Project Fabrication, Design Ideas, and Other Good Stuff

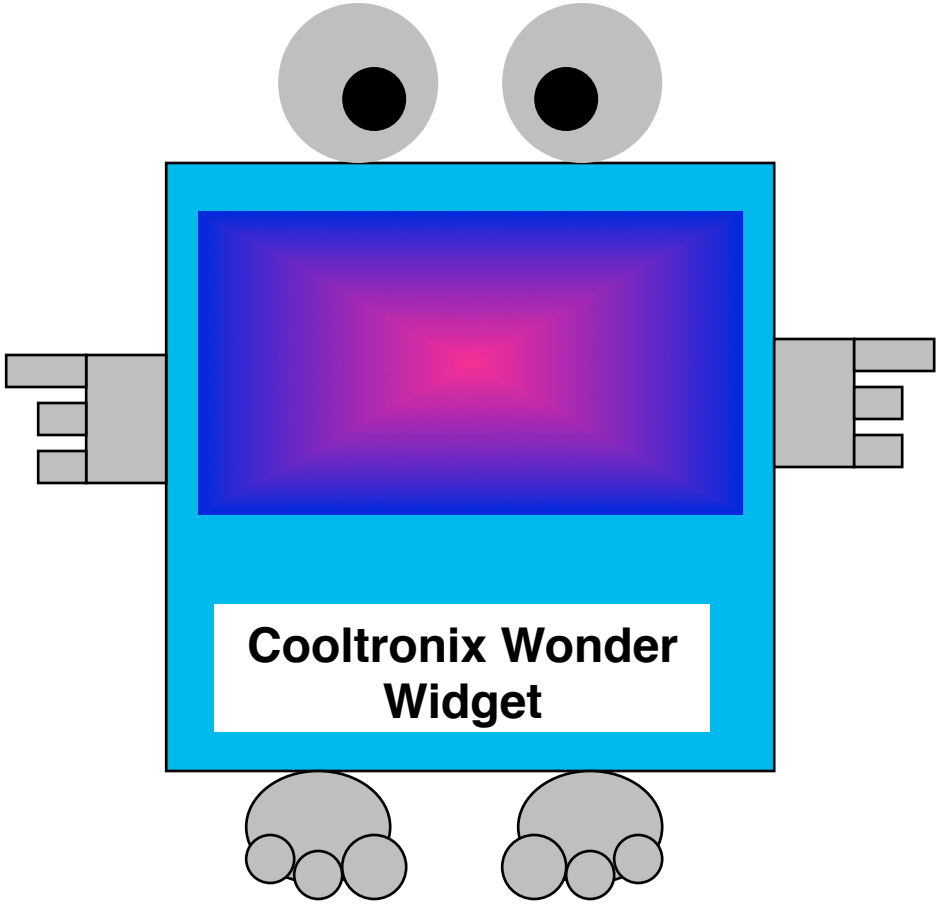
Prof. Greg Kovacs

Department of Electrical Engineering

Stanford University

Time to use this...

To design this...



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Reminder: The Design Process

- Definition of function - what you want.
- Block diagram - translate into circuit functions.
- First Design Review.
- Circuit design - the details of how functions are accomplished.
  - Component selection
  - Schematic
  - Simulation
  - Prototyping of critical sections
- Second Design Review.
- Fabrication and Testing.

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Electronic System Considerations

- Noise and interference.
- Prototyping the circuit.
- Packaging.
- Labeling + graphics for the prototype.
- Demonstration strategies.
- Thoughts on manufacturing.

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Microsoft Corporation, 1978

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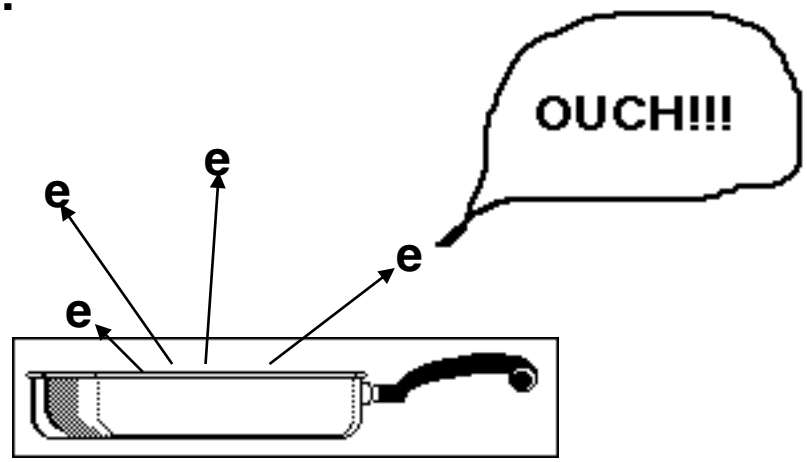
Thermal Noise

- **Thermal (Johnson) Noise - caused by random motion of electrons due to thermal agitation...**



- **Every resistor generates thermal noise!**

$$V_{noise}(RMS) = \sqrt{4kTR\Delta f}$$

$$V_{noise}(RMS) = 1.27 \times 10^{-4} \sqrt{R} \quad \mu V/\sqrt{Hz}$$

- **A 10KΩ resistor at room temperature produces 1.8 *μ*V of RMS thermal noise over the 20KHz audio band....**

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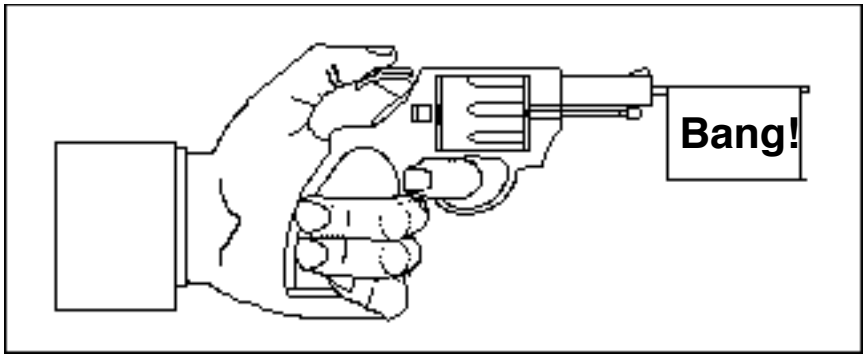
Shot Noise



- **SHOT NOISE**
  - **since currents are quantized, their flow is not entirely uniform...**
  - **this causes Shot noise....**
  - **a 1 Amp current has 57 nA of RMS fluctuation (NOT TOO BAD!)**

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1/f Noise

- 1/f ("Flicker") Noise
  - this noise is caused by fluctuations in the actual VALUES of the components (such as the resistance of a resistor) and is dependent upon the applied voltage.
  - it is expressed in "volts per volt"!
  - therefore, it depends on the TYPE of component used!
  - generally, it is also very small, on the order of 10 nV to 1 μV

EXAMPLE: RESISTORS (from Horowitz and Hill)

FLICKER NOISE OVER ONE DECADE OF FREQUENCY AT 1 V

Carbon-composition	0.10 μV to 3.0 μV
Carbon-film	0.05 μV to 0.3 μV
Metal-film	0.02 μV to 0.2 μV
Wire-wound	0.01 μV to 0.2 μV

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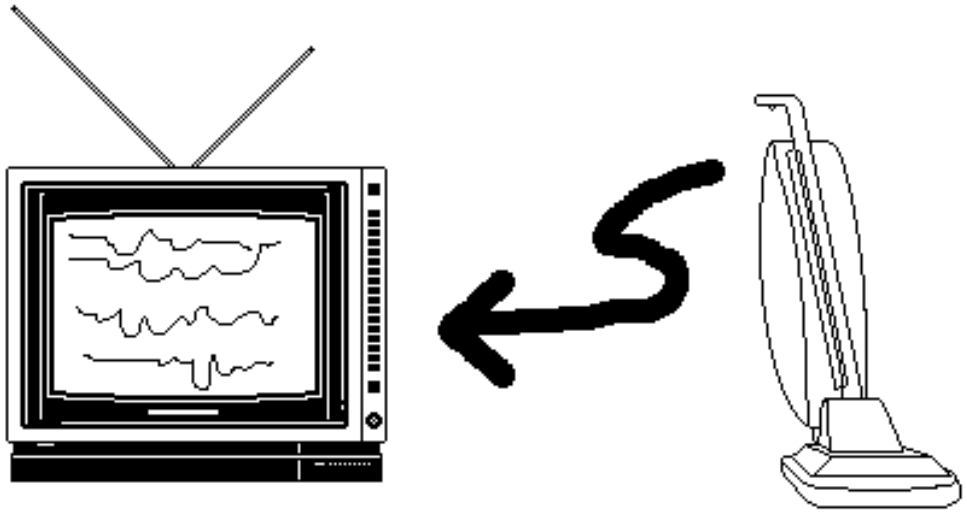
Interference

- **INTERFERENCE**
  - **noise from outside of your circuit!**
  - **60 Hz pickup is the biggest problem in most situations**
  - **RF pickup is also bad!**
  - **FOR REAL PRODUCTS, the FCC makes YOU worry about how much interference YOU cause in other products!!!**



- **REMEMBER... IF THE NOISE IS AMPLIFIED, THE PROBLEM GETS A LOT WORSE!**

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What to Do About EMI

- **Metal packaging, if properly grounded and interconnected, is very effective.**
- **Conductive plastics and paints are also useful.**
- **Careful attention to signals, connectors, and wires entering or exiting the box is critical:**
  - **Shielded cables.**
  - **Ferrites.**
  - **Capacitors.**
- **Verification of compliance with FCC and international EMI specifications usually handled via consulting firms.**

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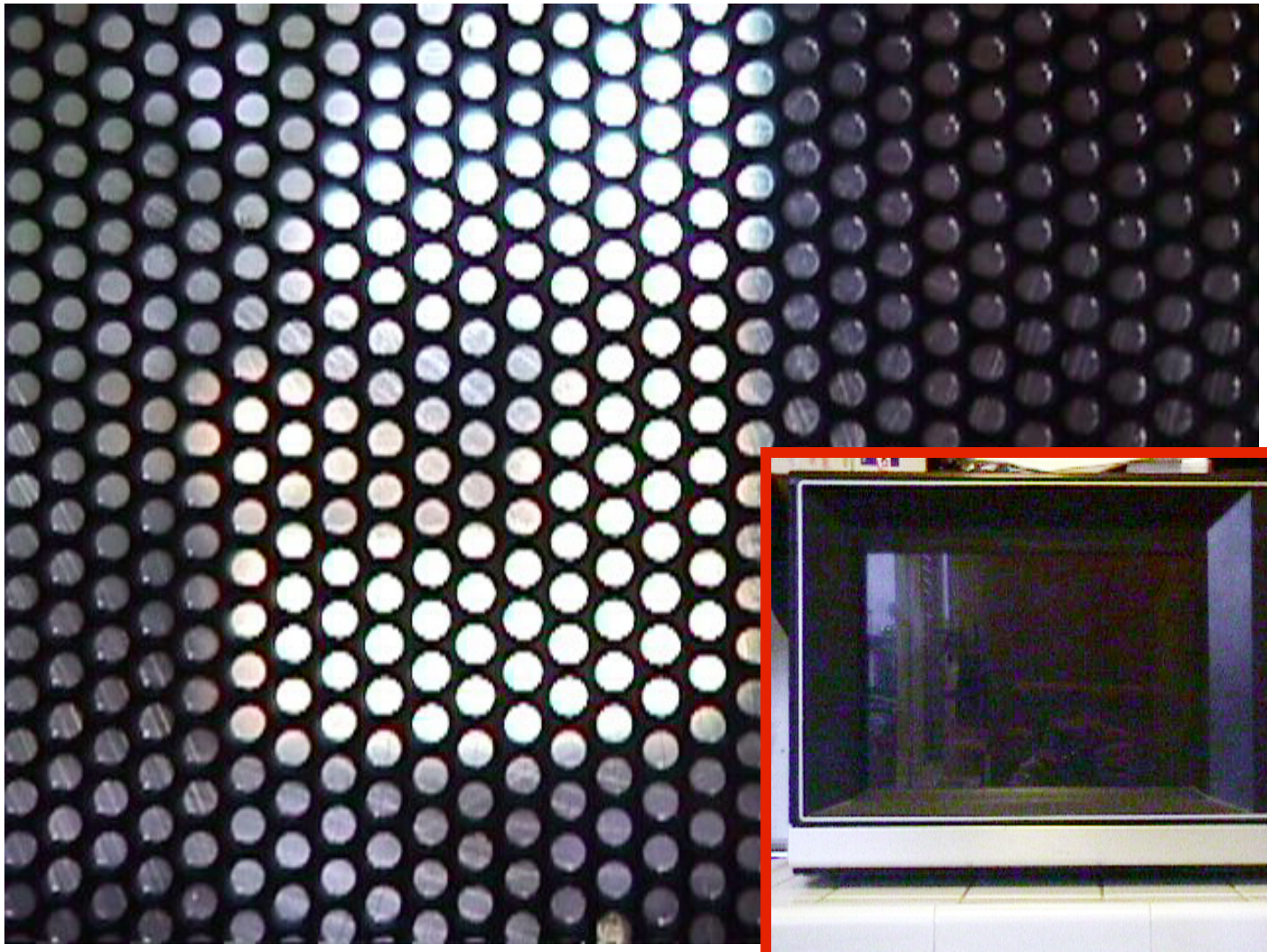
EMI Screens



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The Original "Hotmail"

Courtesy of Mark Shughart, Spr 05 - 06

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Ferrite EMI Suppressor

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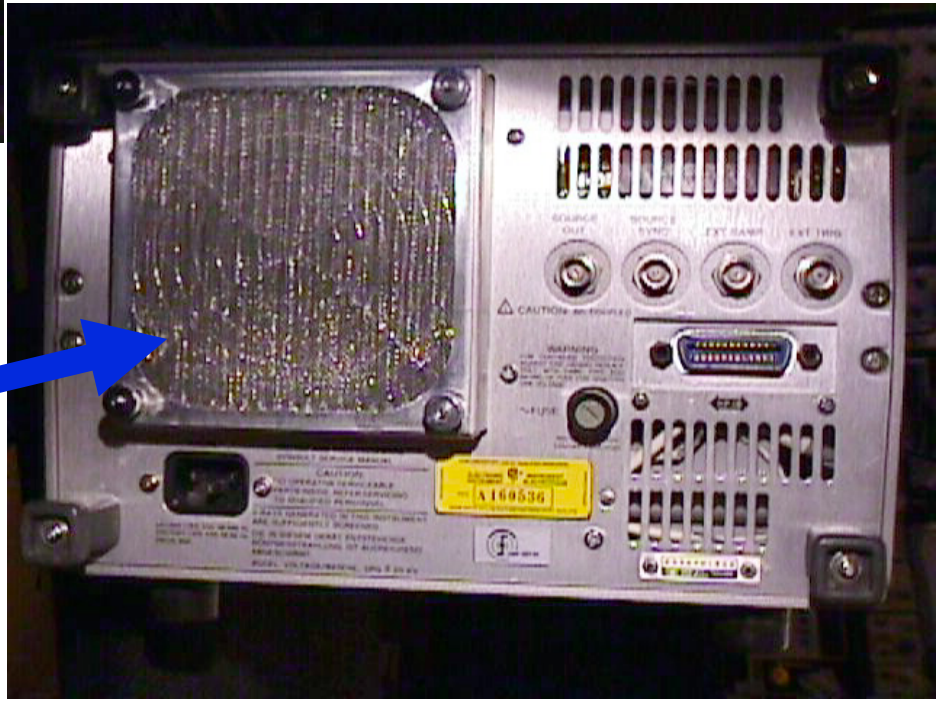
HP3561A Shielding



Note that even the fan is shielded using a metal mesh.

