Power Supply Theory and Practice
4190.309
2008 Fall Semester

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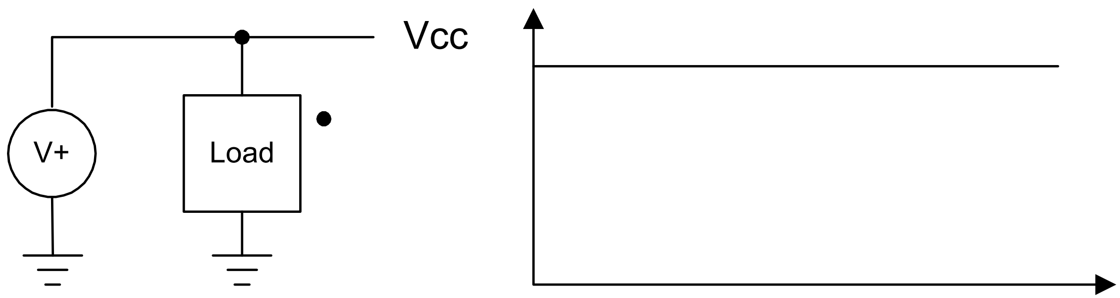
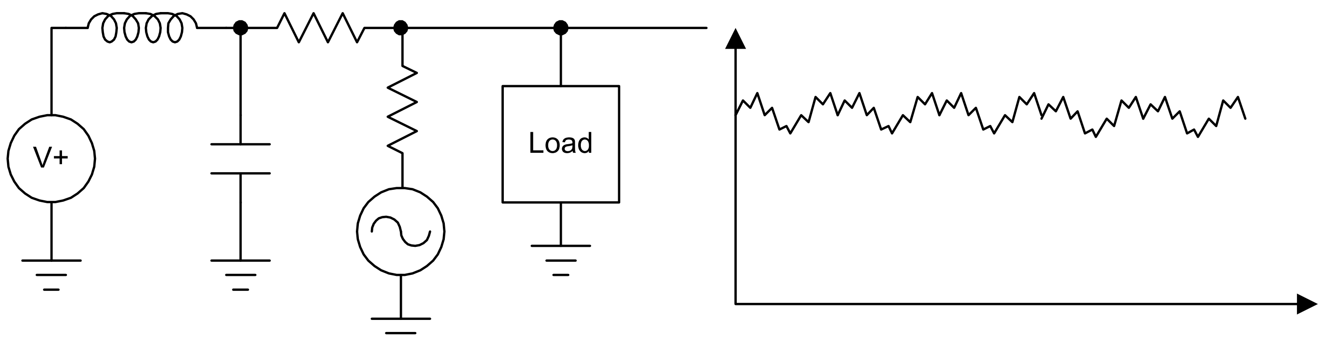
Ideal versus real-world power supply

- Why real power supplies are noisy?



a) Ideal power source: zero line impedance



b) Realistic power source: non-zero line impedance

Good power supply

- Minimize power supply impedance
  - as much as possible.
- Power supply impedance
  - Resistive component
  - Inductive component

$$V_{drop} = iR + L\frac{di}{dt}$$

Voltage drop:

$$V_{drop} = iR + L\frac{di}{dt}$$

- 20A current with DC resistance 0.05Ω
  - yields 1V droop.
  - TTL operating range is 4.75V to 5.25V
- 0.1A current change in 2ns with 500nH
  - yields 25V drop!
  - In practice, yields much less voltage drop since 500nH prevents 0.1A current change itself in 2ns.

Reducing DC resistance

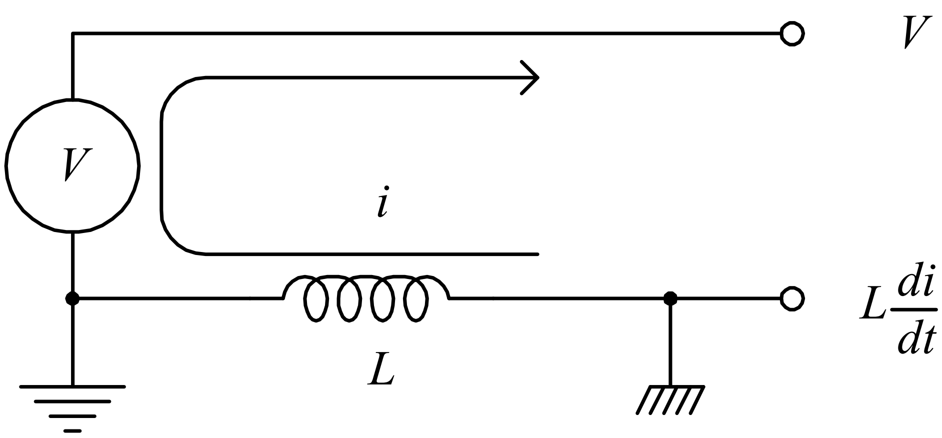
- Use low resistance materials: copper
- Use thick wire
- Reduce contact resistance
- Internal impedance (resistance) of a power supply is also important.

Reducing inductance

- Use short wire.
- Make no bend or loop if possible.
- VCC is as important as GND.
- Use bypass capacitors.
- Wire thickness is not so important!
- If somebody fails in reducing inductance, he or she may suffer from ground bounce.

