

# Electronics for IoT

## Electricity

Bernhard E. Boser

University of California, Berkeley

[boser@eecs.berkeley.edu](mailto:boser@eecs.berkeley.edu)

# Electricity

---

Topics:

- Characteristics
- Metrics (voltage, current)
- Measure
- Devices
- Circuits

# Electricity

---



# Electricity

---

- Charged particles
  - Usually electrons
- Can't see electrons
  - Only consequences of their actions



# Feel?



# Feel!



# In the EE 49 lab ...



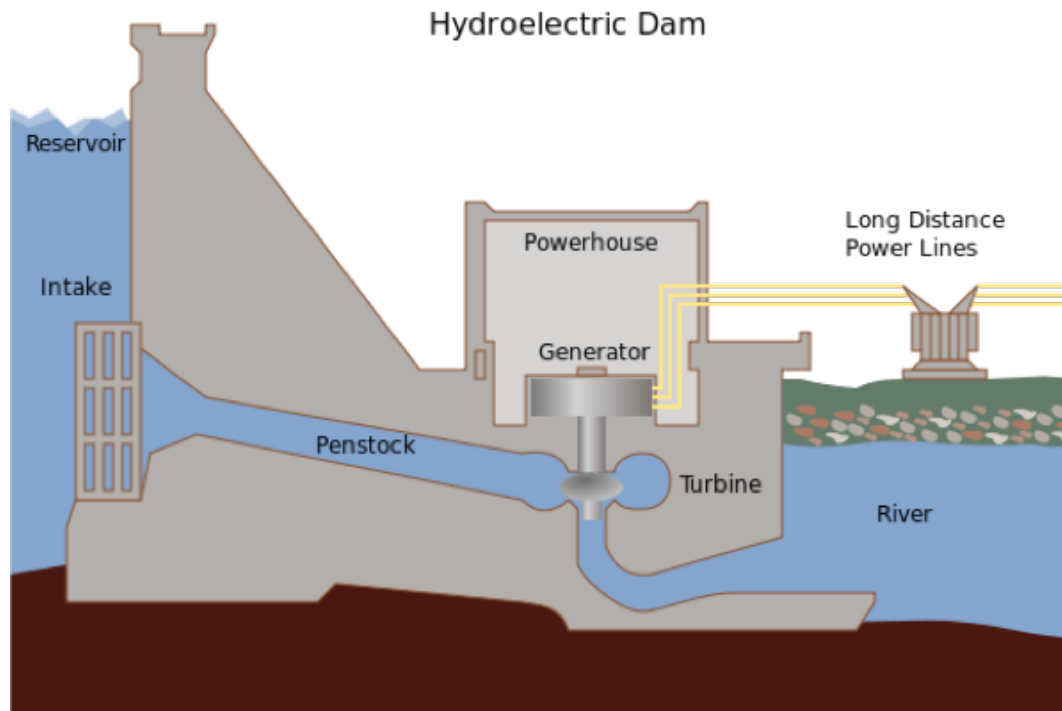


# Water Analogy

---



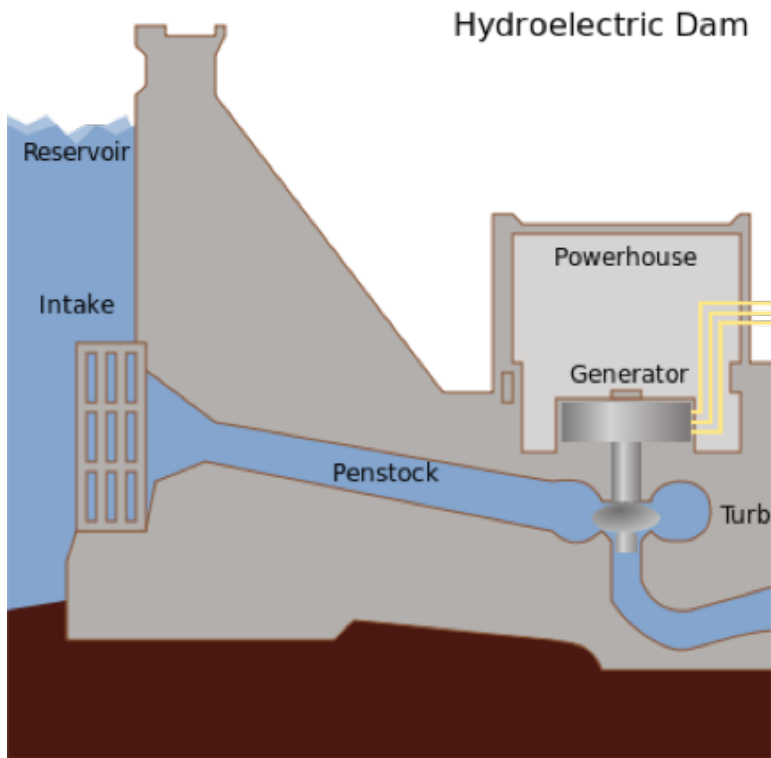
# Water Analogy



Water molecules ~ Electrons

# Voltage

Pressure [  $\text{N/m}^2$  ]



Voltage [ V ]



# Measuring Voltage

- Digital Multi-Meter
- AC versus DC
- Wires (pipes for electrons)
