EECS 373
Design of Microprocessor-Based Systems

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Lecture 15: Interface circuits and wireless

9 March 2017

Outline

- Context and review
- Power supplies
- Voltage regulators
- Signal conditioning
- Wireless communication

Context and review

- Relationships among power, temperature, and reliability.
- PCB power integrity.
- Several mechanical devices.
- H bridges.
- Shaft encoders.

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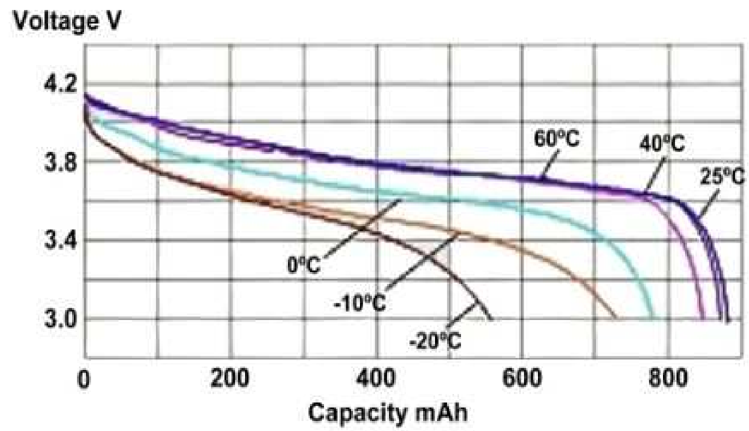
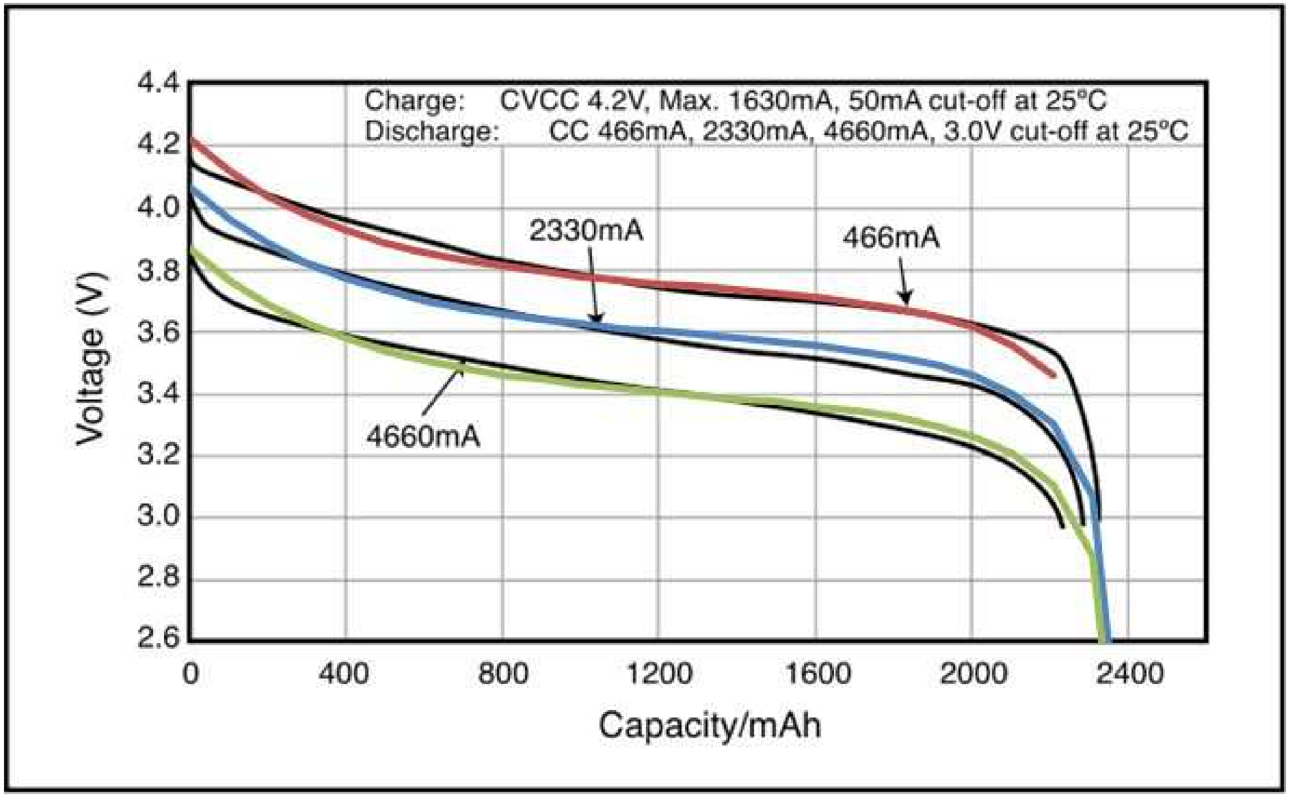
Power supplies

- Goals (Why?).
  - Always stably output desired voltage.
  - V requirements may change w. time.
- Reality
  - Available voltage wrong sometimes or always.
  - High parasitics.
    - $L \rightarrow dI/dt$ = droops/spikes w. current var.