Ground bounce

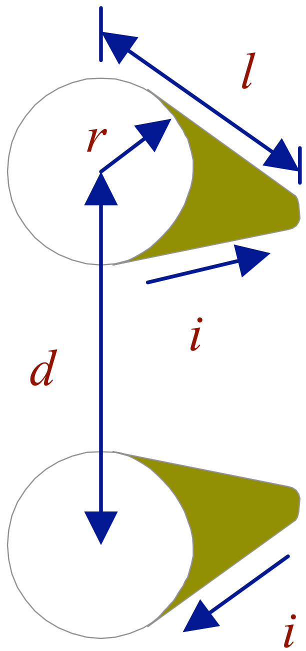
- Earthquake!



$$v = V - L\frac{di}{dt}$$

Low inductance

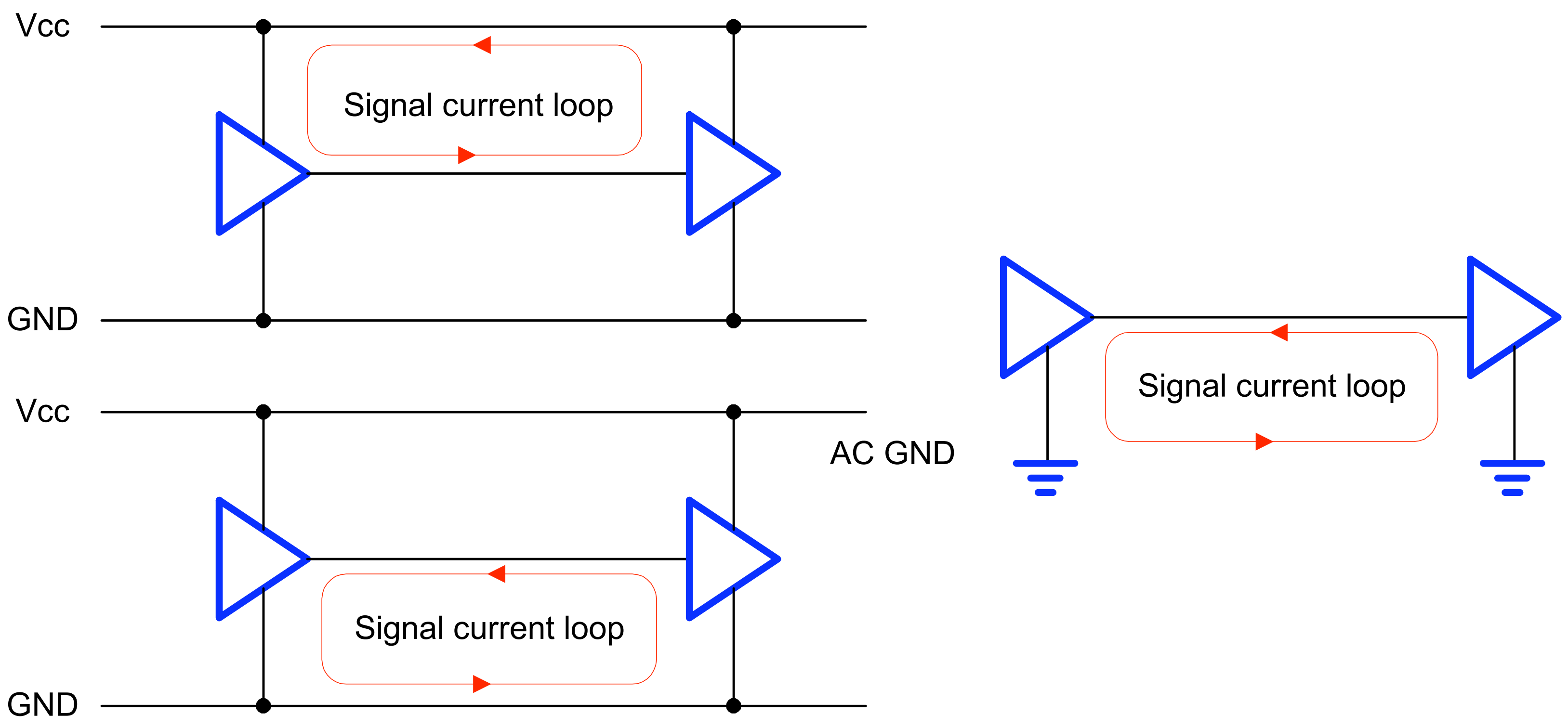
- Short wire, no bend or loop



$$L = Kl\ ln\frac{d-r}{r}$$

Signal return path

- VCC and GND are signal return paths!



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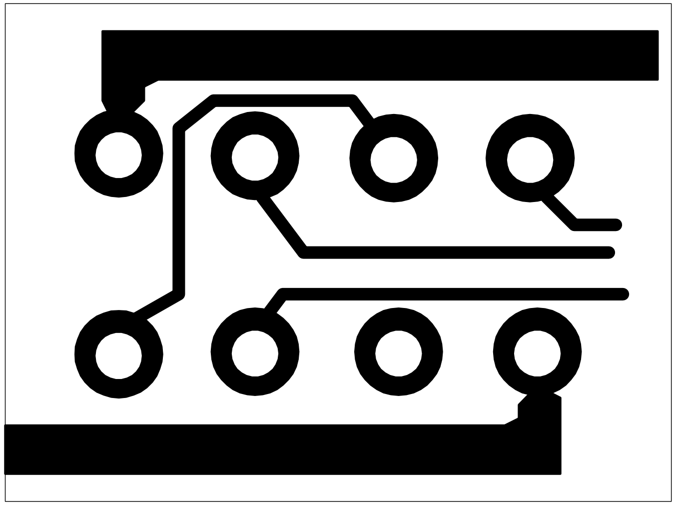
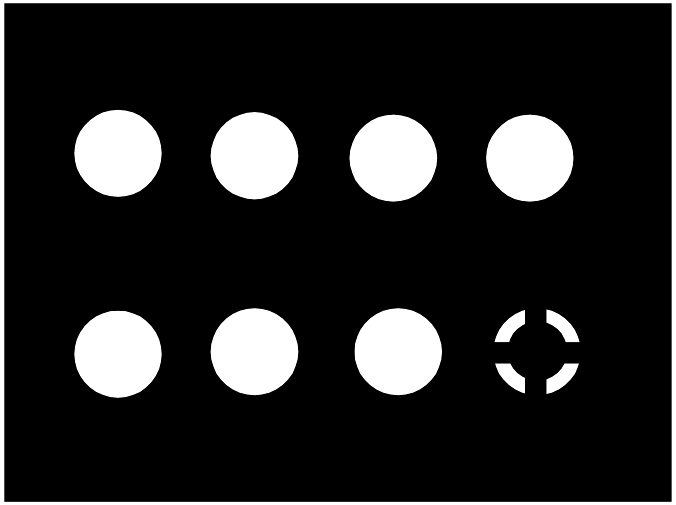
Minimize signal return path

