

# Digital Logic Design

4190.201

2014 Spring Semester

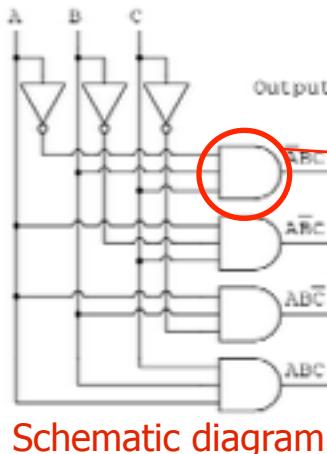
## 2. Prototype Implementation Techniques

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# What is prototyping?

- A prototype is an early sample or model built to test a concept or process or to act as a thing to be replicated or learned from - from Wikipedia
- Prototyping of digital logic
  - Requirement - not a formal description
  - Specification - technical terms and descriptions
  - Design entry - Boolean equations, schematic diagram, hardware description language, block diagram, etc.
  - Back-end processing - optimization, conversion for technology mapping
    - Technology mapping - mapping the design to real hardware components
  - Prototyping

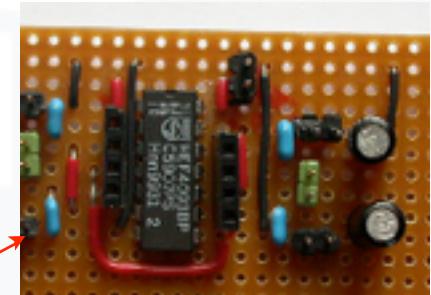
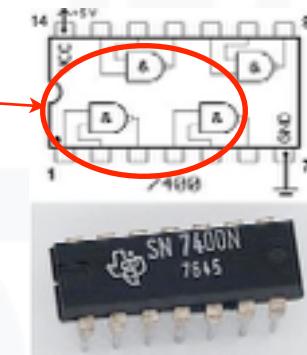


Boolean equation

$$\text{Output} = \bar{A}\bar{B}C + A\bar{B}\bar{C} + \bar{A}BC + ABC$$

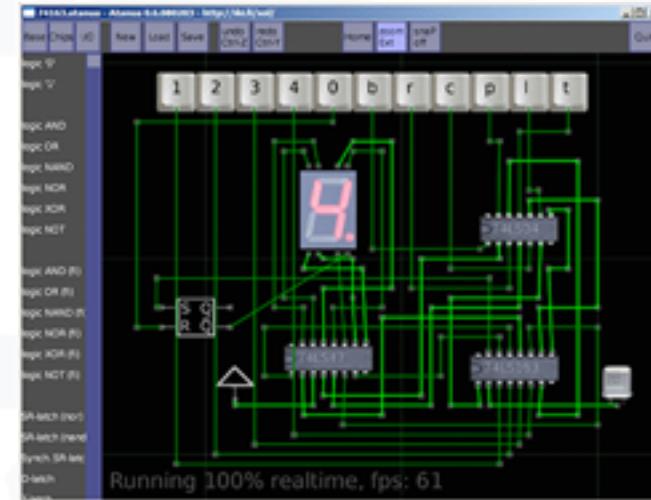
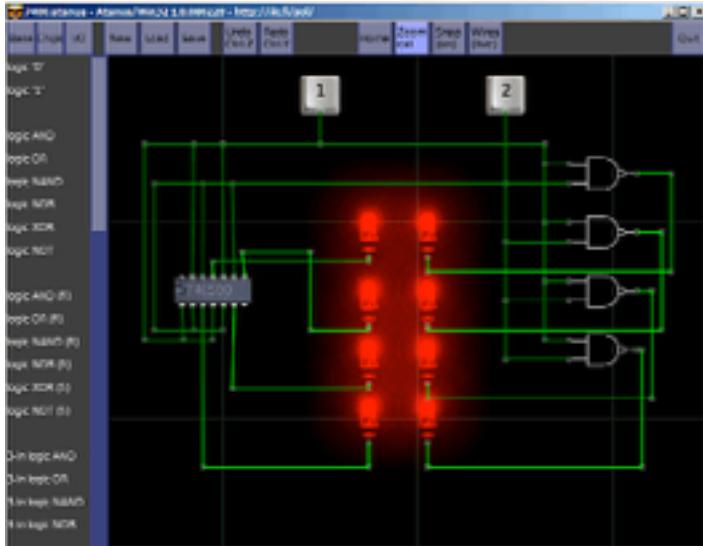
Optimization

Technology mapping



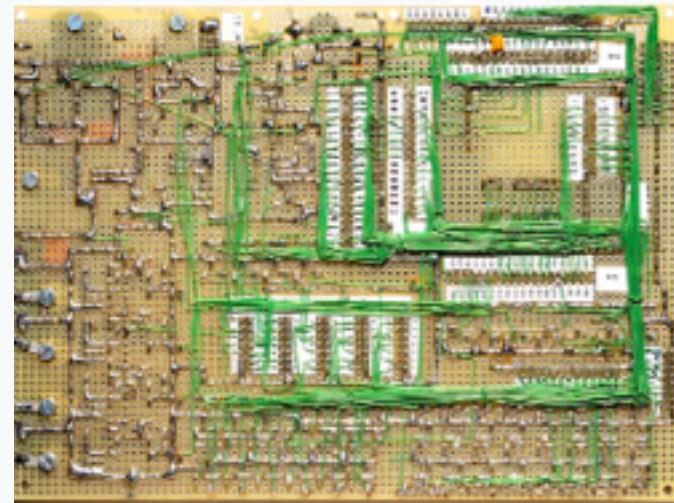
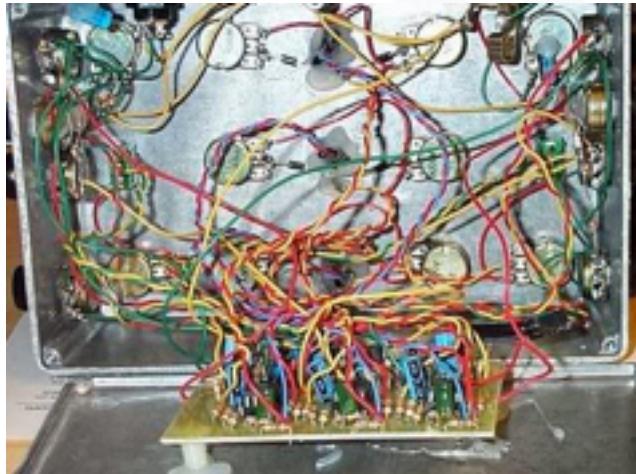
# Why prototyping?

