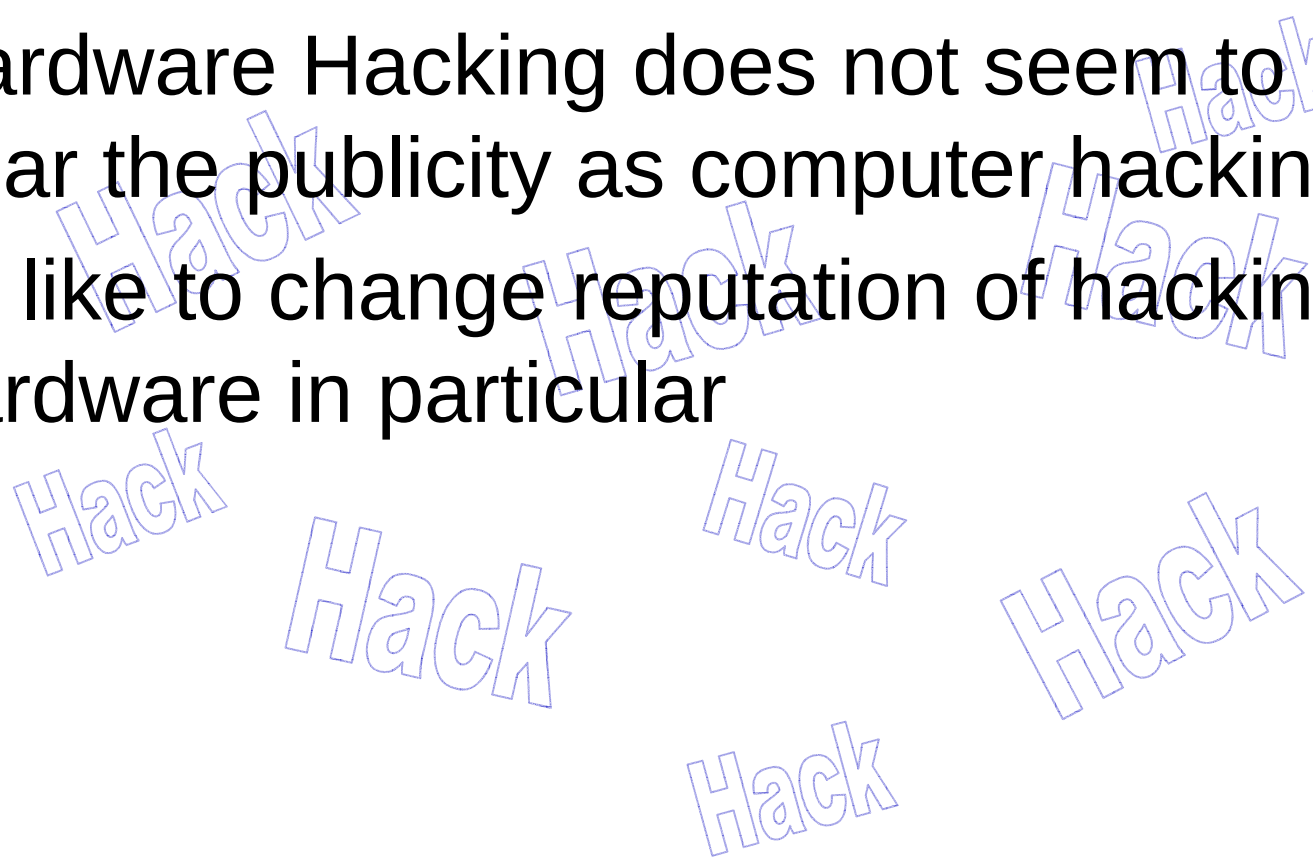
Introduction to Hardware Hacking

Scott Fullam

Why Hardware Hacking?

- Hardware Hacking does not seem to get near the publicity as computer hacking
- I’d like to change reputation of hacking, hardware in particular



Hardware Hack: A Definition

- A (sometimes) clever modification or fix made to a piece of equipment that improves its performance or makes the equipment do something for which it was not originally designed.
  - The results of the hack need not be ‘useful’ in the strict sense of the word.
- The word ‘hack’ can be used as a noun or a verb.
  - Noun: “That hack you made to your toaster was great!”
  - Verb “Let’s hack your brothers TV set tonight to only tune in channel 13!”

Hack Hack Hack Hack Hack Hack Hack Hack Hack

Why is Hardware Hacking Easier than Software Hacking?