- Power bus and power plane



Power Bus

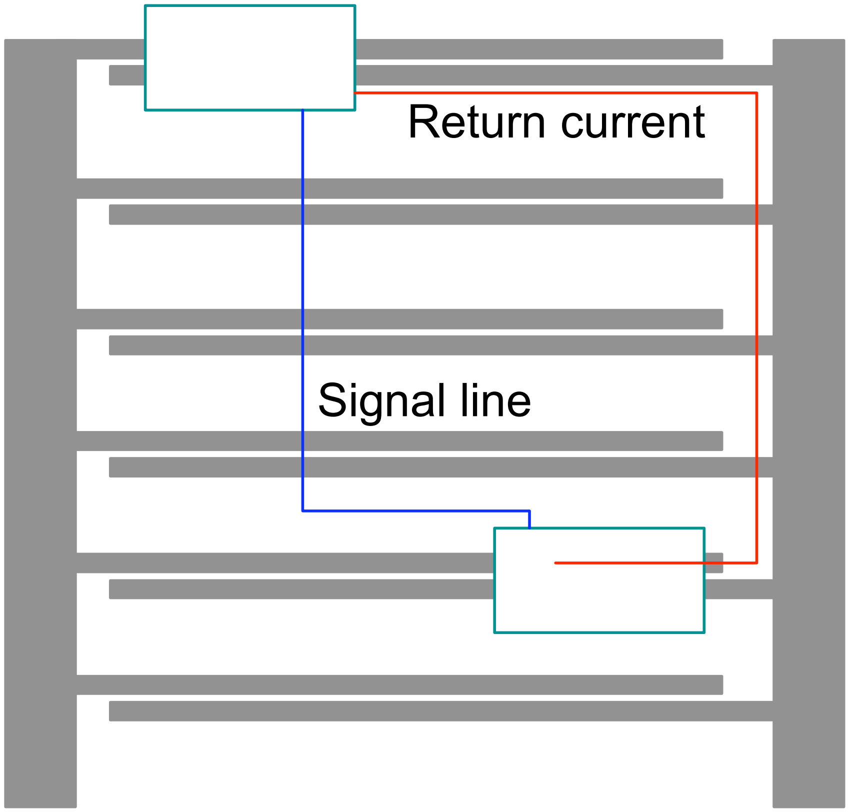


Power plane

Power bus

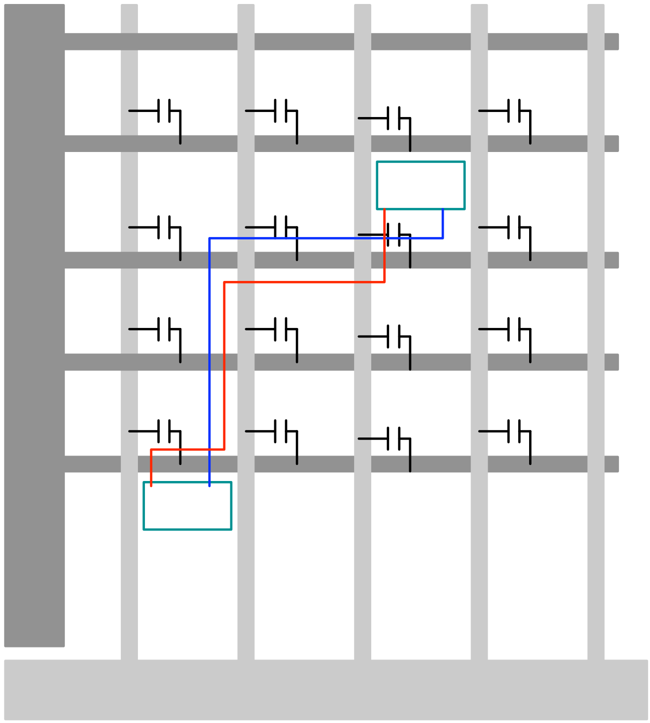
- VCC and GND fingers layout
- Track width?

$$L = Kl\ ln\frac{d-r}{r}$$



Power bus (2)

