Review of Basic Electronics

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Voltage, Current, and Power

- Voltage:
  - Electromotive force that drives flow of electrons
  - Measured relative to some point
  - Fluid analogy: pressure
  - Unit: volts (V)
- Current:
  - Rate of flow of electrons
  - Fluid analogy: flow rate
  - Unit: ampere/amp (A)
- Power:
  - Rate of energy expenditure/dissipation
  - $P = VI$
  - Unit: watts (W)

The Laws

- Kirchoff's Current Law (KCL):
  - The sum of all currents entering and exiting a node is zero

$$\sum_{k=1}^{N} I_k = 0$$

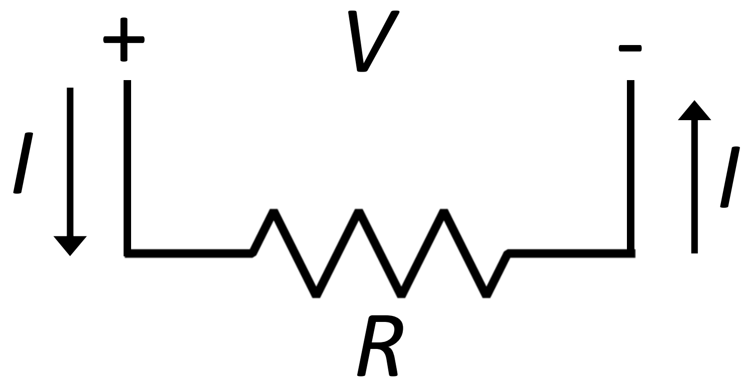
- Kirchoff's Voltage Law (KVL):
  - The sum of the voltage drops around a closed loop in a circuit is zero

$$\sum_{k=1}^{N} V_k = 0$$

Resistors

- Dissipate energy
- Resistance in Ohms (Ω)
- Trades current for voltage or vice versa
- Most used and lowest cost discrete passive component