- When you buy a piece of hardware, lets say a toaster for example, you can open it up and see what is inside and see how it works.
  - Repair manuals available for many pieces of equipment
  - Your GF/SO can benefit from your hardware skills!
    - You can fix stuff in the house
    - When was the last time your GF/SO asked you to fix their copy of MS Word?
- When you buy a piece of commercial software, you cannot open it up to see how it works.
  - You are stuck with the executable file only and no source code that shows the inner workings
  - Its behavior is fixed to that which the original programmer intended.
  - You cannot examine it and change how it works.
  - Open Source software is the exception to this

Hack Hack Hack Hack Hack Hack Hack Hack Hack

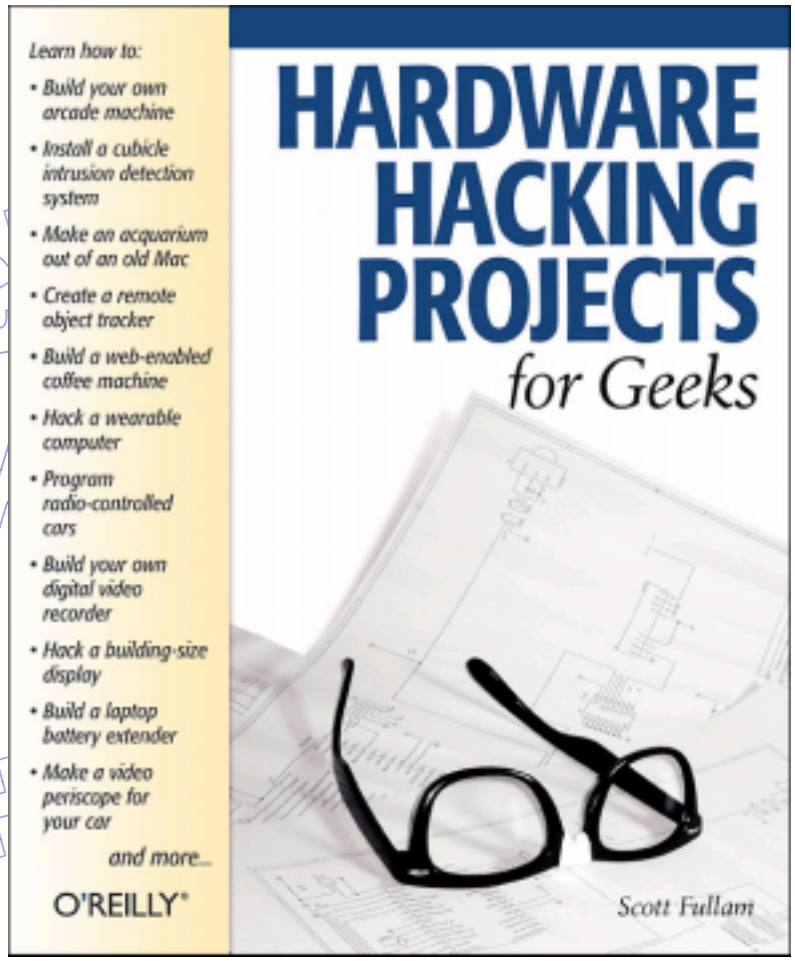
About Me

- Graduated in 1990 with MS and BS in EECS from MIT
- Have been hacking since I was a kid
- Have held many interesting jobs:
  - Toy Designer
  - Digital Camera Architect
  - Startup Founder (PocketScience Inc)
  - Writer (My book)

Hack Hack Hack Hack Hack Hack Hack Hack Hack

My Book

- “Hardware Hacking Projects for Geeks”
  - Published by O’Reilly
  - Started the book 2 years ago
- Gathered together a number of hacks I put together along with a few cool ones that I found



Talk Overview

- EE Basics
  - Basic Electronic Components and what they do
- Cracking the case
  - How to open up electronics enclosures without destroying it
- Building Circuits
  - Reading schematic diagrams
  - Bread boarding
  - Soldering equipment and techniques
- Where to Get Parts
  - Online sources
  - Offline sources
- Project Walk-Throughs
  - Hacked Toaster
  - Electric Beer Mug
  - LED Flashlight conversion
- Large Scale Hack Description
  - Blinkenlights

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EE Basics

- Passive and Active Parts
  - Passive Parts
    - Resistors
    - Capacitors
    - Inductors
    - Transformers
  - Active Parts
    - Transistors
    - Diodes
    - Integrated Circuits

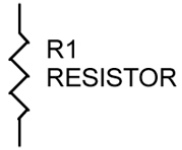
Hack Hack Hack Hack Hack Hack Hack Hack Hack

EE Basics Cont.

- Resistors
  - Limits (or Resists) the flow of electrical current
  - Value of resistor measured in Ohms
  - Voltage (V), Current (I), and Resistance (R) follows the equation V=I x R.
  - An example of how a resistor can be used
    - Current limiter for LED
    - LEDs can be burned out if too much current is allowed to pass through them. If an LED is connected to a directly battery with no current limit, the LED will stop working. Add a resistor in series to limit the current to the LED to fix this problem.







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EE Basics Cont.

- Capacitors
  - Stores electrical energy in the form of an electric field
  - Act like small batteries
  - Value of capacitor measured in Farads. (after Michael Farady)
  - Voltage, Current, Capacitance follow this equation: I = C dv/dt
  - Are sometimes polarized (they have a ‘plus’ side and a ‘minus’ side)
  - Are often used to filter noisy circuits
    - Most circuits will place many capacitors across their power supplies to decrease overall noise









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EE Basics Cont.