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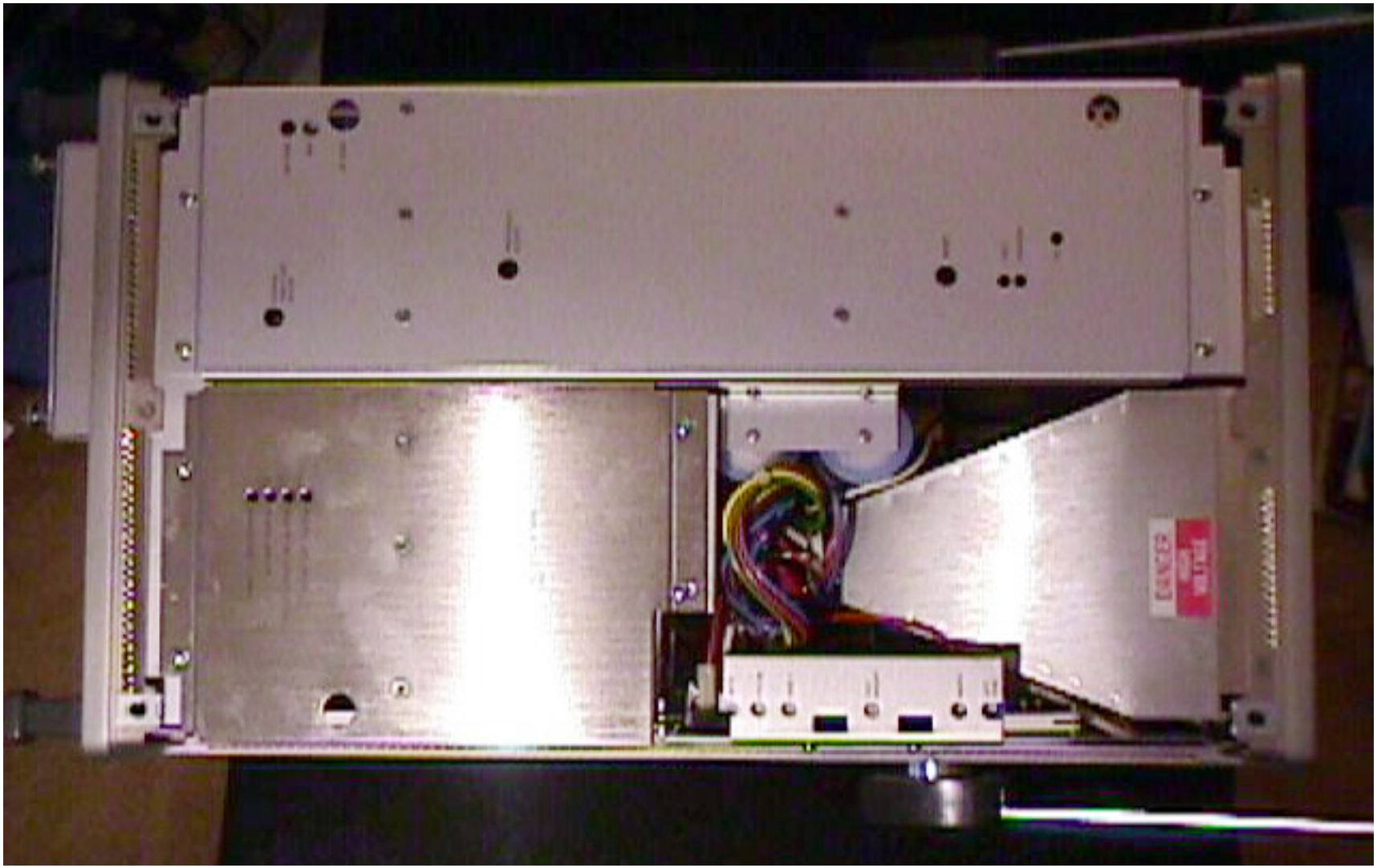
HP3561A Insides



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Prototyping Your Circuit

- For EE122, the high-frequency plug-boards are adequate in most cases.
- Usually, hand-soldered prototypes are best for analog circuits and most closely simulate final performance of a printed-circuit board.
- Ground-planed boards are essential for precision, low-noise analog circuits.
- Proper power decoupling is ABSOLUTELY KEY - one 0.1 μF capacitor per supply rail (to ground) per chip, located as close as possible to the supply pin(s).

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Always True - NO!!!

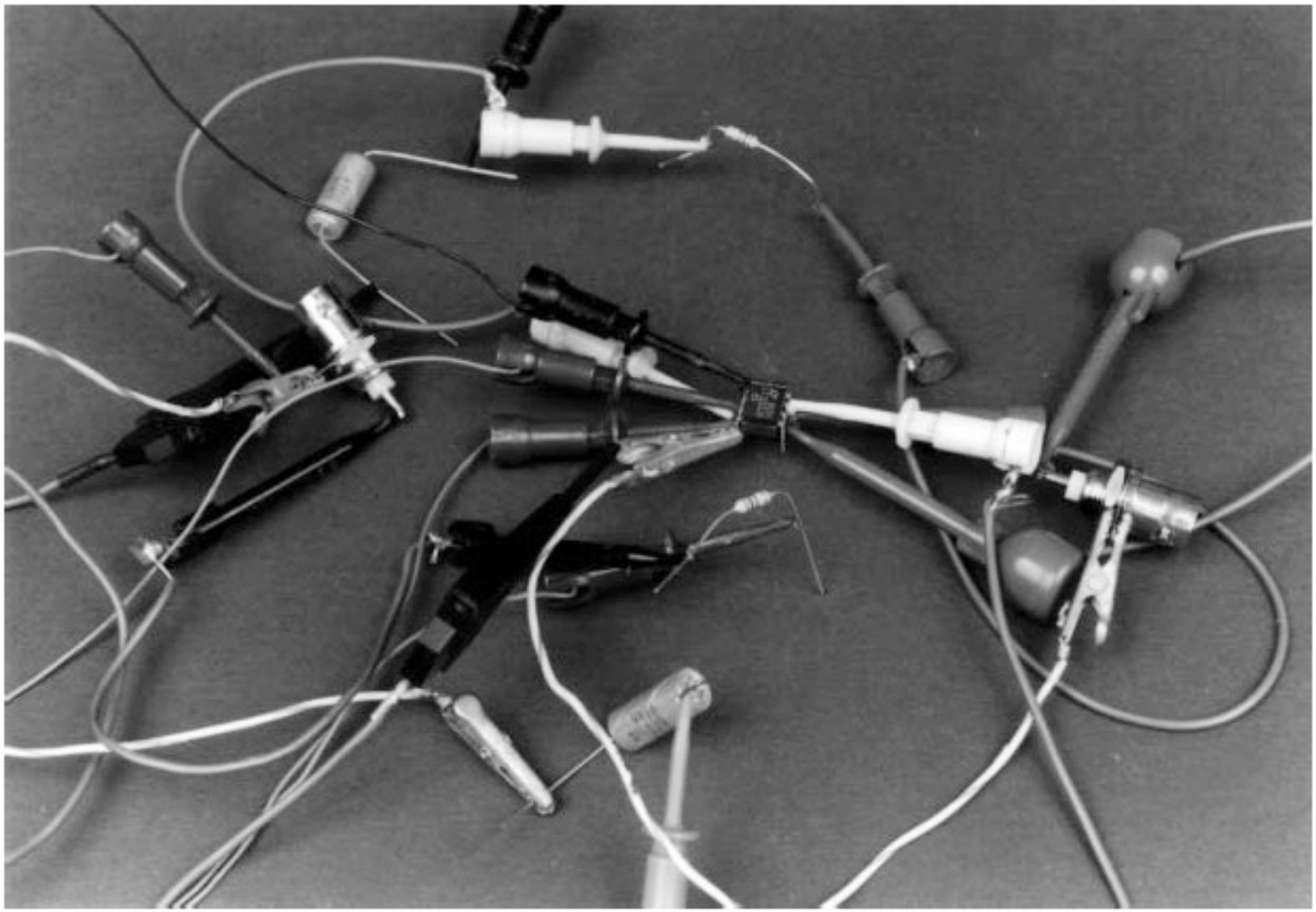

Figure F3. No

Source: Linear Technology AN-47.

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“No” Is Generally Correct Here...

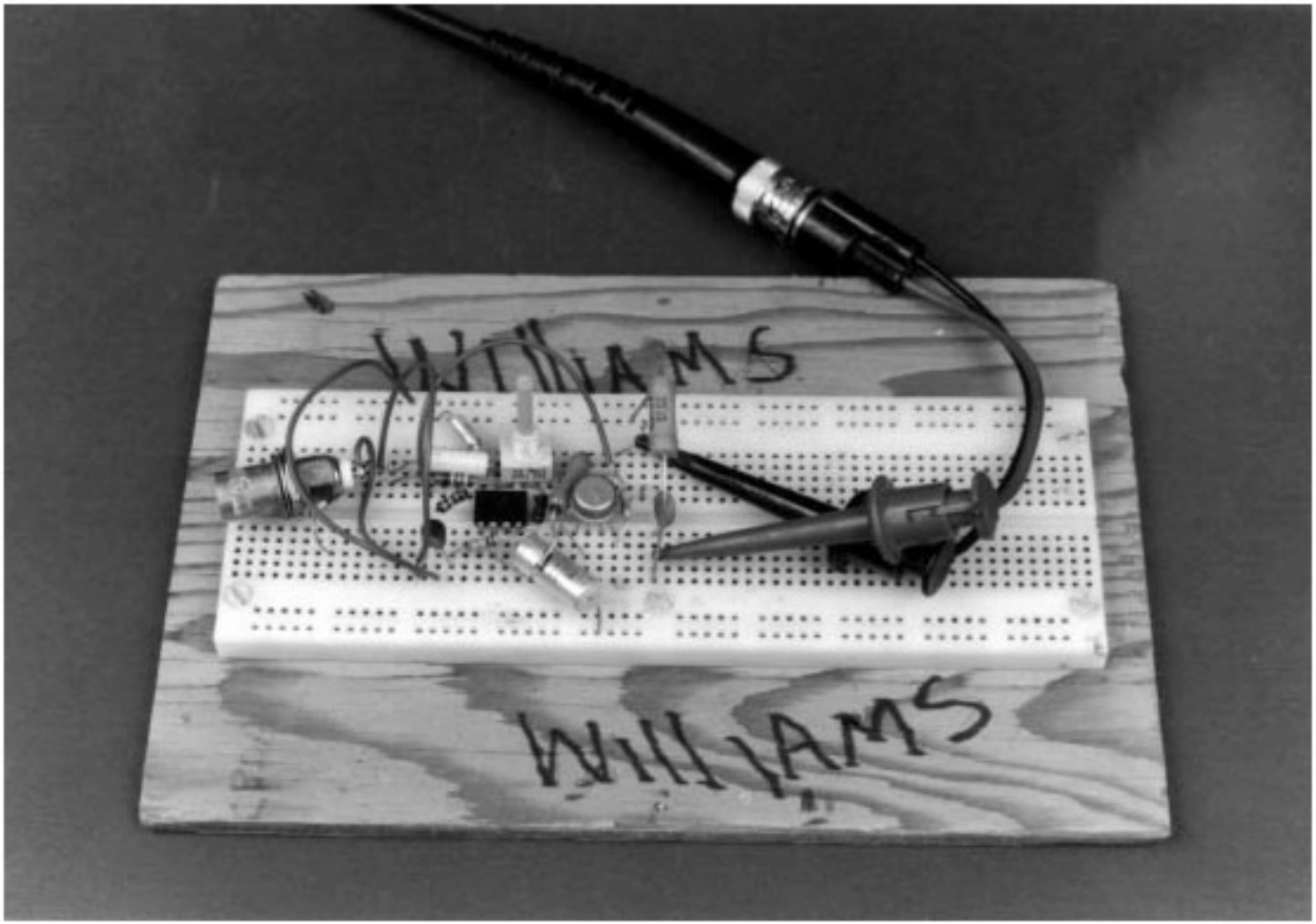

Figure F1. No

Source: Linear Technology AN-47.

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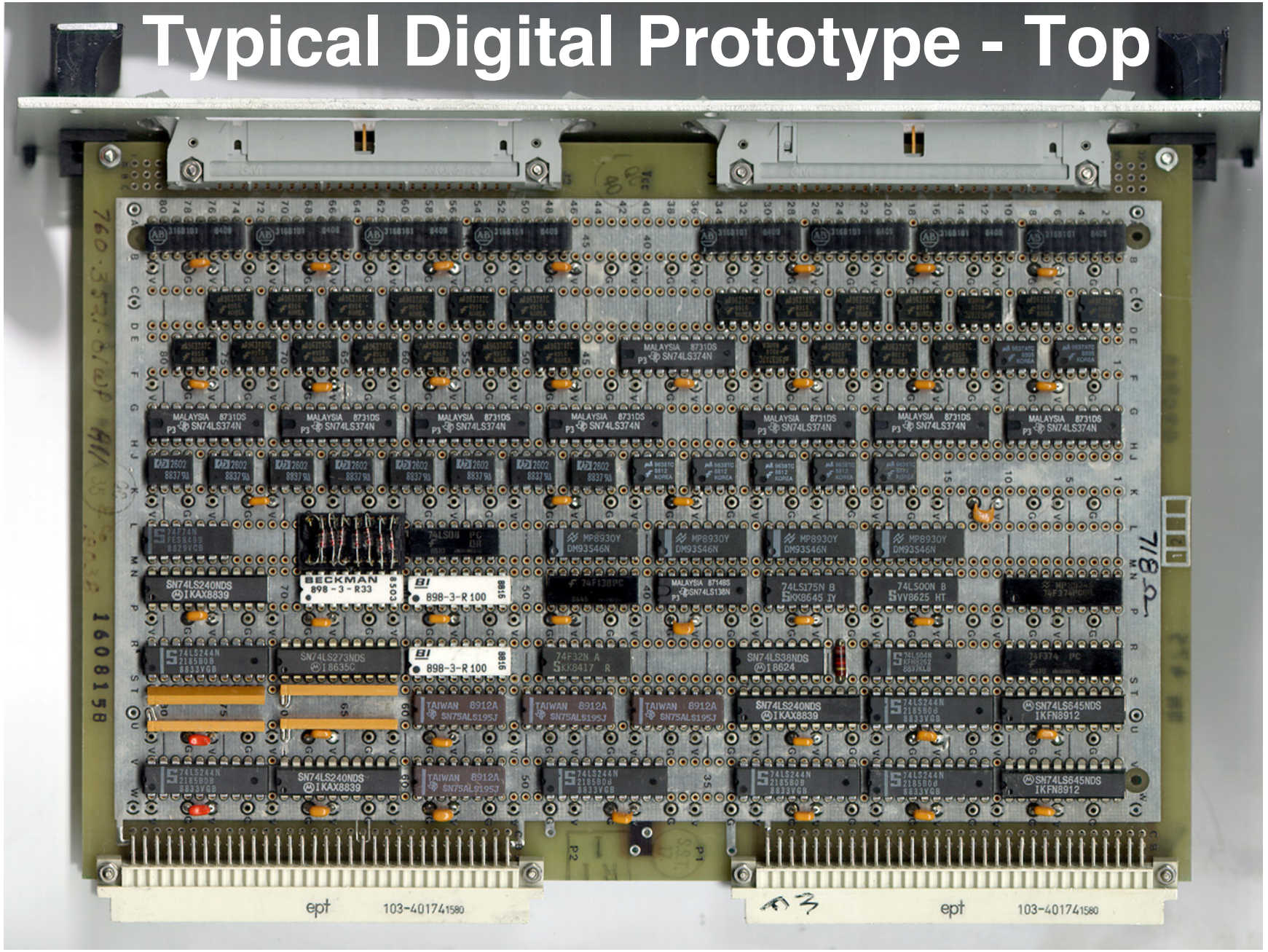
Typical Digital Prototype - Top