- Loop:
  - Electrons need to get back to where they came from
  - Water is more flexible
    - But it's also nice when it eventually comes back ...





# Experiments ... Parts!



# Parts

- Distributed to each team of two in the first lab
- You'll use them throughout the semester
- **A storage box is more convenient than the bag they come in**
- Many parts are “multi-use”: used in several labs and the project





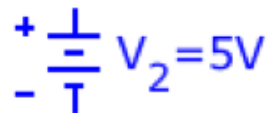
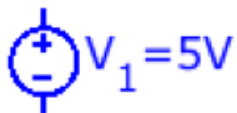
# Electrical Circuit



# Circuit Symbols



# Circuit Symbols

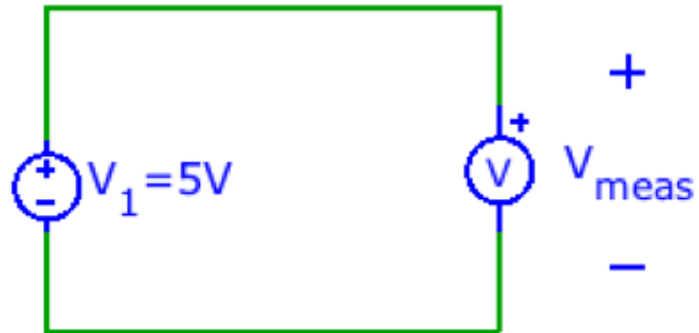


# Circuit Diagram

---

# Circuit Diagram

---





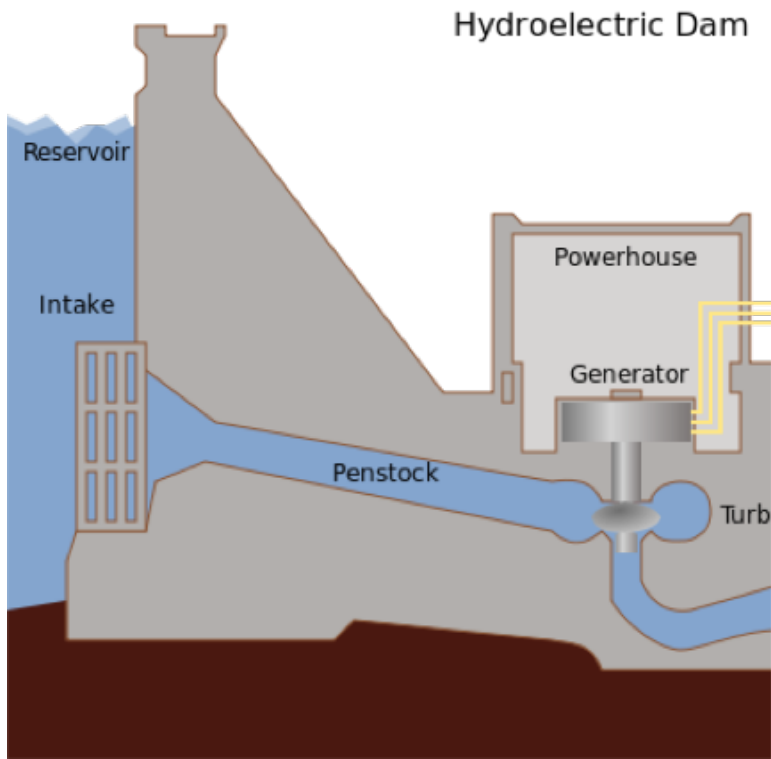
# Mixing up wires – red to black???