- Validate your design
- Simulation versus prototyping
  - Simulation is accurate only when
    - Based on accurate and realistic information
    - Use of range of information
  - Accurate simulation is generally expensive and time consuming
    - No free lunch
  - Experienced engineers better minimize prototyping overhead
  - Students must maximize possible chances for prototyping



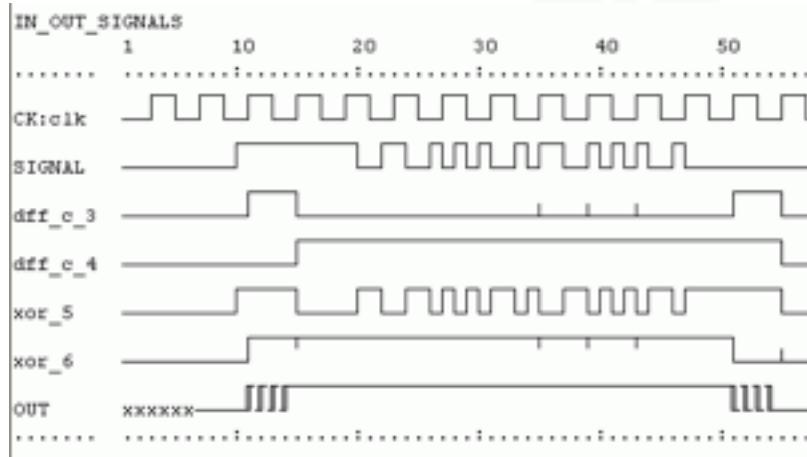
# Various prototyping methods

- What prototyping technique is good?
  - Good signal integrity
    - Less parasitic capacitance, inductance and resistance
    - Less crosstalk and coupling
    - Less reflection
  - Good power integrity
  - Close to the final product
  - Less cost and time
  - Easy to debug and modify
  - Not very much dependent on the hand skill of the engineer

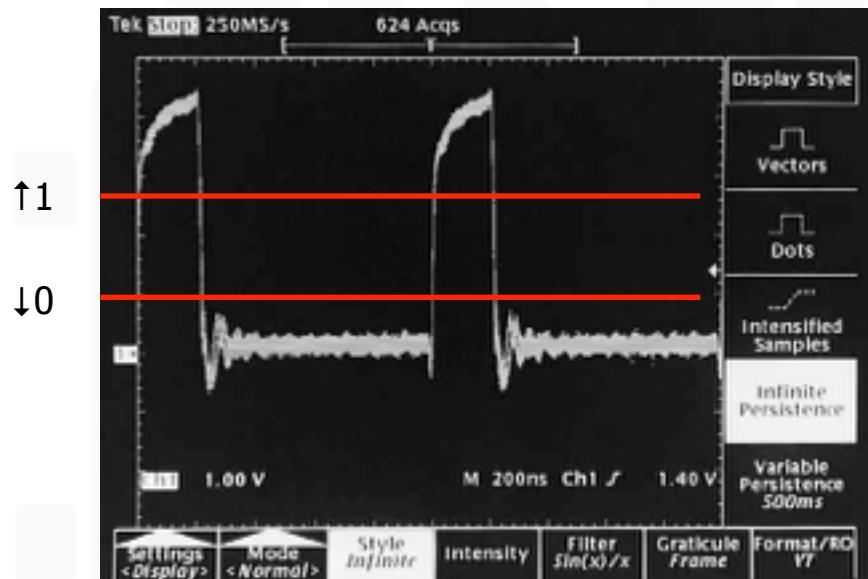


# Digital waveforms

- Actually, it is electric signals
  - Voltage changes over time
  - Interprets digitally: 1 or 0
  - Cannot be perfectly 1 or 0



Theory

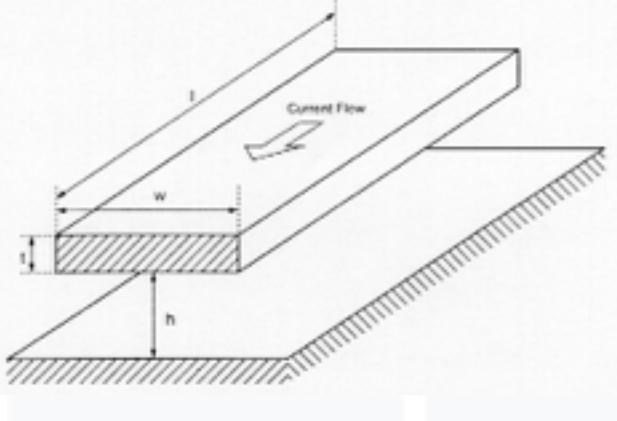
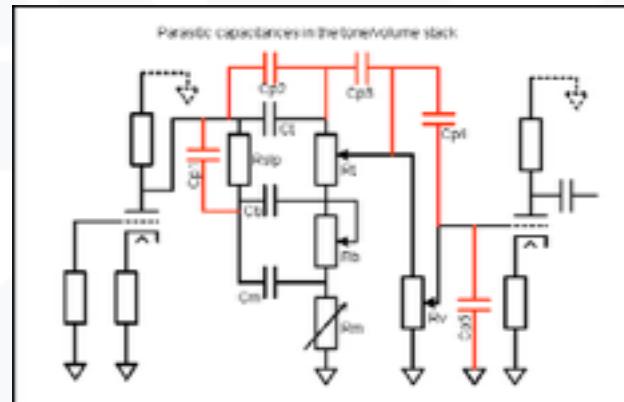
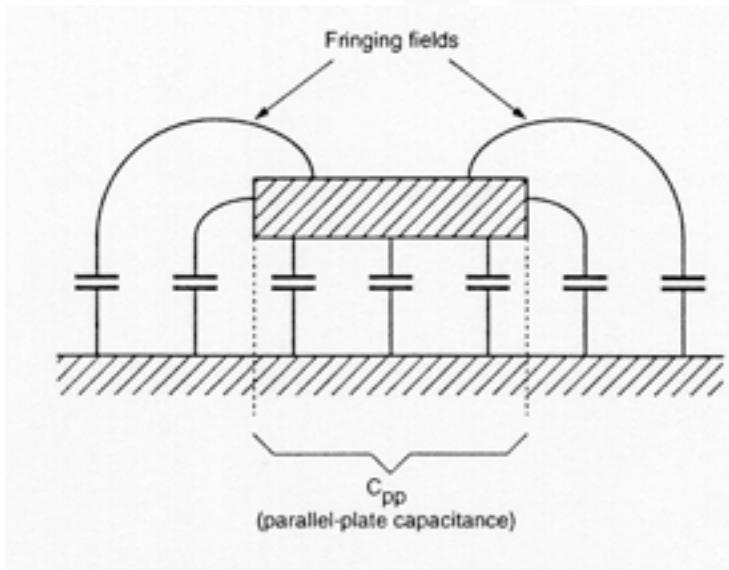