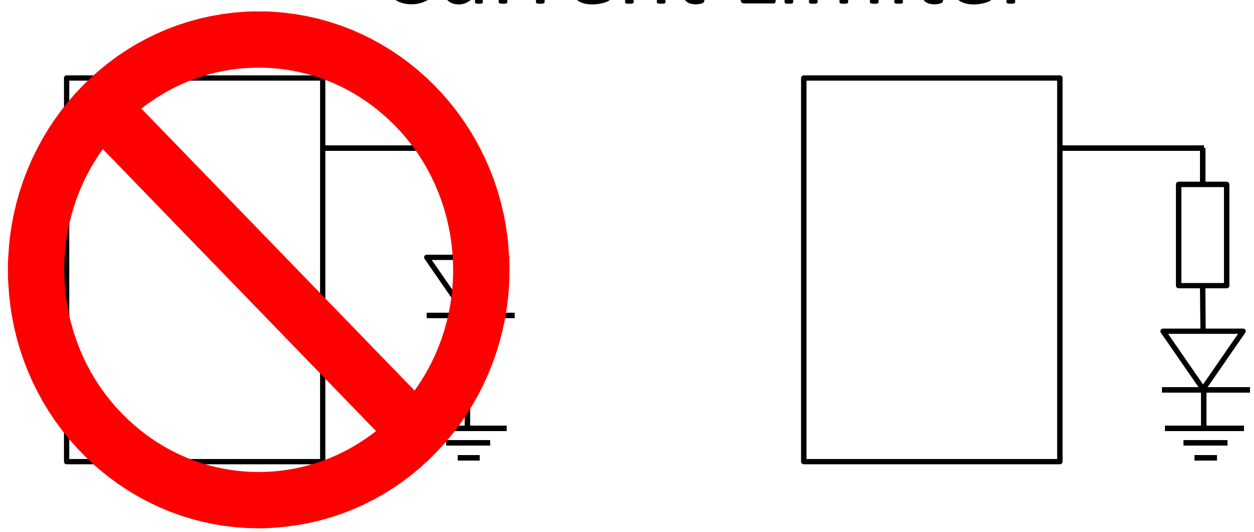
Ohm’s Law



$$V = RI$$

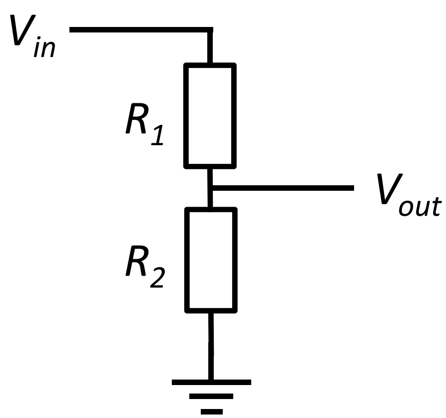
$$P = VI = I^2R = \frac{V^2}{R}$$

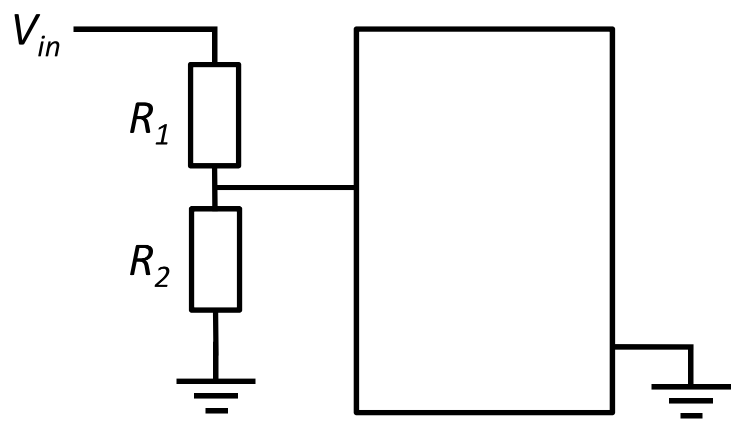
My Favorite Resistor Applications: Current Limiter



- Integrated circuits (and other components) can only sink or source a finite amount of current
- Use resistors to limit the current
- Example: Driving an LED with the digital output of an IC
  - Digital output generates 5 V, but can only source 10 mA of current
  - LED has a forward voltage drop of 2 V
  - Select current-limiting resistor

My Favorite Resistor Applications: Voltage Divider





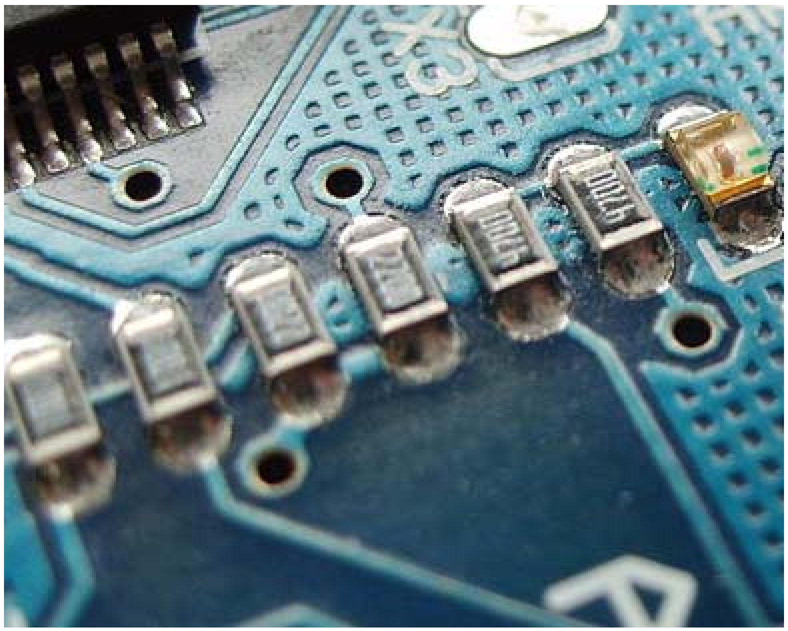
$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

- Used to set a voltage level
- Big assumption: No current flowing out at V_{out} (no I_{out})
- Example: Set the pin on a microcontroller to 1.8 V, given a 5 V power supply