- Inductors
  - Stores energy in the form of a magnetic field
  - Values specified in Henries
  - Voltage (V), Current (I), and Inductance (L) follow this equation: $V = L \, di/dt$
  - Often used to filter out Radio Frequency (RF) Interference
  - Used extensively in power supplies



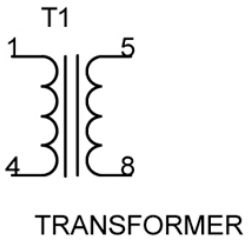


Hack Hack Hack Hack Hack Hack Hack

EE Basics cont.

- Transformers
- Couples energy from one side to the other via magnetic field
- The turns ratio determines the ratio of AC voltage
- Used to isolate signals
  - A signal from one side is transferred to the other without a common ground
- Used to ‘step up’ a voltage
  - Can be used to generate large voltages





TRANSFORMER

Hack Hack Hack Hack Hack Hack Hack Hack

EE Basics Cont

- Active Components
  - Transistors
    - Act as a switch
    - Two basic types
      - BiPolar
      - Metal Oxide Semiconductor (MOS)
  - Diodes
    - One way gate
    - Light Emitting Diode
  - Integrated Circuits
    - Made from many transistors

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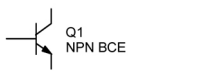
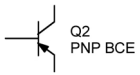
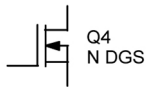
EE Basics Cont

- Transistors
  - Electronic Switches
  - Two basic types
    - Bi-Polar
      - Current Controlled Current Switch
      - Two ‘flavors’
        - » NPN
        - » PNP
      - Three terminals:
        - » Emitter
        - » Base
        - » Collector
    - MOS (Metal Oxide Semiconductor)
      - Voltage Controlled Current Switch
      - Two ‘flavors’
        - » P-Channel
        - » N-Channel
      - Three Terminals
        - » Drain
        - » Gate
        - » Source

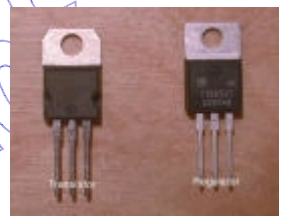












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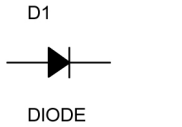
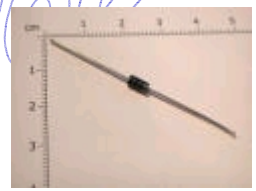
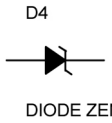
EE Basics Cont

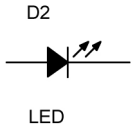
- Diodes
  - One way current switch
    - Three common types
      - Standard
      - Schottkey
      - Zener
    - Each has a ‘plus’ side and a ‘minus’ side
    - The side with the line on it is the ‘minus’ side
    - Current is conducted from the plus side to the minus side
    - Forward Voltage Drop of 0.6V and above
  - Light Emitting Diode
    - Forward Voltage Drop of 1.7V and above
    - Available in many colors
    - Each has a ‘plus’ side and an ‘minus’ side
    - The ‘minus’ side often has a flat spot









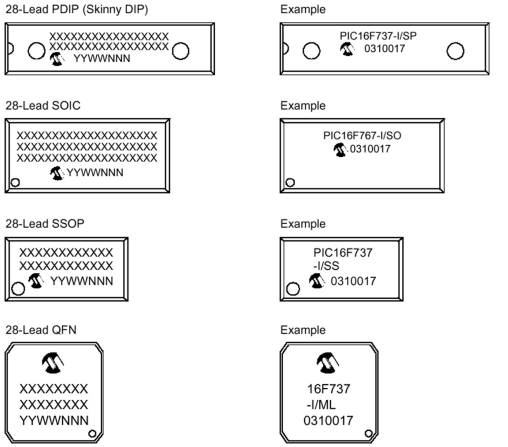


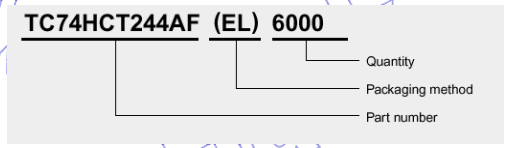




EE Basics cont

- How to read the numbers on an IC package
- Look for manufacturers logo
- Look at first part of numeric string on part
  - Numbers and letters after the ‘dash’ are often speed grades and production date codes
- Look up numbers on the web





EE Basics Cont

- Here are a few examples of well known chip companies



Cracking the Case

- How can you open an enclosure without destroying it?
  - Have the right tools
    - Lots of Small Screwdrivers
    - Philips and flat head
  - Know how most enclosures are fastened together.
    - Fasteners
      - Screws
      - Plastic snaps molded into the case
      - Glue
      - Double Sided Tape

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Cracking the Case cont.

