Electronics Introduction

Curie 2011

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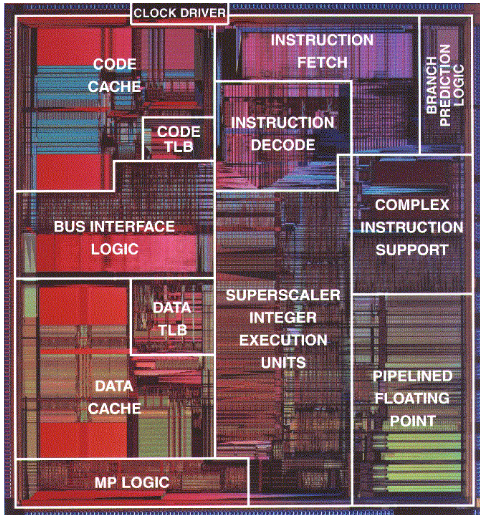
Why Electricity?

- Useful for it to transporting energy
  - Just need wires, instead of pipes, or trucks, or whatever
- Use it to physically move objects
  - Electric motors in cars
  - Actuators to control things

- Use it to transmit information
  - Again, just wires are needed
  - Very very fast (~1000,000 times faster than talking)
- Use it to compute things (electronic chips)
  - Again, very very fast (~1 billion times faster than pencil and paper.
  - Very small (1 million times smaller than a pencil and paper)
- Others…



What is electricity? Charge

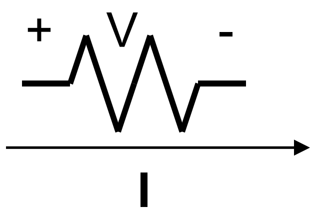
- All matter in the universe is made up of charged particles
  - These can be either positive (protons) or negative (electrons)
  - Positive charges repel each other
  - negative charges repel each other
  - But positive charges attract negative charges.
- Normally have equal amounts of each, nothing happens
- But if move enough charge: zap!

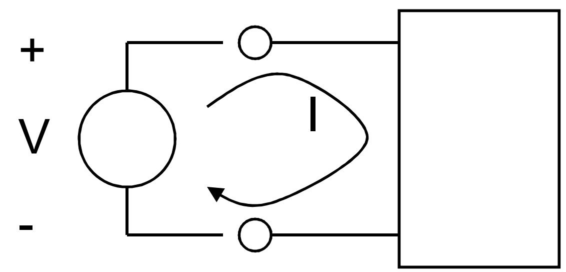
Electricity: Voltage/current

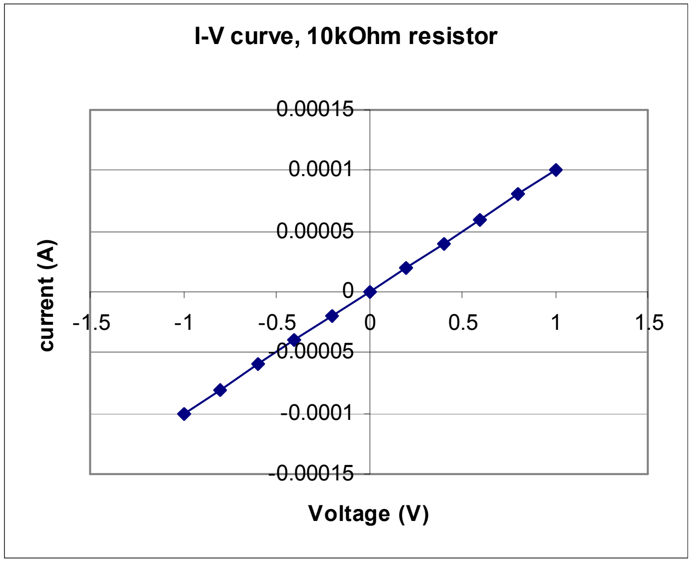
- Voltage: describes how much energy you have from separating +. – charges
  - Energy = voltage (V) times amount of charge (# of electrons).
  - Voltage “pushes on” charge: kind of like pressure on fluid
  - Measured in Volts (V)
  - Can either measure across a component, or as a number relative to ground (0V).
- Current: electrons can move in conductors (metal, people, etc), current describes how much
  - Current: charge /per second
  - Like water flowing in a pipe: gallons/ second
  - Measured in Amperes (Amps: A)
- When you put voltage across a conductor, it pushes on charge, and makes current flow.