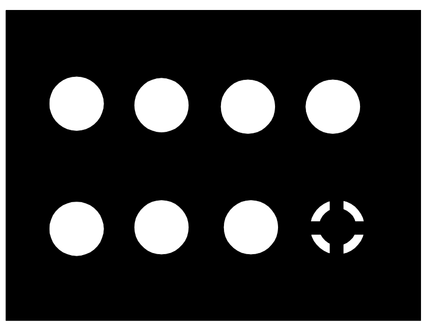
- VCC and GND grid on two layers



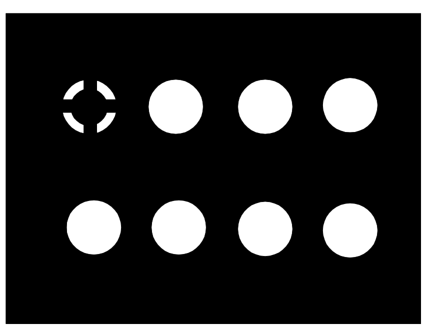
Solid power planes

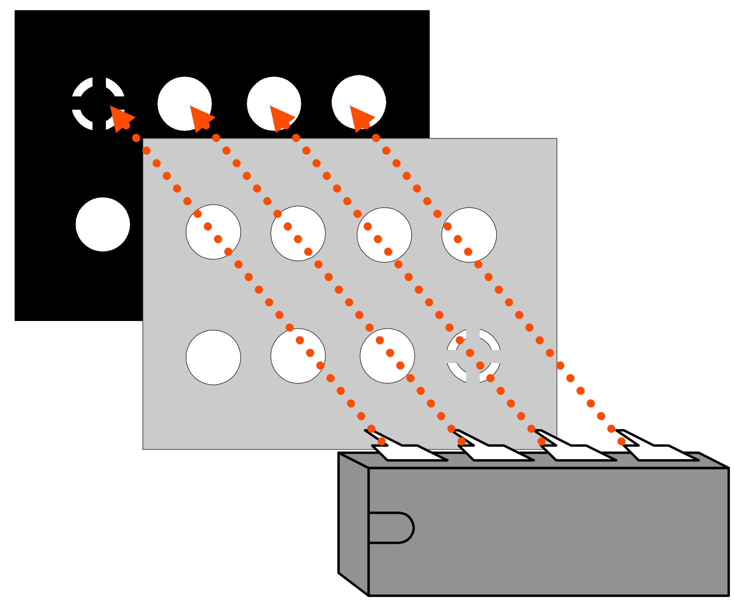
- VCC and GND planes
- Ideal for signal return path

VCC Plane



GND Plane





Solid power planes

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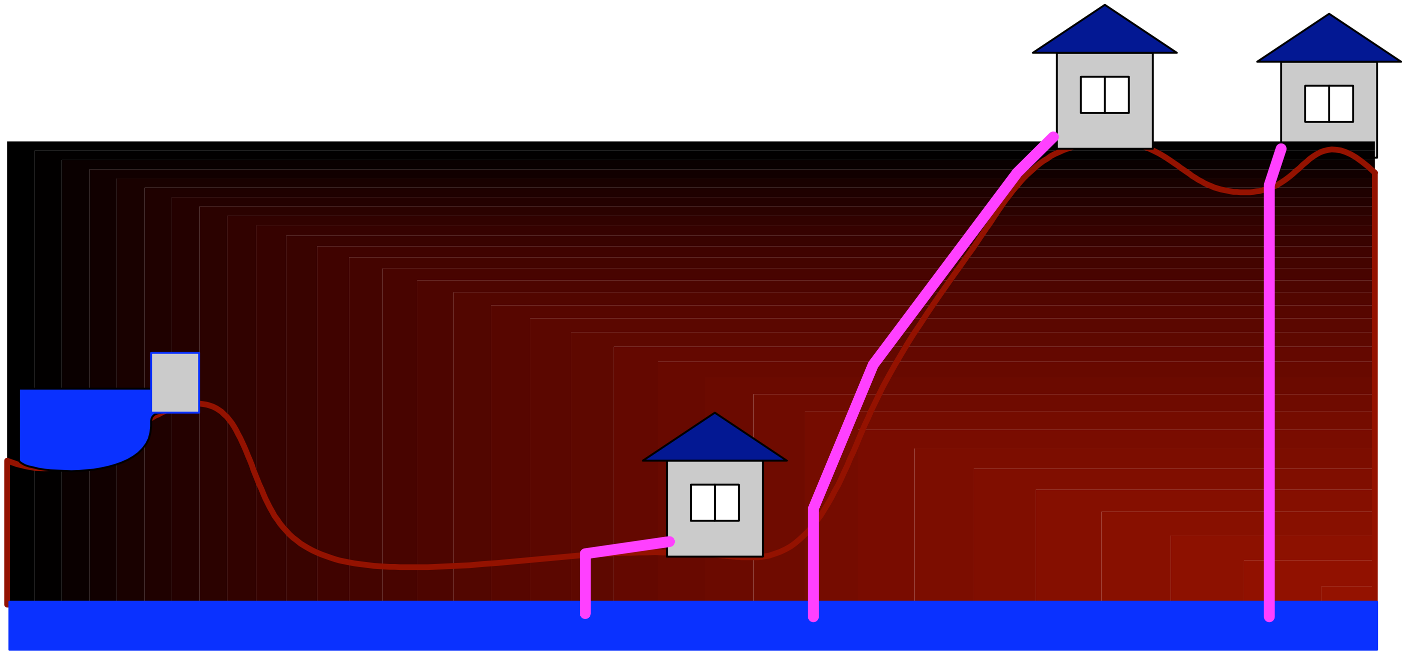
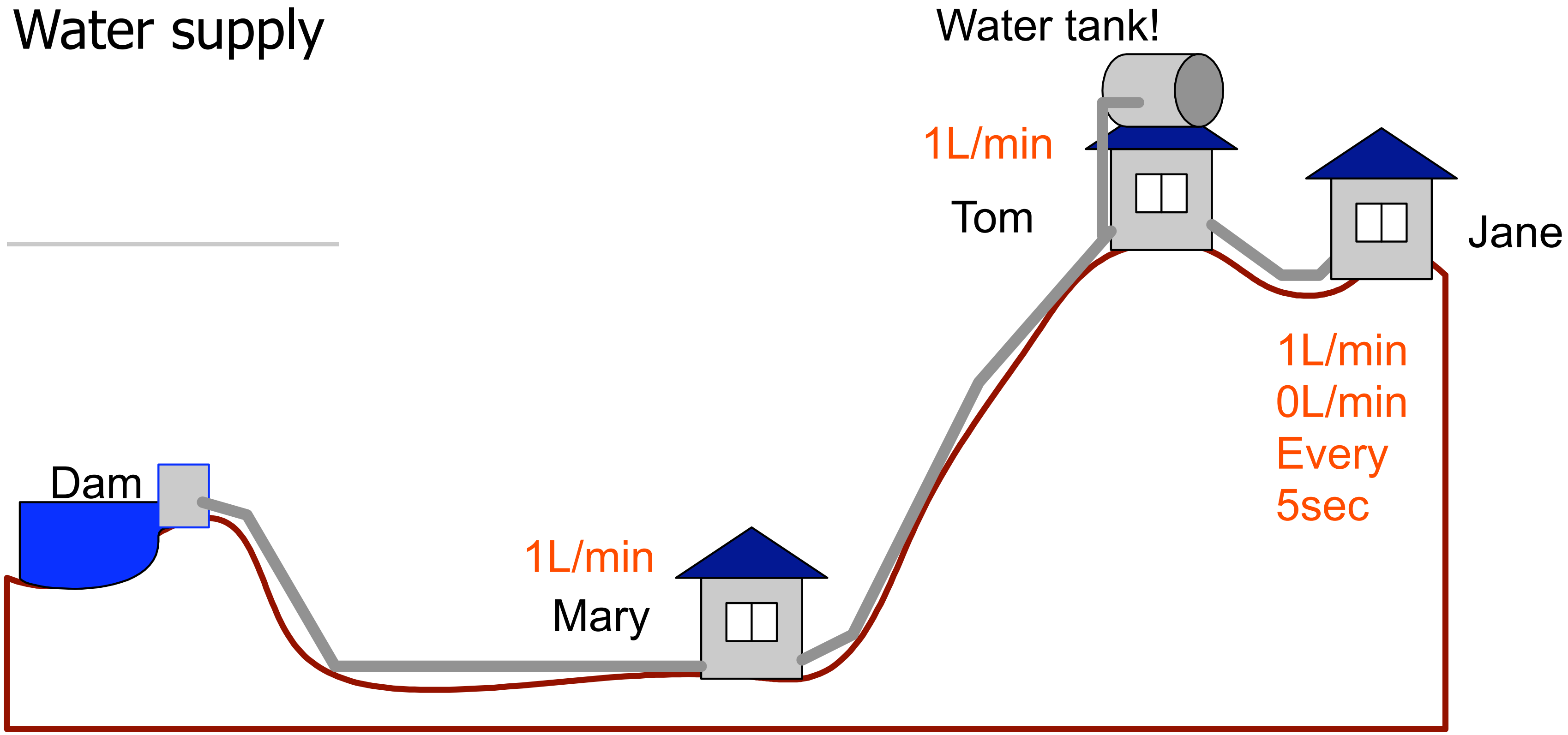