Practice



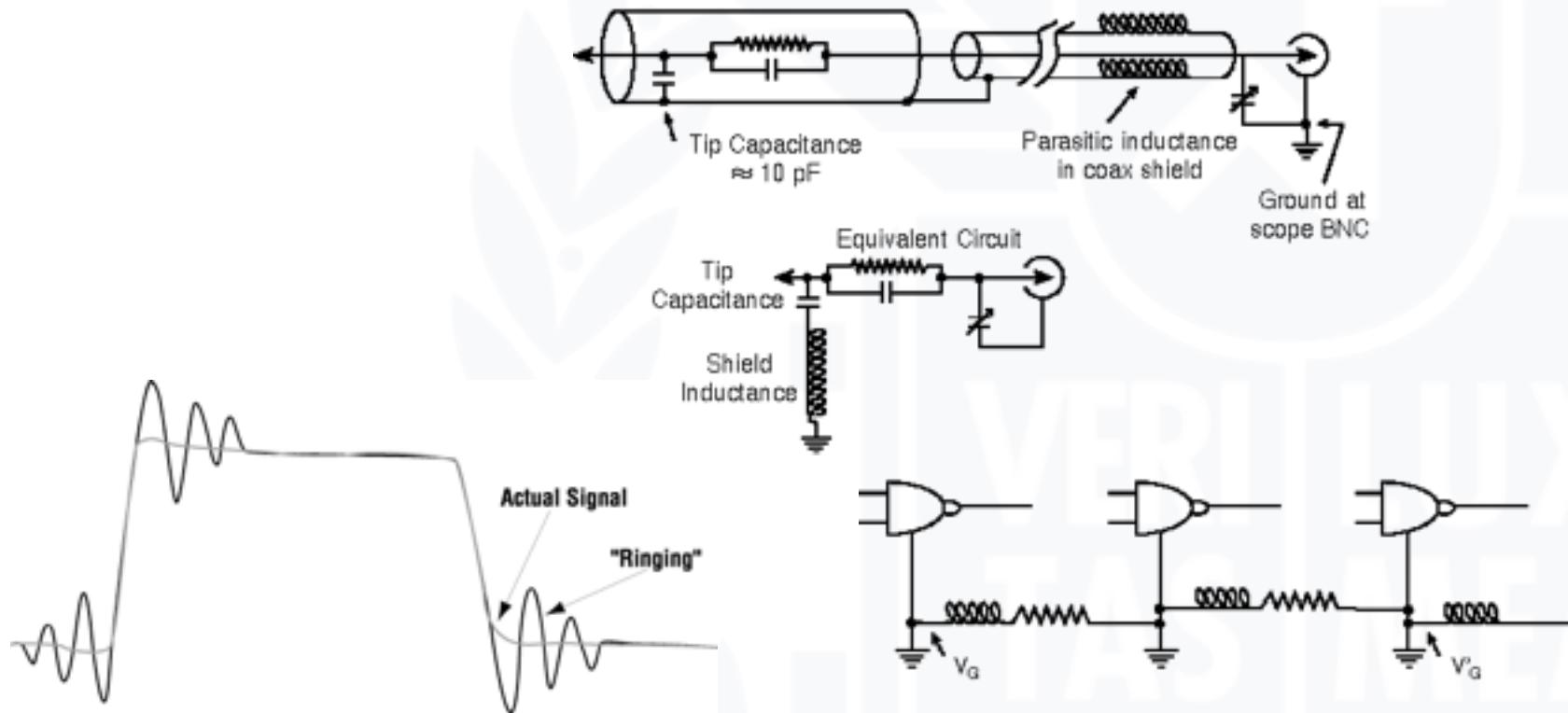
# Parasitic capacitance

- Unwanted circuit modification by adding parasitic capacitors



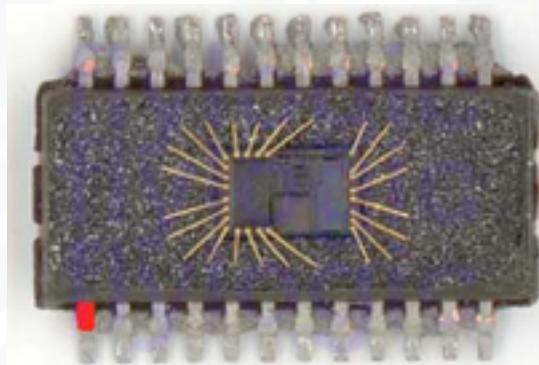
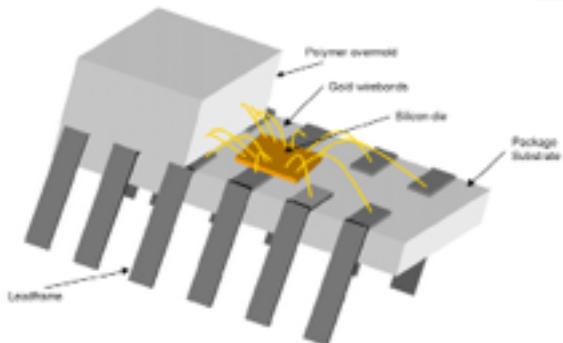
# Parasitic inductance