Battery discharge curve

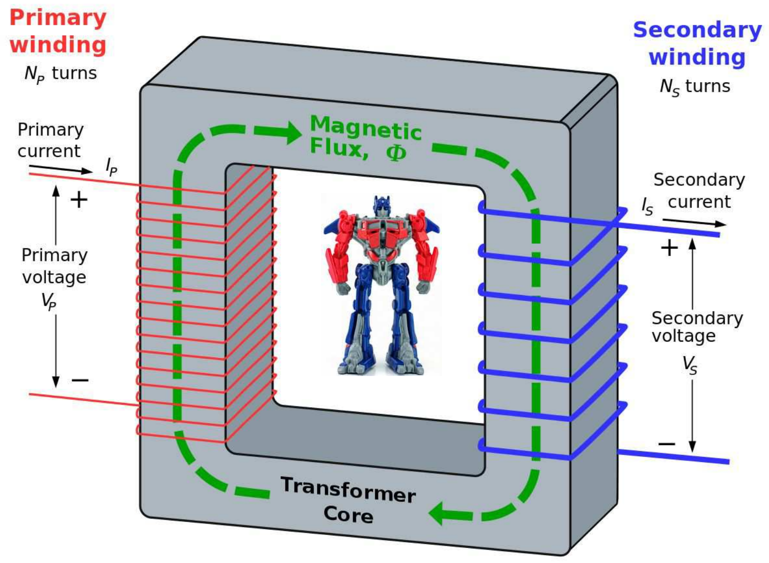
- Beware startup peak.
- Load matters.
  - Series R.
- T matters.





AC-AC

- Winding ratio.
  - Step up or down voltage.
- Expensive and bulky.



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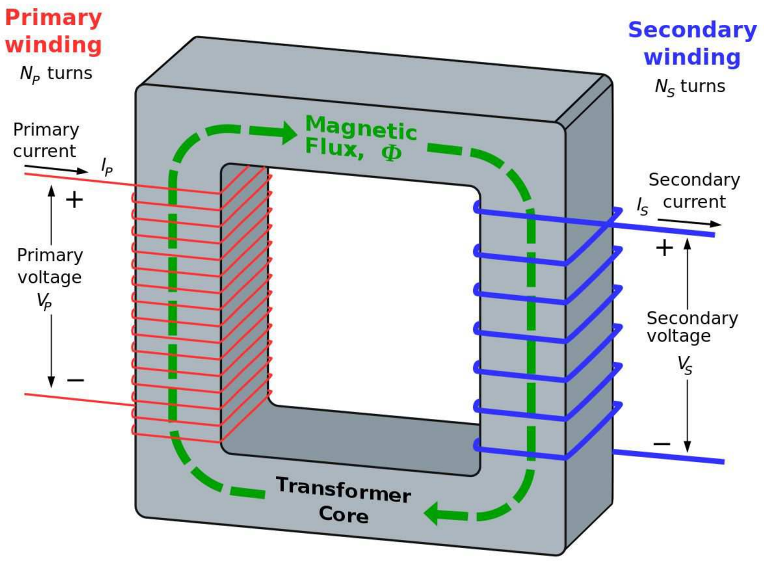
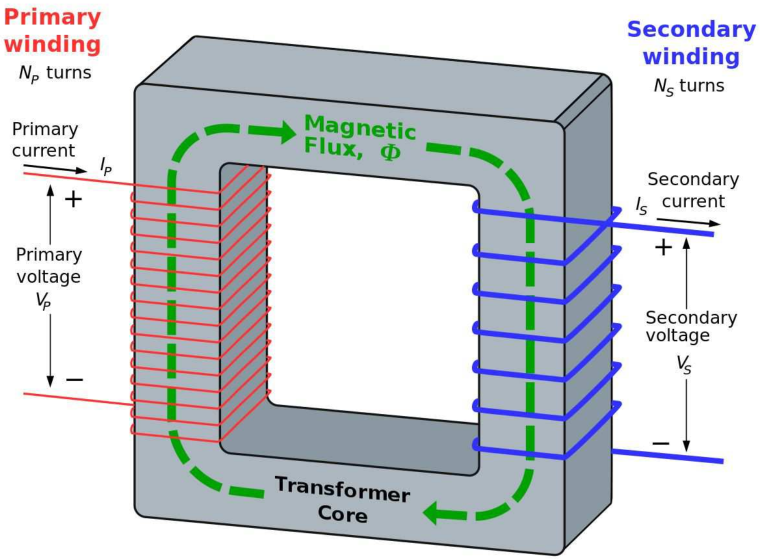
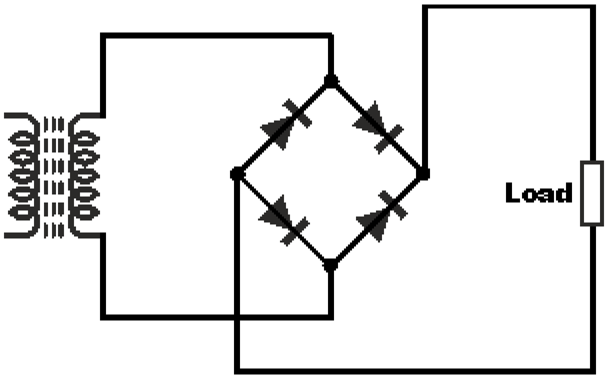


AC-DC

- Need DC.
- Full-wave rectifier.
- What does this do to waveform?
- How to make stable? C.
- Tolerate changing input V? Zener.





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Linear DC-DC

- Simple, Zener-based.
- Inefficient for large V conversion.
- Will give reading material for review.

Charge pump DC-DC

- Charge C.
- Stack with source.
- Repeat.
- Not great for high power.
- Good for communication.
- Can control charging period to control V.

Buck switching DC-DC

- Efficient.
- Step-down, only.
- Max output = Vin – Vloss.

