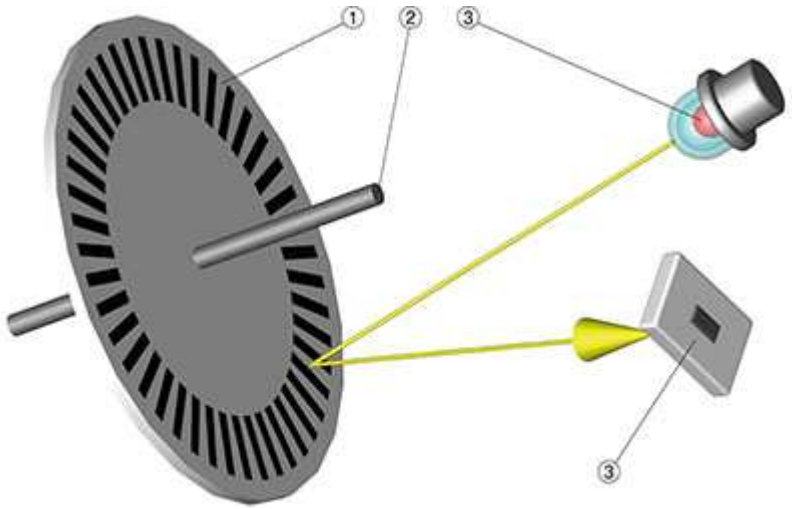
Image source: http://www.gmw.com/magnetic_sensors/asahi/AK877X.html

Motor Encoders

- **Optical encoder:** An infrared beam is passed through, or reflected off an encoder wheel. This wheel has slots to allow the light to pass, and spokes that will block the light. By counting the light pulses, you can tell how many degrees the motor has turned. Again, the more spokes on the encoder wheel, the better accuracy.



[1]

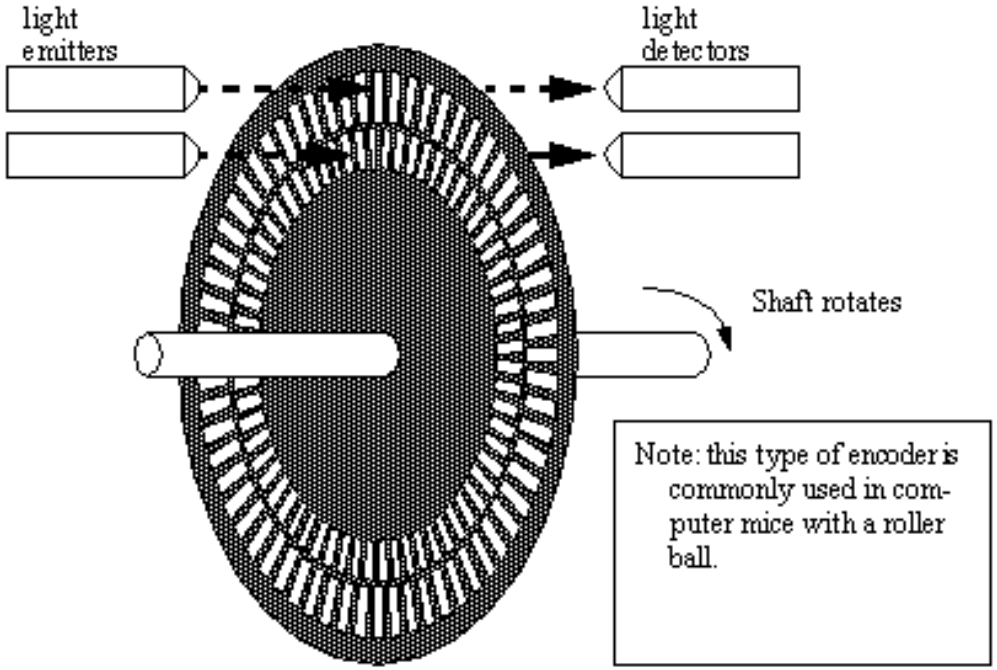


[2]

Image sources [1]: http://www.ni.com/white-paper/4672/en
[2] http://www.citizen-micro.com/tec/encoder.html

Motor Encoders

- **Quadrature Encoder:** Uses two optical encoders per wheel. This allows you to tell which direction the motor is spinning as well as how far it has spun.



Additional Information: http://quantumdevices.wordpress.com/2010/02/22/why-use-an-optical-quadrature-encoder-for-a-motor-encoder/

Image Source: http://www.romanblack.com/trackball.htm

Drive Configurations

- Differential Drive
  - Control each **side** of the robot. Examples?

http://chess.eecs.berkeley.edu/eecs149/documentation/differentialDrive.pdf
http://rossum.sourceforge.net/papers/DiffSteer/

- Ackerman Steering
  - Like a car, or the Autonomous ATV

- Chapter 2 shows more options
- Chapter 3 goes into detail about mathematical methods for calculating position ("dead reckoning")

Other Neat Ideas

- **Swedish Wheel (Omni-directional)**
  - Sidewinder Forklift http://youtu.be/vAiwLRGsNrE
  - Omni-wheel Robot: http://youtu.be/5vJCucpVdX0
  - Three-wheeled robot http://youtu.be/mNy09kuIdzs
- **Spherical Wheel**
  - http://youtu.be/sB9IowB8nx8
  - LEGO Robot http://youtu.be/OAc1ipVpn3k