- Unwanted circuit modification by adding parasitic series inductors

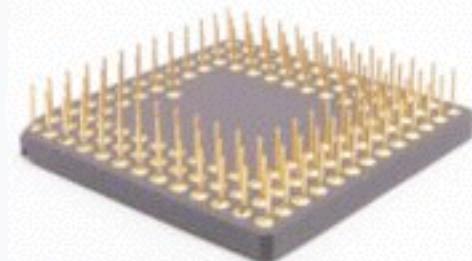
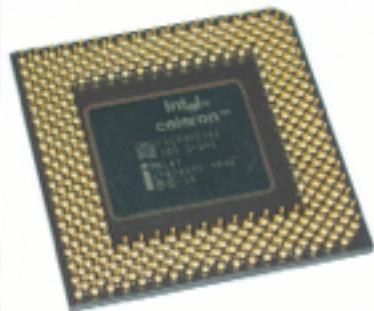


# Minimization of parasitic inductance

- DIP (dual inline package)

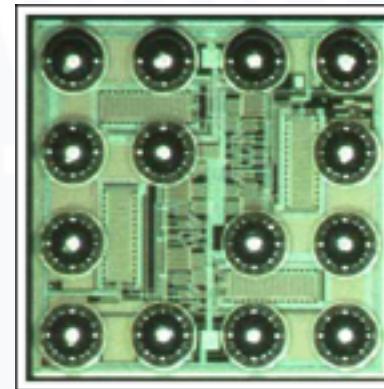
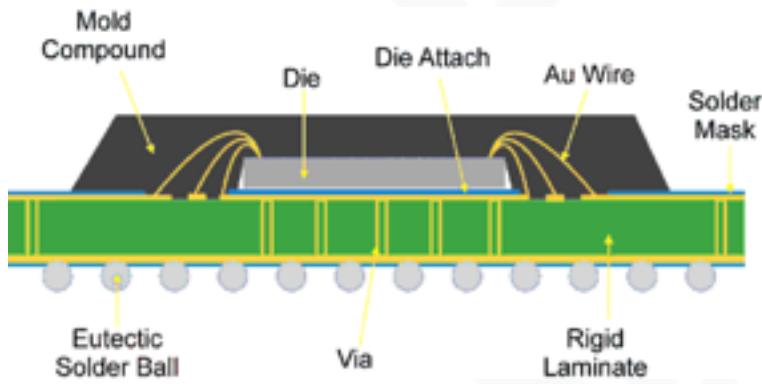
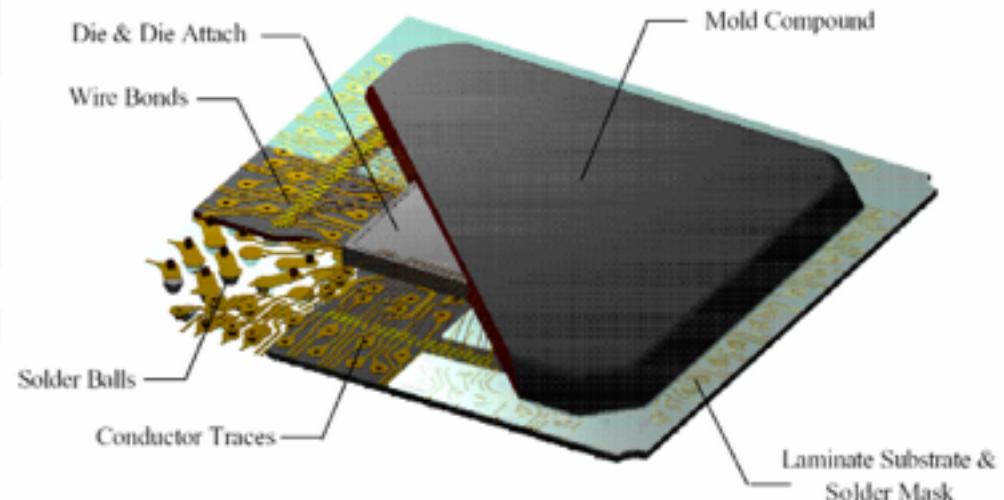


- PGA (pin grid array)



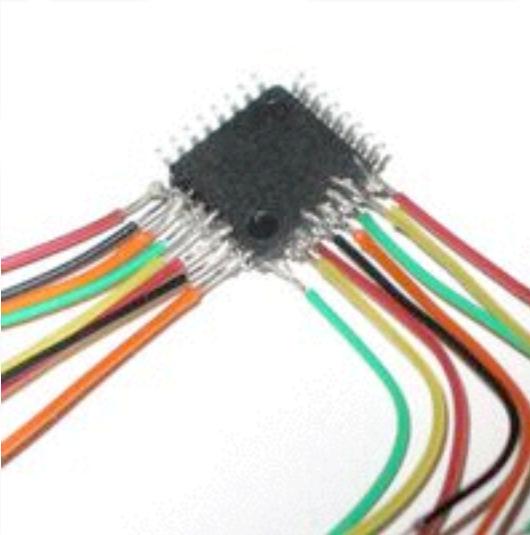
# Minimization of parasitic inductance

- Ball grid array
  - Very low inductance



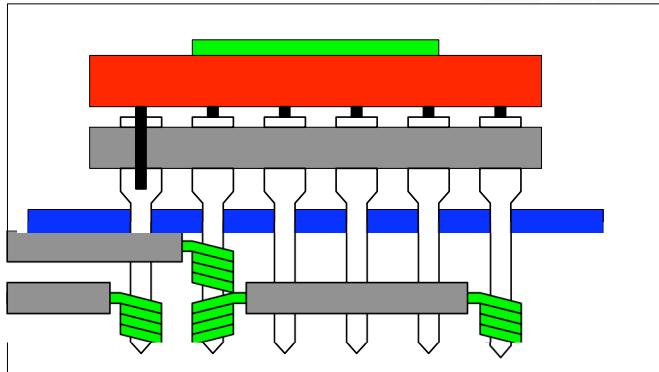
# Minimization of parasitic inductance

- Parasitic inductance makes resistance (impedance) of the wire variable by the signal frequencies