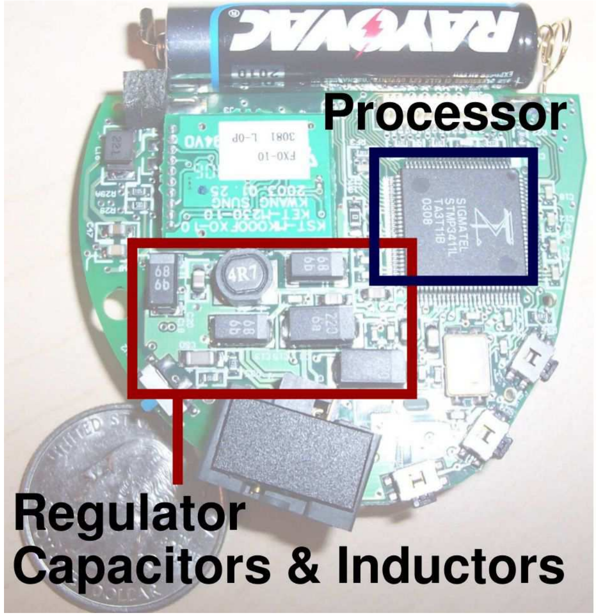
Buck-boost switching DC-DC

- Efficient.
- Step up or down.
  - 0X $\rightarrow$ 2X.
- Inverting.

None

- Don't always need regulator.
- They're only around 85% efficient.
- Terrible for usually-sleeping systems.
- Built-in battery C is useful.
- Can components can tolerate full swing?
  - Consider LiIon start-up peak!

See http://robertdick.org/publications/kim07oct.html



Will post many other regulator references to website today.

Outline

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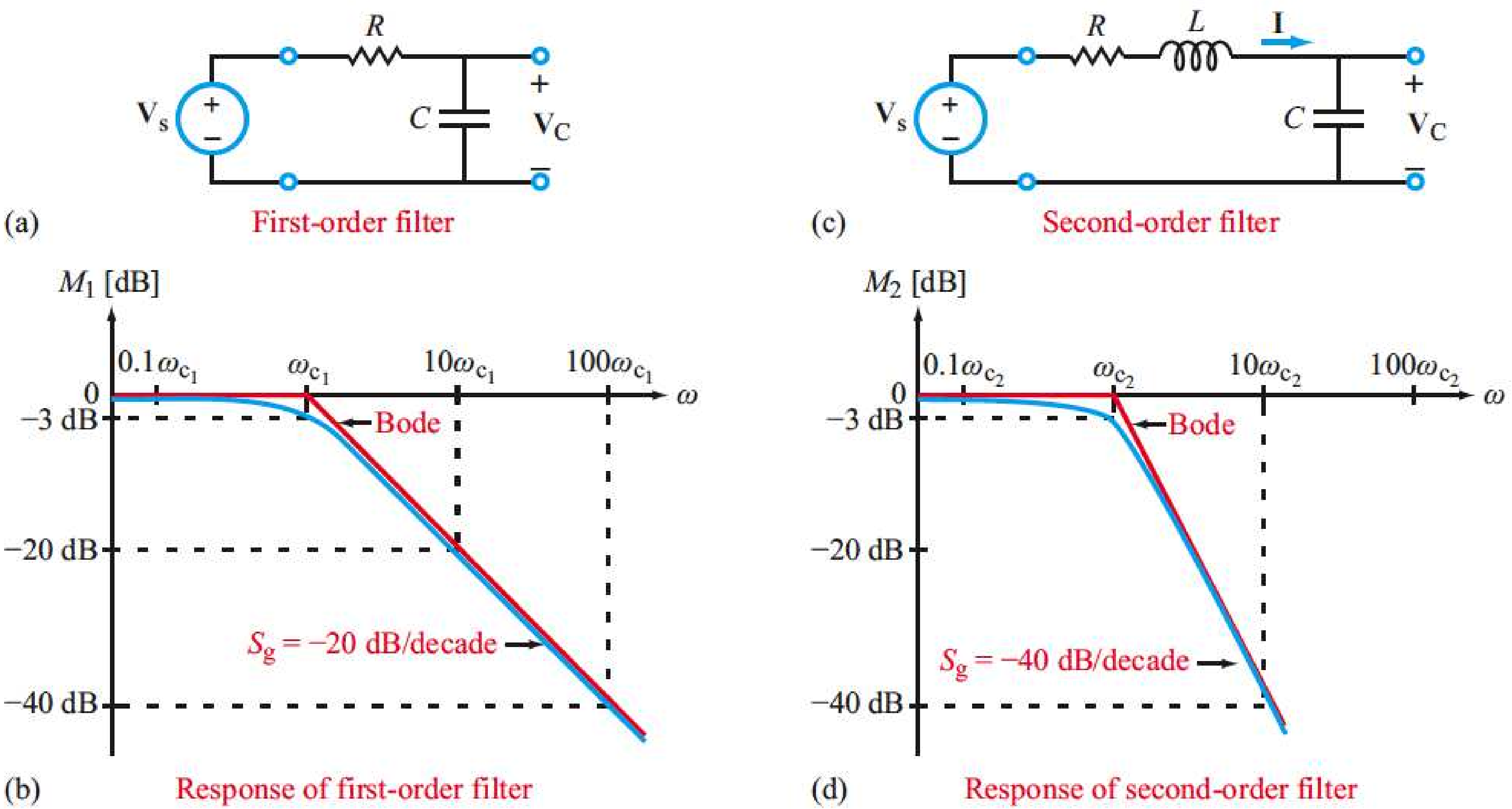
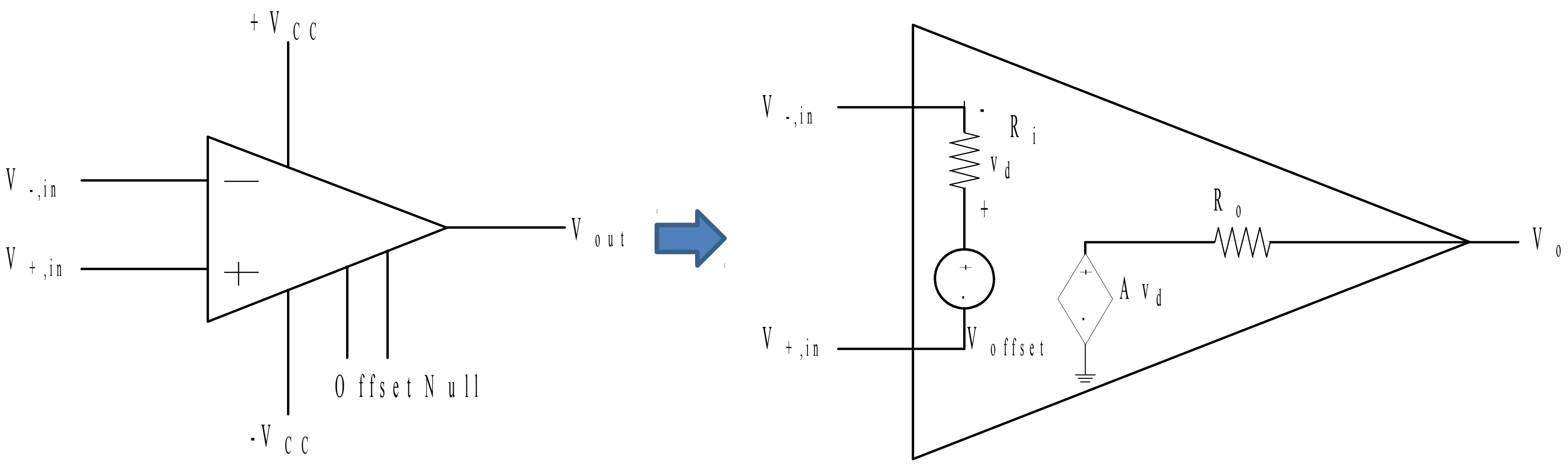
Signal conditioning