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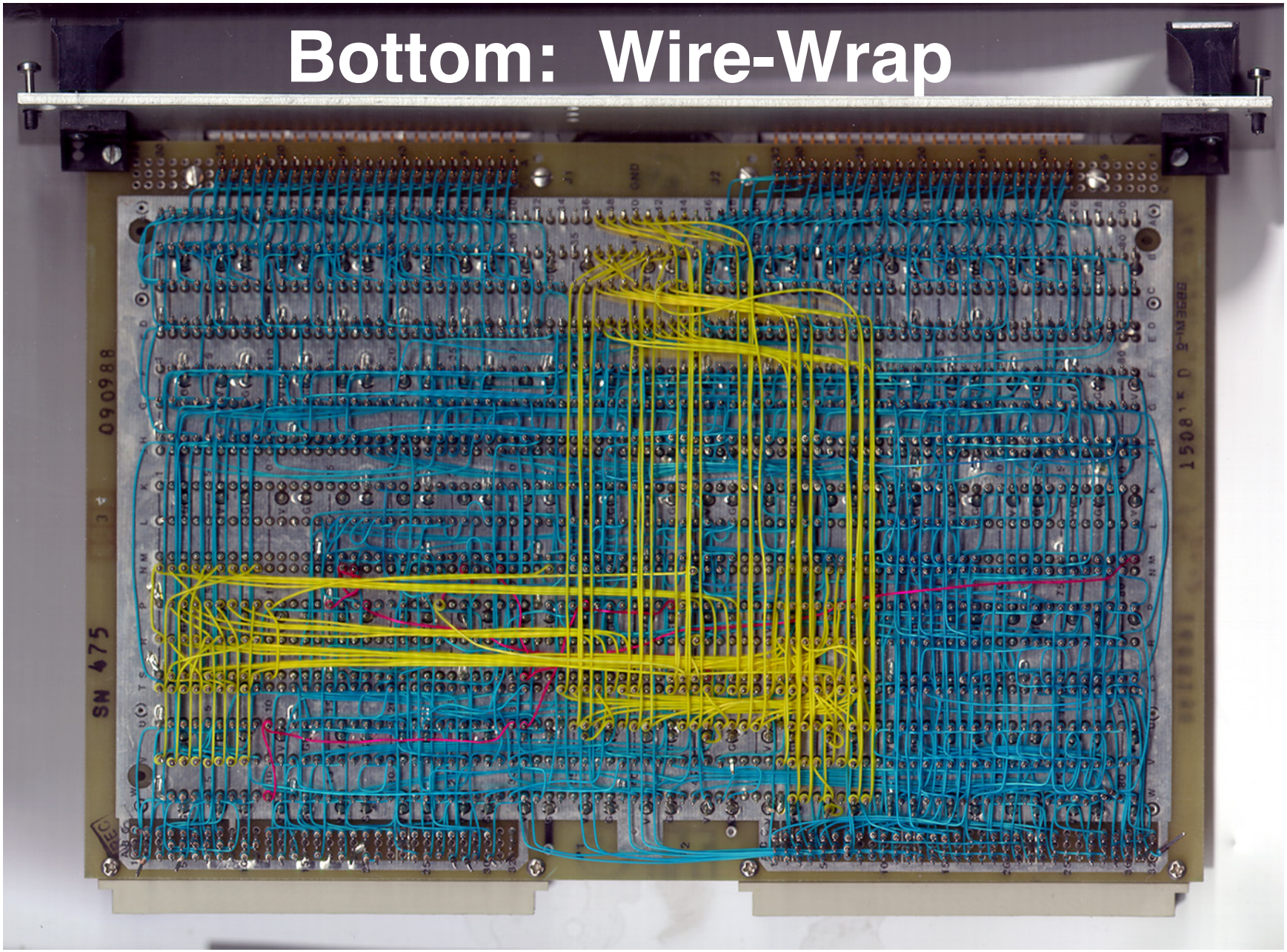
Bottom: Wire-Wrap



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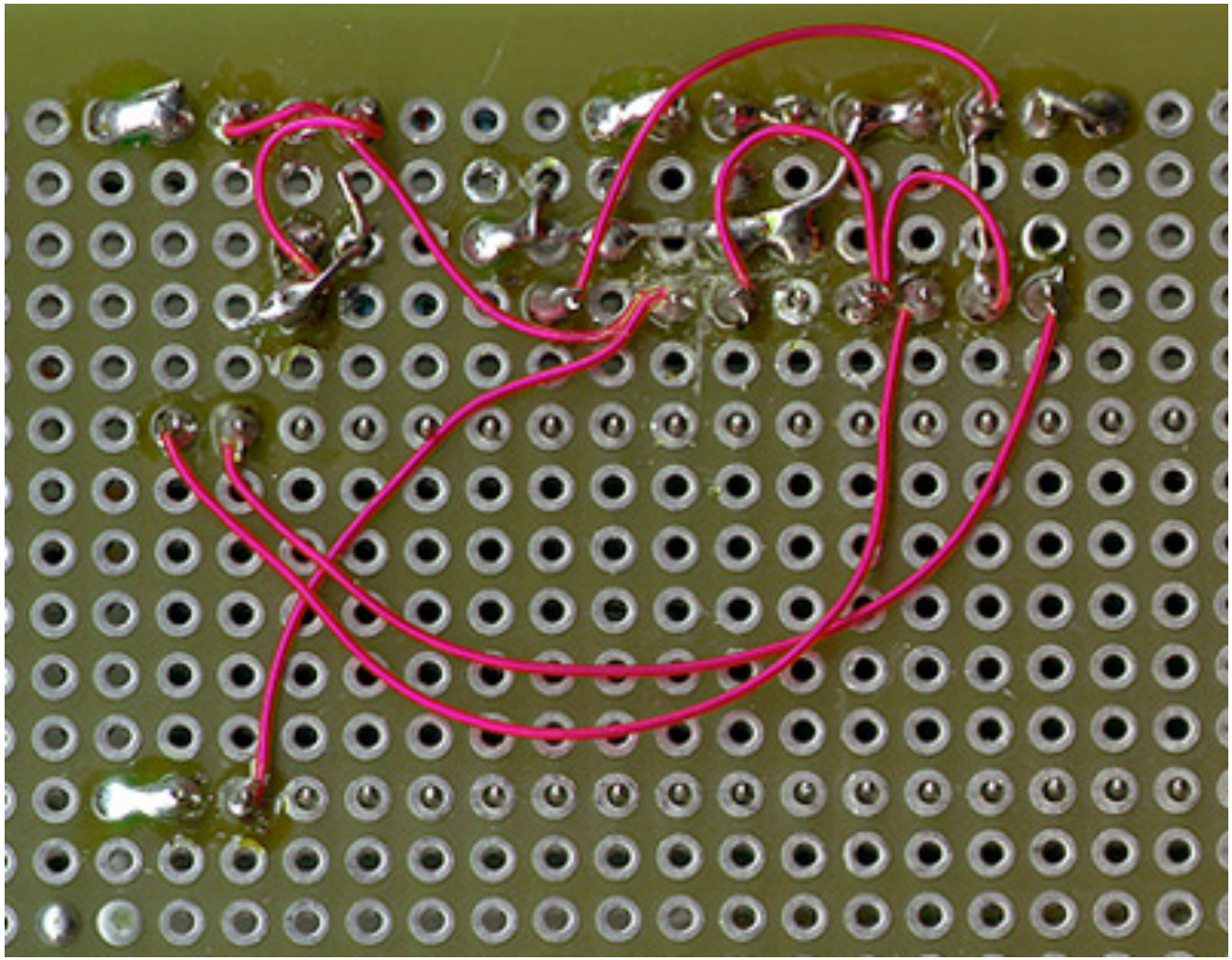
Point-To-Point Soldered



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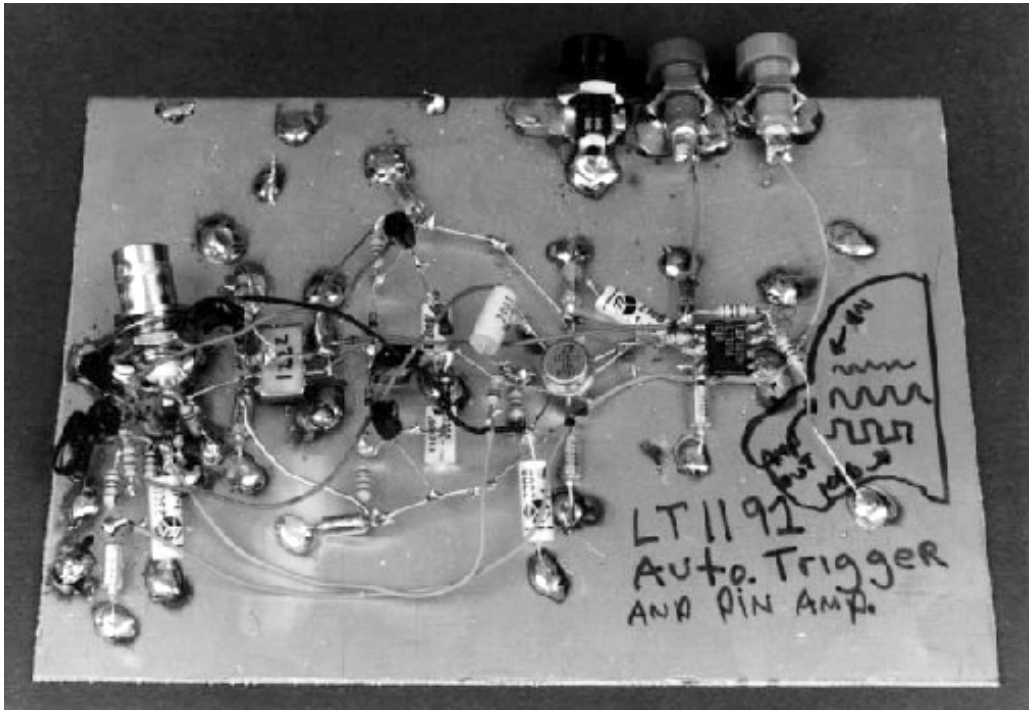
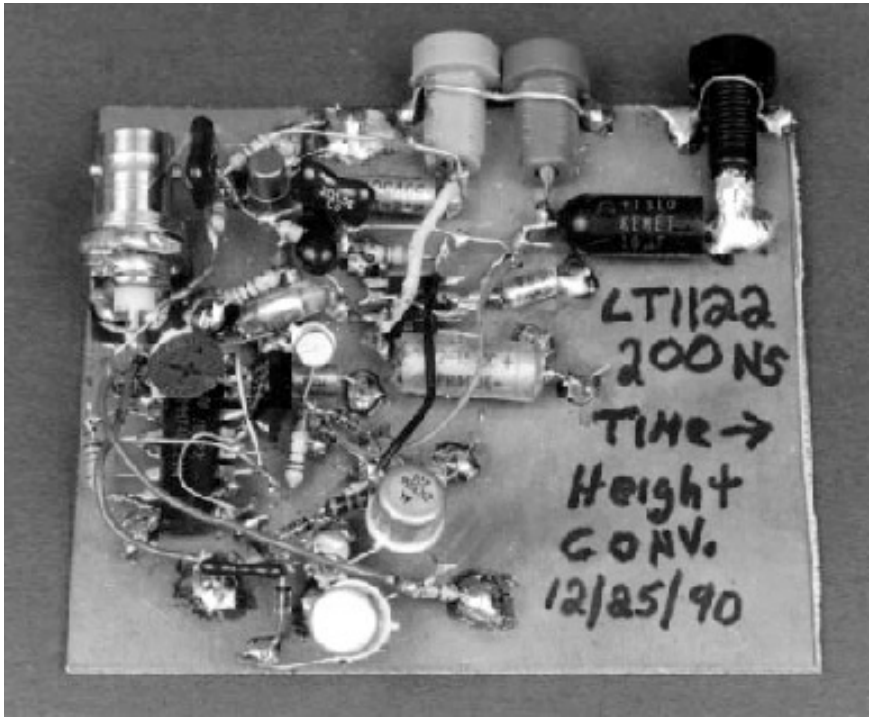
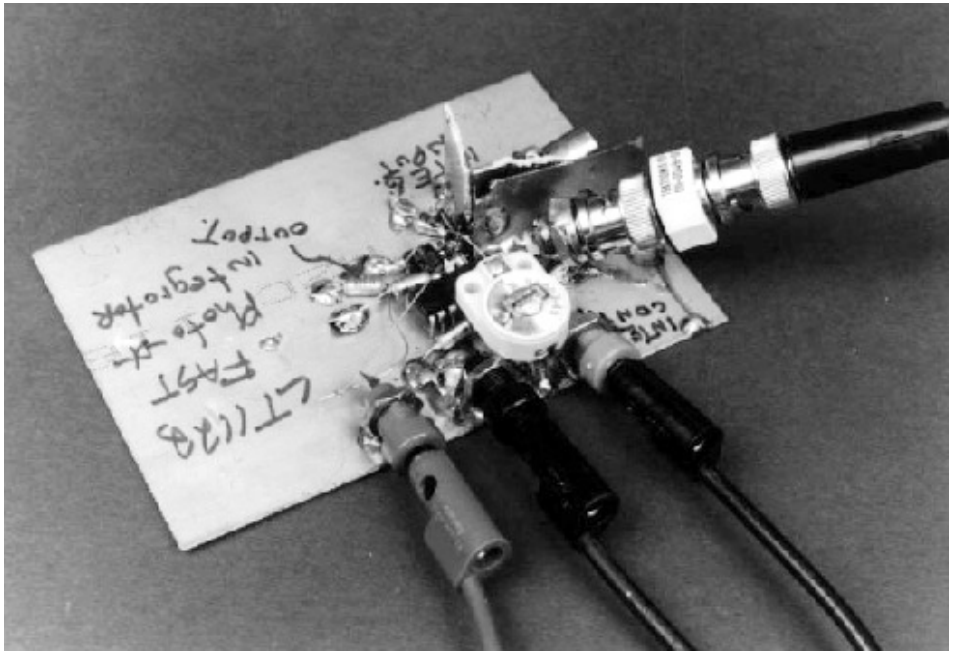