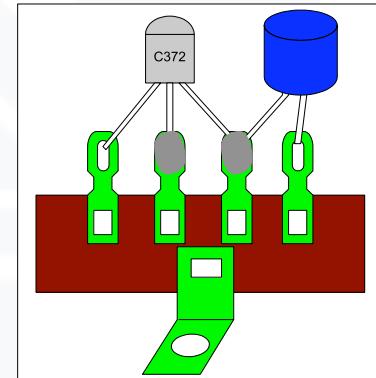


Large series inductance and coupling capacitance

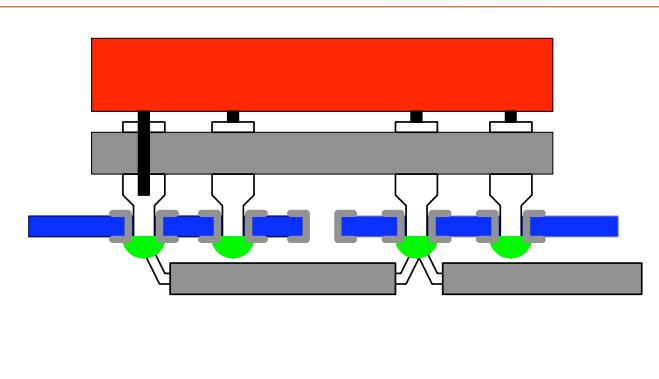
# Various types of prototyping methods



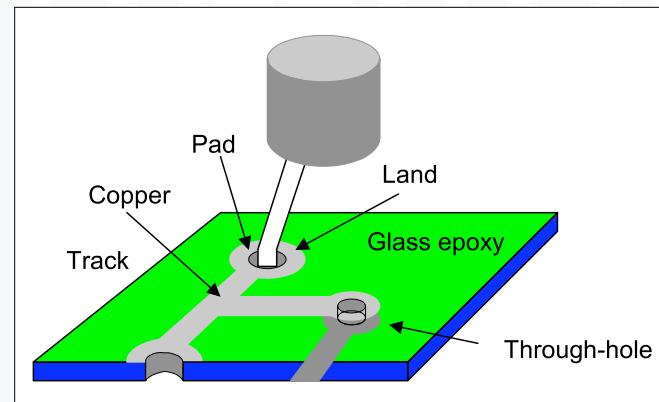
Wire wrapping



Lug terminals



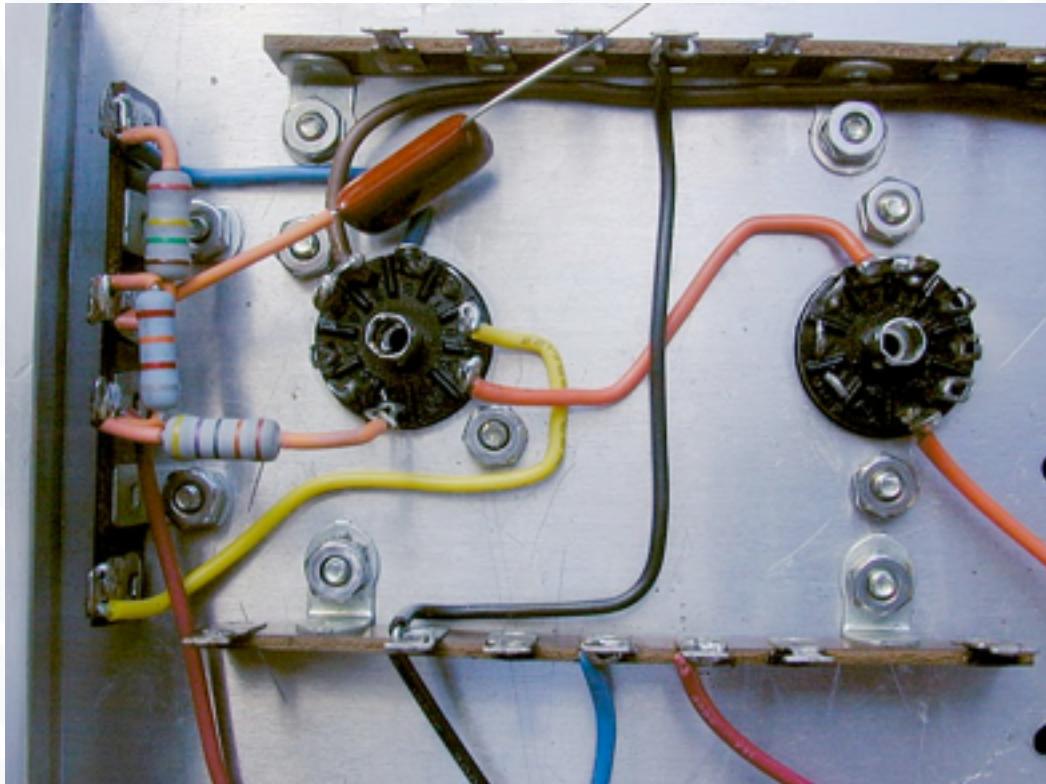
Soldering



Printed circuit board

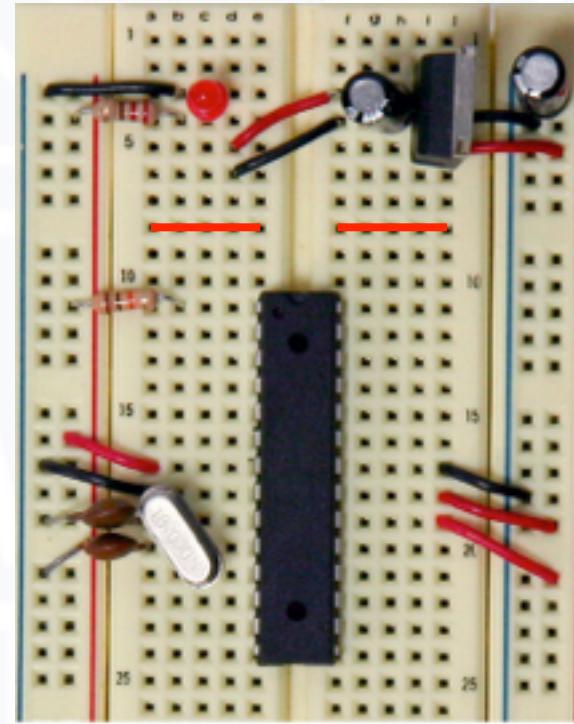
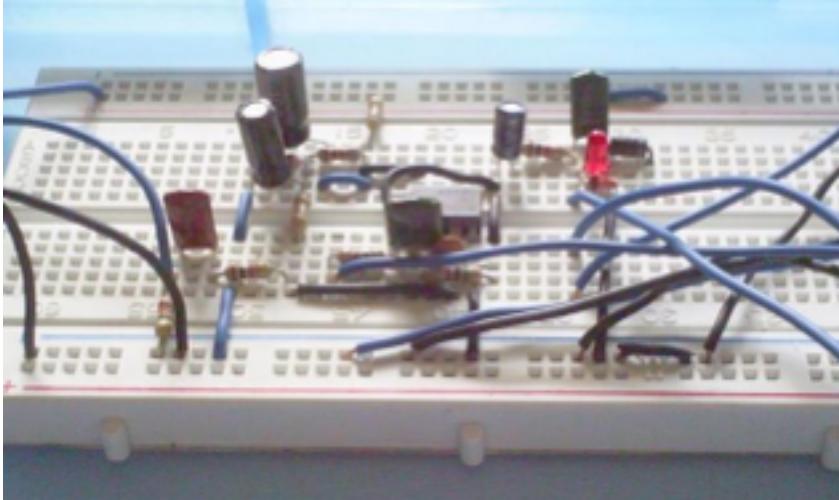
# Lug terminal circuits