- Why? Bare sensor characteristics clash with ADC.
- Problems with many sensor outputs.
  - High internal resistance.
  - Voltage range mismatch.
  - Unwanted frequencies.
  - Fluctuating near-DC offset.
- Solutions.
  - Low-pass/high-pass/notch filters.
  - Amplifiers.

Filter order



Realistic op-amp model

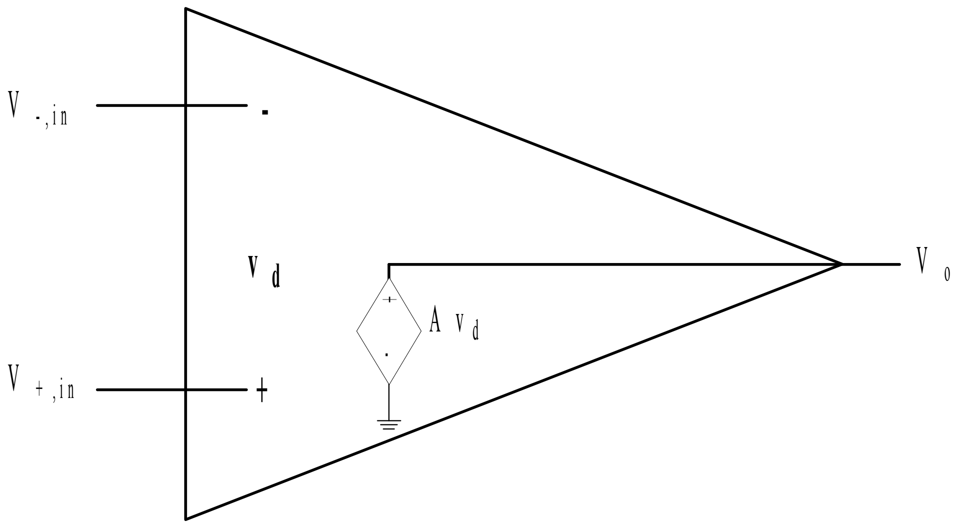


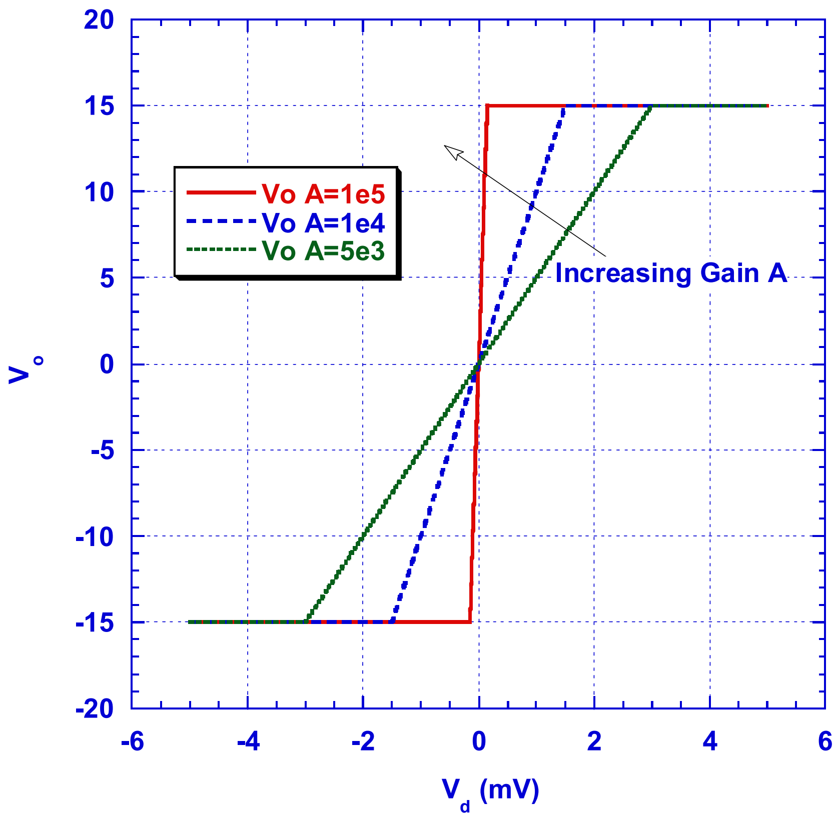
Ri = 2 MΩ
Voffset = 4 mV
A = 20M
R0 = 75 Ω