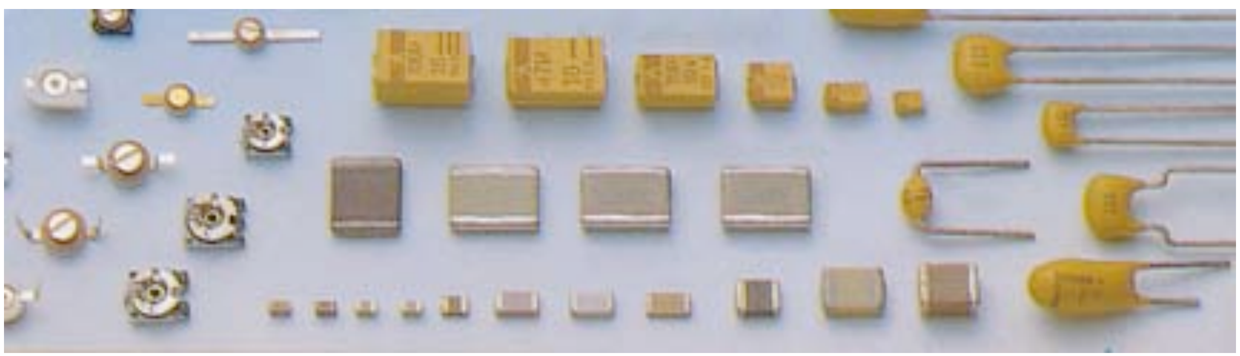
Bypass capacitor

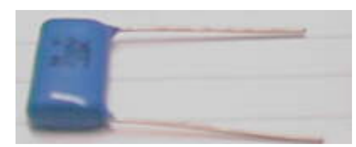
- Water supply



Bypass capacitors

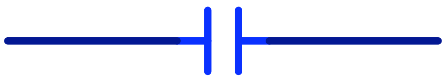
- Reduce power supply impedance.
  - Reduce impedance between VCC and GND.
  - Prevent from abrupt current change thus reducing ground bounce.
  - Monolithic and chip capacitors



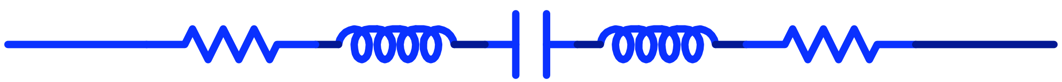


Bypass capacitors (contd.)

