Circuit Protection, Tips, and Debug

ECE 445

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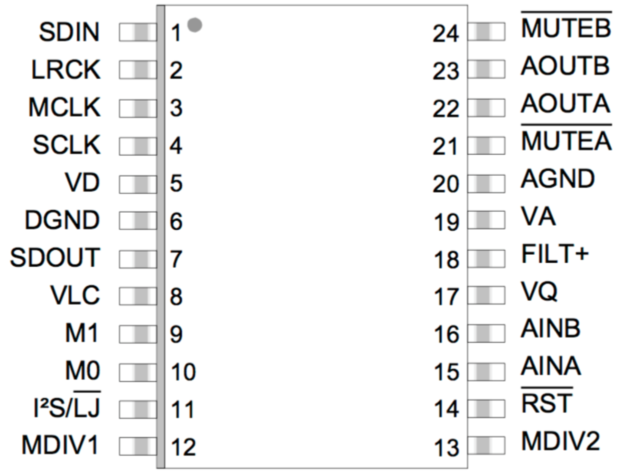
Becoming a Good Design Engineer

- 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
  - Vih/Vil, Voh/Vol, 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



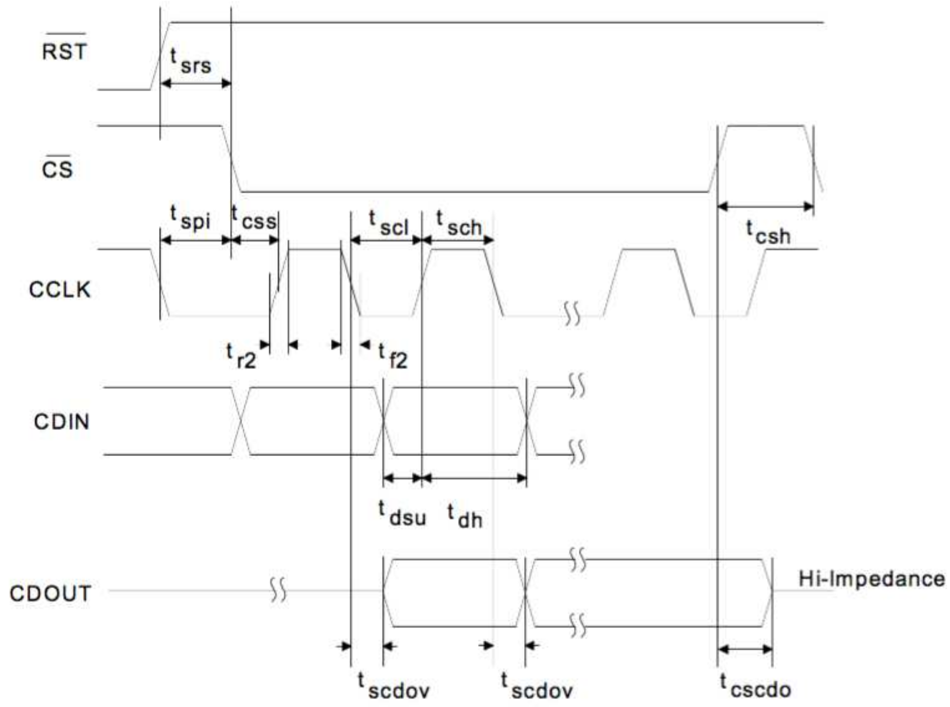


Figure 13. SPI Control Port Timing

[1] Cirrus Logic, “24-Bit 192-kHz Stereo Audio CODEC”, CS4270 datasheet, [Revised Aug 2