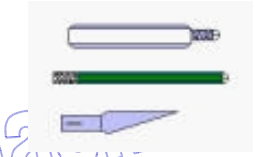
- Hardware Hacking is like surgery!
  - You wouldn't want your doctor using an axe to perform an appendectomy… Good Tools
  - Get high quality hardened steel tools
    - The cheap stuff breaks and strips the heads off the screws
  - Torx drivers
    - Star shaped head
    - Many consumer electronics cases now use these
  - Hex Drivers
    - Hexagon shaped head
    - Also popular in consumer electronics
  - Tweezers
    - Useful for fishing out dropped screws from inside cases
    - Flat end can be used as a pry bar
  - Dental Picks
  - Razor Blades
    - I prefer Xacto style with handles
  - Collecting the tools can be an obsession of its own
    - Be the envy of the other hardware hackers by having the latest German hardened steel drivers











Cracking the Case cont.

- Common case fasteners
  - Screws
  - Plastic snaps molded into case
  - Glue
  - Double Sided Tape
    - The Palm V case is held together this way. You need a hair dryer to heat up the tape so that it releases to open it
- Screws are often placed so that they cannot be seen
  - On the bottom of the product
  - Under labels
  - Under the ‘feet’ of the product

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Cracking the Case cont.

- Good ways to open up the case
  - Clear a table top
  - Place sheets of white paper under the items to be opened
    - You can see dropped screws better on the white paper
  - Make sure power has been removed from the device being taken down
    - Unplug it
    - Remove all batteries
  - Carefully remove all of the screws you can find
    - Make sure to look under all labels and feet
    - Take another piece of paper and sketch a rough outline of the case on it.
    - After each screw is removed, tape it to the diagram in its approximate location.
      - This makes it a lot easier to put them all back when you are done

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Cracking the Case cont.

- Look for seams and gently pull at them
  - Don't force it.
  - Use tweezers or a pick to open up a crack along the seam
  - Pull the two halves and feel for any resistance
    - Anywhere there is resistance, look for a screw that was not removed
    - Look for a plastic snap and pry it apart with the back of the tweezers
- Once the electronics are exposed, be careful not damage them with static electricity
  - Use a commercial static wrist strap that is plugged into a Ground point
  - If no commercial static wrist strap is available frequently touch the screw that holds the power outlet to the wall
    - Better yet, attach a wire to this screw and attach the other end of the wire to your wrist by stripping 8" of the insulation and wrapping the exposed wire around your wrist
    - Do _not_ plug the wire into any of the outlet holes.

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Building Circuits

- Reading Schematic Diagrams
- Bread boarding
  - Try out the circuit before soldering
- Soldering
  - Irons
    - Lab bench style
    - Portable
    - Cordless
      - Electric
      - Gas
  - Solder
  - Perf Board
  - Tools

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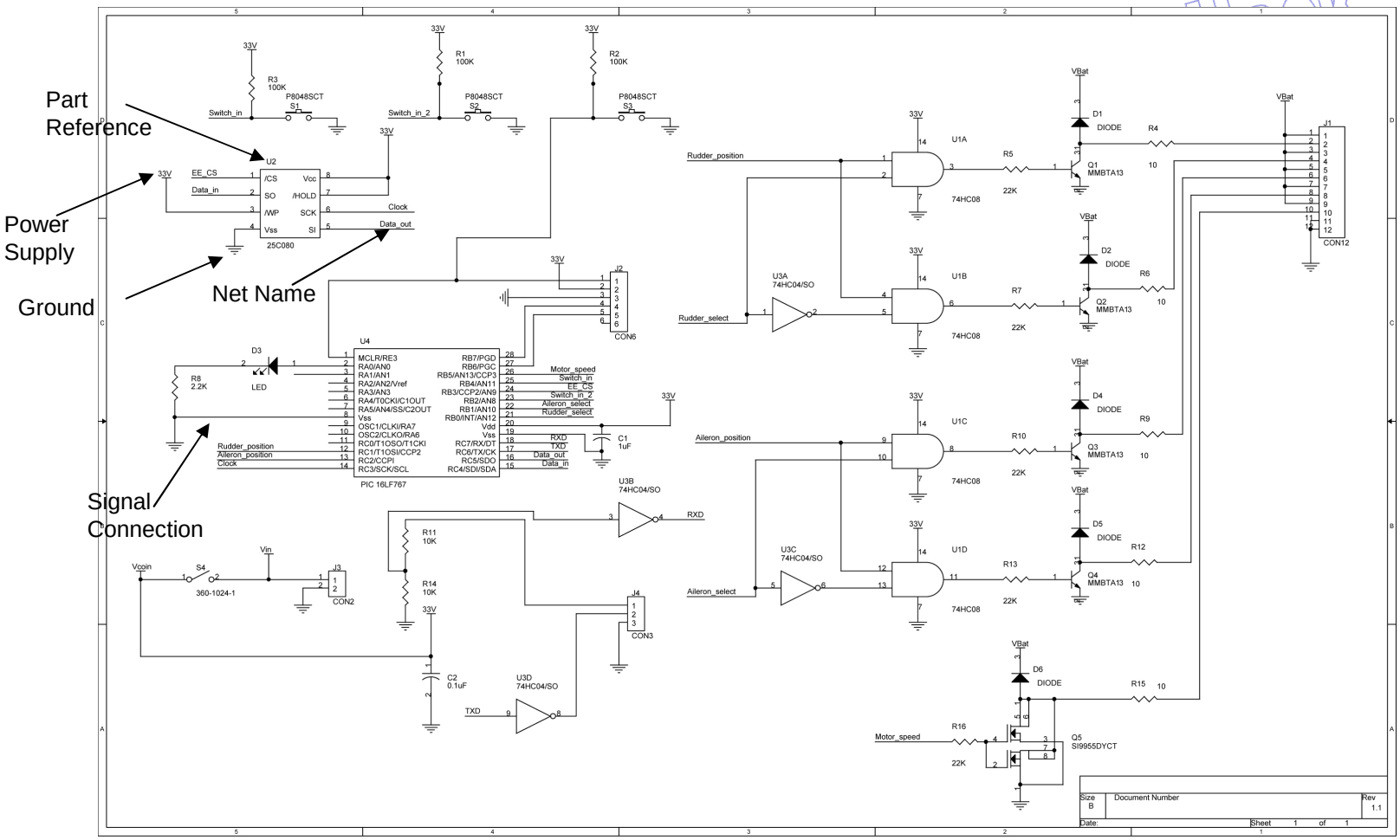
Building Circuits cont.