---



# What can we do with it?

## Spin a turbine ...

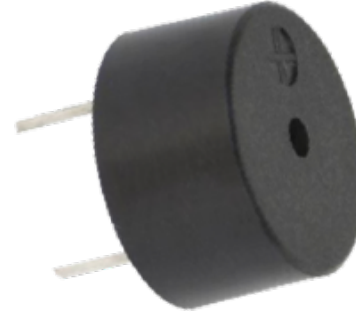


## Make “sound”

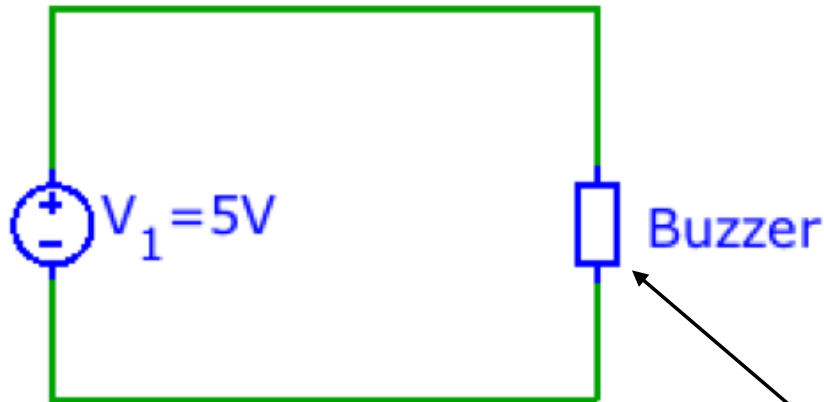
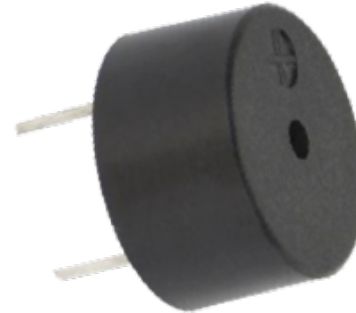


# Circuit Diagram

---



# Circuit Diagram



Rectangle:  
Generic circuit  
symbol

# Current

---

## Water flow

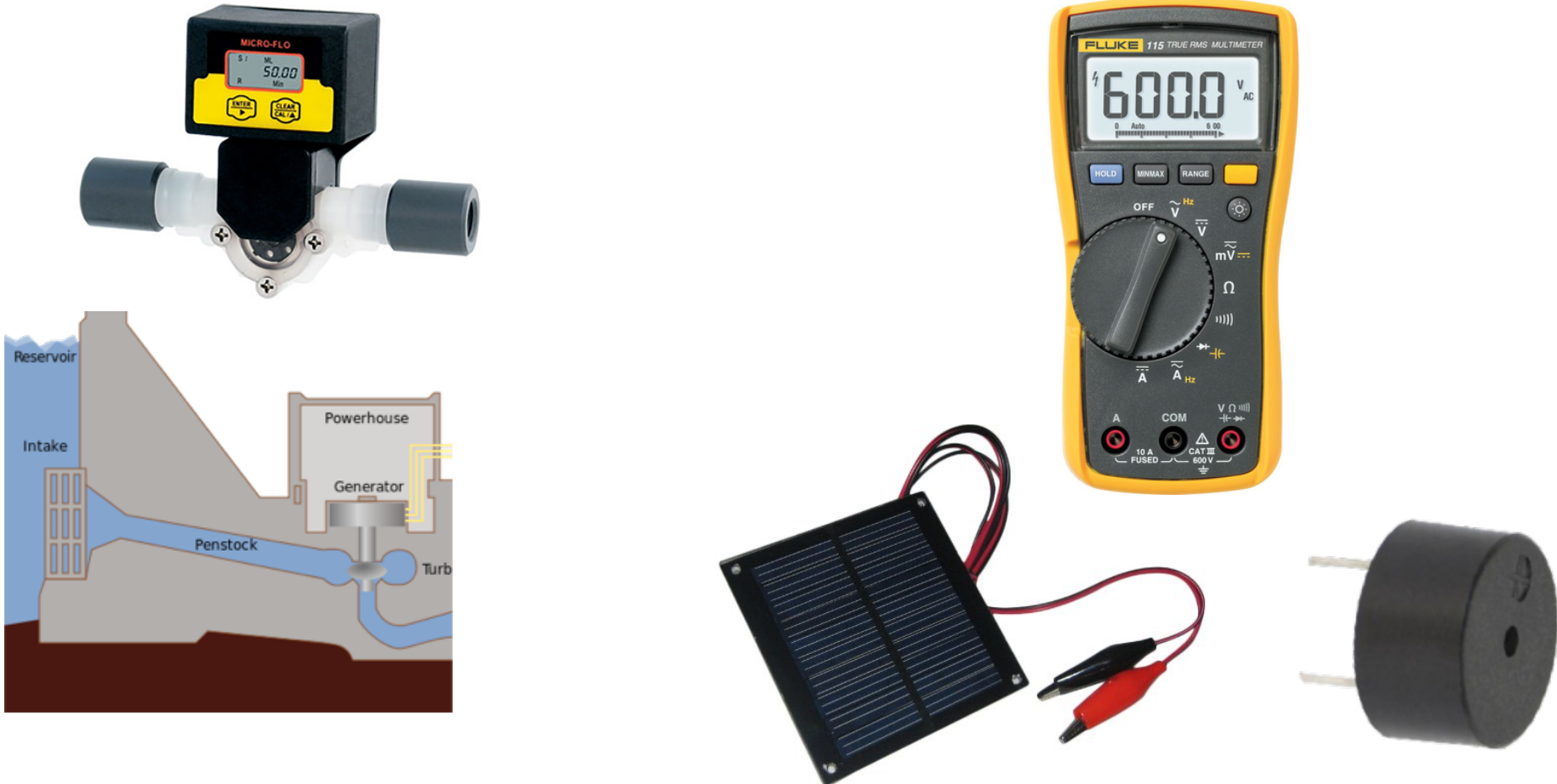
- Water molecules
- Water volume [  $\text{m}^3$  ]
- Flow [  $\text{m}^3 / \text{s}$  ]