Point-to-Point Williams Style



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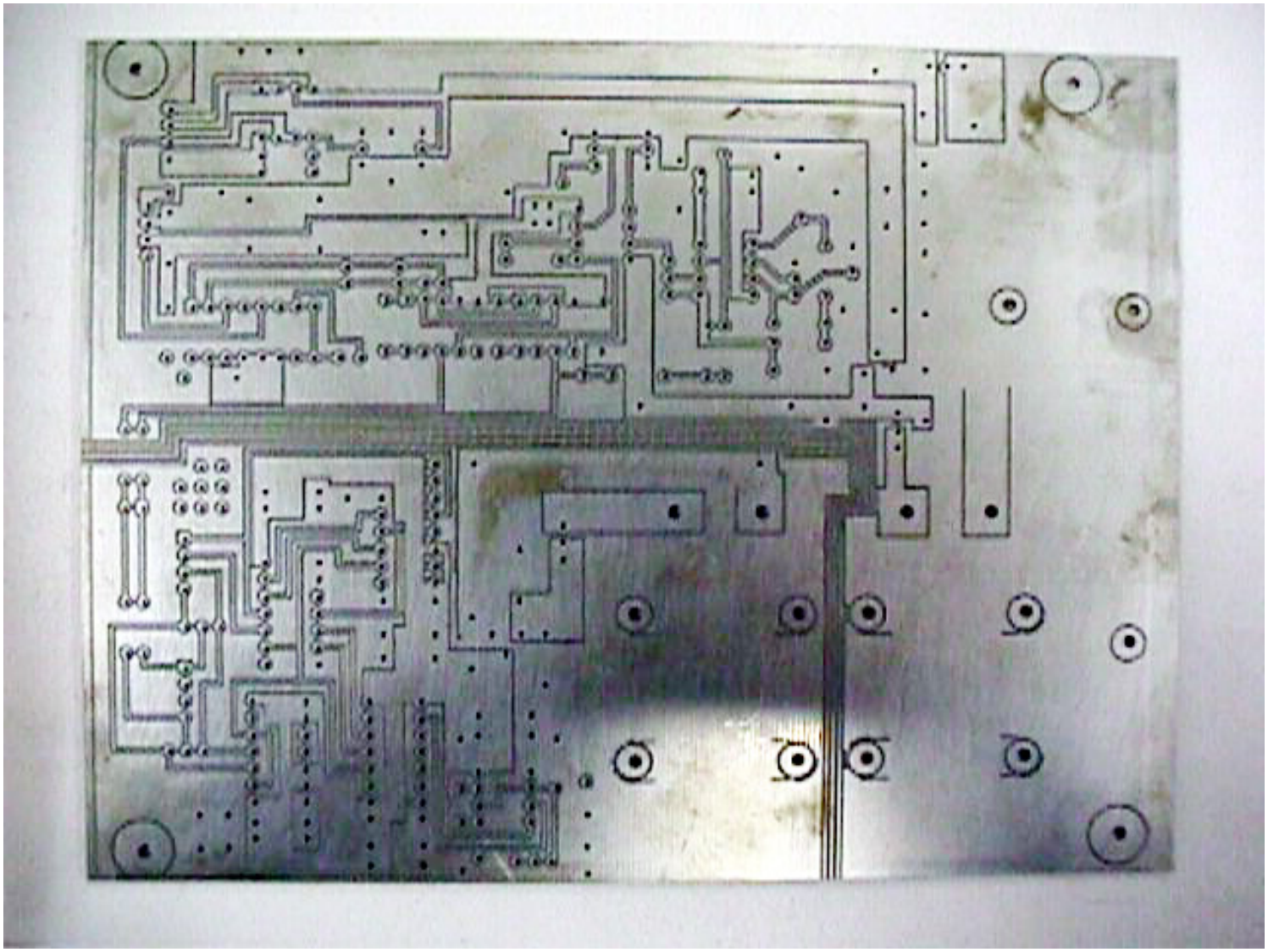
Milled Prototype PCB



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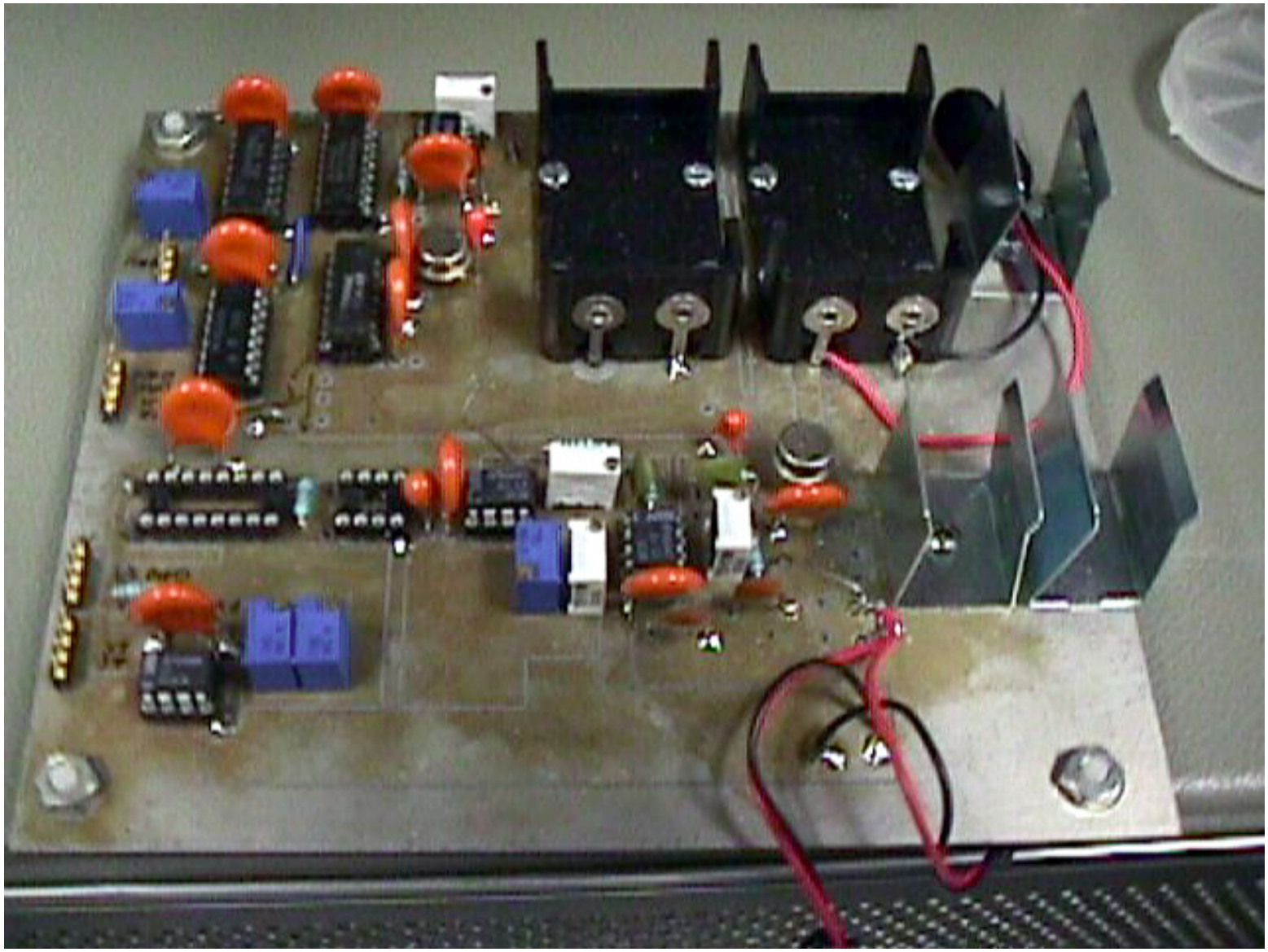

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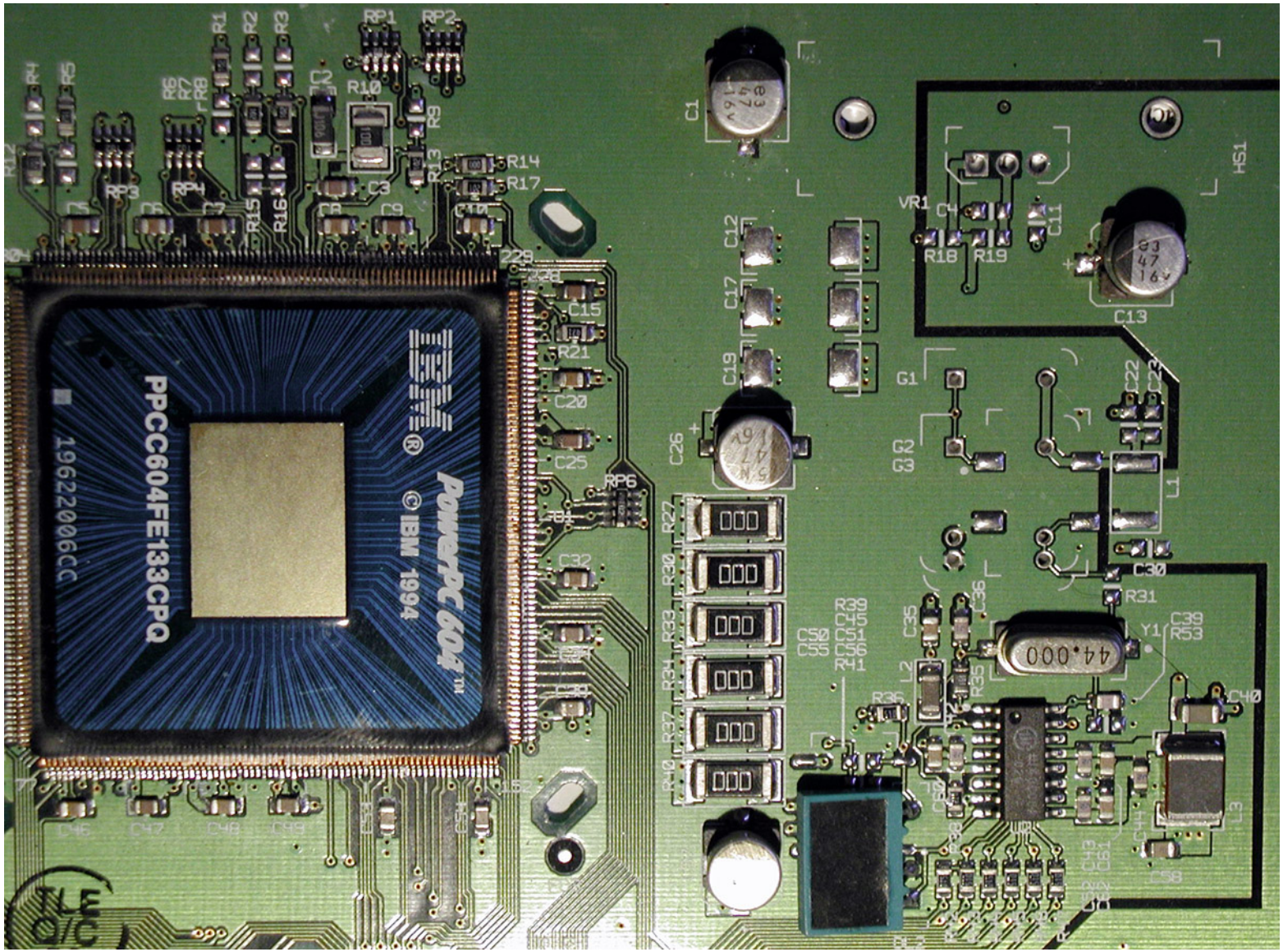
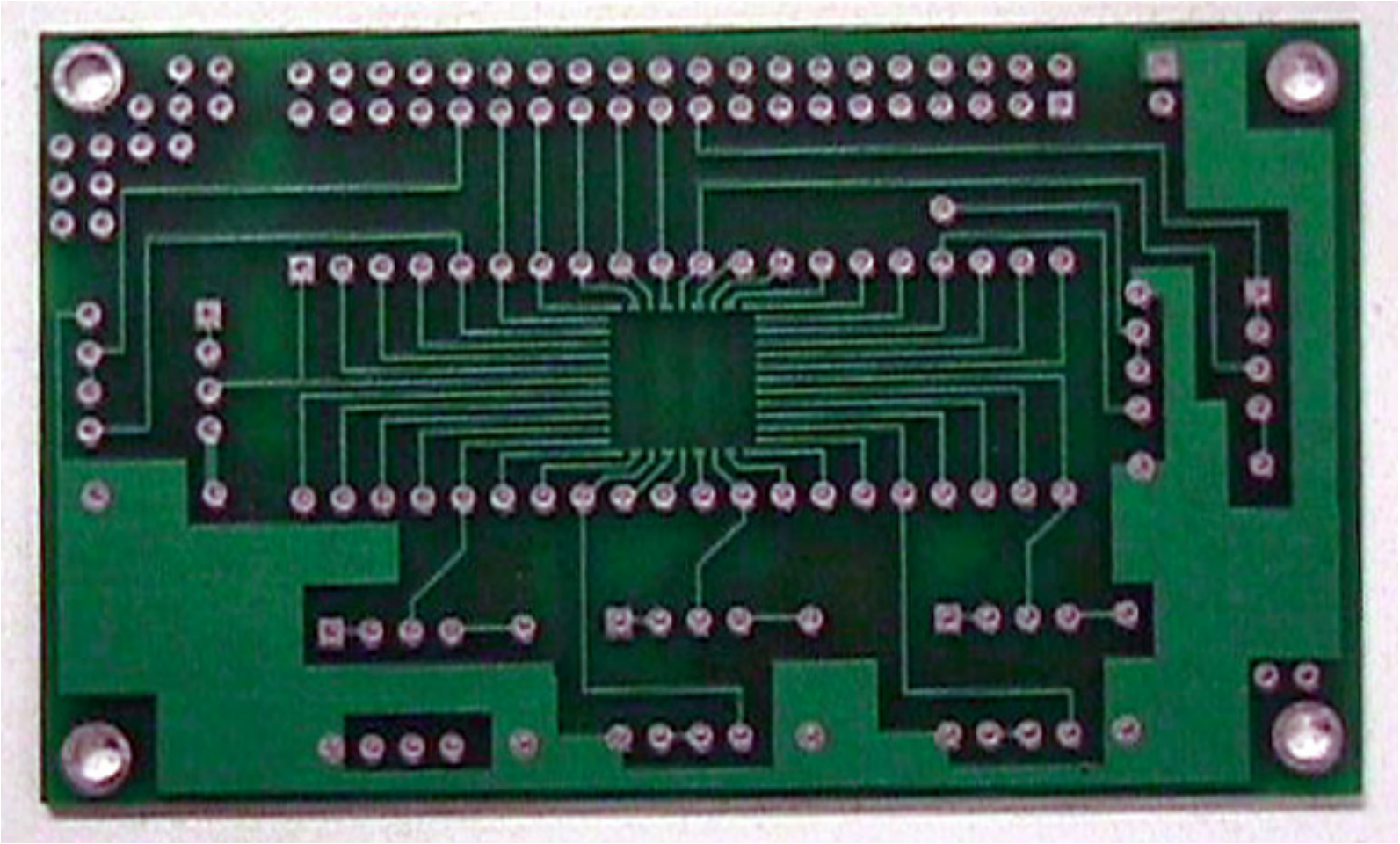
Surface Mount Components



Commercial PCB



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Commercial Options

- Many quick-turn, low-volume, low-cost PCB options.
- Example: Advanced Circuits, ExpressPCB, Batch PCB
- Free CAD tools online (for Windows and Mac): Eagle, PcbArtist, gEDA, ExpressPCB, Ultiboard

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Very Basic Layout Tips

- **Placement:**
  - Like a Puzzle! 1-2 layers for components.
  - Group components on board the same way you do in a schematic.
  - Want to avoid crossing of rats/nets/wires/traces (less vias).
  - Sets up your routing difficulty.
  - Leave enough space between components.
- **Routing:**
  - A cool mess of wire connections, 1-16 layers for routing (we use only two for cost reasons).
  - Avoid 90° turns, 45° better.
  - Larger trace width for power rails, smaller for signals.
  - DRC checks.
  - Auto-routing quality varies – may want to avoid it for now.
- **Look online or ask us for help/advice!**