- For digital systems
  - Low equivalent series inductance (ESL) and low equivalent series resistance (ESR) capacitors.



a) Ideal



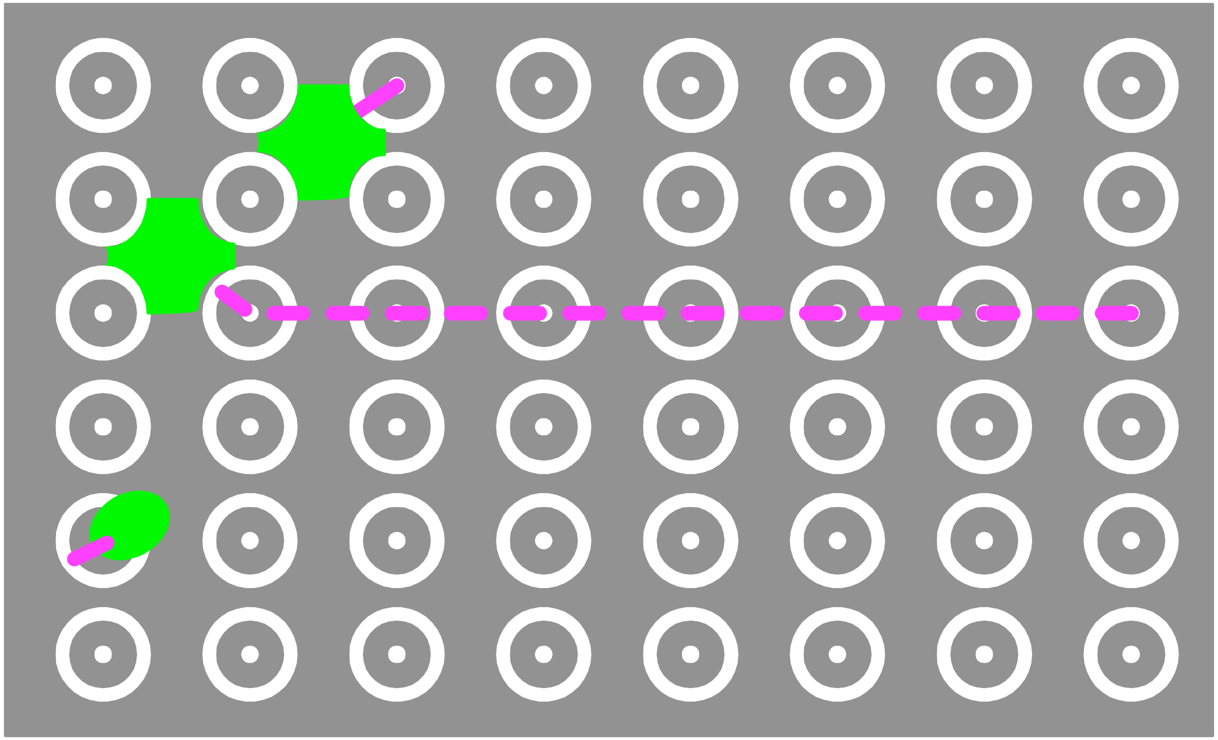
b) real condition

Single sided universal PCB

- Use power bus
  - VCC and GND fingers layout
  - As straight as possible
  - Use tin-plated wire
  - Use bypass capacitors
  - RLC, diode and transistor experiments

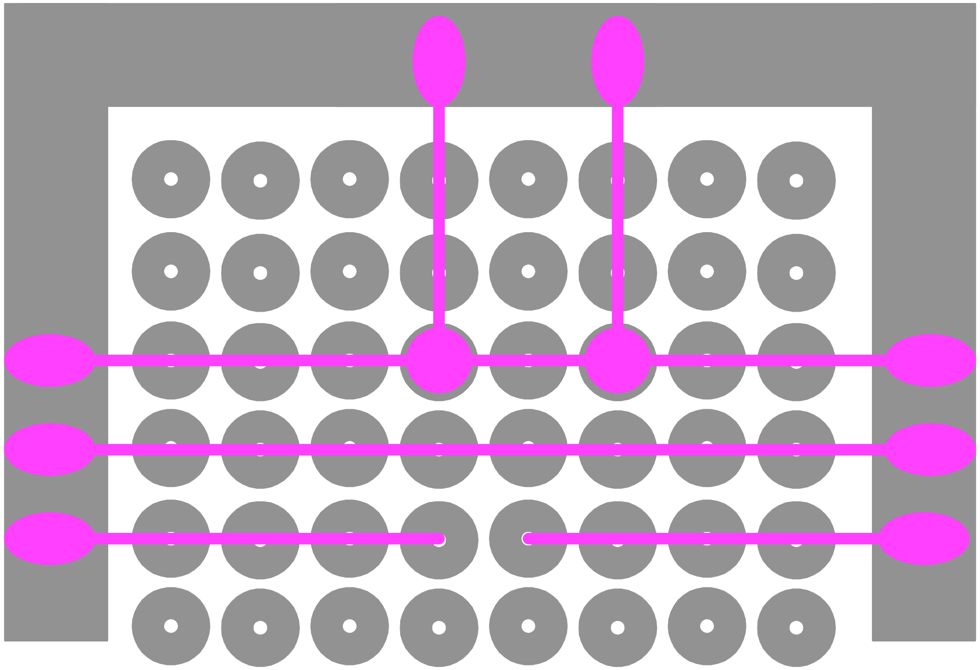
Double sided solid GND plane universal PCB