## Current

- Electrons
- Charge [ Coulomb = C ]
- Current [  $\text{C} / \text{s} = \text{A}$  ]

# Measuring Current

Where does the meter go?



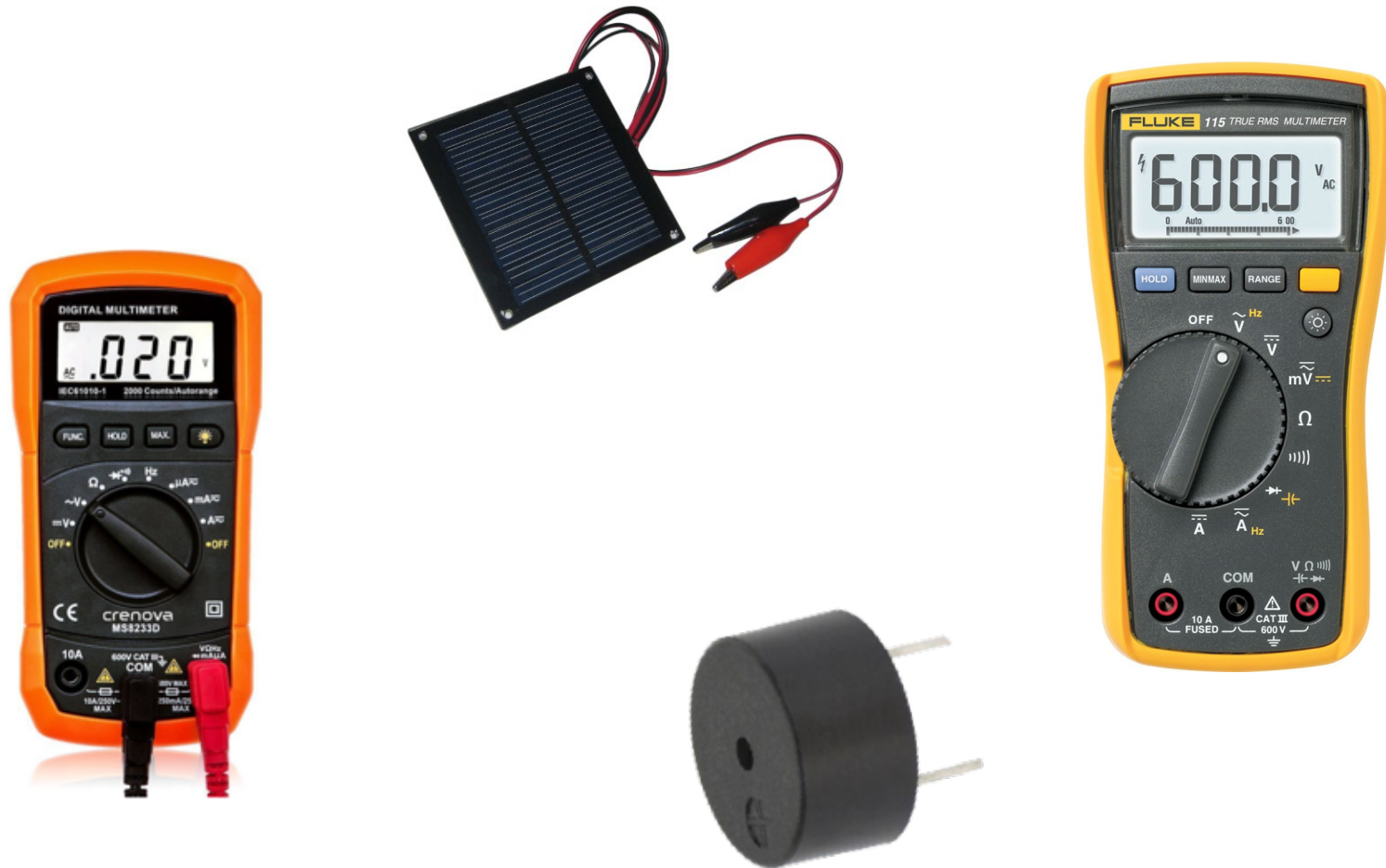
# Circuit Diagram

---





# Measuring Voltage and Current



# Circuit Diagram

---

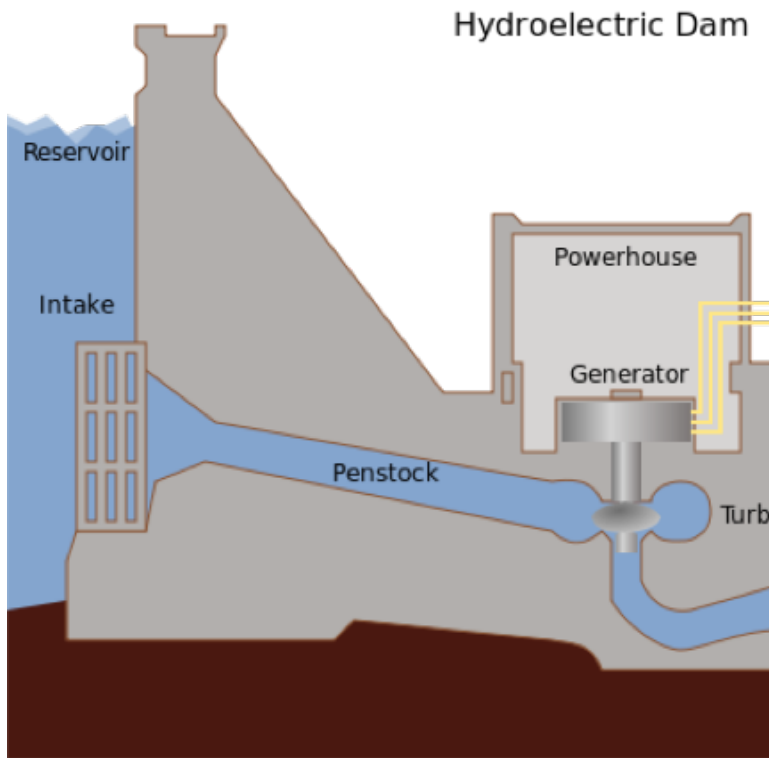
# Beyond “sound” ...