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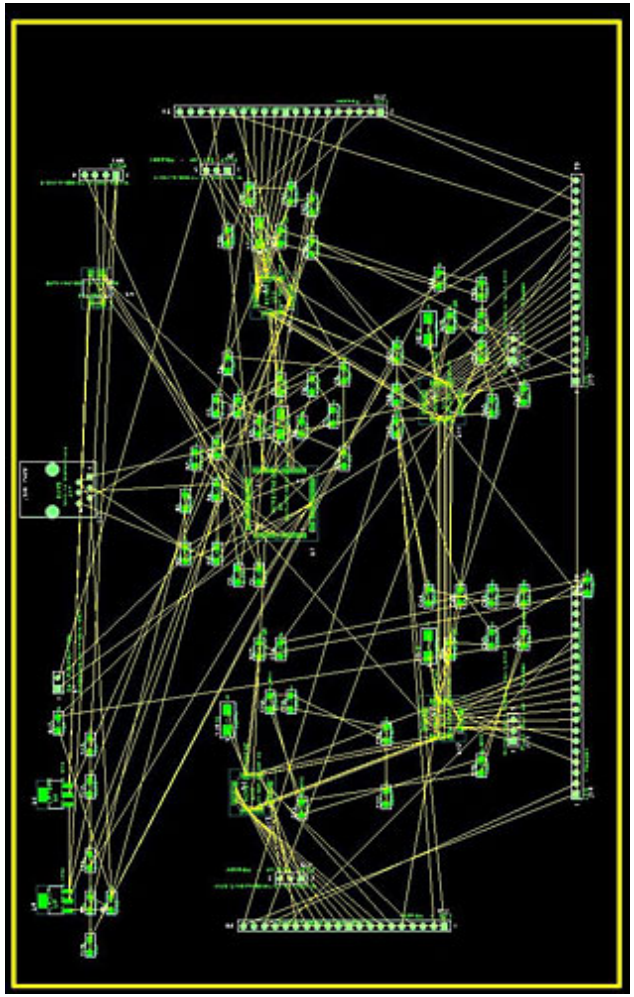
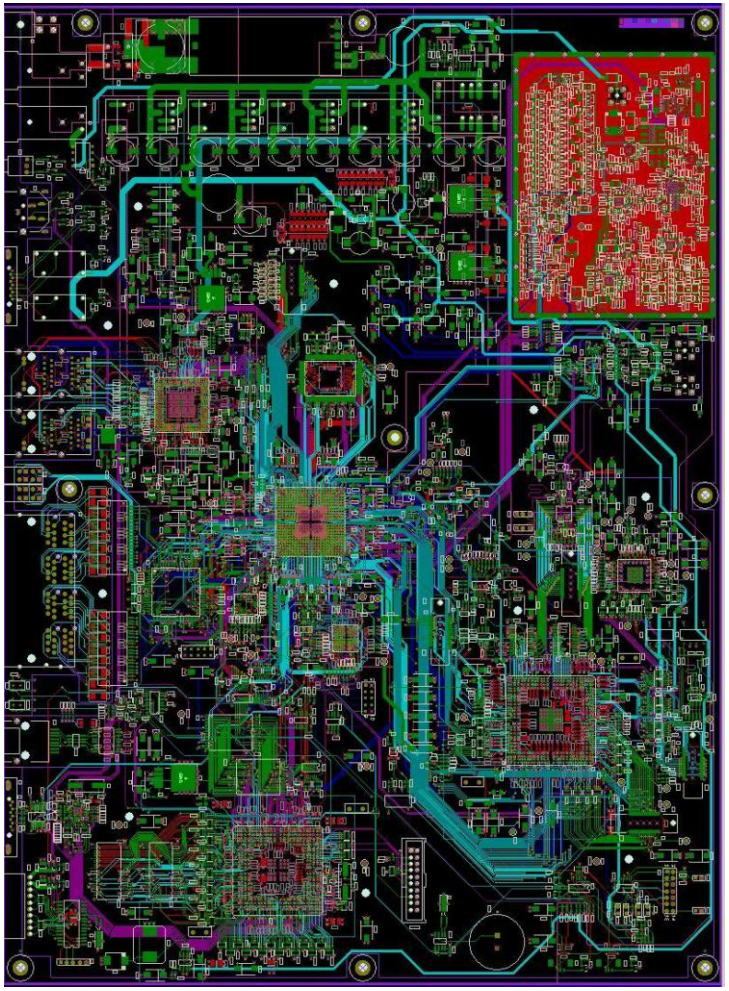
Unrouted pcb



vs

Routed pcb



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Grounding and Supply Distribution

- Power supply voltages should be distributed using "bus-lines" on the board - on a printed circuit board, these are typically heavy (wide) traces.
- Grounding is critical, particularly in mixed-signal systems.
- Digital and analog grounds should be kept SEPARATE, coming together at ONLY ONE point - the power supply.
- Failure to observe this can result in extremely hard to debug ground-related problems.

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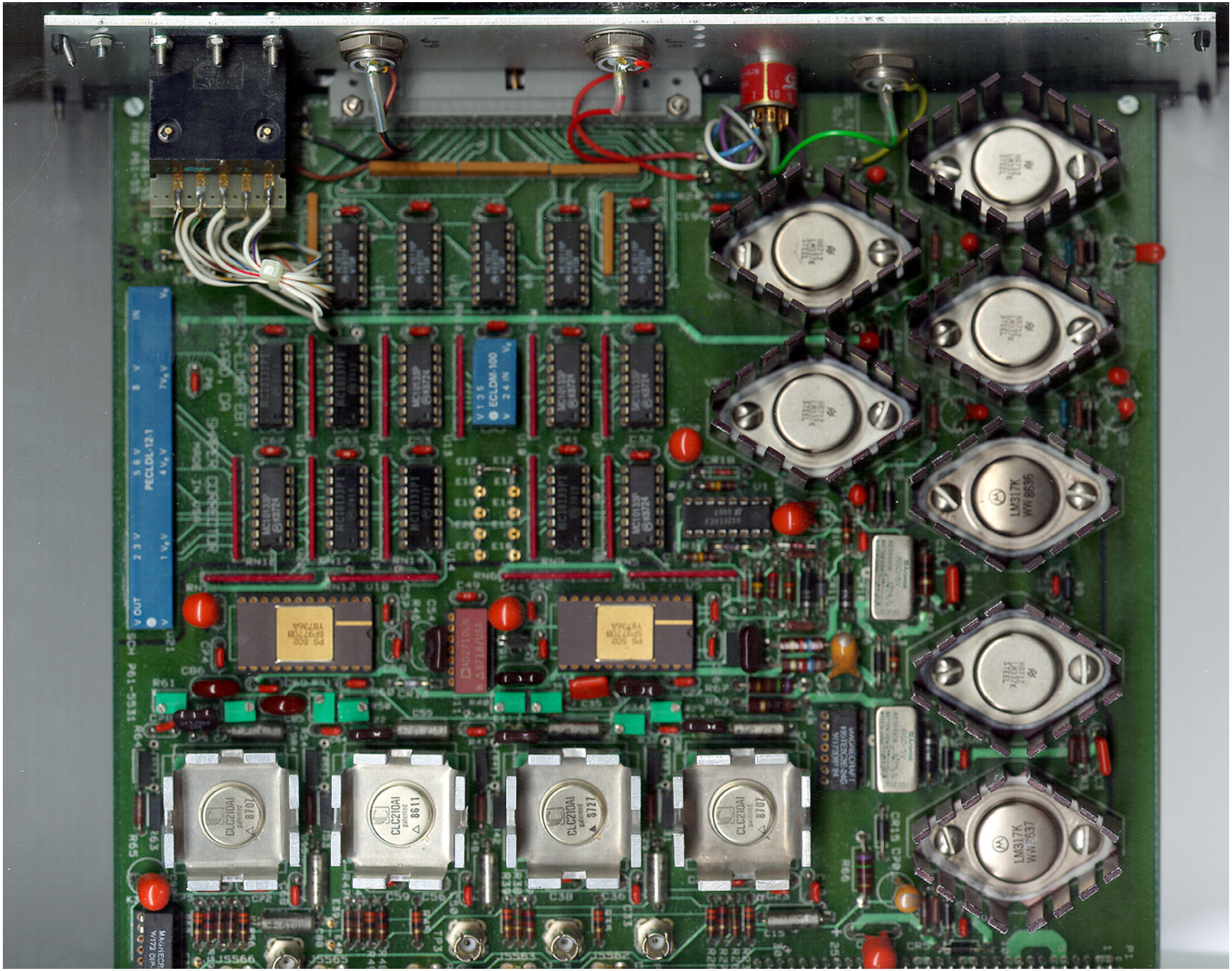
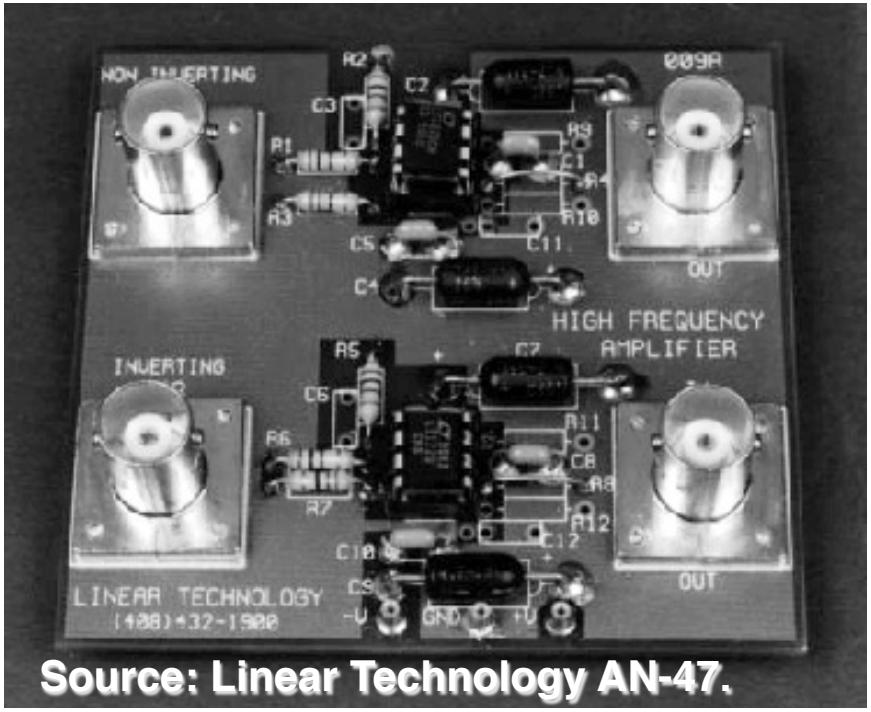
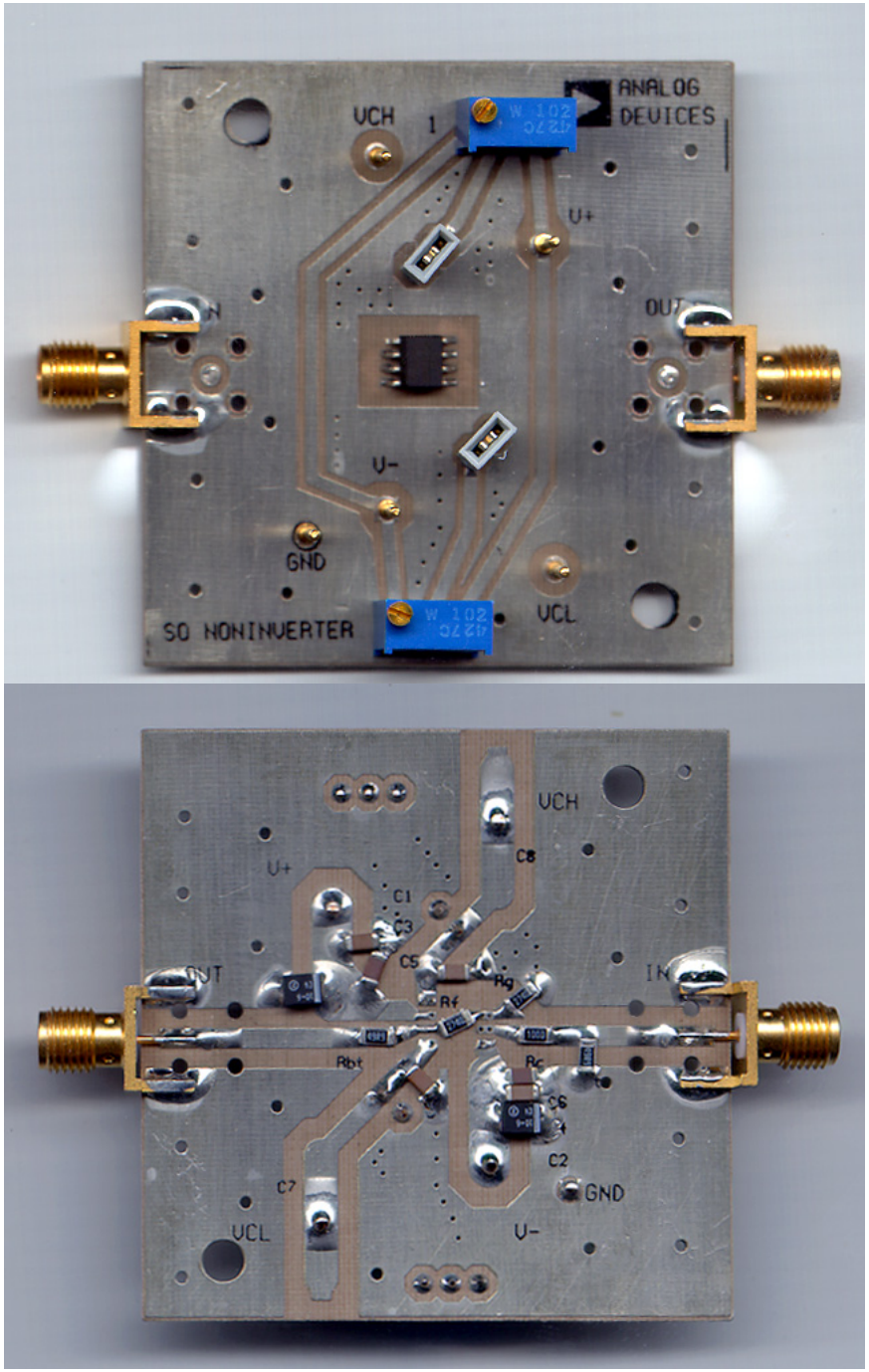

ECLDM-100
PECLDL-121
LM317K
CLC210AI

Layout for High-Speed Circuits



Source: Linear Technology AN-47.