I-V curves + conductance

- You can characterize component by:
  - placing voltage across it
  - Measure current through it
  - Changing the voltage, and repeating
- Plotting an "I-V" curve:
  - V on x-axis
  - I on y-axis
- Ohm's law: V=I·R ↔I=V/R
  - R: resistance: small in metal, big in other things (like people, except when they lie), measured in Ohms: Ω
  - Symbol:

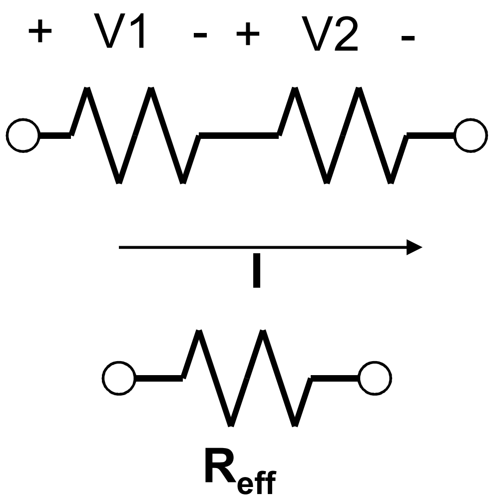




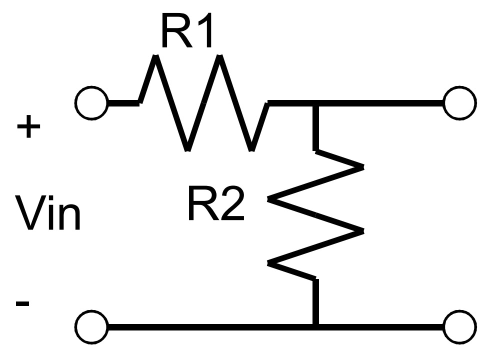


Resistor combinations

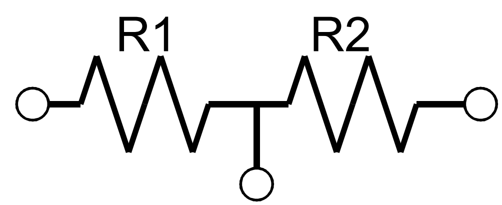
- Series Resistors:
  - V1=IR1
  - V2=IR2
  - Total voltage: add up voltages
- Effective resistance:



$$R_{eff} = R_2 + R_1$$



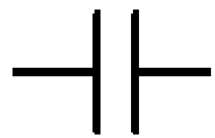
$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$$



$$V_{out} = \frac{V_1 R_2 + V_2 R_1}{R_1 + R_2}$$

Capacitance

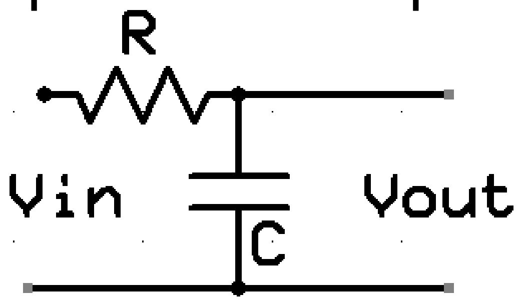
- In addition to resistors, another kind of component, called a capacitor, is used a lot in circuits. The symbol used is