- Use solid GND plane

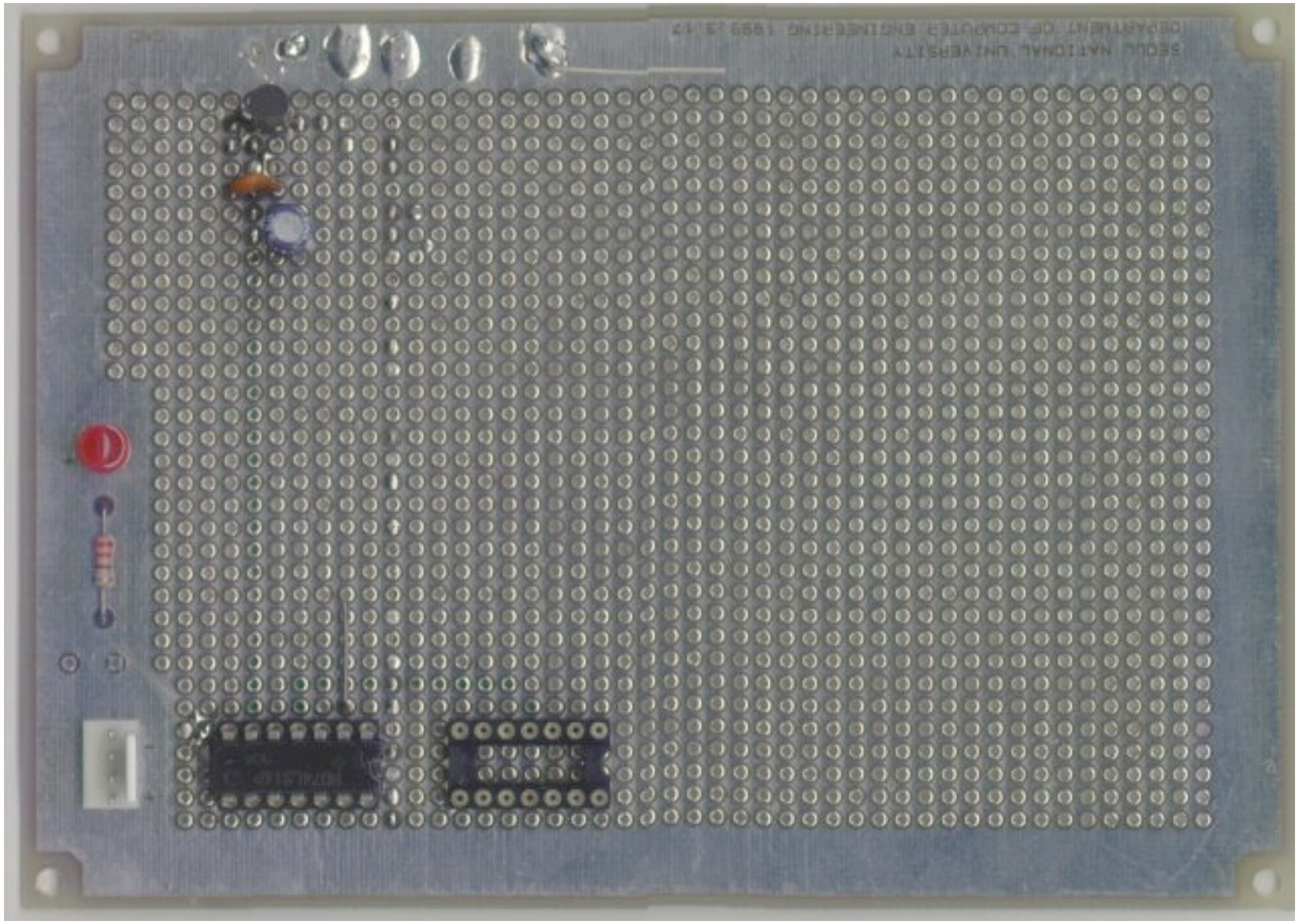


Double sided solid GND plane universal PCB (contd.)

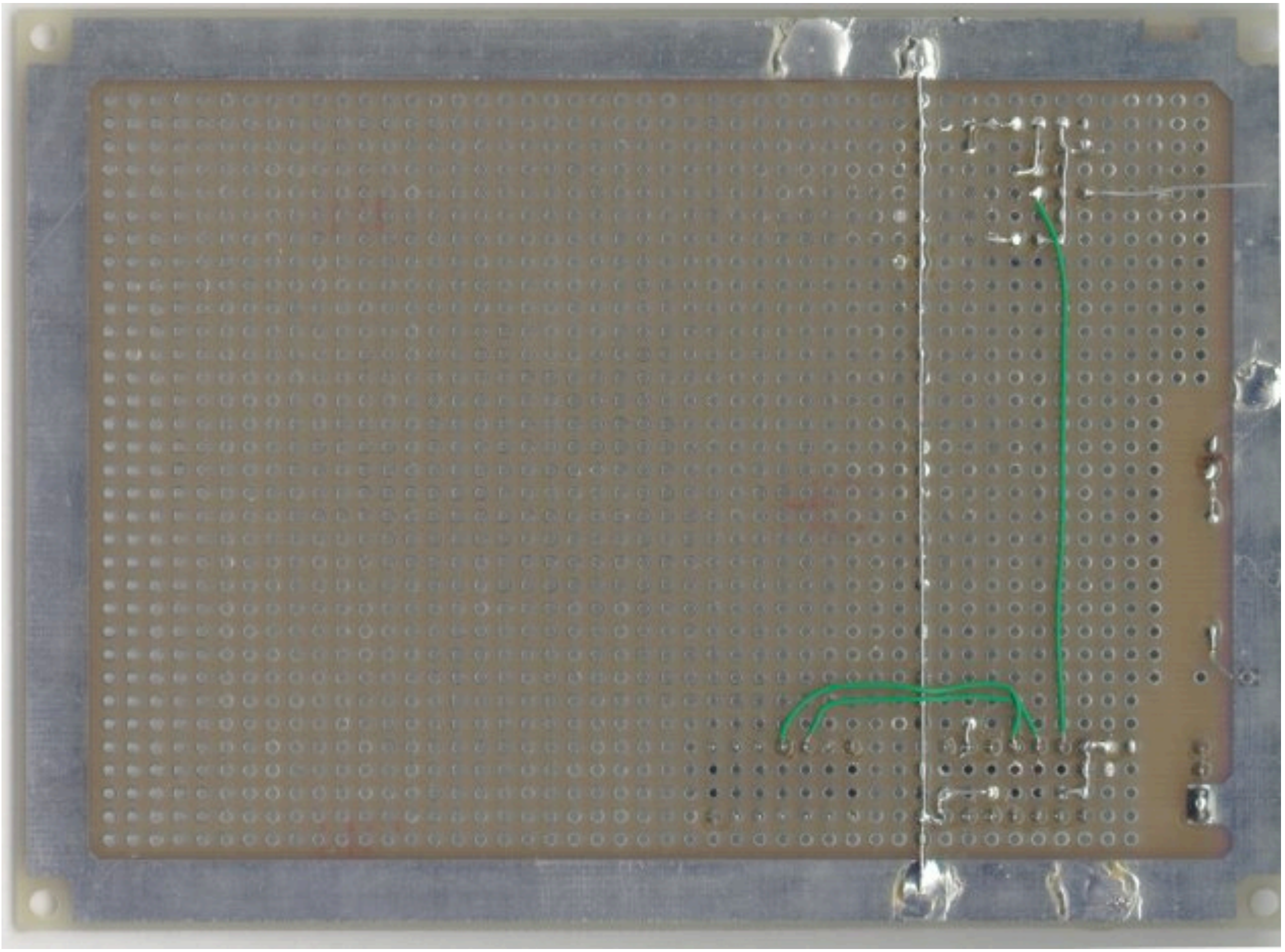
- Make VCC mesh (grid)
  - Still worse than GND
- Use plenty of bypass capacitors
  - Compensate VCC impedance