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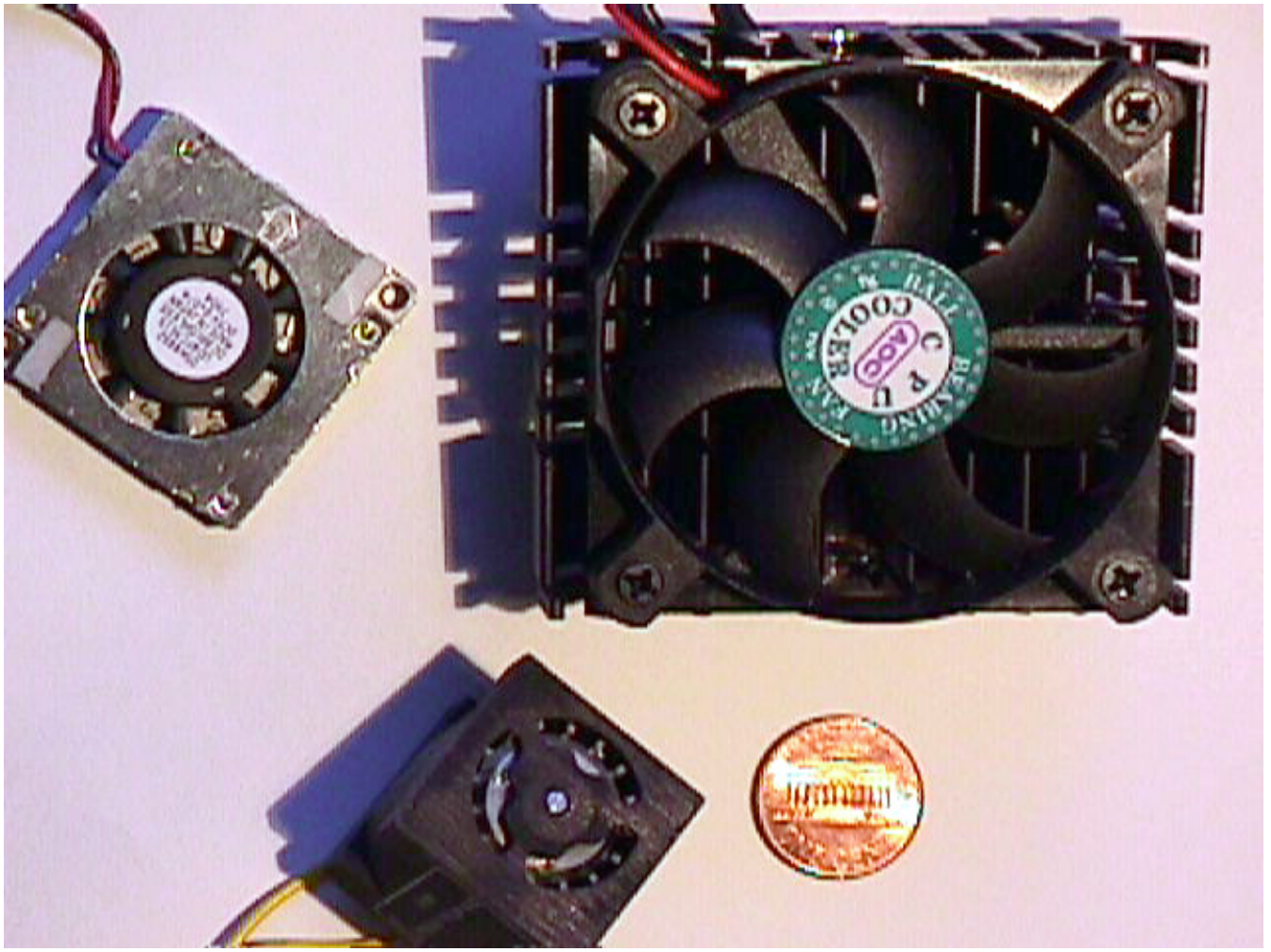
Thermal Management



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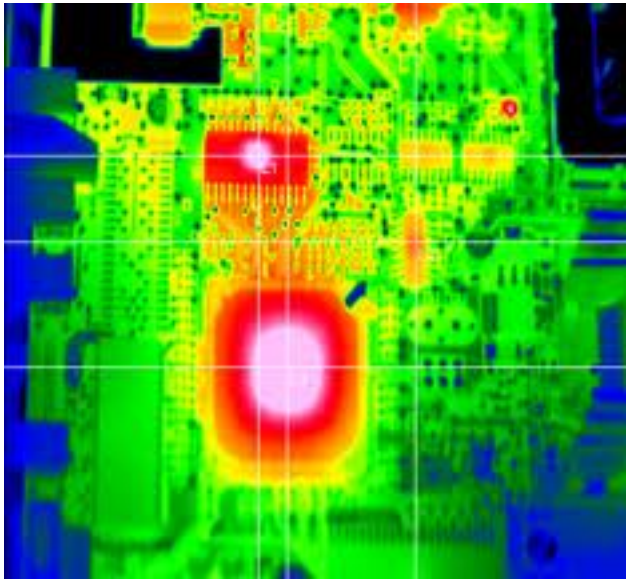
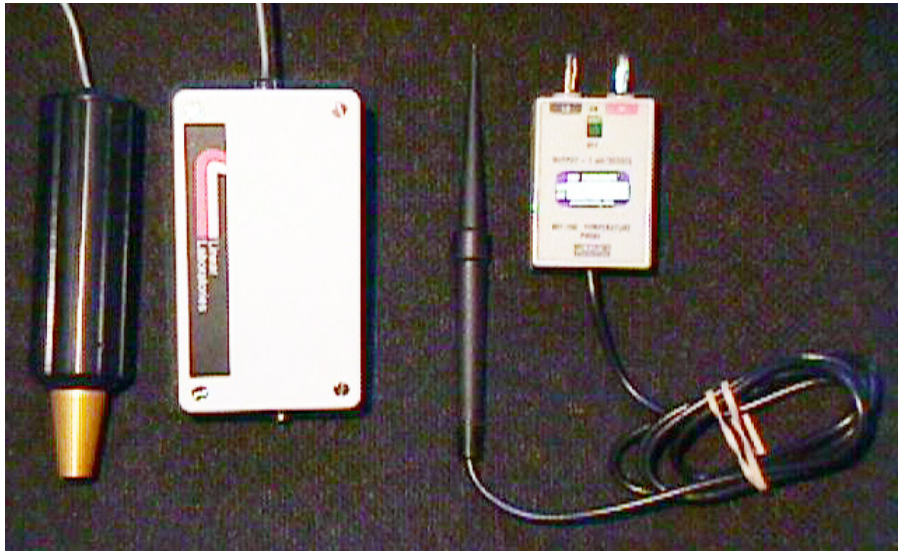
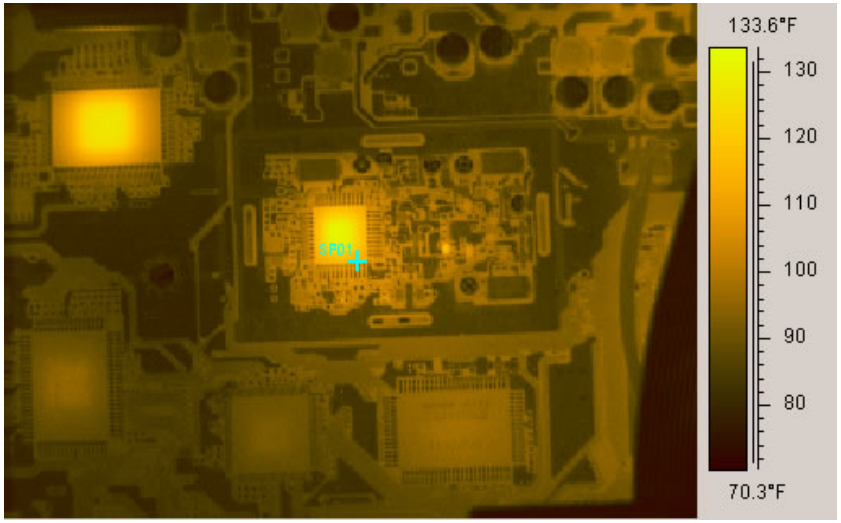
Temperature Measurement







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Packaging Your Circuit

- For EE122, building your project in the high-frequency plug-board will be fine.
- Of course, you are encouraged to be creative about packaging.
- Old food containers, recycled instruments, or even hand-made boxes are relatively easy to organize.
- Humor is always welcomed!

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Example Prototype Packages

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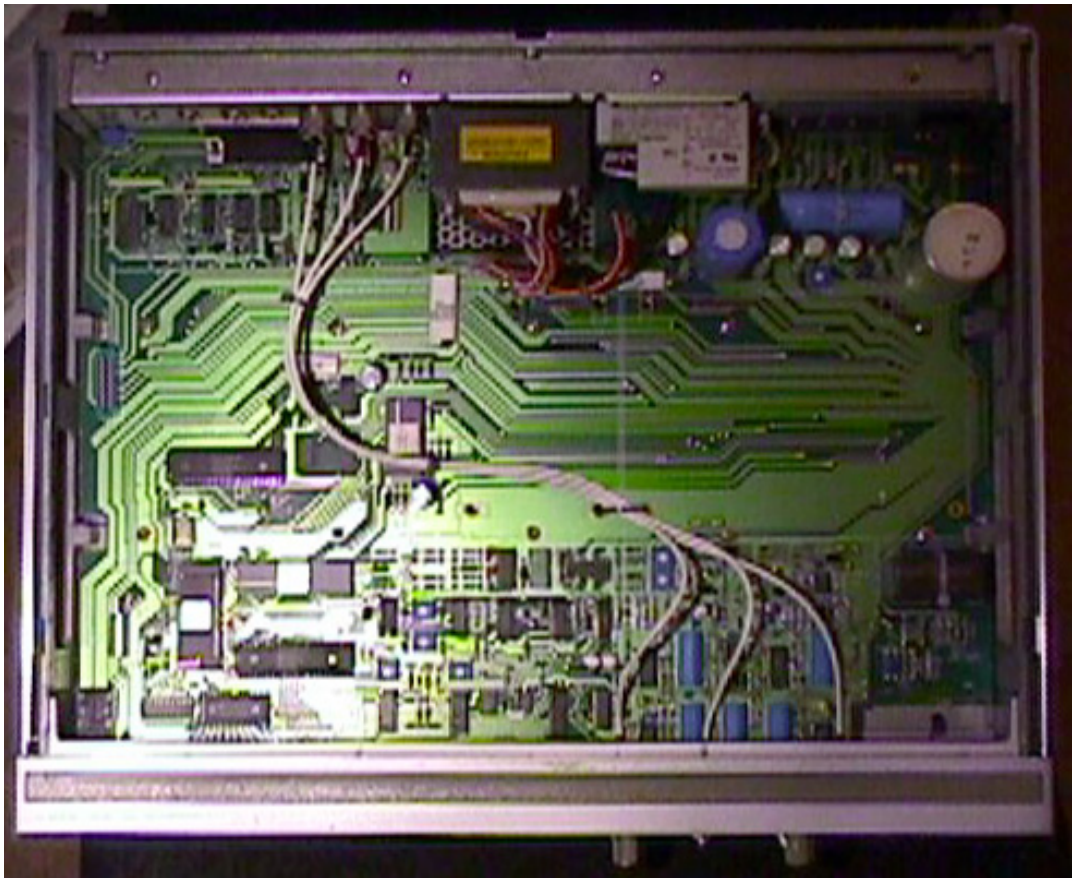
HP5334A - Compartmentalization



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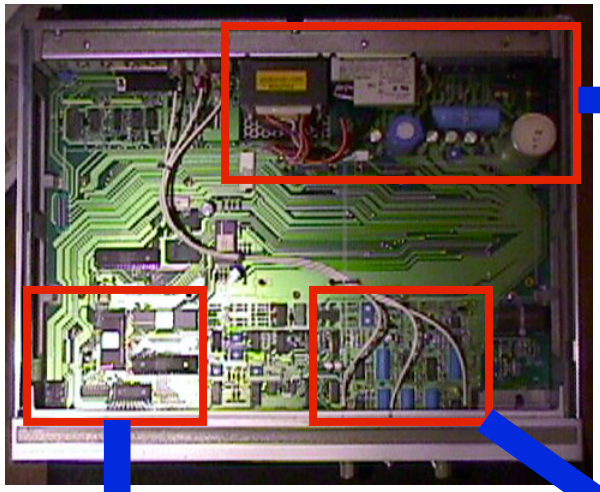

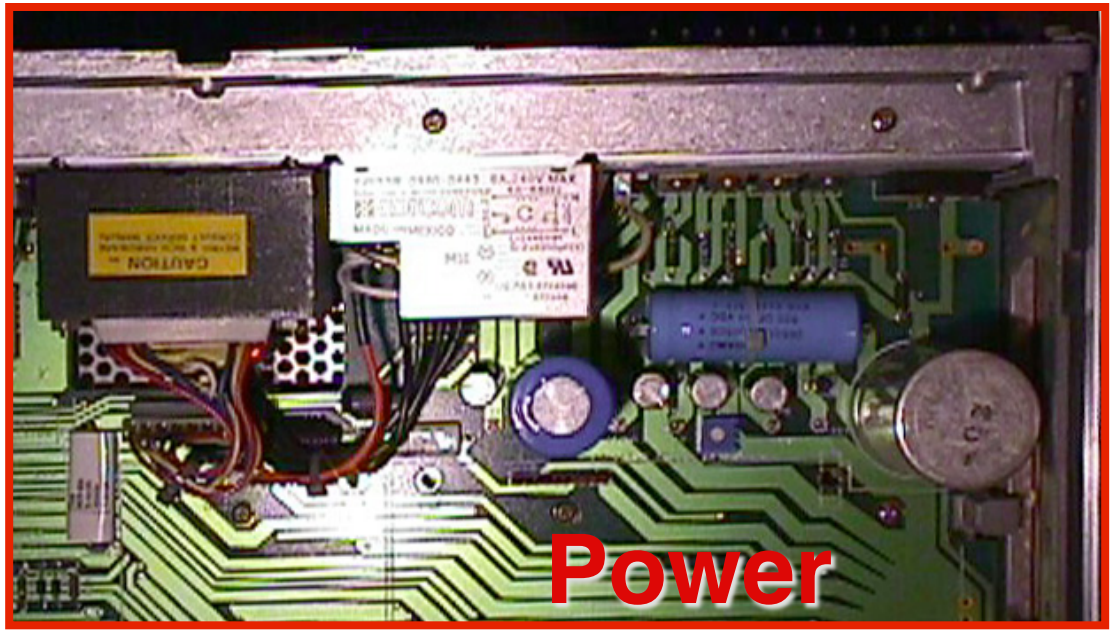

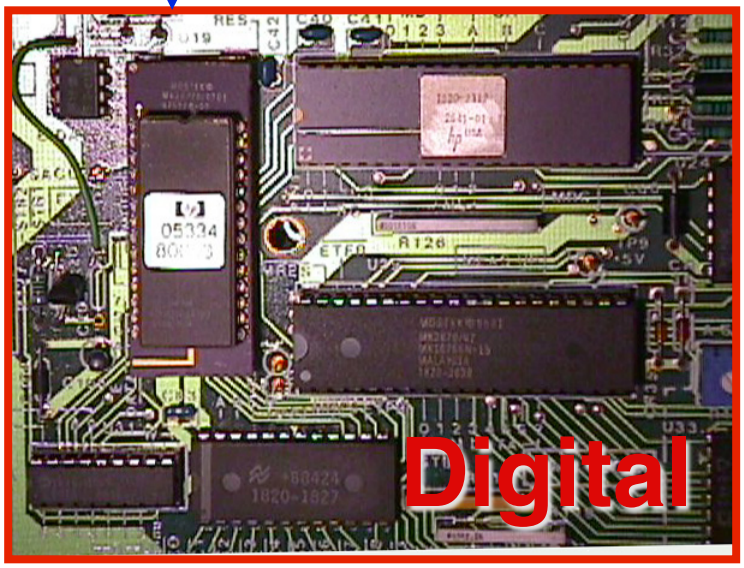

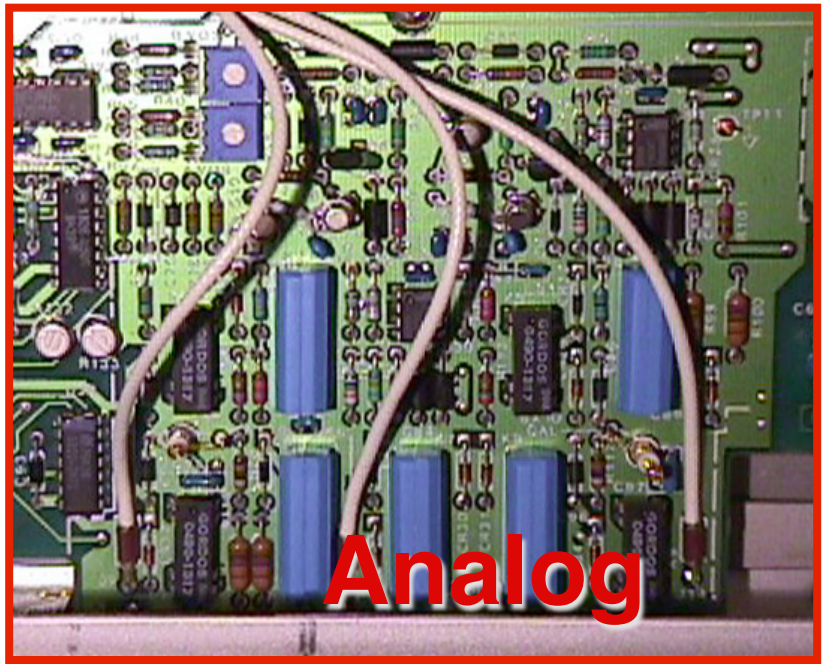

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Safety - Ground-Fault Interrupters