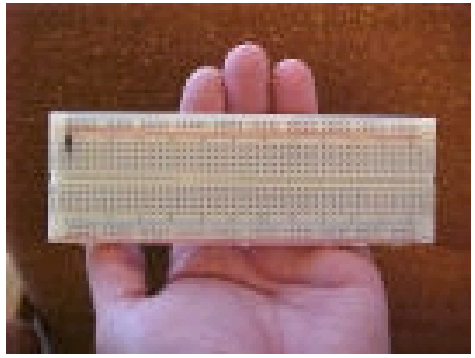
- The basics of reading a schematic diagram



Building Circuit cont.

- Bread-boarding
  - Utilizes a plug board and 24 gauge solid core wire
  - A way to build a circuit without soldering
  - Useful for small circuits
  - Not useful for high frequency circuits (No RF)





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Building Circuits cont.

- Soldering
  - Iron
    - Electric Irons
    - Butane Irons
  - Solder
    - Tin/Lead
    - Lead Free
    - Silver
    - Tip Cleaner
      - Sponge
      - Copper sponge
  - Flux
    - Cleans surfaces to be soldered
      - Helps solder to ‘stick’
    - Rosin
    - Water Soluble
    - No Clean
  - Solder Remover
    - Solder Wick
    - Solder Sucker







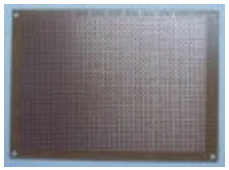




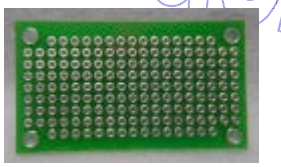


Building Circuit cont

- Perf Board
  - Fiberglass board with evenly spaced metal plated holes
  - Used to build more permanent circuits
- Tools
  - Wire Strippers
  - Wire
  - Wire cutters
  - Needle Nose Pliers







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Where to Get Parts

- On Line
  - Digikey: www.digikey.com
  - Mouser: www.mouser.com
  - Jameco: www.jameco.com
  - American Science and Surplus: www.sciplus.com
  - Halted on line: www.hsc.com
- Off Line
  - Frys
  - Radio Shack
  - Halted Specialties

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Project Walk Throughs

- Toaster
- Beer Mug
- LED Flashlight



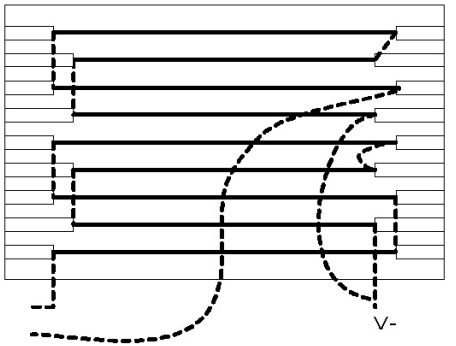
Toaster

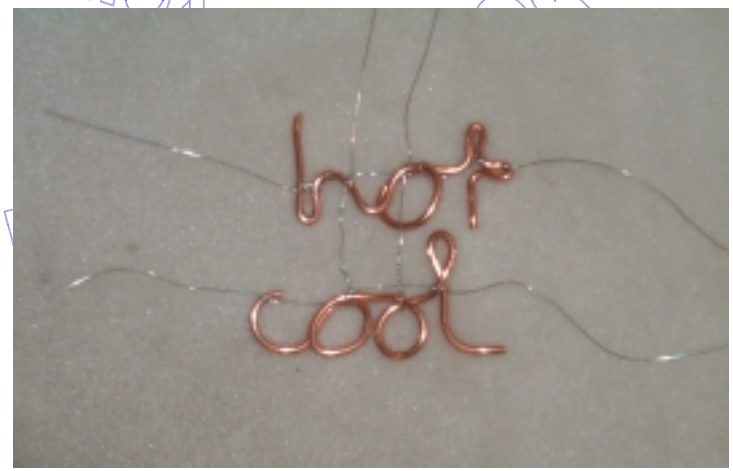
- Read about Weather Toaster from a design student in the UK
  - Toaster would toast picture of the days weather on your bread in the morning
  - Thought his design was too complicated
  - Wanted to replicate the idea with less work
  - Made design trade offs
- Hacked together the basic concept in a weekend