---

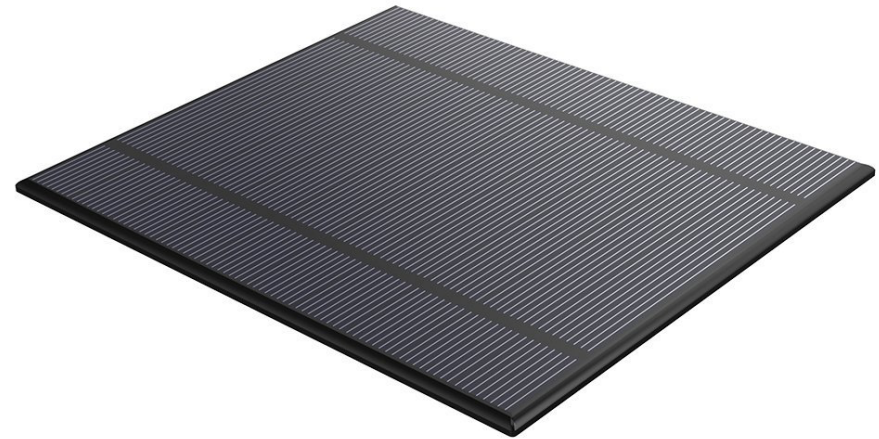
- What can we do with it?
  - Light the room?
  - Charge the smartphone?
  - Run the microcontroller?
  
- How can we figure that out?
  - Voltage
  - Current
  - ???

# Power

Pressure x Flow [ W ]



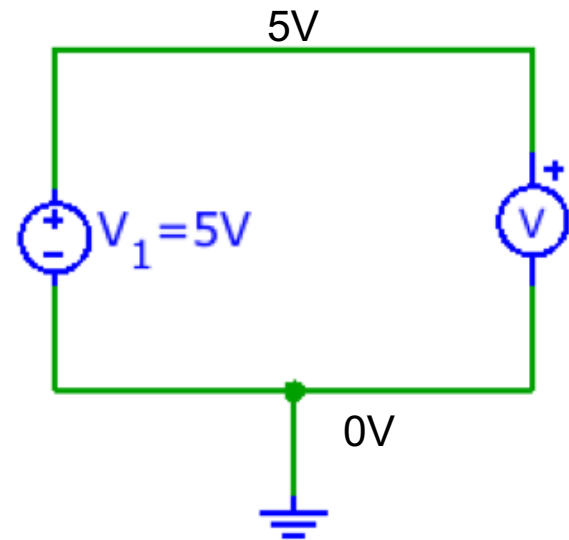
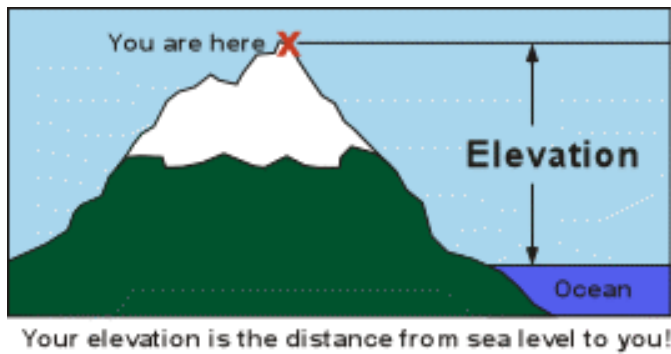
Voltage x Current [ W ]