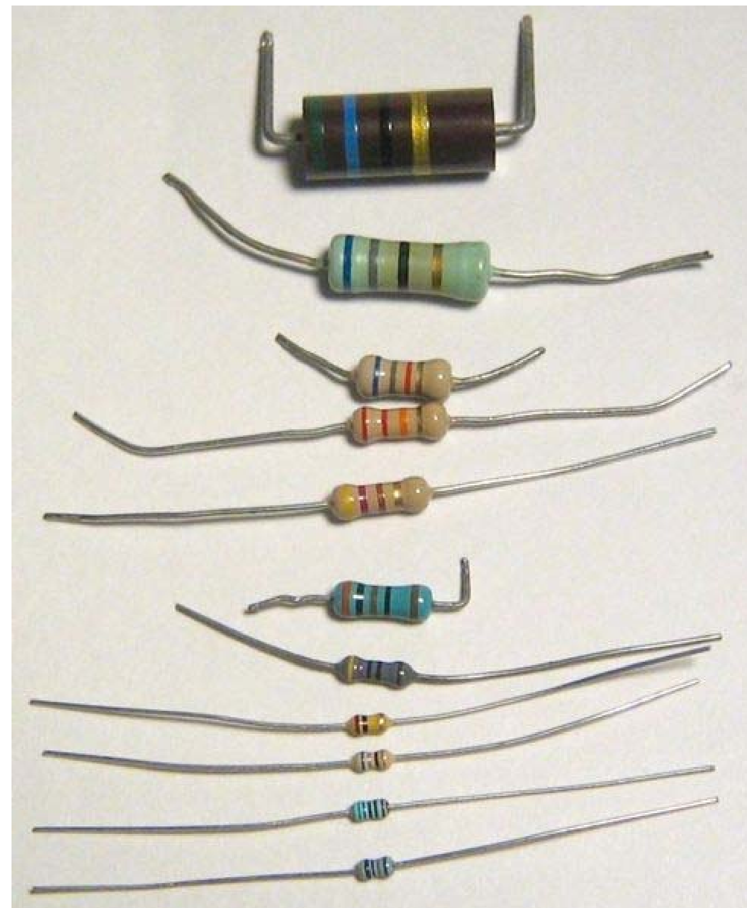
My Favorite Resistor Applications: Others

- Pull-up and pull-down
- Biasing
- Set gains in amplifiers
- Filter time constants
- Measure currents
- Discharge capacitors

Real Resistors



http://commons.wikimedia.org/wiki/File:Arduino_led-1.jpg



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Resistor Specs

- Resistance
- Power dissipation
- Tolerance
- Temperature coefficient
- Parasitic inductance/capacitance

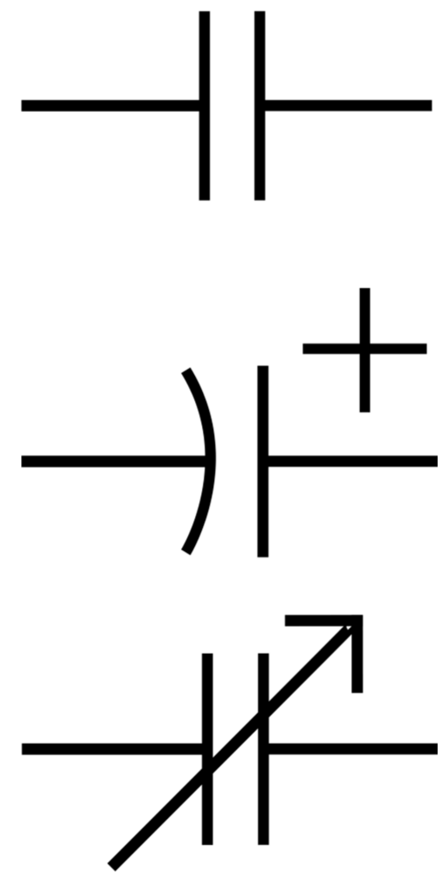
- Example: Choose a resistor to limit the current flow to 20 mA

Capacitors

- Store charge
- Capacitance in Farads (F)
- Change in voltage causes current

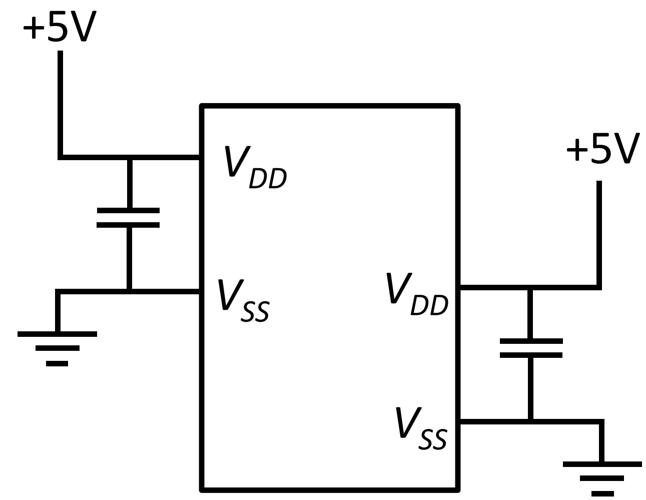
$$I = C\frac{dV}{dt}$$

- Medium cost discrete passive component



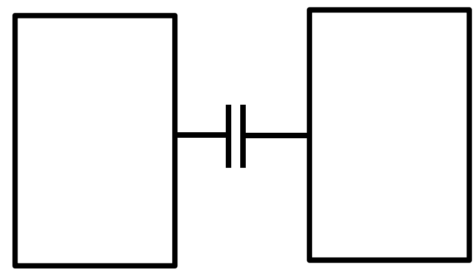
My Favorite Capacitor Applications: Bypass Capacitors