- Typically used for vacuum tube circuits
- Good for analog circuits with a limited bandwidth
- Good isolation but higher inductance



# Breadboard

- The same row holes are electrically connected
- Why the breadboarding is not working now?
- Parasitic inductance!



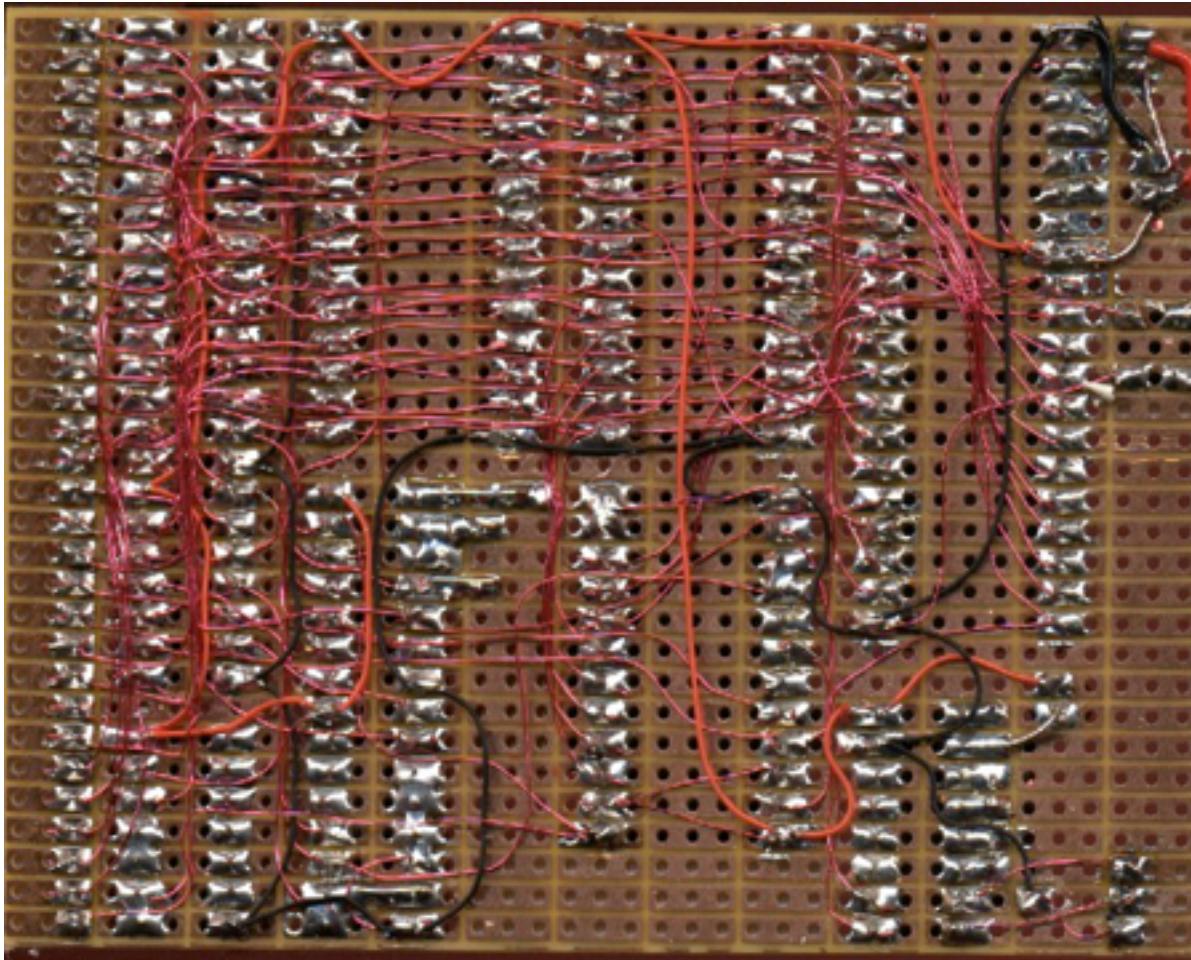
# Wire wrapping

- No soldering and high reliability
- High impedance due to the distance from the ground plane



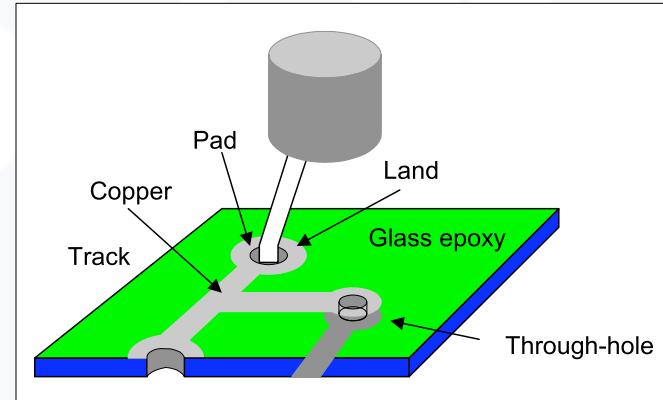
# Soldering on universal PCBs

- Lower impedance due to low distance from the ground plane if used
  - This photo does not have the ground plane