Toaster Insides

- I modified the toasting element wiring and added a mask inside for the toasting patterns





Self Chilling Beer Glass

- I had a extra Pentium III cooling system on hand (from some overclocking experiments
- I wanted to keep my drink cool
- The Self Chilling Drinking Mug was born



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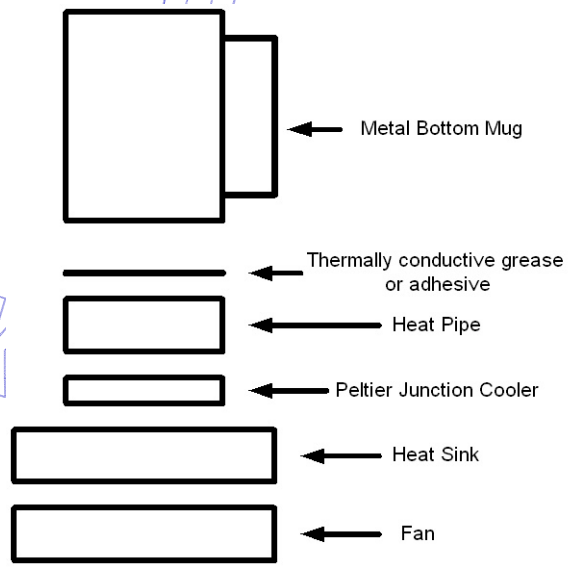
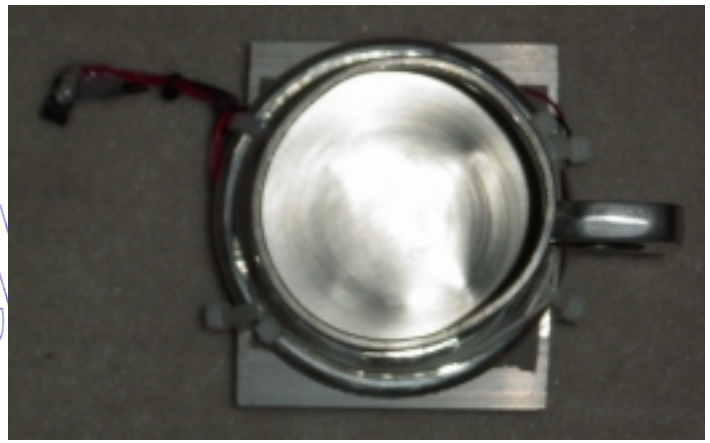
Self Chilling Beer Mug cont.

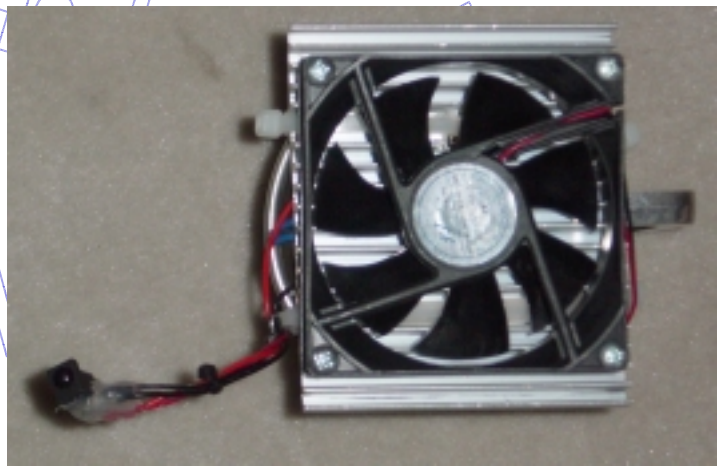
- Need to use a metal mug
- Powered from either a 12V cigarette lighter outlet or a PC power supply



Self Chilling Beer Mug Cont

- Here are some other view of the mug





Hack Hack Hack Hack

LED Flashlight

- Convert Standard flashlight to LED Flashlight



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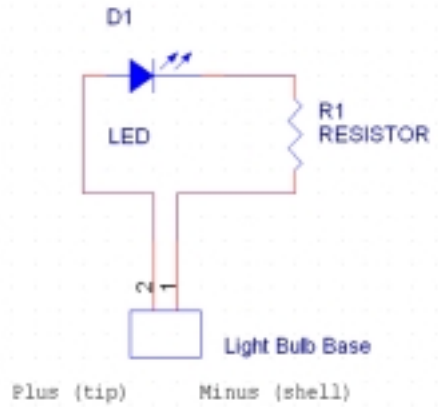
LED Flashlight cont.

