Bipolar Junction Transistor (BJT)
Announcements

• HW5 due Mar. 9

• Razavi Ch4
  • 4.1-4.4, 4.6, 4.7

• Razavi Ch5
BJT Circuit Symbols

- BJTs are 3 terminal devices
  - Collector, Base, & Emitter
- 2 complementary BJT devices: NPN & PNP
NPN BJT Device Structure

- BJTs consist of 2 back-to-back junctions (diodes) with a shared middle region
  - np & pn for the NPN transistor
- Doping level varies dramatically with region

[Sedra/Smith]
PNP BJT Device Structure

- BJTs consist of 2 back-to-back junctions (diodes) with a shared middle region
  - pn & np for the PNP transistor
- Doping level varies dramatically with region
# BJT Modes of Operation

<table>
<thead>
<tr>
<th>Mode</th>
<th>Base-Emitter Junction</th>
<th>Base-Collector Junction</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutoff</td>
<td>Reverse</td>
<td>Reverse</td>
<td>Digital Logic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>“Switch Off”</td>
</tr>
<tr>
<td>Saturation</td>
<td>Forward</td>
<td>(Strong) Forward (&gt;0.4V)</td>
<td>Digital Logic</td>
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<td></td>
<td></td>
<td></td>
<td>“Switch On”</td>
</tr>
<tr>
<td><strong>Active</strong></td>
<td><strong>Forward</strong></td>
<td>Reverse (Weak Forward &lt;0.4V)</td>
<td>Analog Amplifier</td>
</tr>
<tr>
<td>Reverse Active</td>
<td>Reverse</td>
<td>Forward</td>
<td>??</td>
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</tbody>
</table>

**Diagrams:**

- **Cutoff**
  - Base-Emitter: 5V ±
  - Collector: 5V ±
  - Emitter: 5V ±

- **Saturation**
  - Base-Emitter: >0.4V ±
  - Collector: 0.7V ±
  - Emitter: 1V ±

- **Active**
  - Base-Emitter: 0.7V ±
  - Collector: 0.7V ±

- **Reverse Active**
  - Base-Emitter: 0.7V ±
  - Collector: 0.7V ±
NPN Active Mode Operation

- Emitter current $i_E$ consists of injected electrons into the base and injected holes from the base
  - Due to the doping disparity, the electron current is much greater than the hole current
- The electrons injected into the base diffuse across the narrow base region and are swept or “collected” into the collector due to the $V_{CB}$ bias
- The net result is a collector current which is almost equal to the emitter current, and whose values are determined by the $V_{BE}$ bias