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Fuses

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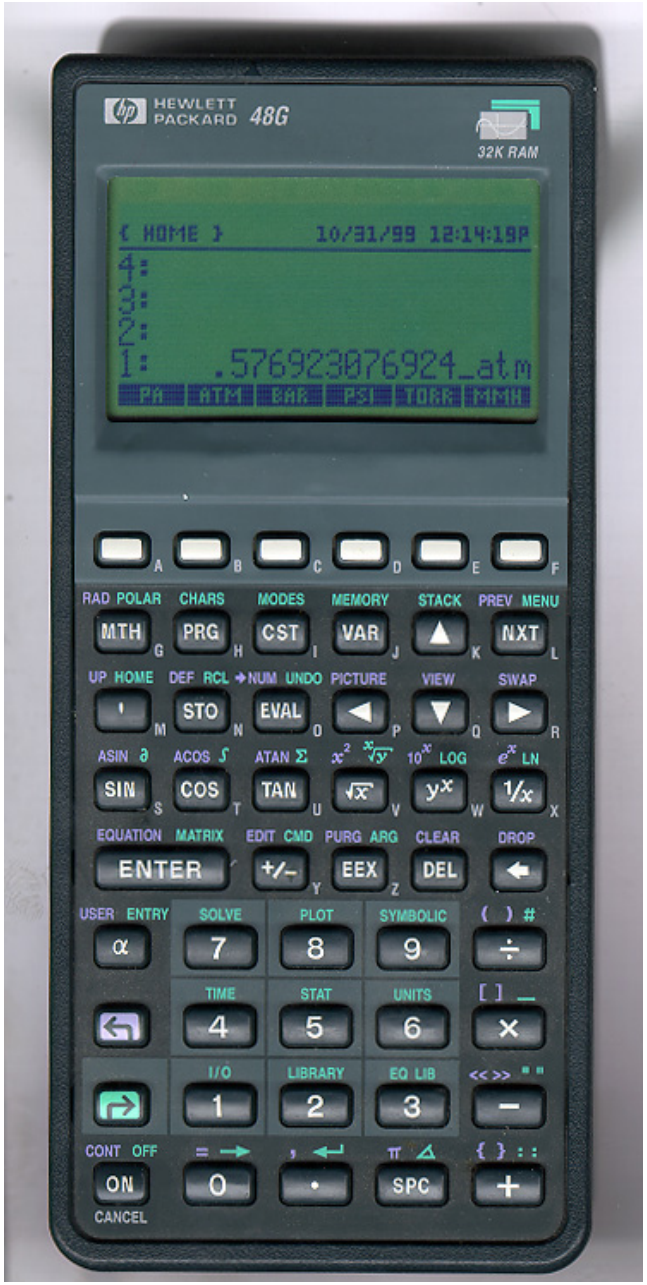
Ergonomics



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“Classic” Cessna 172

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Modern Cessna 172

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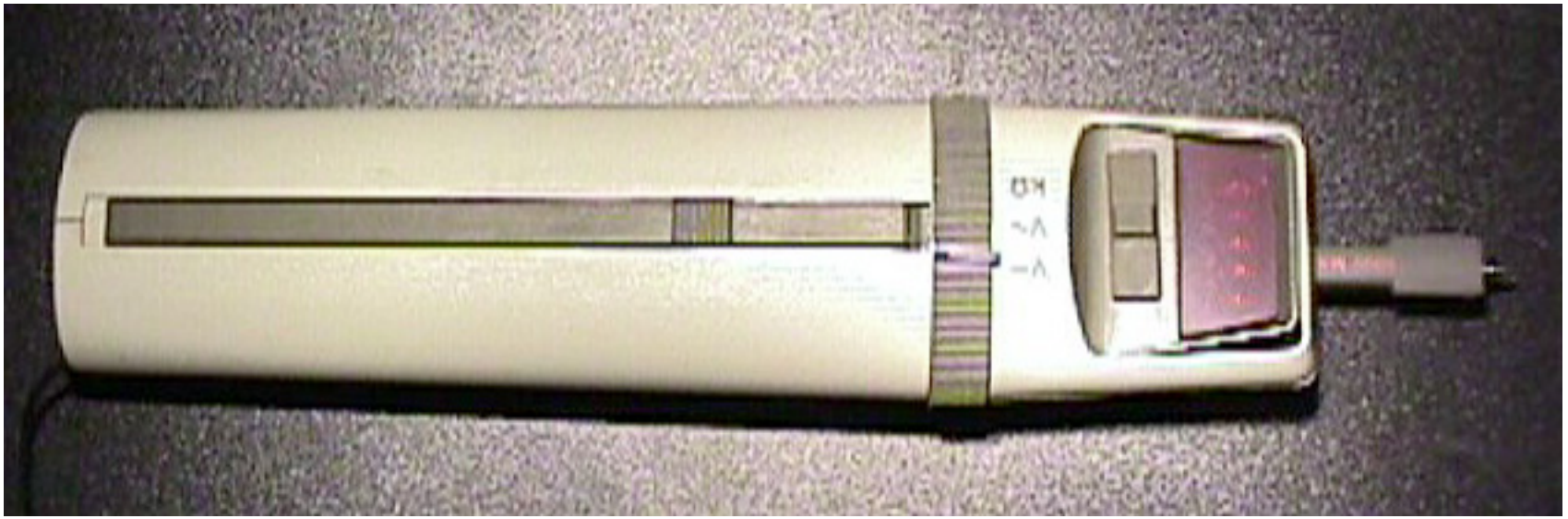
HP970A - 1972



- Hand-held digital multimeter.
- Integrated rechargeable batteries.
- LED display could invert to suit viewing angle.
- Ergonomic design!

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HP970A - 1972

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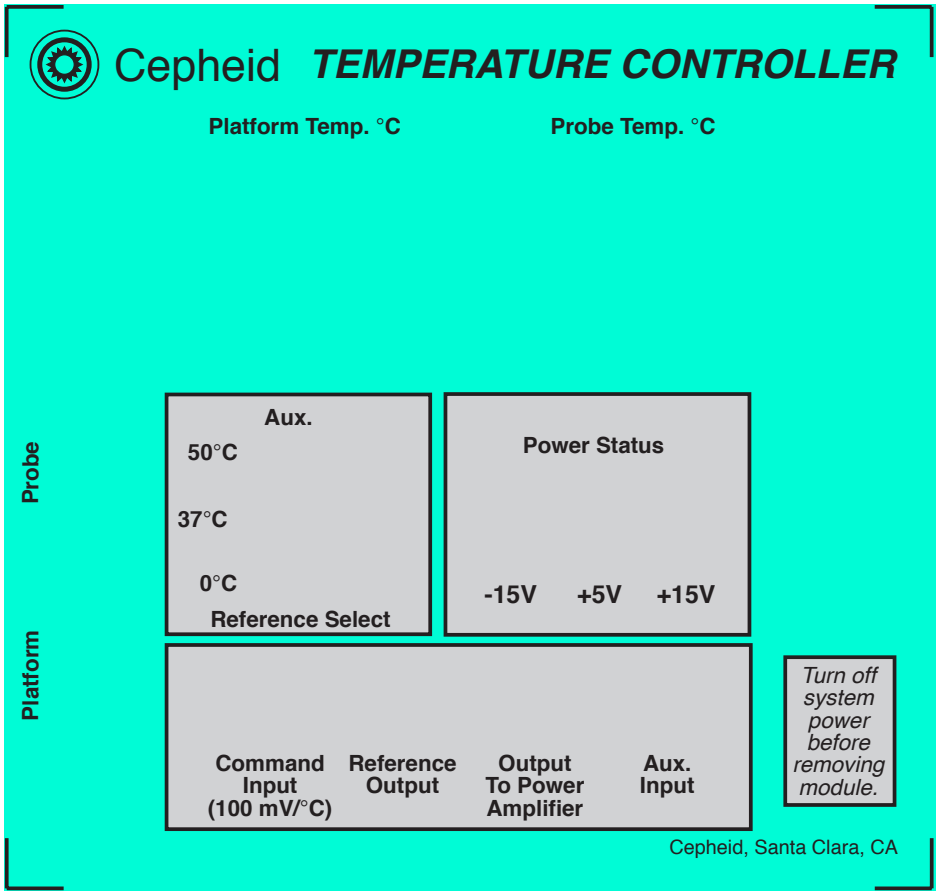
Labeling and Graphics for Your Circuit

- **A good drawing tool such as Freehand™, Illustrator™, Corel Draw™, or many others can be used to make precise front-panel layouts with a laser printer.**
- **The layout can be printed on sticky-backed transparency material that can be peeled off and applied to the front-panel of your package.**



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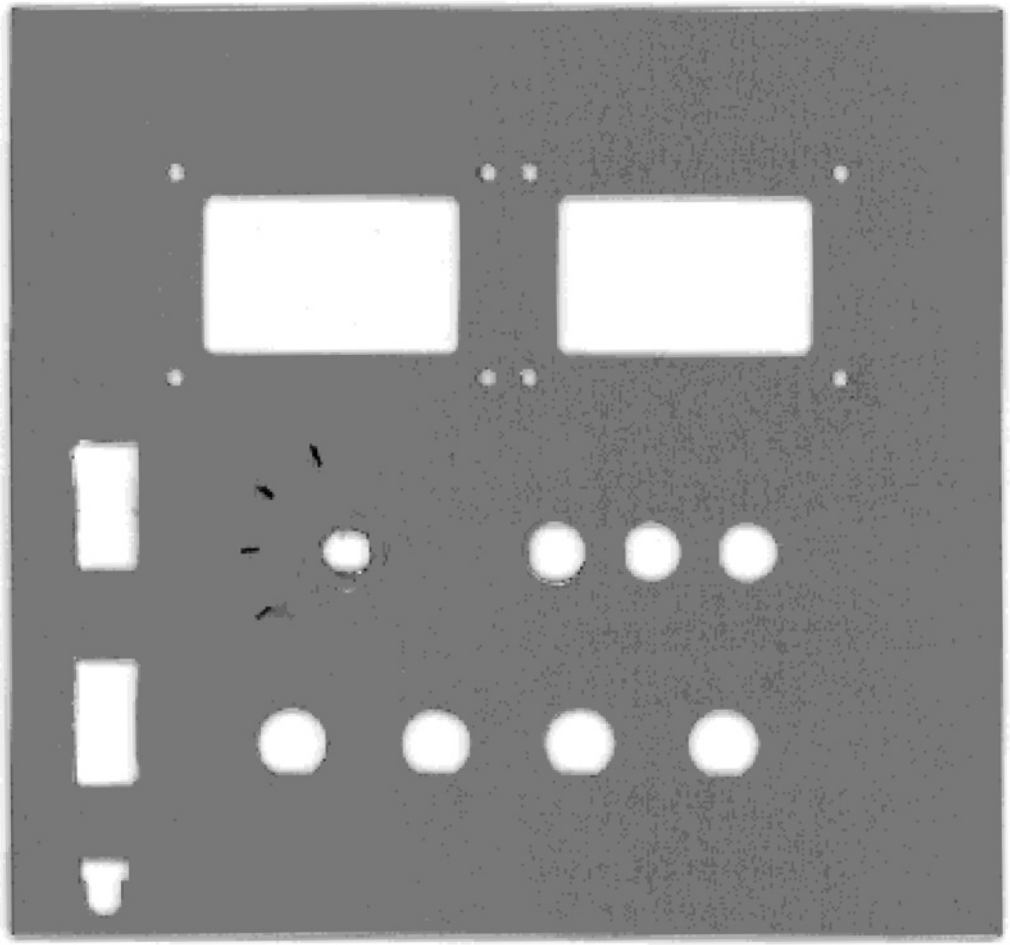
Scanned Front-Panel for Precise Fit



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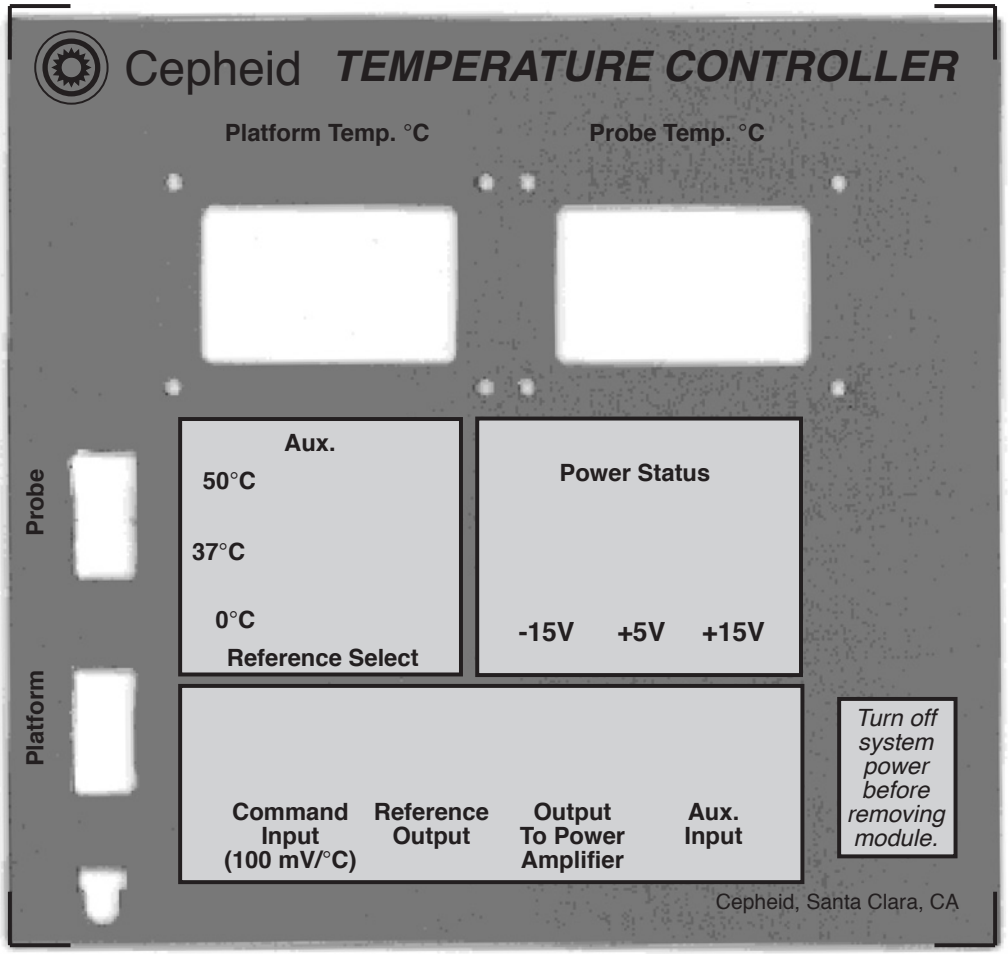
Overlay



