Electronics Design Laboratory
Lecture #5
Notes

• **Attendance**
  – Attendance in the lectures and the lab is required to receive any lab credit

• **Experiment 2 demo tomorrow in the lab; demo setup:**
  – Supply the motor from +10V; separately supply encoder +5V. Supply your speed sensor circuitry from +5V. *Make sure the encoder and the sensor circuitry share the same ground.*
  – Show complete LTspice Lab2.B circuit on a screen; simulation circuit should use the same component values as your actual circuit, and should work.
  – Make sure the circuit includes dc decoupling capacitors, is neat and easy to debug, with all component leads cut down
  – Use 2 scope voltage probes: show encoder pulses and 555 timer output (PWM signal); display measurement of the PWM signal duty cycle
  – Know how to probe and measure \( t_{on}, T_{enc}, \) PWM, filtered output, etc.

• **Experiment 2 report due in Canvas by 5pm on Wednesday**
  – Double check your submission for completeness
  – Make sure you and your partner(s) agree who is submitting the report
  – Late or messy work will receive no credit
Experiment 3 – Motor Drivers/Speed Control
Experiment 3a

0-10V

Rb1

10VDC

Q3

Q1

Q4

Q2

GND

VDC+

VDC−

0-10V

Rb2

Forward Controller

Reverse Controller

NOT Forward

Forward

Speed error

0-5V Speed Output proportional to actual motor speed

0-5V Speed Output proportional to desired motor speed

Experiment 3b

Experiment 1 & 2

Speed Sensor and Filter

5VDC

GND

wheel

ENCA

V_{speed}
DC Motor Driver

- Motor requires up to 1 A in each direction
- Bipolar Junction Transistors (BJTs) used to drive the motors
- BJTs have high current gain, which reduces the output current required from the feedback circuit op-amps
PN Diode

- Needs positive voltage to conduct
- Current flow from Anode to Cathode only
- Multiple models used, depends on how much information you need
  - Always use simplest model that works.
NPN Bipolar Junction Transistor (BJT)

- Three port device
  - Voltage differences between ports control device operation
- Three common modes of operation
  - Cutoff (Off-State Switch)
  - Active (Current Amplifier)
  - Saturation (On-State Switch)
PNP Bipolar Junction Transistor (BJT)

- Dual of the NPN device.
- All characteristics are the same, voltages are simply reversed.
- Chapter 5 of Sedra/Smith for more information on both NPN and PNP.

PNP equivalent active mode model:

\[
i_c = \beta i_b
\]
• BJTs provide current gain, $\beta \approx 200$
• Limiting the base current can be used to limit the motor current
Motor current limit design

- Consider a test at maximum motor current
  - Wheel locked.
- Full speed in one direction: B1 = 10V, B2 = 0V
- What mode does each transistor operate in?
  - Only one device is ‘on’ per side

<table>
<thead>
<tr>
<th>Mode</th>
<th>PNP</th>
<th>NPN</th>
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</thead>
<tbody>
<tr>
<td>Active</td>
<td>$V_{EB} &gt; 0.8V$</td>
<td>$V_{BE} &gt; 0.8V$</td>
</tr>
<tr>
<td></td>
<td>$V_{CB} &lt; 0.8V$</td>
<td>$V_{BC} &lt; 0.8V$</td>
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<tr>
<td>Sat.</td>
<td>$V_{CB} &amp; V_{EB} &gt; 0.8V$</td>
<td>$V_{BC} &amp; V_{BE} &gt; 0.8V$</td>
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<tr>
<td>Cutoff (C/O)</td>
<td>$V_{CB} &amp; V_{EB} &lt; 0.8V$</td>
<td>$V_{BC} &amp; V_{BE} &lt; 0.8V$</td>
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<table>
<thead>
<tr>
<th>Transistor</th>
<th>Active</th>
<th>Cutoff</th>
<th>Cutoff</th>
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<tbody>
<tr>
<td>Q1</td>
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<td>Q2</td>
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Motor current limit design

- Insert equivalent models into circuit
- Solve $R_{b1} = R_{b2} = R_b$ to limit the motor current
- What is the voltage on the motor?
  - Wheel is locked, or when
  - Wheel is at maximum speed
- What is the current through the motor?
  - Wheel is locked, or when
  - Wheel is at maximum speed

\[ i_c = \beta i_b \]

**NPN equivalent active mode model**

\[ i_c = \beta i_b \]

**PNP equivalent active mode model**

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<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>C/O</td>
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</tbody>
</table>
Equivalent Circuit: Locked Wheel

NPN equivalent active mode model

PNP equivalent active mode model
DC Motor Driver Board
Soldering

- Be careful with the soldering irons!
  - Do not burn anyone
  - Do not burn anything

- Make sure you know what you want to do before you do it. Double check everything before soldering.