Lecture #11 Outline

• Motors
  – DC motors
  – Stepper motors
• Motor-driving Electronics
• RC Servos
DC Motors

• DC motors are distinguished by their ability to operate from direct current (not as evident as it might appear)

• The Parts
  – **Rotor** – The rotating center portion. Term may also refer to the winding that is on the rotor.
  – **Stator** – The static (stationary) windings around the rotor. In many small motors, the stator can be replaced with permanent magnets (not as efficient).
  – **Commutator** – The brush connection to the winding on the rotor.
Simplified DC Motor:

- Stator-induced constant B-field
- Rotor winding
- DC power source

Graphic from application note by MicroMo Electronics at [http://www.micromo.com/03application_notes.asp](http://www.micromo.com/03application_notes.asp)
DC Motor Characteristics:

- Speed varies with applied voltage
  \[ \text{RPM} = \frac{(1000 \times V_a)}{K_e} \]
- Torque varies with current
  \[ \text{Torque} = K_t \times I \]
- Polarity determines direction of rotation
- Requires an external positional encoder to close feedback loop.
DC Torque vs. Speed

Stepper Motors

- Can be thought of as a DC motor without a commutator
- Active windings are on the stator instead of the rotor. Rotor is often a permanent magnet.
- Multiple wires give access to stator coils (typically two coils)
- Requires control electronics for sequencing coils. This replaces the commutator.
- Excellent “Open-Loop” Servo
Two-Phase Stepper Motor

- Power to the two coils must be properly sequenced (phased) to achieve rotor rotation.
- Rotation is synchronous to the drive sequence, which means high rotational precision is possible.

Graphic from Stepper Motor Application Notes available at: http://www.ericsson.com/microe/apn_ind.html
Bipolar Stepper Motor

- Reversing current flow in the stator windings causes B field to change direction and rotor to move

Graphic from Stepper Motor Application Notes available at: http://www.ericsson.com/microe/apn_ind.html
Bipolar Stepper Motor Drive

H-Bridge
Bipolar drive

Graphic from Stepper Motor Application Notes available at: http://www.ericsson.com/microe/apn_ind.html
Unipolar Stepper Motor

Graphic from Stepper Motor Application Notes available at: http://www.ericsson.com/microe/apn_ind.html
Unipolar Stepper Motor Drive

Unipolar drive

Graphic from Stepper Motor Application Notes available at: http://www.ericsson.com/microe/apn_ind.html
Stepper Motor Drive Modes

- Wave-Drive – One phase energized at any instant
- Full-Step Drive – Two phases energized at any instant
- Half-Step Drive – One then two phases, every-other-step
- Micro-stepping – Continuously varying current between phases
- Brushless DC Motor – Closed-loop controlled special case.
Wave-Stepping Sequence

Unipolar motor

Bipolar motor

Full/Half-Stepping Sequence

• Single Direction
  – NPN transistor, MOSFET, or power driver IC
  – ON/OFF control or PWM to control speed, torque, delivered power
  – 2N2222 for small motors (I<200mA)
  – ULN2003/ULN2803 7/8-channel power driver (I<800mA/chip)
  – TIP120 for larger motors (I<5A)

• Bi-Directional
  – Need reversible power, an H-Bridge Driver
  – LMD18200: single H-bridge high-power motor driver. Up to 55V 3A. Accepts enable, brake, and direction inputs
  – LM18293: dual H-bridge motor driver. I<400mA. May be used for both stepper motors and DC motors
**Stepper Motor Electronics**

- **Unipolar Drive**
  - Can use 4 to 8 NPN transistors or MOSFETs, or power driver IC
    - Must provide sequencing logic/signals to make motor operate
    - Could do microstepping using PWM
    - 2N2222 for small motors (I<200mA)
    - ULN2003/ULN2803 7/8-channel power driver (I<800mA/chip)
    - TIP120 for larger motors (I<5A)

- **Bipolar Drive**
  - Needs reversible power for two coils (Dual H-Bridge Driver)
  - LM18293: dual H-bridge motor driver. I<400mA. May be used for both stepper motors and DC motors
  - UCN5408, MC3479, etc: dual H-bridge driver plus sequencing logic for stepping the motor. Accepts STEP, DIR inputs.
RC Servos: Overview

• Servos made for Radio-Control applications can be commanded by your AVR!

• RC-Servos are:
  – Cheap (typically $10, range $5-50)
  – Strong (typically 42 oz-in or 3.1 kg/cm)
  – Small (typically 1.6”x0.8”x1.4”)
  – Have built in control electronics, gearing, mount holes
  – 3-wire interface (Ground, Power, Control)
  – Operate on 4-6V
  – Commanded to a position by pulse width
“Closed-loop” position commanding by pulse width

- 1.50 ms: Neutral
- 1.25 ms: 0 degrees
- 1.75 ms: 180 degrees
Motor Web References:

- **DC Motors:**
  - [http://lancet.mit.edu/motors/index.html](http://lancet.mit.edu/motors/index.html)
  - [http://www.micromo.com/03application_notes.asp](http://www.micromo.com/03application_notes.asp)

- **Stepper Motors:**
  - [http://www.ericsson.com/microe/apn_ind.html](http://www.ericsson.com/microe/apn_ind.html)
  - [http://www.st.com/stonline/books/pdf/docs/1679.pdf](http://www.st.com/stonline/books/pdf/docs/1679.pdf)
  - [http://www.thomsonind.com/airpax/airpax.htm](http://www.thomsonind.com/airpax/airpax.htm)

- **RC Servos**
  - [http://www.google.com](http://www.google.com) (keywords: RC servo)
  - [http://www.towerhobbies.com](http://www.towerhobbies.com)