# Power



# Signal Ground





# Short Circuit

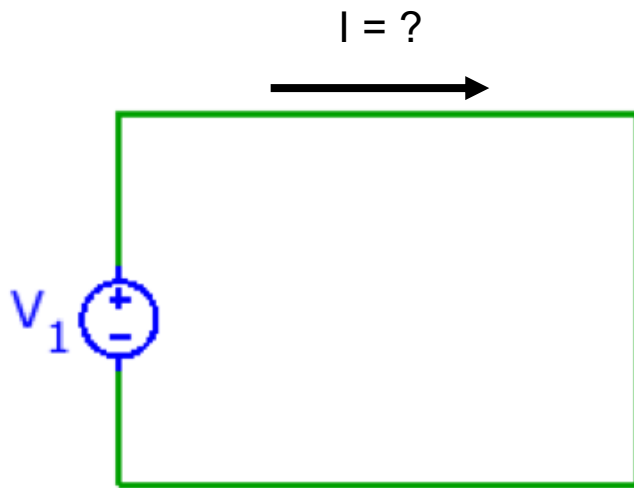


BIGSTOCK

Image ID: 180767107  
bigstock.com



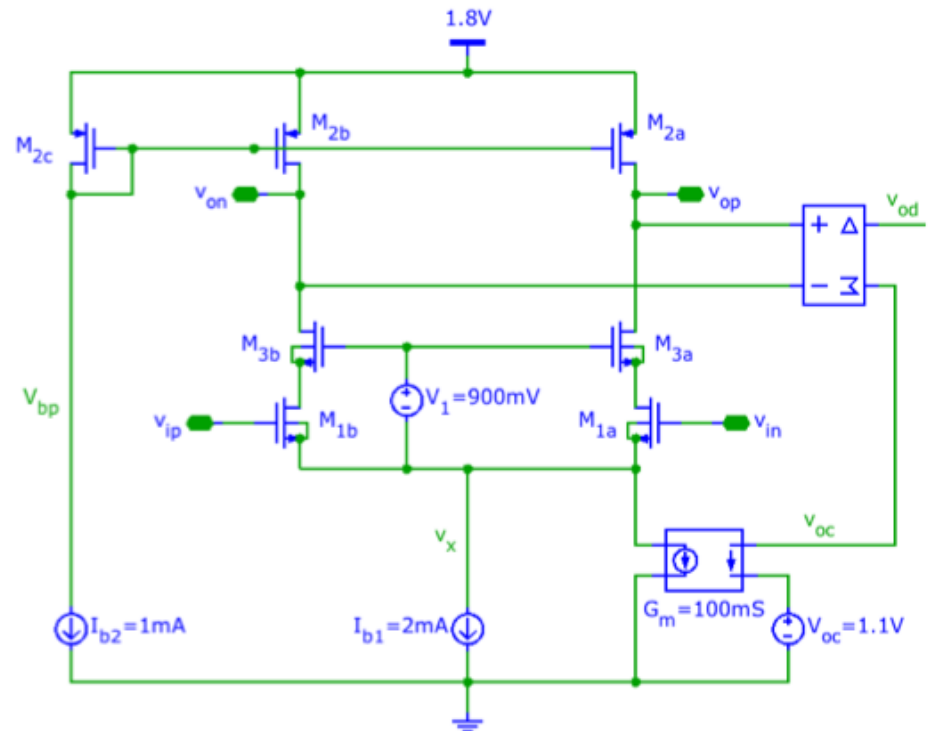
# Interpretation



- What is the current flowing?
- Depends on source, e.g.
  - Nuclear power plant
  - Solar cell
  - ...