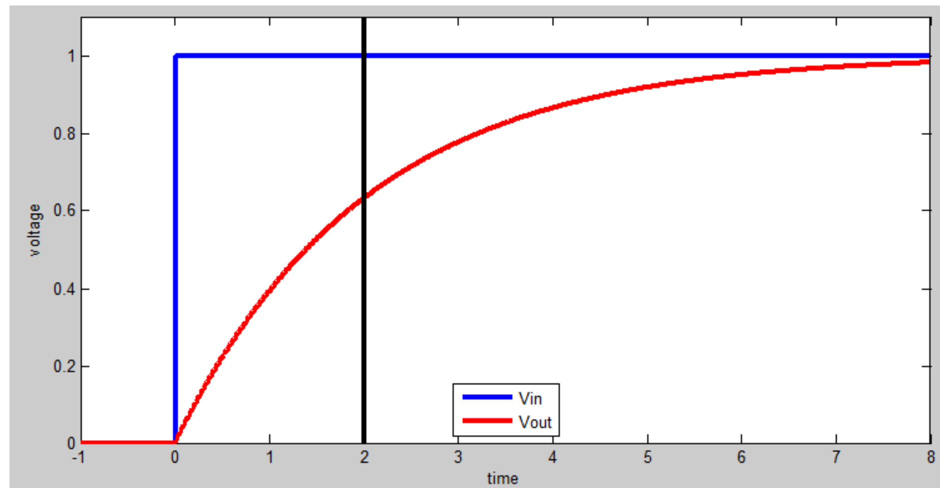


- The equation describing a capacitor is $V= (i*t)/C$ or in words: voltage equals charge/capacitance (remember that current*time=charge). Another way to write this relation is $\Delta V=(i*\Delta t)/C$, which is read as “a small change in voltage results from a current flowing for a small time into a capacitance C”.
- We will see that a combination of resistors and capacitors allows us to make circuits that respond with a certain speed or over a certain time.

Capacitance

- Building a circuit of a resistor and a capacitor and applying a sudden jump in voltage results in a slowing rising output with an exponential shape.





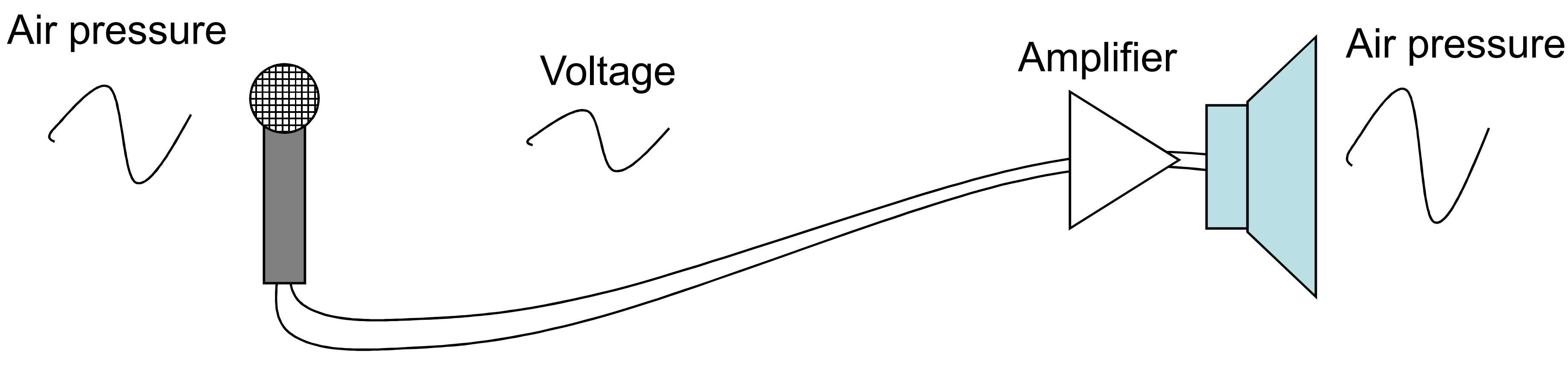
- The blue line is the input (starting at zero at t=0).
- The red line is Vout=Vin*(1-$e^{(-t/RC)}$) (Here RC=2)
- The black line is drawn at the value RC which is called the *time constant* of the circuit. At that point, Vout=Vin*(1-e^{-1})=0.632
- A fast input results in a slower output.

Electricity: power and energy

- When current flows from high voltage to low voltage, energy is dissipated (water down hill)
  - This can be as heat
  - Or as light
  - As force + movement
  - Or even as sound
- When current flows from low voltage to high voltage, electrical energy is generated:
  - Chemically (battery)
  - By light (solar cells)
  - By force and movement (wind generator)
- Power (in Watts) equals voltage times current: $P = V\cdot$
  - *Example: A light bulb conducts 1 Amp of current when 100 Volts are applied across it: What is:*
    - *The power dissipated in the bulb?*
    - *The resistance of the bulb?*

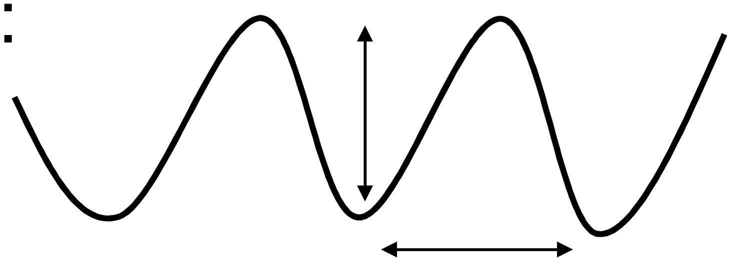
Analog Voltage signals

- Now voltage directly represents a value:
  - Like temperature (so $V = T \cdot k$): example 1V for every 20° above 0: 32°→1.6V.
  - Or light intensity
  - or air pressure (from sound)
- This is useful because it is easier to send a voltage over a wire over a long distance than sound (or heat, etc)