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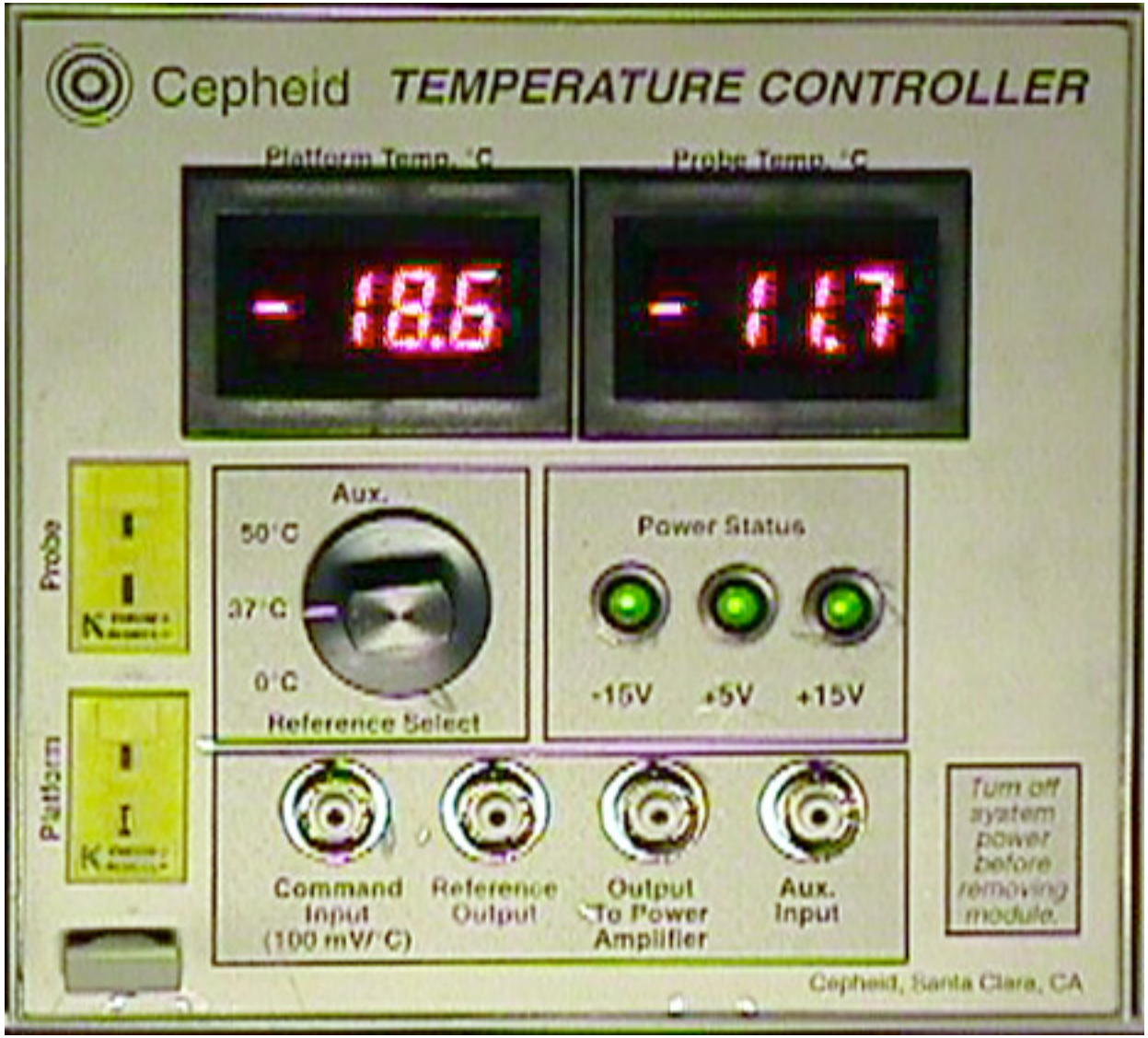
Finished Prototype



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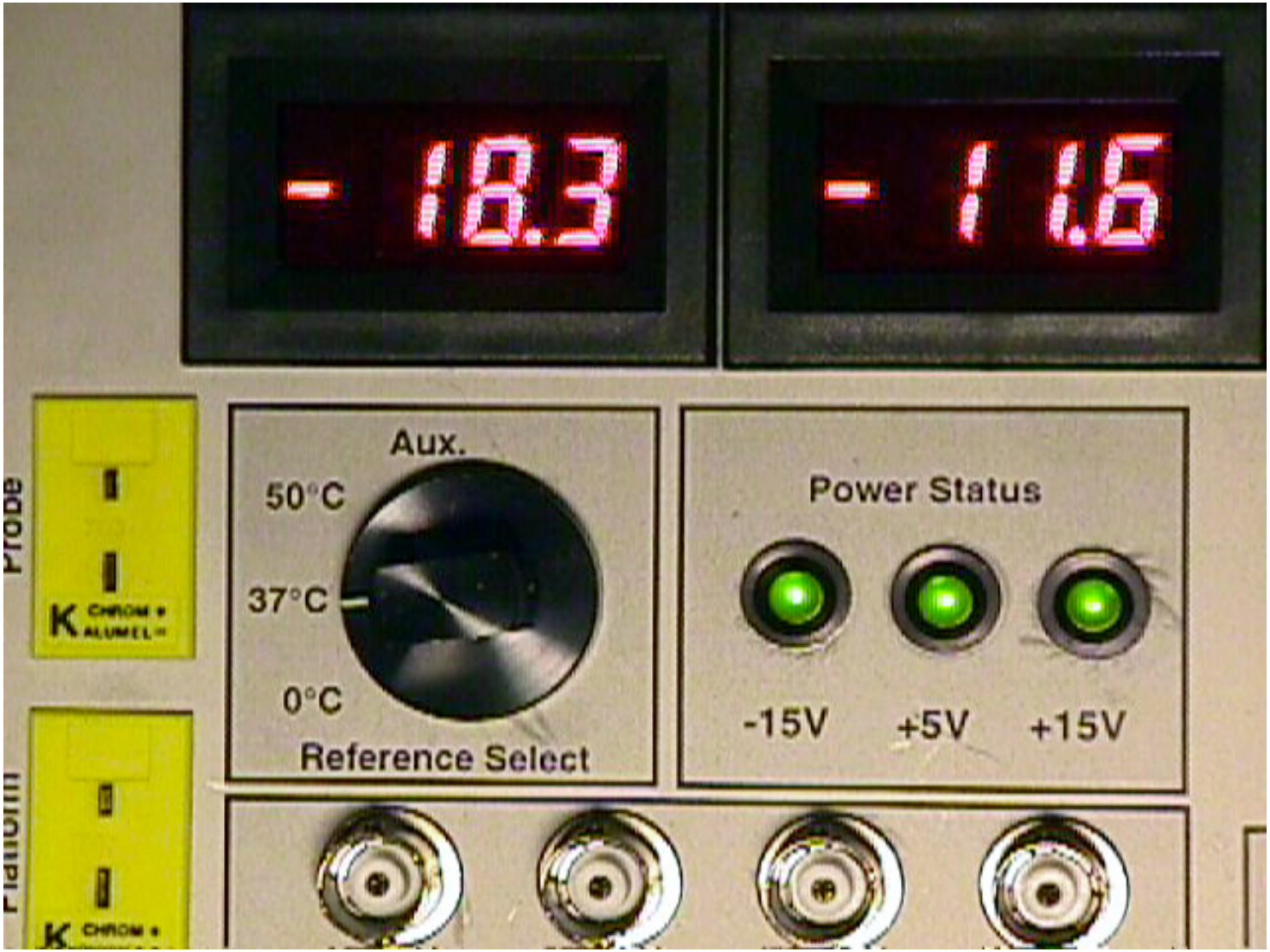
Minor Pitfalls...



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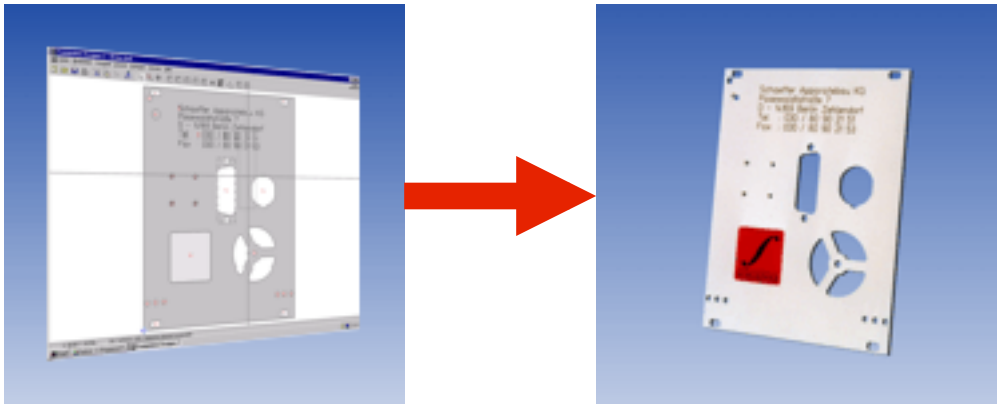
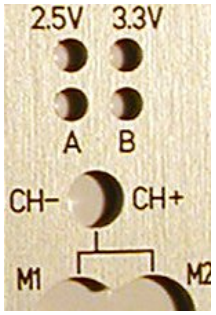
Commercial Options

- **Fast-turn, low-cost beautiful front panels:**
- **http://www.frontpanelexpress.com/**
- **Free CAD tool (for Windows).**





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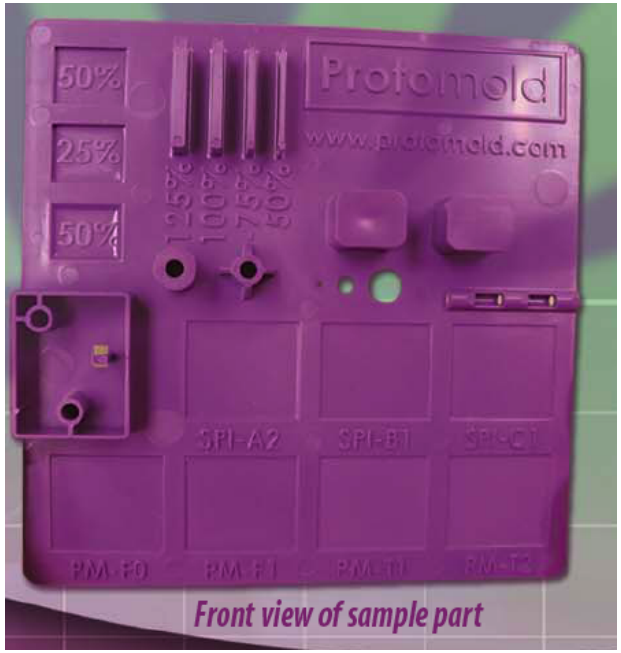
Low-Cost Injection Molding

- Traditionally very expensive (mold costs), approaches are emerging that allow low-volume prototyping inexpensively.
- Example (prices starting ≈ $2k): http://www.protomold.com/



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LEXINGTON MIDDLE SCHOOL
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Demonstration Strategies

- **Demonstrations are intended to:**
  - **Demonstrate the technical features of a product.**
  - **Excite potential customers (or graders!).**
  - **Sell hardware/software (if in the real world).**
- **Good demos are:**
  - **Concise - attention spans are limited.**
  - **Clear - no confusing stuff.**
  - **Organized - progress clearly from front-end to back-end.**
- **Suggested strategy:**
  - **Introduce team.**
  - **Explain purpose of device.**
  - **Explain how it works.**
  - **Demonstrate it working.**
  - **Summarize.**
  - **Ask if there are questions.**

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THE FINE ART OF MARKETING.....

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Thoughts on Manufacturing

- In production, circuits are optimized for cost.
- In some domains (e.g., consumer), performance can be traded off quite freely for savings.
- In other domains (e.g., precision instruments), peformance goals tend to be fixed.
- "Discretes are free" - true to some extent.
- Automated, low-cost assembly is typical.
- Economies of scale rule.
- Testing and rework strategies are valuable.

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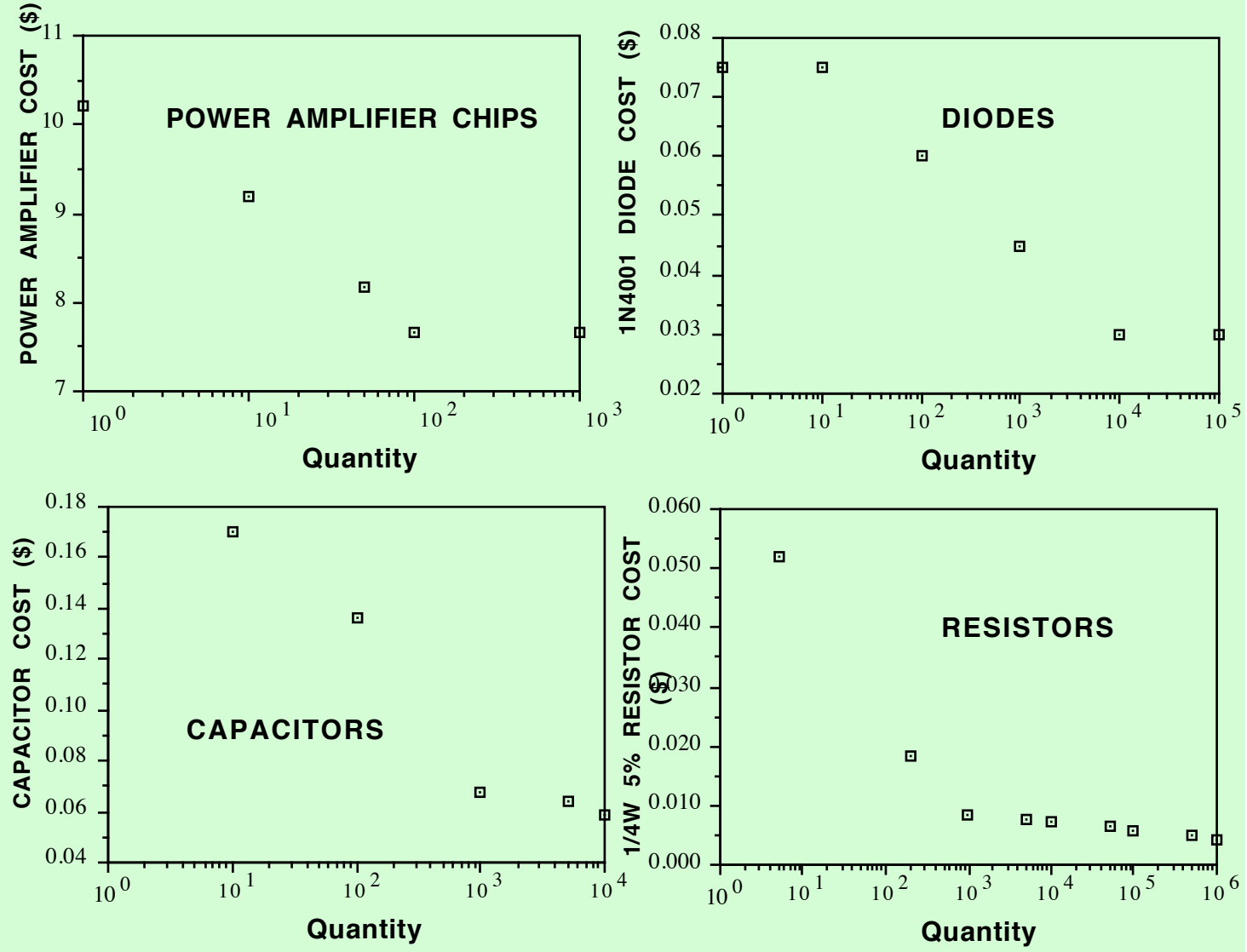
PRODUCTION: COST VS. QUANTITY



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