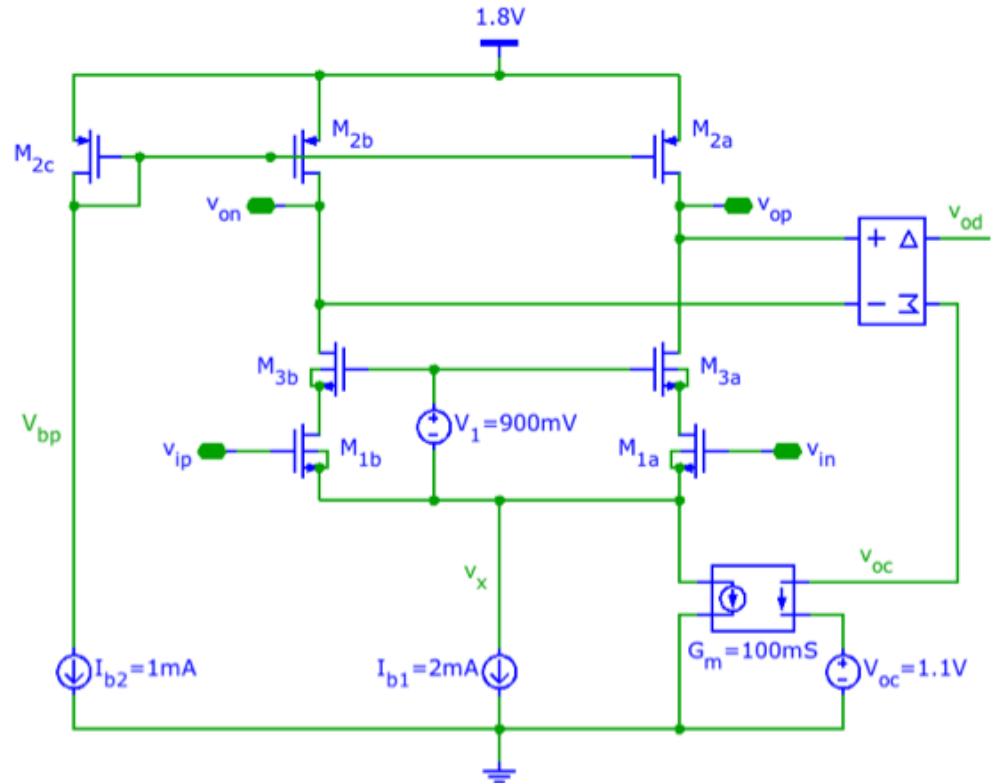
# Short Circuit Current

- “Current through wire between any two points in a circuit”
- Whether this is a good idea or not (e.g. causes fire) depends on circuit and connection points
- Common terminology used by electrical engineers
- Use ammeter to measure, behaves like short circuit (“wire”)



