Mens et Manus

Controlling a Brushless Motor

October 1, 2018

Parts: Layout and Fabrication

Finish your design and fabrication of parts this week:
- a base plate that supports a motor shaft,
- 1+ electromagnets attached to the base plate to form the stator,
- 1+ Hall-effect sensors attached to the base plate, and
- a rotor with 1+ permanent magnets.

Fabrication tips:
- Laser cut acrylic (1/4", 1/8", and/or 1/16") for planar parts.
- 3D print non-planar parts (but note that 3D printing is slow).
- Our power supplies provide 5V to drive electromagnets
  - limit power to 2 watts per electromagnet to avoid overheating
  - use 32 gauge wire for simple designs with plastic bobbins
- Use screws to hold pieces together – NO glue or tape

Mapping Sensor Readings and Torque Versus Angle

Teensy 3.2 Microcontroller

The Teensy3.2 is a powerful and inexpensive controller.
Compatible with Arduino, supported on Linux, Windows, and Macs.
Programmable in C/C++. Controllable in any language.
Four dedicated pins:
- two power pins: power in (5V) and power out (3V, 0.1A max)
- two grounds: analog and digital.
24 programmable pins:
- any of these can be used for digital in/out
- 10 pins (A0-A9) can be used for analog in/out

Switches for Electromagnets

Adafruit TB6612 board: 2 H-bridges to control electromagnets.

Each H-bridge can supply up to 1.2A at 5V to one or multiple coils
- connected in parallel (so that currents add) or
- connected in series (so that voltage is divided among them).

External Power Supply

Power for motors is provided from an external microUSB connector.

To use the same source for Teensy (so that motor can run without
a laptop) we must disconnect power from the Teeny’s USB port.

Then power comes from external microUSB connector, and USB
connector on the Teensy is only used to control the Teensy.
**Wiring**

Solder wire-wrap connectors to Teensy, TB6612, and USB boards.

Use wire-wrap to connect power and ground leads as follows.

```
<table>
<thead>
<tr>
<th>Teensy</th>
<th>+3.3V</th>
<th>gnd</th>
<th>agnd</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB6612</td>
<td>+5V</td>
<td>gnd</td>
<td></td>
</tr>
<tr>
<td>USB</td>
<td>+5V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+3.3V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vcc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

**Test Power Wiring**

Test power connectors to avoid damage to your laptop or circuits.

**Step 1:** Plug USB power supply into Teensy USB connector and then into wall power. Since we cut the USB power supply, the integrated led shown below should **NOT** blink. If it does, recut the power trace on the backside of the Teensy and repeat this test.

**Step 2:** Remove USB power supply from Teensy USB connector and plug it into the microUSB board. Now the integrated led **should blink**. If it does not, then power is not getting to the Teensy from the microUSB board. Check your power connectors and repeat test. Do not proceed until you get no blink in step 1 and blink in step 2.

**Connecting Hall-effect sensors**

Connect Hall-effect sensors.

- **left pin (red):** +3.3V
- **center pin (black):** gnd
- **right pin (blue):** one of Teensy's analog pins (A0 to A9)

Multiple sensors can share +3.3V and gnd, but each must have a separate analog pin.

**Connecting Electromagnets**

Each TB6612 board has two H-bridges.

Multiple electromagnets can share the same H-bridge if they are always switched on and off at the same time.
- If connected in series, the voltage across each coil will be halved.
- If connected in parallel, the total current required will double.

Voltage from H-bridge = 5V.
Maximum current from each H-bridge is 1.2A.

**Controlling an H-Bridge**

Switches in each H-bridge are controlled by input pins: IN1 and IN2.

```
OFF
IN1: L; IN2: L

V M
X1H
X1L
X2H
X2L

BRAKE
IN1: H; IN2: H

V M
X1H
X1L
X2H
X2L

CW
IN1: H; IN2: L

V M
X1H
X1L
X2H
X2L

CCW
IN1: L; IN2: H

V M
X1H
X1L
X2H
X2L
```

H = high = +3.3V; L = low = gnd.
Unused inputs: PWM and STBY should be tied H.

**Wiring an H-Bridge**

Any of the Teensy pins 0 to 23 can be used as a digital control line.

```
+3.3V

IN1
IN2
```

Connect coils to TB6612 using wire-wrapped connections.

Use very fine sandpaper (600 grit) to remove the insulation from the last 2” of magnet wire. To prevent accidental short circuits, wrap 3” of magnet wire (1” with insulation and 2” without) so that ALL of the bare magnet wire is wrapped.