Device Ratings – Discrete Components

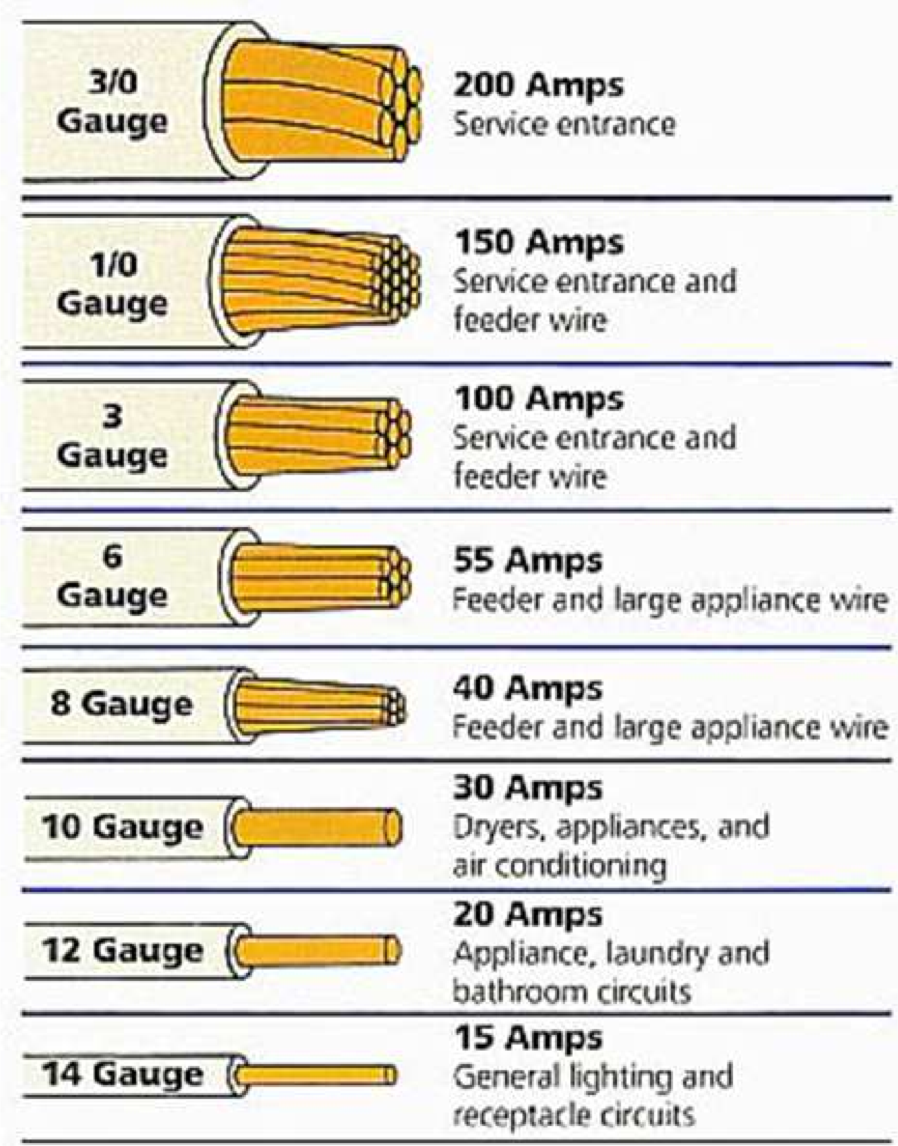
- Resistors
  - Power rating
  - Tolerance
- Capacitors
  - DC derating – V at which the C is “spec’d” (…but not really…)
  - Tolerance
  - Z vs. frequency
  - ESR
- Inductors
  - Rated vs. saturation current
  - Self-resonant frequency
  - Tolerance
  - DCR
- Diodes
  - V (reverse standoff vs. breakdown 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

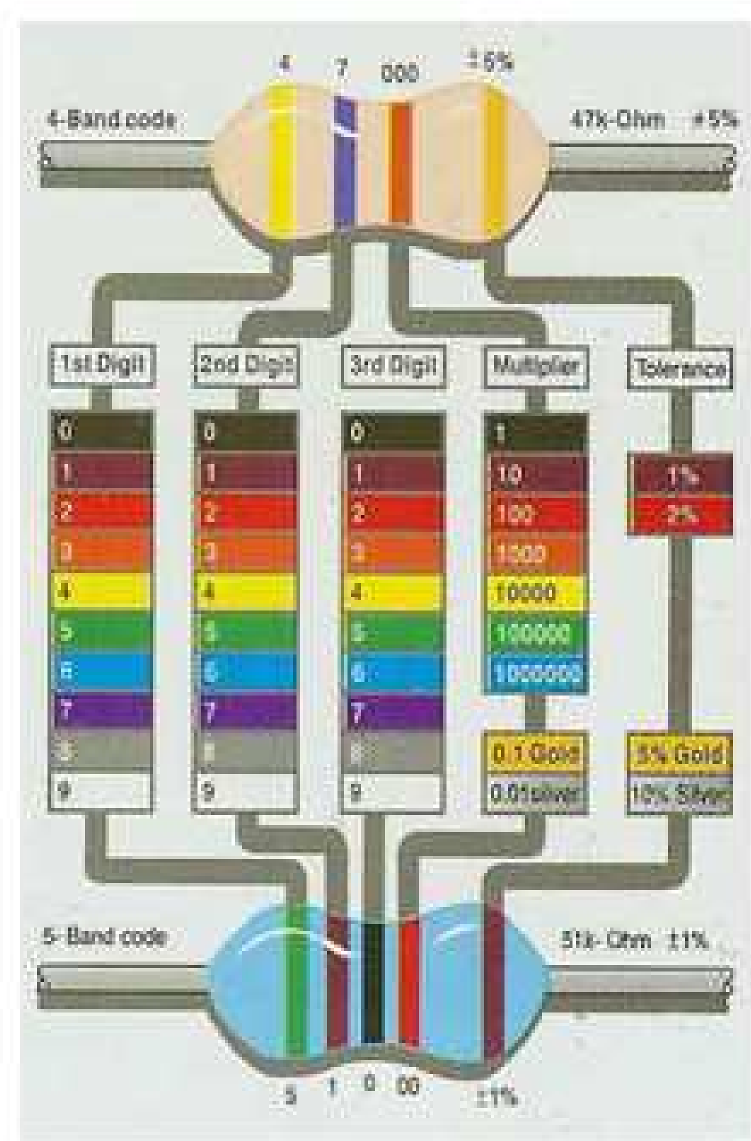
- Other common gauges:
  - 16 AWG: 3.7 A
  - 18 AWG: 2.3 A
  - 20 AWG: 1.5 A
  - 24 AWG: 0.58 A
  - 26 AWG: 0.36 A
  - 28 AWG: 0.23 A