- A 3 or more cell flashlight is easy to convert
- Only the bulb need be converted

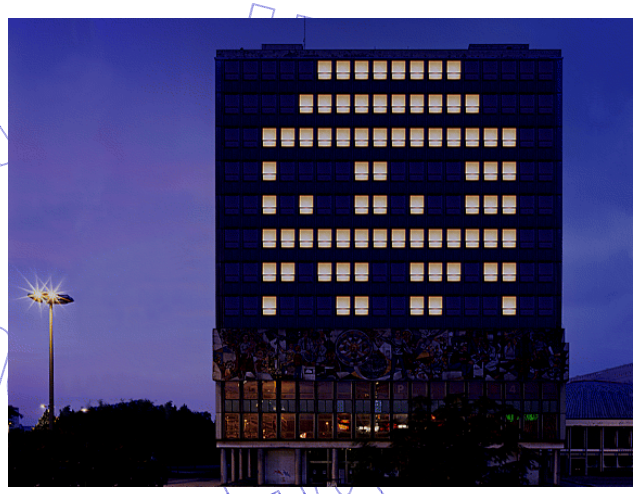






BlinkenLights

- An 8 story building is turned into a giant display
- Hack developed and put on by the Chaos Computer Club of Germany
- Each window in the building is a pixel
  - An individually controlled halogen lamp is placed in front of each window
  - Over 5,000 meters of Cat5 cable is used
- The system is controlled by a Linux PC with a 192 channel parallel I/O card
- Photos courtesy of the Chaos Computer Club in Germany



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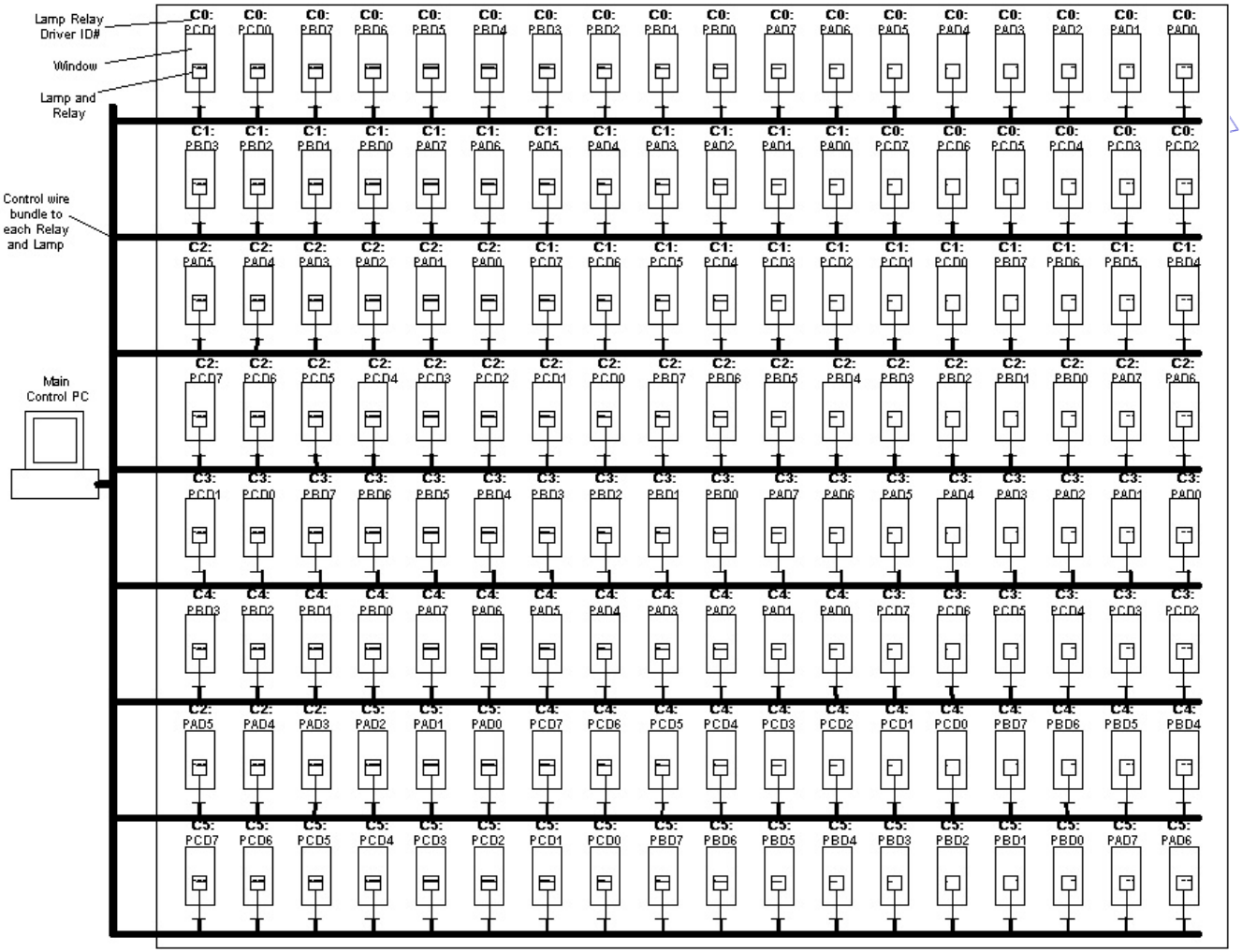

