Safety

• Remove metal jewelry

• When around high voltage, don’t create a potential circuit from the high voltage to ground that might pass through your body

• A clean workspace

• Plenty of bench area
Essentials

- Tools
- Knowledge
- Time/Patience
  - Put it aside for a while if you aren’t making progress
Tools

- Multimeter
- Oscilloscope
- Soldering iron
- Screwdrivers/wrenches/ect.
Multimeter

- High impedance input -10 megaohm minimum
- More digits/precision in ohms mode useful for tracking down shorts
- Quality probes helpful

http://www.digikey.com
Oscilloscope

- 100MHz or higher
- 2 or more channels
- Newer digital can be easier to use
- Older analog may be less expensive

http://www.eevblog.com
Soldering Iron

- Temperate controlled
- Changeable tips

http://www.apexhandtools.com
Assumptions

• Connectors can degrade or fail
• Components can degrade or fail
• Cables can degrade or fail
• Start with the idea that the design is “correct”

http://www.diyaudio.com
Case in Point

- My 4th subwoofer fails in 15 years
- Power FETransistors failed
- Replaced - failed again immediately
- Removed DIAC and tested with specially created test circuit
- Finally found issue

http://www.diyaudio.com
Steps

- Research
- Check power supplies
- Look for obvious damage
- Check for hot parts
- Look for bad connections
- Compare duplicate/parallel circuits
- Component level troubleshooting
Comparing Duplicate/Parallel Circuits

- Examples:
  - Working system of the same type
  - Individual Lines on a Bus Should Appear Similar
  - Duplicate Circuits (stereo)
Research

• The Internet is your friend
  • Wrong answers probably outnumber right answers
• Manuals/Schematics
  • Might find exact same problem and solution
  • Might find similar, but different problem
  • Might not find anything comparable
• Component knowledge can be more useful than system knowledge
Macintosh 128K Intermittent Blank Screen

• Several sources describe common problem with bad solder joints on J4 on analog board
• Wiggling cable showed that the problem seemed likely to match
• Tried re-soldering several times to no effect
• Finally determined problem was actually connector on digital board

http://www.ccadams.org/se/classicmac2.pdf
Components

- Integrated Circuits
- Capacitors
- Transistors and Diodes
- Resistors
Integrated Circuits

- Logic types
  - normal TTL
  - open collector
  - tristate

- When you detect a bad signal with a lot of parts connected to a bus
  - lift transmitters leg and recheck signal on lifted leg and receivers
Normal TTL Output

- One transmitter
- One or multiple receivers
- Common failure mode - transmitter fails, signal will float at around 2 volts
- Receiver can also fail and prevent source from driving signal to correct level
- Shorts and opens on PCB can also disrupt signal integrity
Open Collector Output

- Multiple transmitters
- Multiple receivers
- Uses an external resistor tied to power supply to set default signal to high
- Outputs will drive signal down to indicate low state
- Multiple outputs on same or different ICs can be connected to same signal
- Will not “float” unless resistor is bad
- Shorts and opens on PCB can also disrupt signal integrity

http://denethor.wlu.ca/pc200/logic/IC3_lab.shtml
Tristate Output

- Multiple transmitters used on “busses”
  - three states high/low/off
- Multiple receivers
- Frequent failure mode - transmitter fails, signal will “float” at around 2 volts
- Receiver can also fail and prevent source from driving signal to correct level
- Transmitters can fight, looks similar to float
- Shorts and opens on PCB can also disrupt signal integrity
Capacitors

- Capacitors
- Many types
- Decouple power planes (often ceramic usually small values)
- As small sources of power (usually larger value electrolytic)
- In RC timing (in combination with resistors)
Capacitor Failure Modes

- Capacity Degrades
  - ripple on power rails
  - timing off
- Internal Short
  - in power circuits, often results in physical damage
Testing

- Capacitance - many multimeters can test capacitance
- ESR (equivalent series resistance)
  - ESR can be tested with an oscilloscope and a 555 timer or a CMOS 4049

**Bread Board parts for 100 kHz**
- IC 4049 Hex Inverter
- R1 10K
- R2 1.6K
- R4 700 ohm
- R6 5 ohm
- C1 1μF
- C2 1nF
- C<sub>T</sub> Capacitor Under Test
- R<sub>T</sub> ESR

**Simple Version of ESR Scope Adapter**
Marginal Cap Example

- Apple 1 intermittent DRAM test failure
- First checked all signals going to/from 6502 and DRAM for integrity
- Determined RAM timing off due to 74123 one shot circuit not generating correct 480 nsec pulse due to out of spec 47pF mica capacitor
Transistors and Diodes

- Bipolar transistors are essentially back to back diodes
- Check with DMM diode check function
  - Instructions: http://www.vetco.net/blog/?p=184
- FET type transistors checked differently
  - Simple sanity check: http://www.utm.edu/staff/leeb/mostest.htm
Resistors

• Rarely fail when used within spec
• When they do fail, they will normally show it
• Color code for value and tolerance
Replacement Components

• If possible, replace with exact type

• Save broken part and document if you have a rare collectors piece

• “A”, “B”, or “C” revision parts usually work, but not always

• DRAM and CPU component speed important,
  • Faster is often OK
Component Sources

• Digikey, Mouser, Jameco

• Unicorn Electronics
  • http://www.unicornelectronics.com

• Surplus vendors
  • Minimum quantities
  • May need to generate a purchase order

• Donor systems
Sometimes it is a Long Forgotten Design Issue

- Apple 1 cassette interface
  - [http://www.willegal.net/appleii/aci.htm](http://www.willegal.net/appleii/aci.htm)
- Apple II rev 0 video flagging
  - [http://www.willegal.net/appleii/applesync.htm](http://www.willegal.net/appleii/applesync.htm)
- Brain Board Ground
  - [http://www.willegal.net/blog/?p=1880](http://www.willegal.net/blog/?p=1880)
Questions?

• This document posted to:

• [website link](http://www.willegal.net/appleii/troubleshooting)