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

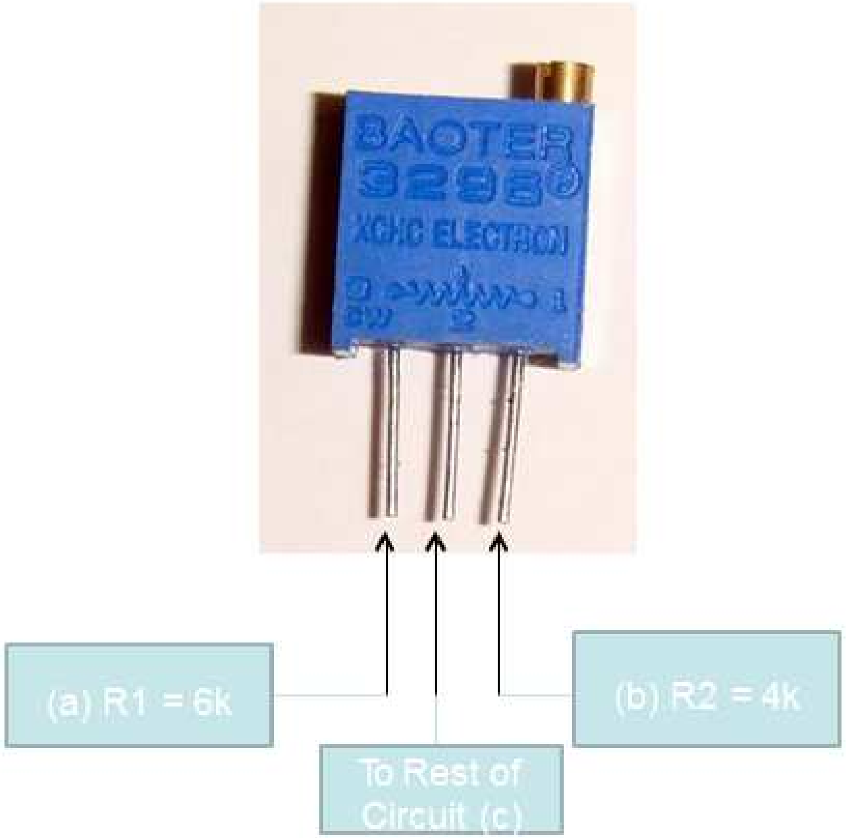
- Variable Resistors

- Example:

  Trimpot, $R = 10\ \mathrm{k\Omega}$

  (a) to (c): $R_1 = 6\ \mathrm{k\Omega}$

  (b) to (c): $R_2 = 4\ \mathrm{k\Omega}$



Device Polarity

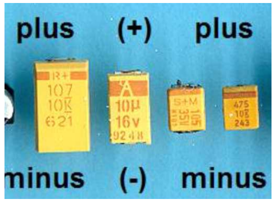
The longer length is the (+) terminal

- Capacitors

Al electrolytic: marked on - terminal

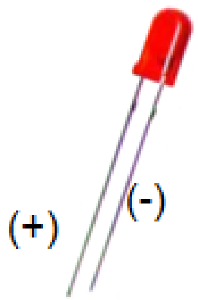
No polarity: ceramic or polyester

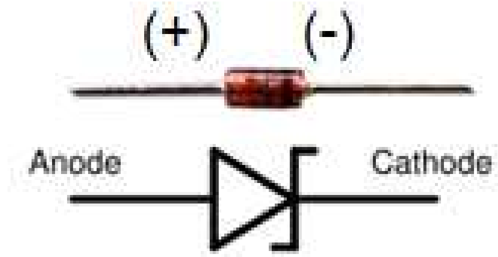
Tantalum: marked on + terminal



- Diodes

The bar indicates cathode





Earth Ground vs "Ground"

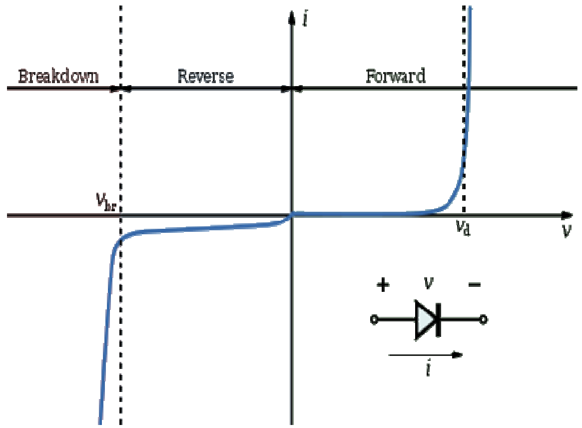
- Green Terminal = Earth Ground
- Black Terminals = Signal Grounds

Voltage Current Limiting

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

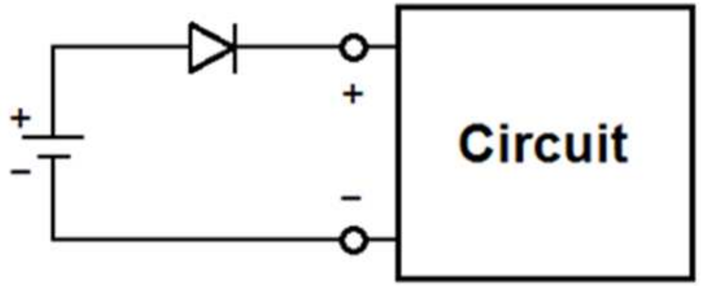
- Diodes
  - Conduct when V > 0.7 V

- Best solution: use both diodes and fuses

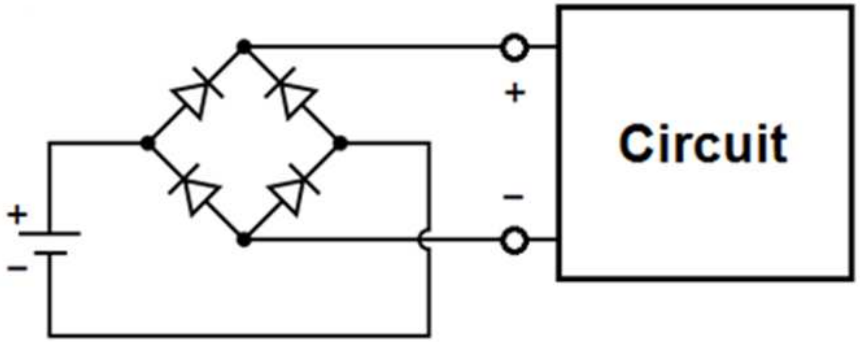


Reverse Polarity Protection

2 different configurations to ensure correct voltage polarity:



Simple Diode
- Circuit will not operate with incorrect polarity

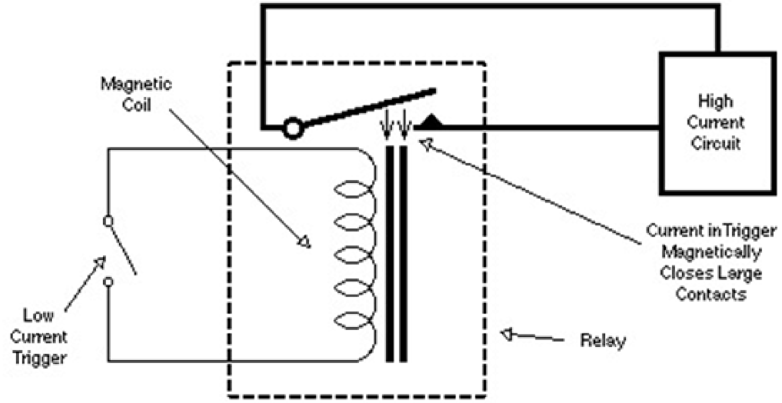


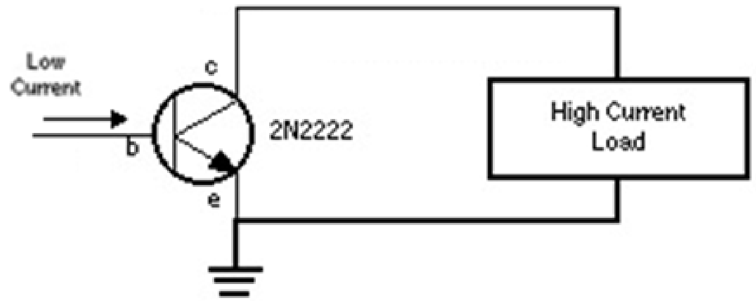
Diode Bridge
- Circuit will operate under either polarity
- Higher losses

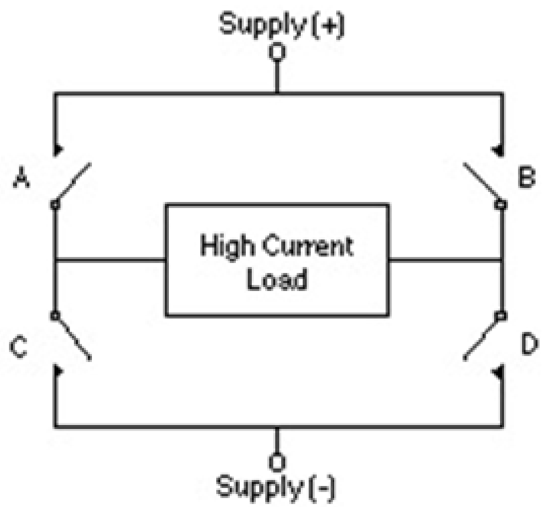
Driving High Current Load

- 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

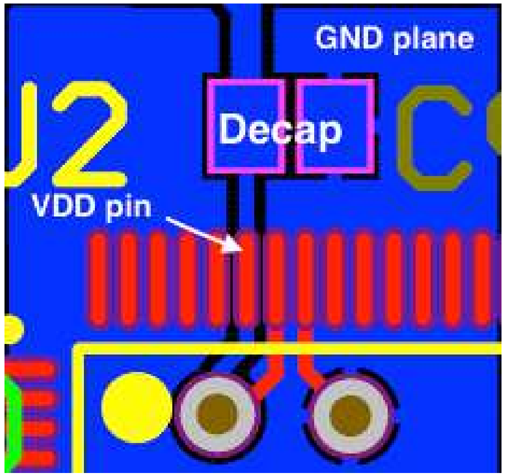


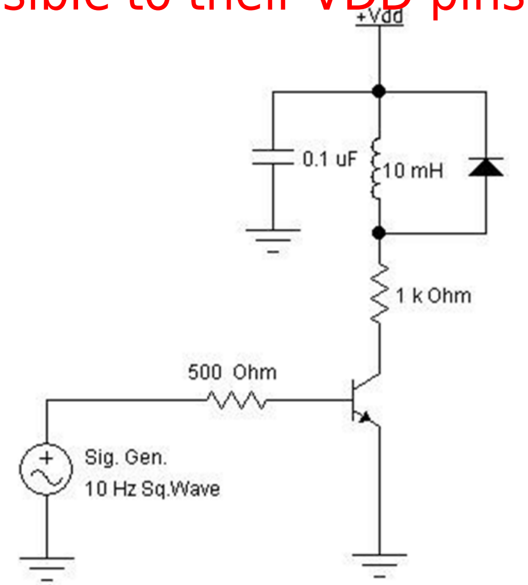




Power Supply Bypass/Decoupling Capacitors

- 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

- http://www.intersil.com/data/an/an1325.pdf
- http://en.wikipedia.org/wiki/Diode
- http://en.wikipedia.org/wiki/Fuse_(electrical)
- https://en.wikiversity.org/wiki/Tantalum_capacitors
- http://www.learnabout-electronics.org/resistors_07.php
- http://www.rbeelectronics.com/wtable.htm
- Previous ECE 445 Lecture Slides
- Staff of the ECE Electronics Shop,

  Dan Mast, Mark Smart, Skot Wiedmann