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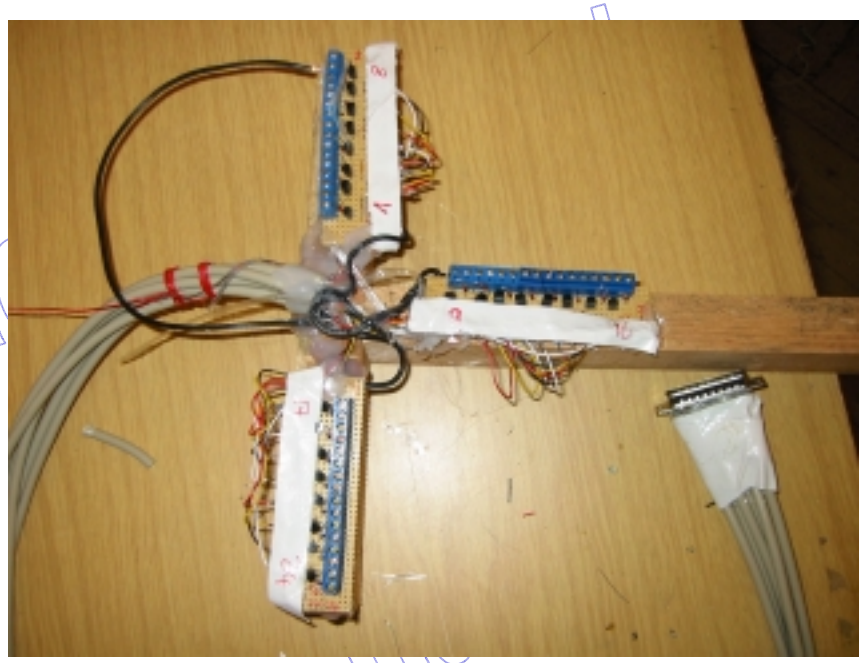

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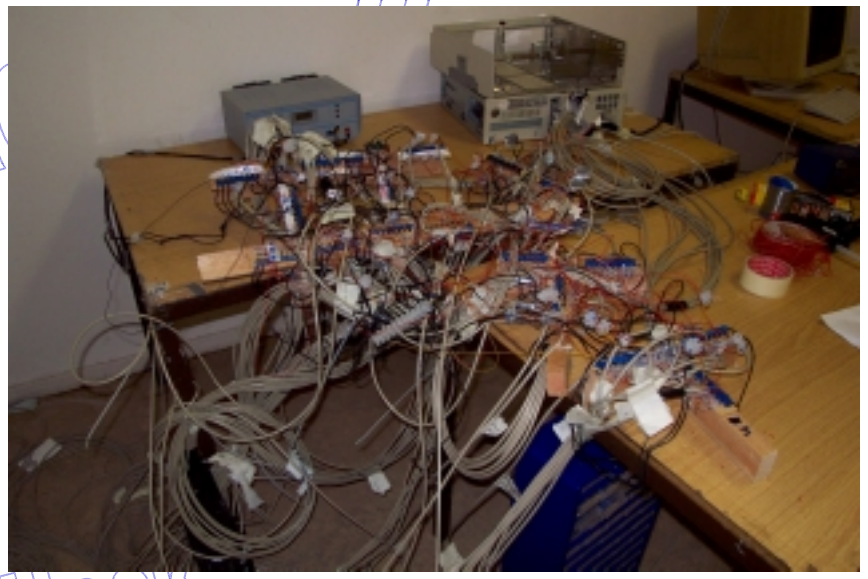
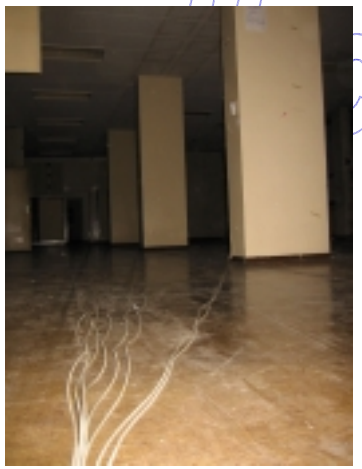


BlinkenLights









A Renaissance in Hacking!

- Hardware Hacking is Easy and Fun!
- It is akin to recycling
  - Old equipment gets reused
- You can learn something while doing it
  - The process of deconstruction is educational
- Be careful when hacking anything that is plugged into the wall or has powerful motors in it
  - Unplug/deactivate the equipment first
- Go Home today and Hack something!

My Garage Hacking Space

- Old Table
- Two Channel Scope
- Parts Bins
- Lots of Power Outlets
- Lots of junk to salvage parts from
- Soldering iron and tools
- Hand tools
- Desk Lamp
- Magnifying headset



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Questions and Demos