# Open Circuit Voltage

- “Voltage between any two points in a circuit without adding a wire between them”
- Note: no current flow → no sparks
- Use voltmeter to measure, behaves like open circuit (“no wire”)



# Typical Voltages

---

- Household current (ac)
- Car battery
- “Typical” Electronic circuits

# Electric Shock

- Is 5V dangerous?
- 100V?
- What about this:



# “Dangerous” Voltages

- Humans:
  - >30V if current not limited
- Integrated circuits:
  - Typical: < 5V!
  - E.g.

GPIO	ALT	μPy		μPy	ALT	GPIO
			1			
		RESET	2			
		3.3V	3			
			4			
		GND	5			
26	DAC2	A0	6			
25	DAC1	A1	7			
34	ADC6	A2	8			
39	ADC3	A3	9			
36	ADC0	A4	10			
4		A5	11			
5	SCK	A16	12			
18	MOSI	A17	13			
19	MISO	A18	14			
16		A19	15			
17		A20	16			
21		A21	17			
			18			
			19			
			20			
			21			
			22			
			23			
			24			
			25			
			26			
			27			
			28			
			29			
			30			
			31			
			32			
			33			
			34			
			35			
			36			
			37			
			38			
			39			
			40			
			41			
			42			
			43			
			44			
			45			
			46			
			47			
			48			
			49			
			50			
			51			
			52			
			53			
			54			
			55			
			56			
			57			
			58			
			59			
			60			
			61			
			62			
			63			
			64			
			65			
			66			
			67			
			68			
			69			
			70			
			71			
			72			
			73			
			74			
			75			
			76			
			77			
			78			
			79			
			80			
			81			
			82			
			83			
			84			
			85			
			86			
			87			
			88			
			89			
			90			
			91			
			92			
			93			
			94			
			95			
			96			
			97			
			98			
			99			
			100			
			101			
			102			
			103			
			104			
			105			
			106			
			107			
			108			
			109			
			110			
			111			
			112			
			113			
			114			
			115			
			116			
			117			
			118			
			119			
			120			
			121			
			122			
			123			
			124			
			125			
			126			
			127			
			128			
			129			
			130			
			131			
			132			
			133			
			134			
			135			
			136			
			137			
			138			
			139			
			140			
			141			
			142			
			143			
			144			
			145			
			146			
			147			
			148			
			149			
			150			
			151			
			152			
			153			
			154			
			155			
			156			
			157			
			158			
			159			
			160			
			161			
			162			
			163			
			164			
			165			
			166			
			167			
			168			
			169			
			170			
			171			
			172			
			173			
			174			
			175			
			176			
			177			
			178			
			179			
			180			
			181			
			182			
			183			
			184			
			185			
			186			
			187			
			188			
			189			
			190			
			191			
			192			
			193			
			194			
			195			
			196			
			197			
			198			
			199			
			200			
			201			
			202			
			203			
			204			
			205			
			206			
			207			
			208			
			209			
			210			
			211			
			212			
			213			
			214			
			215			
			216			
			217			
			218			
			219			
			220			
			221			
			222			
			223			
			224			
			225			
			226			
			227			
			228			
			229			
			230			
			231			
			232			
			233			
			234			
			235			
			236			
			237			
			238			
			239			
			240			
			241			
			242			
			243			
			244			
			245			
			246			
			247			
			248			
			249			
			250			
			251			
			252			
			253			
			254			
			255			



# Typical Currents

---

- Household
- Train
- CPU
- EE 49 circuits

# Summary

---

- Electrical quantities:
  - Voltage
  - Current
  - Power
- Components (devices):
  - Solar cell (source)
  - Buzzer
  - DMM
    - Voltage and current meter
- Circuits:
  - Symbols, diagrams
  - Short and open circuits