Time varying signals

- If voltage changes in time, can plot that voltage vs time (using an oscilloscope)
  - Important things to note:
    - Amplitude
    - Time scale



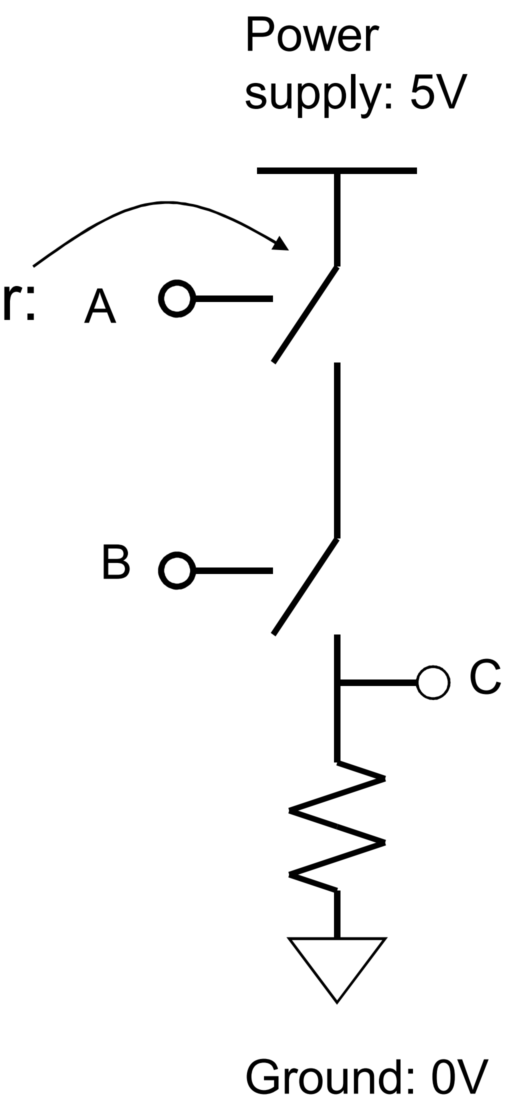
  - One benefit of electronics is it is *very fast*: can send fast-changing signals = lots of information (lots of "voices" at once)

Digital Voltage signals

- Simplest signals are digital: “1” or “0”
- Really 0V or 5V (relative to ground)→ use these to make decisions :
  - 1= light on
  - 0 = light off
- Can combine to make “logical decisions”
  - Example:
  - Rule: turn on the light if it is night time, *and* I am in the room:
  - 2 inputs (time of day, person in the room)
  - Time of day: represent “night” as “1”, day as “0” (call this A)
  - person in the room: yes = 1, no = 0 (call this B)
  - State of light is also digital (call this C): light on = 1, light off = 0
  - Then could say: if A and B are 1, then C is 1, otherwise C is 0.
  - Shorthand: C = A & B
- You can implement this with a circuit!

A simple “AND gate”

- Represent
  - “1” as ~5V (really anything >3V)
  - “0” as ~0V (really anything <2V)
- Use switches with the following behavior:
  - If Vin >3V, R = 30Ω
  - If Vin < 2V, R = 30,000Ω
- Arrange them as shown:



Does it work? Calculate the voltage at “C” for each of the following cases:

A=0, B =0 C = ____

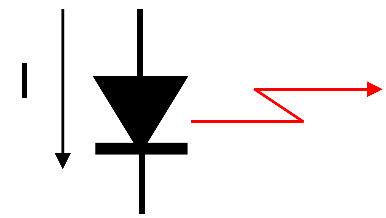
A=1, B=0 C = ____

A=0, B=1 C = ____

A=1, B=1 C = ____

Light and electronics

- Electronics to make light:
  - Light emitting diode:
    - amount of light → amount of current L = k*I
    - Wavelength (color) sets voltage
    - Only works one direction
  - Laser diode: like an LED by with special properties to make a narrow beam



- Electronics to detect light:
  - Photodiode: like an LED but run the other way: now current flows when light is absorbed:
    - I = k*L
    - Only really works if V > 0
  - Photovoltaic: same idea but arranged so that current flows “out” of it: voltage is roughly constant, amount of current set by light .