- Nonlinear behavior not represented in model.
- Consider power supply V.

Ri < ∞
Voffset ≠ 0 V
A < ∞
R0 > 0 Ω

Ideal op-amp model





$Ri \rightarrow \infty$

Voffset = 0 V

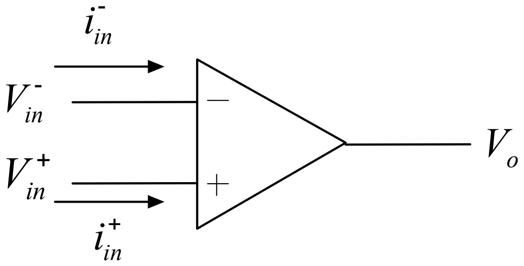
$A \rightarrow \infty$

R0 = 0 Ω

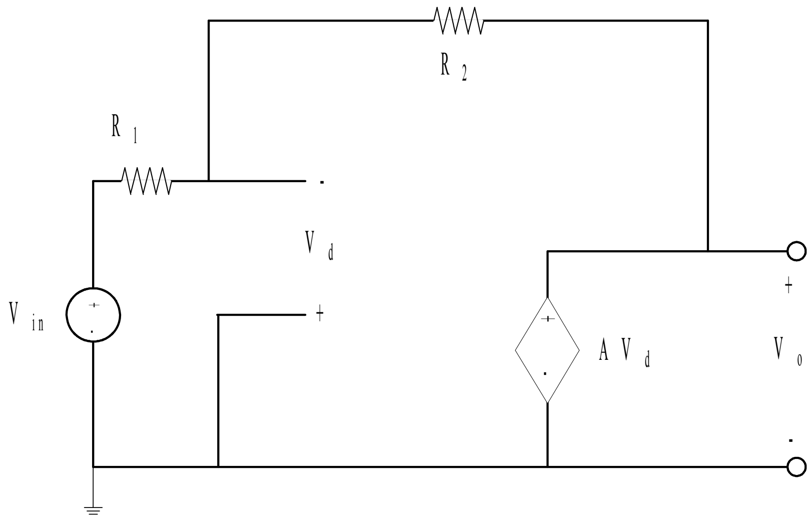
Op-amp “Golden Rules”

For negative feedback

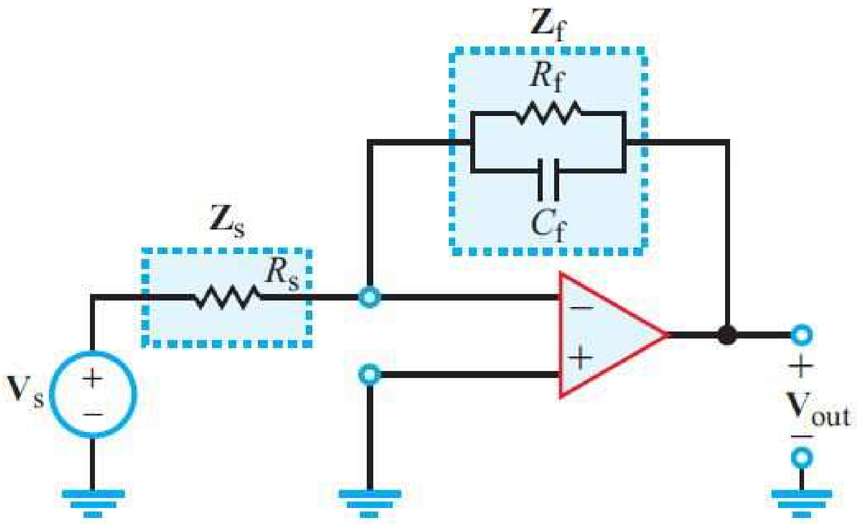
- Gain is infinite so input voltages equal.
- Input resistance infinite so input current zero.