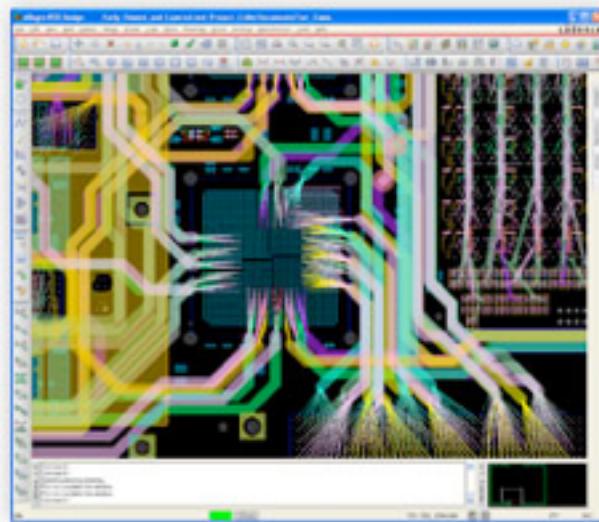
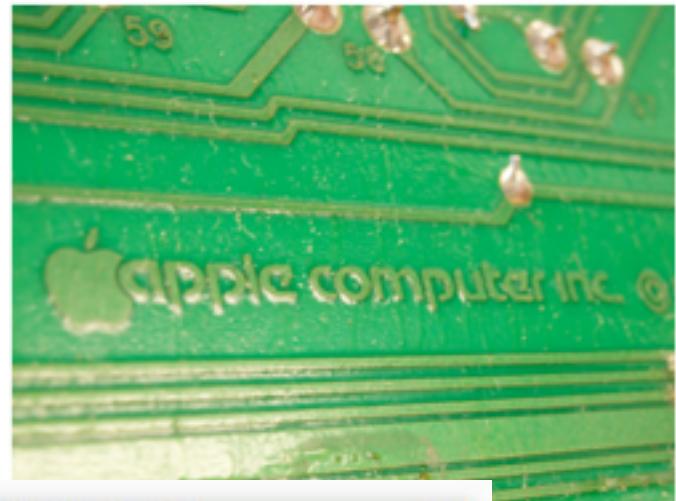
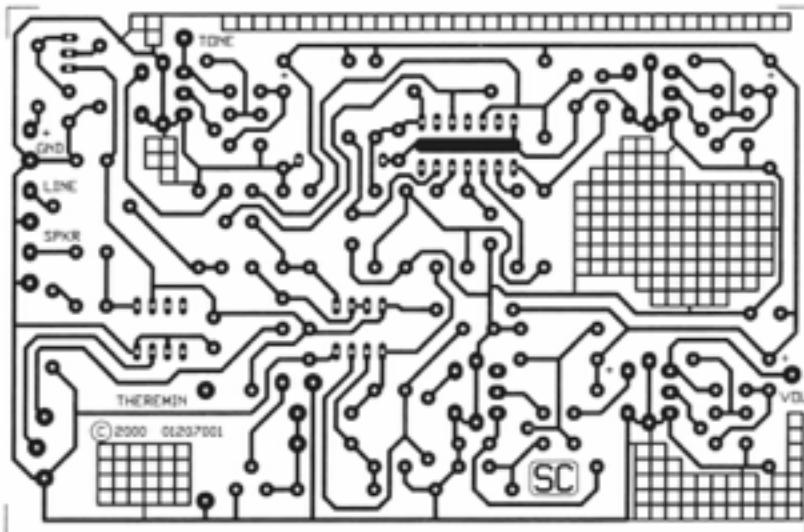
# Printed circuit board

- ➊ Parts are mounted on a board
  - ➋ Base materials
    - ➌ FR2, Phenol Formaldehyde Resin (Bakelite)
    - ➌ FR4, Fiber Glass Resin
  - ➋ Layers
    - ➌ Single sided
    - ➌ Double sided
    - ➌ Multi-layers with solid ground planes
- ➋ Printed circuit board
  - ➋ Wiring is already printed on the board
- ⌁ Universal circuit board
  - ⌁ Wire wrapping
  - ⌁ Soldering



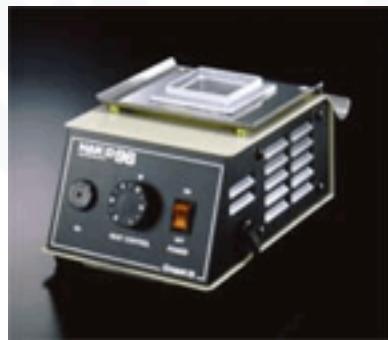
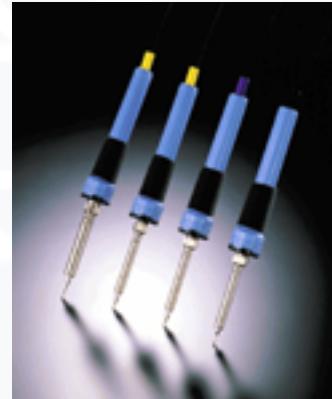
# Printed circuit board

- Ideal implementation
  - Layout and route
  - Film printing with a photo laser printer
  - Developing and etching
  - Drilling



# Soldering tools

- Soldering iron
- Temperature controlled Soldering iron
- Solder tube and dispenser
- Solder pot



# Desoldering tools

- Desoldering braid



- Desoldering pump



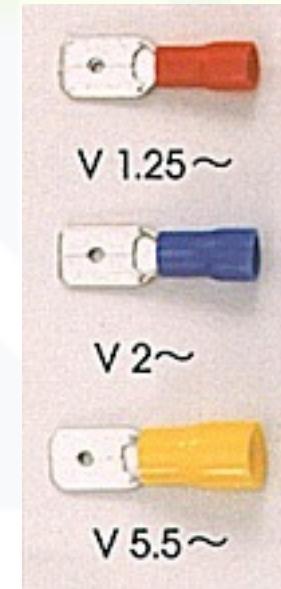
# Wire and lead management tools

- Bead nippers
- Side cutting pliers
- Long nose pliers
- Diagonal cutting nippers
- Pincers
- Wire strippers



# Terminals

- Ring terminals
- Spade terminals
- Square terminals
- Female disconnectors
- Male disconnectors
- Terminal crimping tools