SNUCOM board: component side

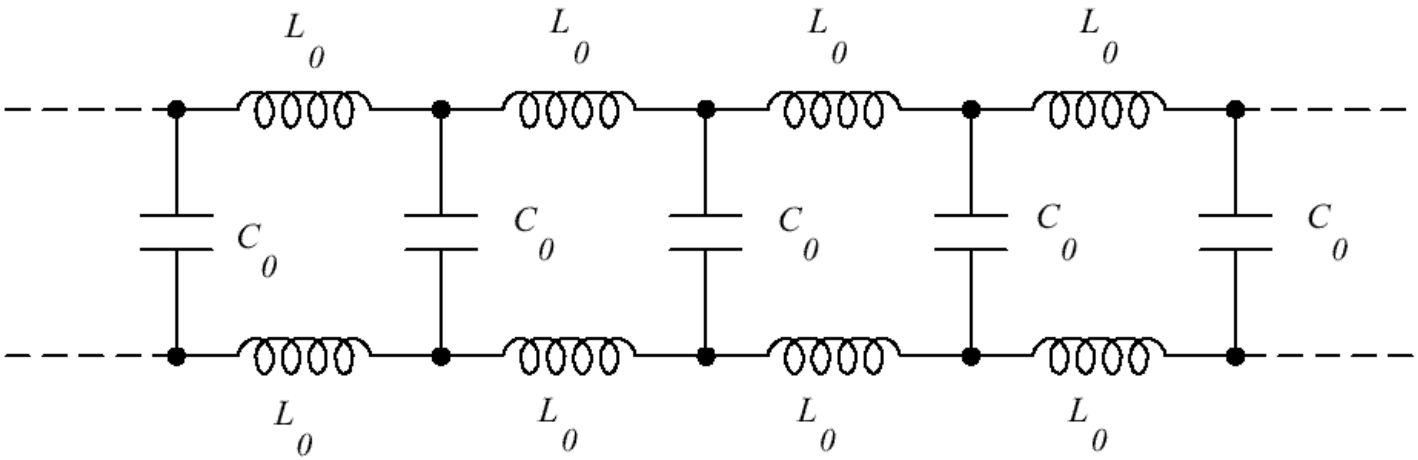


SNUCOM board: solder side



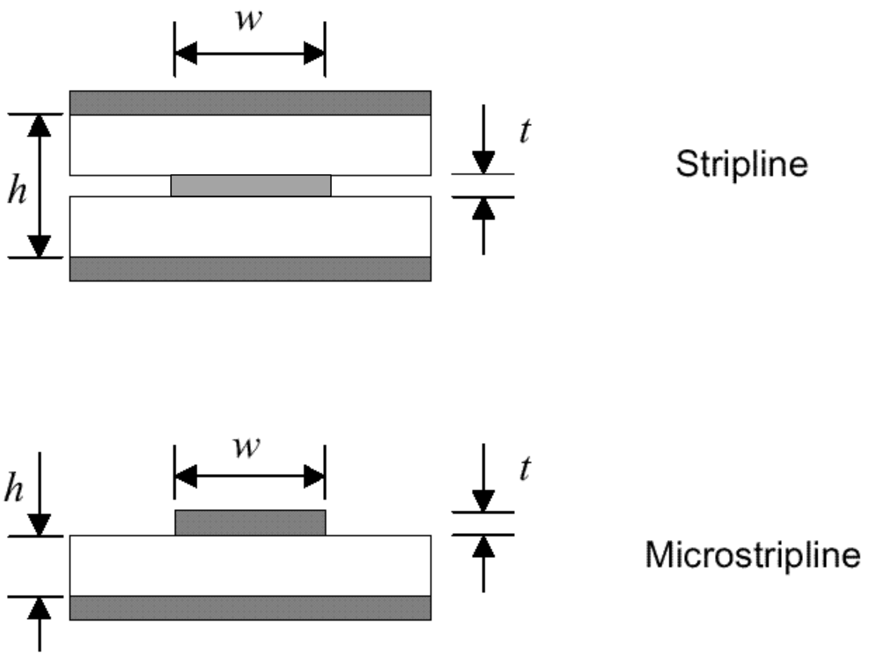
Controlled impedance line

- Inductance and capacitance are evenly distributed along the length of the line



Controlled impedance line (contd.)

- Stripline and microstripline



Controlled impedance line (contd.)

- Coplanar waveguide
  - Often used in RF circuits
  - Often can be seen with copper pour