- Bypass capacitors smooth out power source
- Capacitors store charge that can be delivered to respond to transient changes
- Bulk bypassing:
  - Placed at circuit’s power connection
  - Large capacitors (10’s-100’s µF)
  - Aluminum electrolytic or tantalum
- Local bypassing:
  - Placed at each integrated circuit
  - As close to power and ground pins as possible
  - Small capacitors (0.01-0.1 µF)
  - Ceramic

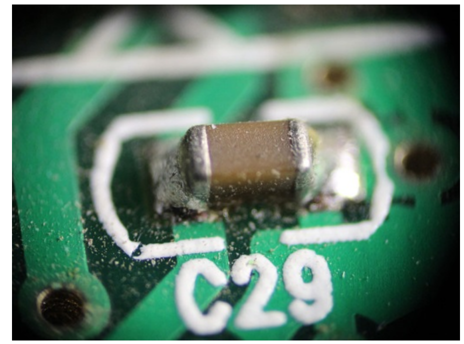


My Favorite Capacitor Applications: AC Coupling

- Only lets the varying component of a signal pass through – sort of like high-pass filtering



Real Capacitors



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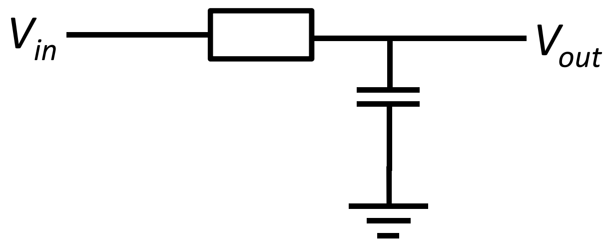
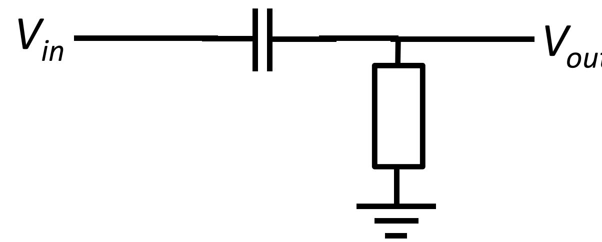
Type	Capacitance range	Maximum voltage	Accuracy	Temperature stability	Leakage	Comments
Mica	1pF–0.01μF	100–600	Good		Good	Excellent; good at RF
Tubular ceramic	0.5pF–100pF	100–600		Selectable		Several tempcos (including zero)
Ceramic	10pF–1μF	50–30,000	Poor	Poor	Moderate	Small, inexpensive, very popular
Polyester (Mylar)	0.001μF–50μF	50–600	Good	Poor	Good	Inexpensive, good, popular
Polystyrene	10pF–2.7μF	100–600	Excellent	Good	Excellent	High quality, large; signal filters
Polycarbonate	100pF–30μF	50–800	Excellent	Excellent	Good	High quality, small
Polypropylene	100pF–50μF	100–800	Excellent	Good	Excellent	High quality, low dielectric absorption
Teflon	1000pF–2μF	50–200	Excellent	Best	Best	High quality, lowest dielectric absorption
Glass	10pF–1000pF	100–600	Good		Excellent	Long-term stability
Porcelain	100pF–0.1μF	50–400	Good	Good	Good	Good long-term stability
Tantalum	0.1μF–500μF	6–100	Poor	Poor		High capacitance; polarized, small; low inductance
Electrolytic	0.1μF–1.6F	3–600	Terrible	Ghastly	Awful	Power-supply filters; polarized; short life
Double layer	0.1F–10F	1.5–6	Poor	Poor	Good	Memory backup; high series resistance
Oil	0.1μF–20μF	200–10,000			Good	High-voltage filters; large, long life
Vacuum	1pF–5000pF	2000–36,000			Excellent	Transmitters

My Favorite Capacitor Applications: Analog Filters



Low-Pass Filter



High-Pass Filter

$$\omega = \frac{1}{RC}$$