Nodal analysis for noninverting case

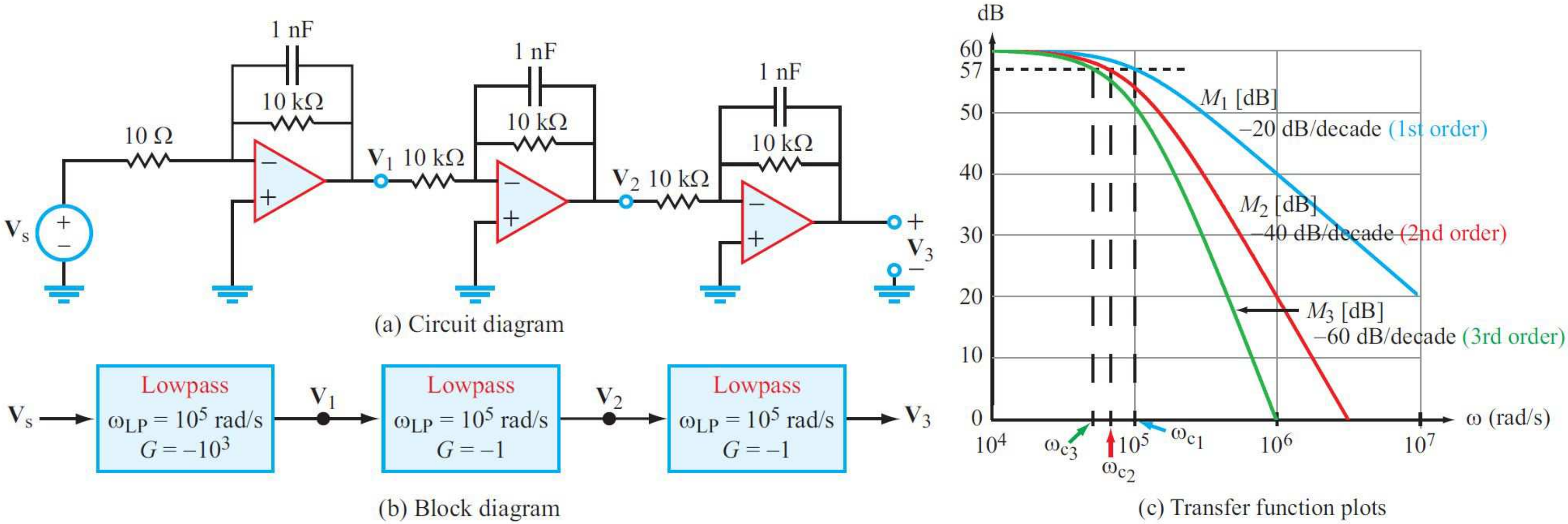


First-order active lowpass filter



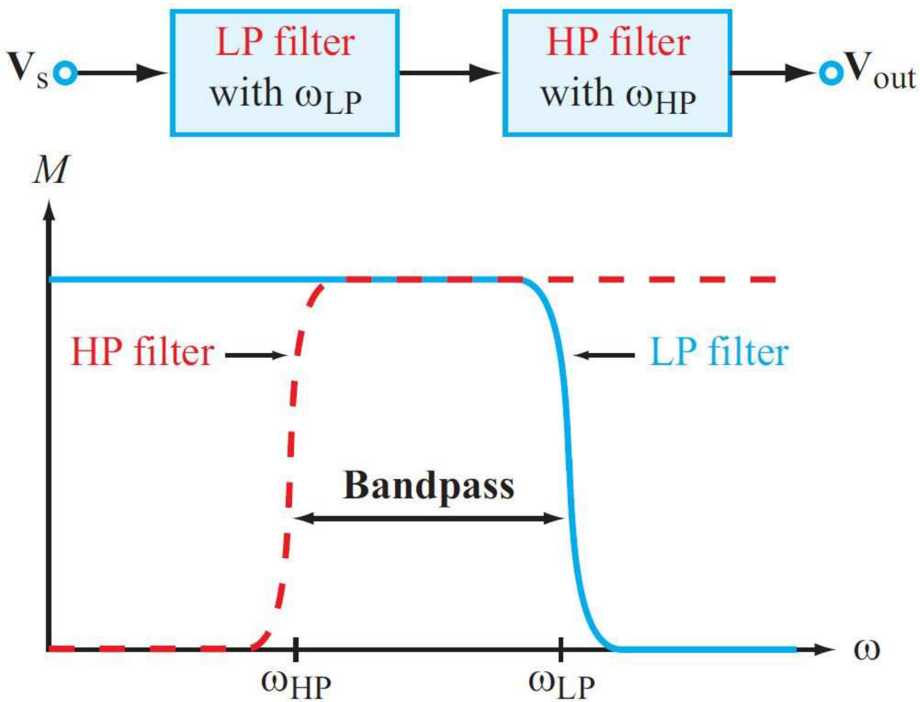
Cascading of active filters

Create a higher-order filter by cascading.

