Circuit Protection, Tips, and Debug

ECE 445
Becoming a Good Design Engineer

• Break complex circuits down into manageable blocks
  - With accessible I/O for probing!

• Troubleshoot problems at a modular level

• Understand previous approaches to the problem

• End goal of senior design:
  - Solve new problems in innovative ways
  - Learn about the process of creating electronics
Data Sheets - ICs

- Pin-outs
- I/O pin ratings
  - $\text{Vih}/\text{Vil}$, $\text{Voh}/\text{Vol}$, $\text{Iout}$ as appropriate
  - Part likely breaks if these are violated
- Potential applications (example circuits!)
- Power requirements
  - All the VDD rails needed for operation
- Timing diagrams for digital ports

Device Ratings – Discrete Components

• **Resistors**
  - Power rating
  - Tolerance

• **Capacitors**
  - DC derating – V at which the C is “spec’d” (...but not really...)
  - Tolerance
  - Z vs. frequency
  - ESR

• **Inductors**
  - Rated vs. saturation current
  - Self-resonant frequency
  - Tolerance
  - DCR

• **Diodes**
  - V (reverse standoff vs. breakdown vs clamping)
  - Leakage current
Wire Gauges

- Wire gauge is a standard for the size of the wire (proportional to current rating)

- Typical wire in lab is 22 AWG Cu
- Maximum for breadboard
- 52.9 mΩ/meter
- 7 A for short wiring in air
- 0.92 A for power transmission

- Other common gauges:
  - 16 AWG: 3.7 A
  - 18 AWG: 2.3 A
  - 20 AWG: 1.5 A
  - 24 AWG: 0.58 A
  - 26 AWG: 0.36 A
  - 28 AWG: 0.23 A
Resistor Codes

Reading Surface Mount Resistors

• 332 is 3.3 kilo-ohms
• 3K3 is 3.3 kilo-ohms

Use reference tables for resistors and wire gauges!
Potentiometers

• Variable Resistors

• Example:

  Trimpot, $R = 10 \, \text{k}\Omega$
  
  (a) to (c): $R_1 = 6 \, \text{k}\Omega$
  
  (b) to (c): $R_2 = 4 \, \text{k}\Omega$
Device Polarity

The longer length is the (+) terminal

- Capacitors
  - Al electrolytic: marked on - terminal
  - Tantalum: marked on + terminal
  - No polarity: ceramic or polyester

- Diodes
  - The bar indicates cathode
Earth Ground vs “Ground”

- Green Terminal = Earth Ground
- Black Terminals = Signal Grounds
Voltage Current Limiting

• Fuses
  - Typically allow for passage of “normal” current
  - A fuse will “blow” above its current rating

• Diodes
  - Conduct when $V > 0.7\,\text{V}$

• Best solution: use both diodes and fuses
Reverse Polarity Protection

2 different configurations to ensure correct voltage polarity:

Simple Diode
- Circuit will not operate with incorrect polarity

Diode Bridge
- Circuit will operate under either polarity
- Higher losses
Driving High Current Load

• Most microprocessor/TTL can drive <20mA (approximately an LED)
  - Interface microprocessor I/O with a gate.
  - Let the gate break instead of the microprocessor!

• Methods
  - Relays
    - Simple but may wear out and have delays
  - Transistor
    - Fast switching but have current limit
  - H-bridge
    - More involved but allows for forward and reverse current
    - Good for motors
Power Supply Bypass/Decoupling Capacitors

- Protect voltage rail from noisy ICs/circuits
- Provide instantaneous current for fast-transitioning (digital) signals
- Best to use a few caps in parallel:
  - smaller C to work at higher frequencies
  - large or “bulk” C to provide large amounts of energy
- Almost all ICs (microprocessors, DSPs, etc) need some decaps for every voltage rail: place as close as possible to their VDD pins
Troubleshooting Steps (1/2)

1. PCBs: Remove/disconnect power and measure DC resistance at power supply rails (VDD-to-GND) with a multimeter.
   - If reading is less than ~50 to 100Ω, you may have a damaged part connected to that rail somewhere— DON’T power on
   - If possible, try removing parts 1 by 1 to see if the reading increases

2. Power on. Check supply voltages with a multimeter.
   - If any rails show 0V: is power actually plugged in? Is any switch off? Is the fuse blown?

3. Probe signal at intermediate stages or at individual function blocks I/O.
   Equipment available:
   - Digital Signals: Oscilloscope, Logic Analyzer
   - Analog Signals: Oscilloscope, Voltmeter, Spectrum Analyzer
Troubleshooting Steps (2/2)

4. Check interconnections
   - Signals incorrectly wired?
   - Are any wires loose/contacts bad?
   - Is any signal floating (tied to nothing)?

5. Double check the design
   - Check the pin diagram
   - Check that you have the correct datasheet for the part number
   - Re-analyze the logic, go through some calculation
   - Ensure correct polarity

6. Faulty devices/breadboard (Last resort if all else fails!)
   - Replace/rewire one part at a time, test after every change
   - Isolate the parts under test from the rest of the circuit
References

- https://en.wikiversity.org/wiki/Tantalum_capacitors
- http://www.learnabout-electronics.org/resistors_07.php
- Previous ECE 445 Lecture Slides
- Staff of the ECE Electronics Shop,
  Dan Mast, Mark Smart, Skot Wiedmann