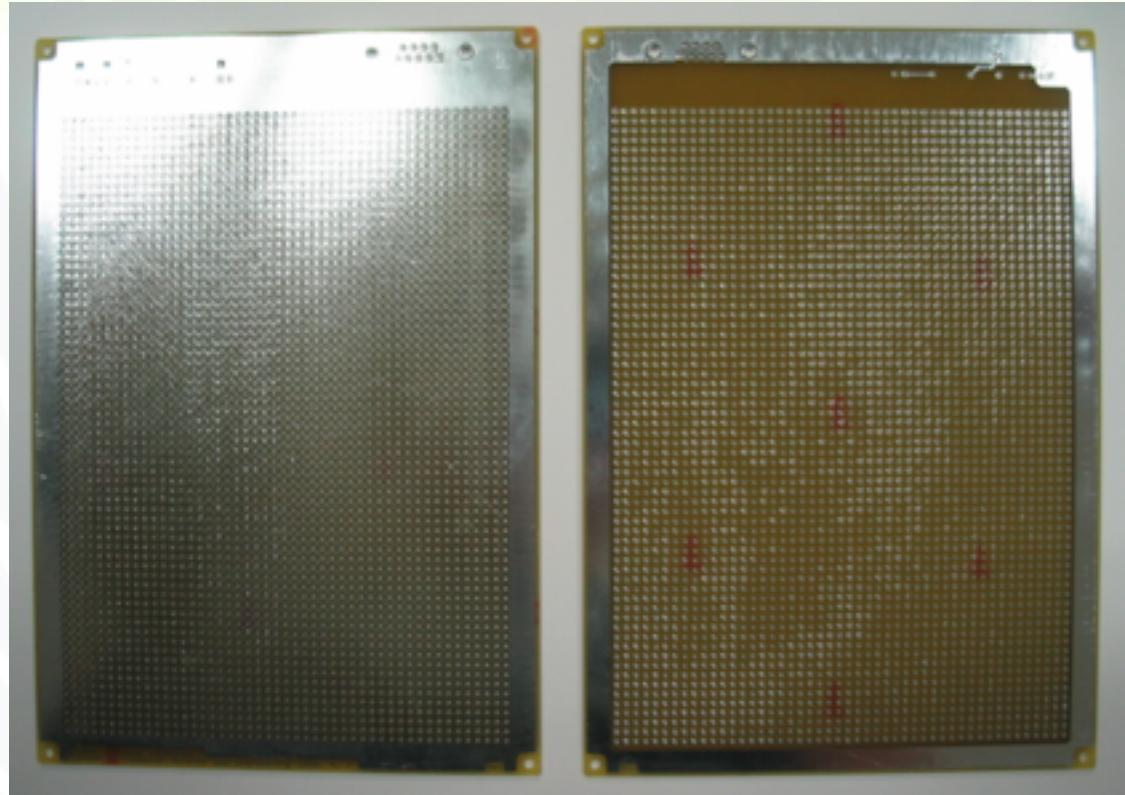
# Cabling

- Cable tie
- Tie mount
- Heat shrink tube
- Hot air gun



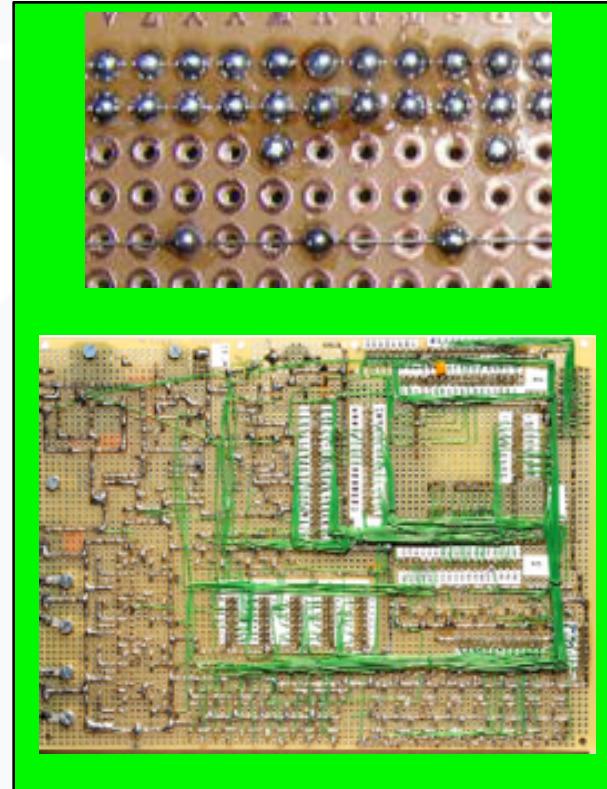
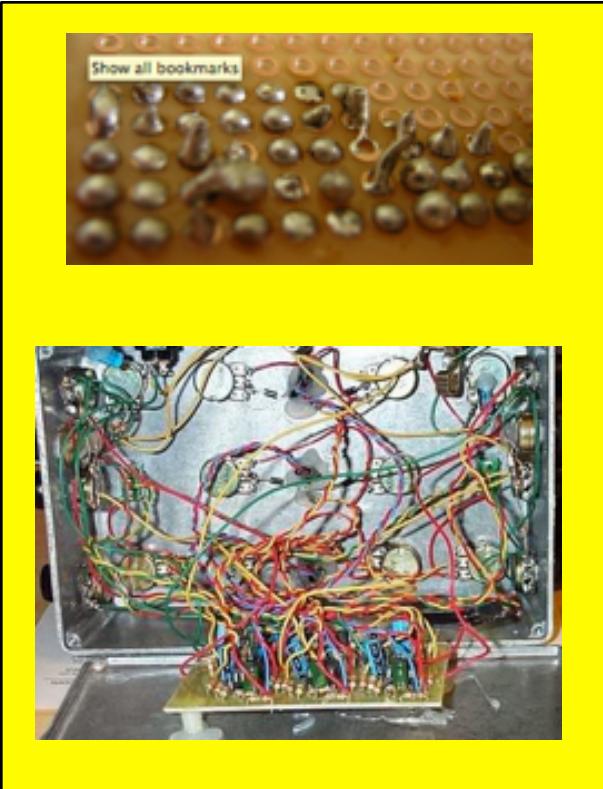
# Universal PCB

- Array of dangling pads
  - Various pitches
- Single or double sided
- FR2 or FR4
- Power supply routes
  - Wiring
  - Pre-printed
  - Solid ground plane



# Rule of thumb

- If a prototype looks good, it works well
- If a prototype looks bad, it works badly



Which color do you want? Yellow or green?



# Conclusion

## • Facts

- You are smart enough to design digital logic well
- You will be well educated enough to design digital logic well
- Prototyping is simple and does not involve a very good talent

## • Challenges

- How are you going to prove your design?
- What if your design validation is failed due to bad prototyping?

## • Similarly

- What if your idea was mislead due to a bad communication skill?
- What if your ability was underestimated due to a bad presentation attitude?