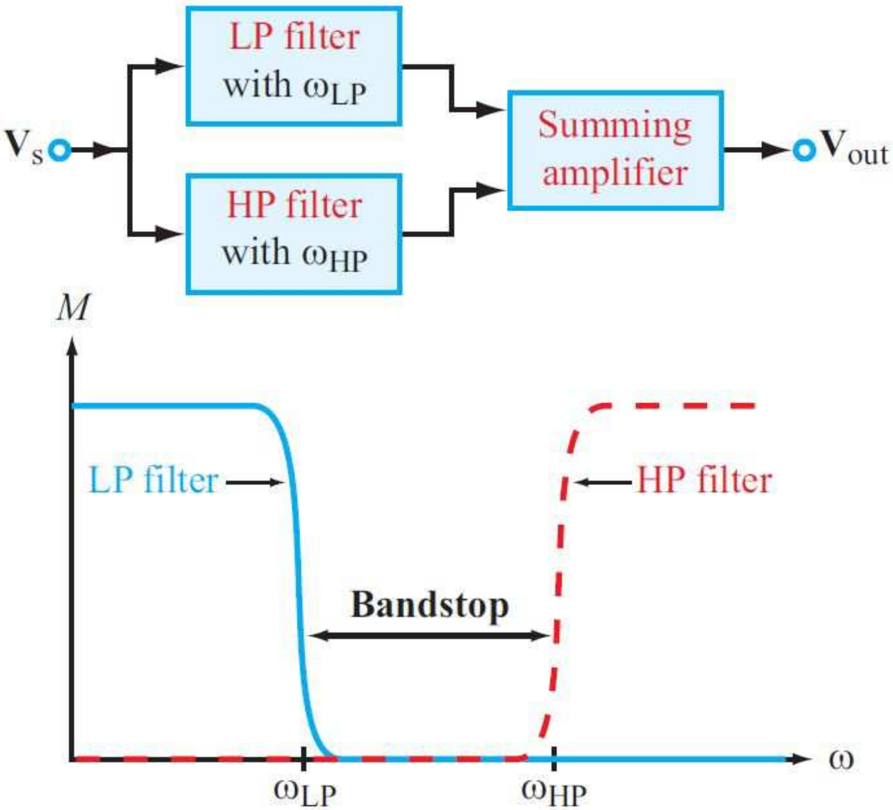


Cascading active filters

Create band filters by cascading.



(a) Bandpass filter



(b) Bandreject filter

Instrumentation amplifiers

- Amplifies differential signal.
- Rejects ground (common-mode) noise.
- Most designs use multiple op amps.

References

- Paul Horowitz and Winfield Hill, “The Art of Electronics.”
- Howard M. Berlin, “Design of OP-AMP Circuits.”
- Any decent introductory circuits book.
- Application notes from op amp manufacturers.

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Wireless communication

- Reliability.
- Power.

Wireless environment

- Noise.
- Absorption.
- Reflection.
  - Multipath.
- Environmental conditions.

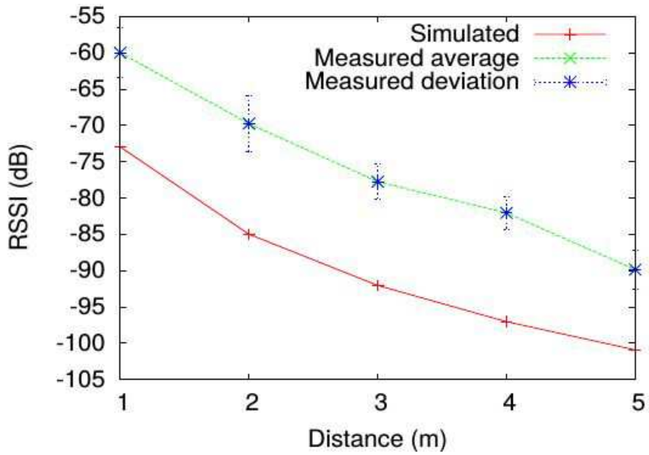


Figure 6.10: Comparison of measured and simulated RSSIs with nodes sitting on the ground.

