Solderless Breadboards

Power bus (red)
Ground bus (blue)
Component bus

Note that the two sides are not connected
Wiring Standards

When possible, use wire colors for different types of signals:

- Black: ground
- Red: power
- Other: various signals
Clean Wiring

A clean breadboard will make debugging easier – and it makes circuits more robust
Care with Power

- Only insert components and wires into the breadboard when power is disconnected
- “Wire, check-twice, then power”
  - Never reverse power and ground (this is a very common mistake)
- Most chips that we will use expect +5V
  - More can destroy the chips
  - We will use DC/DC converters to step battery voltages down to +5V
Care of Chips

- Use insertion and extraction tools: never use your fingers.
- Minimize your contact with pins: static electricity can destroy a chip.
- Use a wrist strap when you handle chips.

www.a7vtroubleshooting.com
www.chantronics.com.au
Andrew H. Fagg: Embedded Real-Time Systems: Digital Practice
www.hvwtech.com
TTL Chips: 2-Input AND Gates

Chip number: 7408

Pin 1 is marked on the chip

Ground

Power

www.dcs.warwick.ac.uk

www2.117.ne.jp
TTL Chips: 2-Input OR/XOR Gates

7432 or 74LS32

7486 or 74LS86

www.dcs.warwick.ac.uk
TTL Chips: 3-Input AND Gates

7411

digikey.com
Constant Inputs

How do we configure a chip input as a constant?
Constant Inputs

How do we configure a chip input as a constant?

• For a constant 0: connect to ground
• For a constant 1: use a pull-up resistor to +5V (e.g., 10K ohm)
Wiring Procedure (Suggested)

- Power supply
- Power/ground buses
- Insert primary components
- Wire power/ground for components
- Add signals and remaining components
- Test incrementally
Debugging Techniques

• Multimeter:
  – Use *voltage mode* to check logic levels
  – Use *continuity mode* to confirm connections
    (but never with power turned on)

• Oscilloscope:
  – View voltage as a function of time on 2 channels

• Test incrementally

• Test intermediate sub-circuits
Debugging Techniques

Wire in LED to indicate logic level on a line

- For most components, do not allow the line to be driven by more than 20mA (check the specs if in doubt)

- Note that in this circuit, the LED turns on when logic level is LOW
Next Time

• Homework 1 discussion
• Central Processing Units
What Is It?
A Mechanical Implementation of an OR Gate

goldfish.ikaruga.co.uk/logic.html
A Mechanical Implementation of an OR Gate
A Mechanical Implementation of an OR Gate
A Mechanical Implementation of an OR Gate
Last Time

• Demultiplexers
• Tristate buffers
• Digital logic in practice:
  – Chips with gates
  – Power
  – Constant inputs
Today

• Homework 1
• More circuit details
• Project groups
• Sequential logic
Administrivia

• Homework 2 due on Tuesday @5:00

• Appendix B:
  – Note gate symbol errors on page 596 (in particular, AND and OR)
Homework 1

- Mean: 88.37%
- Median: 89.59%
- Standard deviation: 10.35%
Proposed Groups

Group 1:
- Hawkins
- Edwards*
- Hopkins
- ?

Group E:
- Watson
- Ritz
- Barajas Cortes
- Thompson
- Nicholas

Group 2:
- Littlefield
- Torres
- Goepfert
- ???

Group 3:
- Valentas
- Nakajima
- Sullivan
- Nelson

Group 4:
- Moerbeek
- Habib
- Murphy

Group 5:
- Striz
- Imai
- Lucas
- Bent
Our resistors use the 4-band code.

### Resistor Codes

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1st BAND</th>
<th>2nd BAND</th>
<th>3rd BAND</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1Ω</td>
<td>± 1%</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10Ω</td>
<td>± 1%</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100Ω</td>
<td>± 2%</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1KΩ</td>
<td></td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>10KΩ</td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>100KΩ</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>1MΩ</td>
<td>± 0.25%</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>10MΩ</td>
<td>± 0.10%</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
<td>± 0.05%</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>± 5%</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
<td>± 10%</td>
</tr>
</tbody>
</table>

### 5-Band Code

- 0.1%, 0.25%, 0.5%, 1%
- 237Ω ± 1%
Next Time

Project 1:
• Specification
• Initial group work