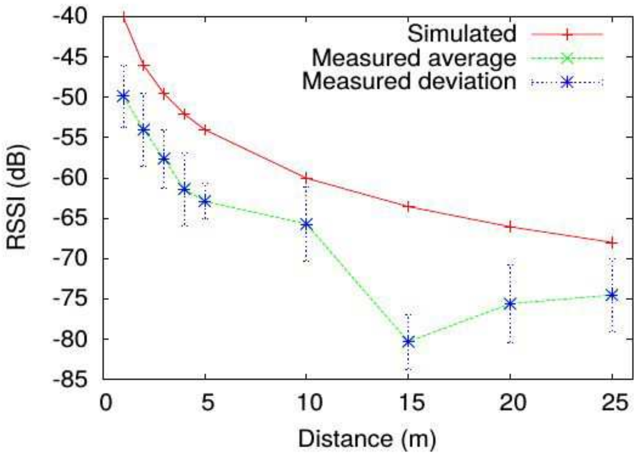
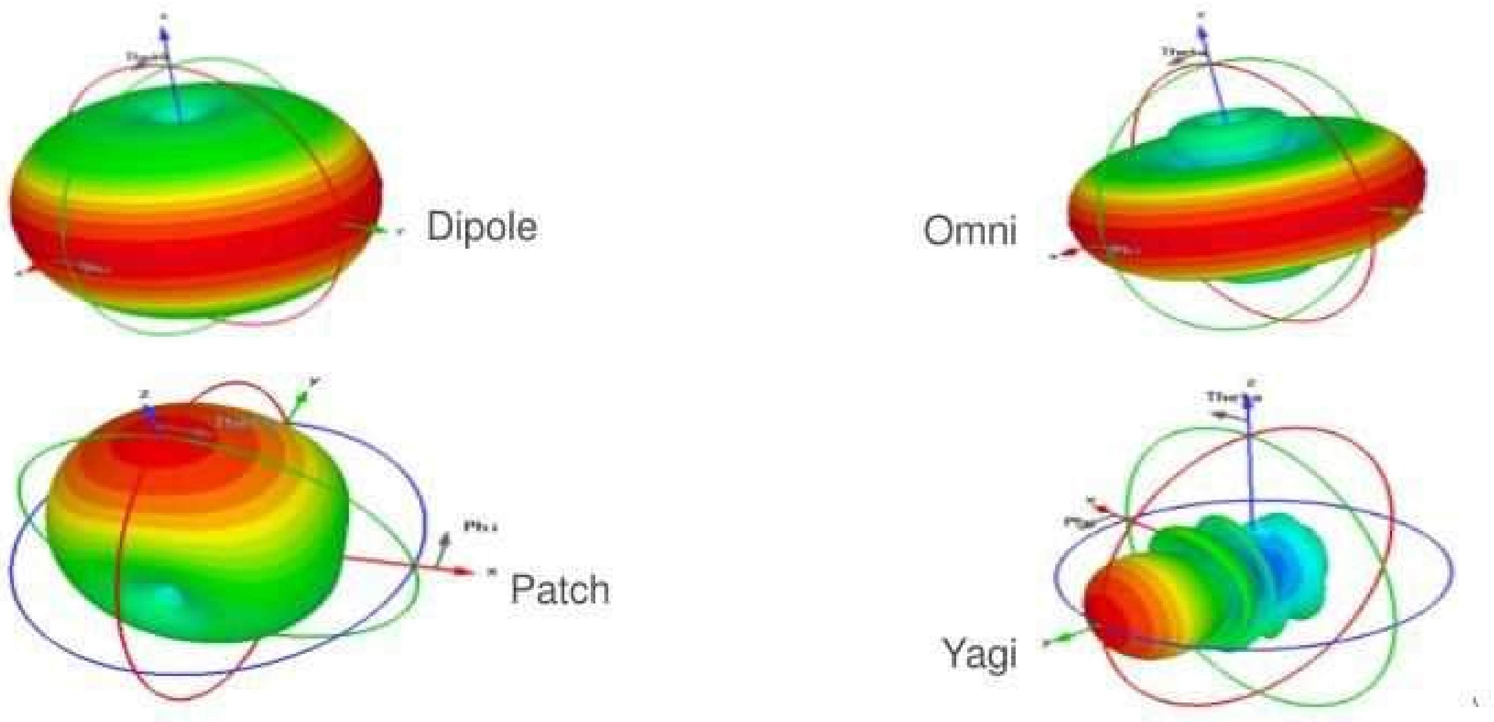


Figure 6.11: Comparison of measured and simulated RSSIs with nodes raised 0.95 m from ground.

Anisotropic radiation patterns



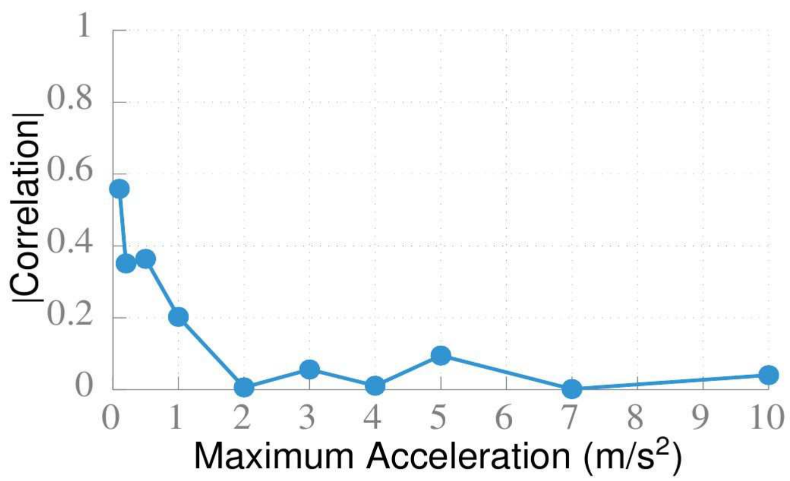
Credit to fpvlair.com for image.

Wireless motion

- Antenna motion.
- Conductive material motion.

Table 2.3: Classification Performance

Environment	Sensitivity (%)	Specificity (%)
Office I	99.6	96.5
Office II	100.0	87.7
Cafeteria	91.4	86.6
Outdoor	95.9	61.1



Communication power

1. Antenna.
2. Electronics.

Radiated energy

- Radiated power depends on distance.
  - Hit target SNR at receiver.
  - For given rate, $P_r \propto d^{\alpha}$, $\alpha \approx$ 3-4.
- Small antennas may be inefficient.
- Power into amp often $\approx$ 4 times transmitter power.

Communication energy

- Circuit energy is roughly constant and independent of distance.
    - On order of 1-10mW.
- For large distances, transmission energy dominates.
- For short distance, circuit energy should also be considered.

Communication energy

Example: For a particular radio the power consumption while on is 2mW. When transmitting at a peak power of 10mW the power amplifier has an energy efficiency of 25%.

What is total power while transmitting?

Communication power and multi-hop

- Are two hops better than one?
- Superlinear increase in energy with distance.
- Constant energy hit regardless of distance.

Processing vs. transmitting

- For motes, transmitting 1-bit costs same as executing $\approx$ 1,000 processor instructions.
- Can save on transmission costs by intelligently processing data before transmitting!
- Data aggregation/fusion.

Dynamic power management

- Dynamic power management also useful for communication power.
- Turn radio off when nothing to send/receive.
- Note while off can not receive.
- Taking into account DPM can change transceiver trade-offs.
  - Better to send fast and sleep or slow?

Hibernation

When to wake up?

Possibilities

1. At regular intervals.
   - Need synchronization.
2. Trigger by stimulus.
   - E.g., heat-sensitive circuit.