Basic Electronics

CSCI 2050U - Computer Architecture

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OntarioTech UNIVERSITY

Lecture Outline

- Basic physics and electronics components
- Digital logic gates

Background

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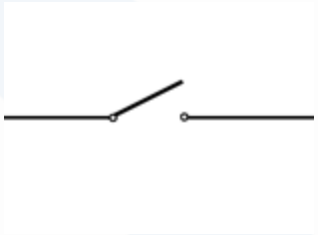
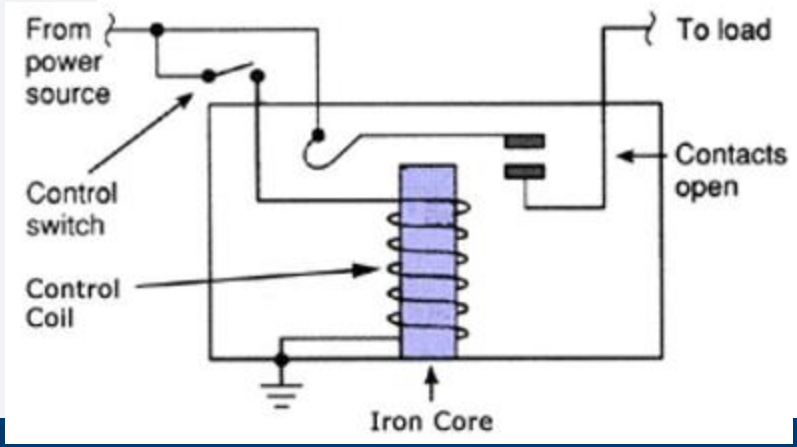
Mechanical Computers

- Charles Babbage (1791-1871)
  - Difference engine (~1822)
    - Calculating astronomical tables
  - Analytical engine (never completed)
    - Programmable

Electromechanical Computers

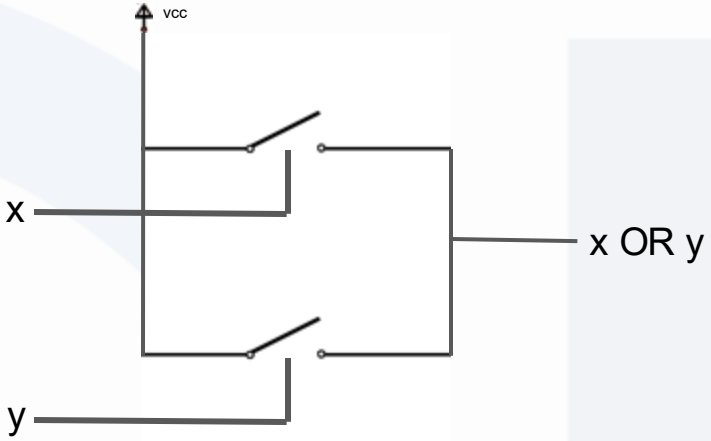
- A relay is an electromechanical device which acts like a switch
  - Conceived by telegraph operators to relay (forward) a signal
  - The incoming data creates a new signal with the same output

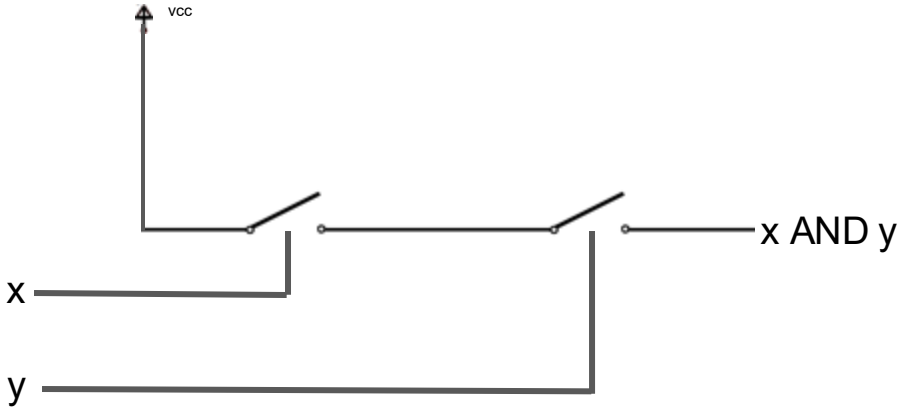




Electromechanical Computers

- Imagine two relays, configured as in these diagrams:



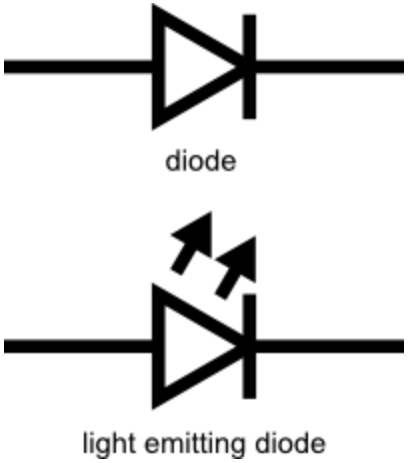


Electromechanical Computers

- In theory, we could build a computer out of relays
  - It would be huge
  - It would use a lot of power
  - It would be expensive
  - It would break down a lot
- Computers like these were created by Harvard, Bell
  - 1940s - 1950s
- Alan Turing used a computer like this to crack the Enigma code in WWII

Electronics - Diodes and LEDs

- Some basic electronics terminology:
  - Diode: A device that forces flow in one direction
    - Anode: Electrons flow out (+)
    - Cathode: Electrons flow in (-)
  - Light Emitting Diode (LED): A diode that produces light

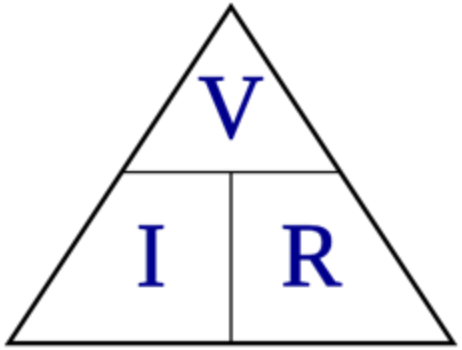


Electronics - Resistors

- Some basic electronics terminology:
  - Resistance: The degree to which a material resists electron flow
    - Analogy: A narrow pipe
    - Measured in Ohms (Ω)
    - Conductor: A material with low resistance (e.g. gold, copper)
    - Insulator: A material with high resistance (e.g. glass, rubber)
    - Semiconductor: A material whose resistance can be modified (called doping)
      - e.g. silicon, germanium

Ohm's Law

- Voltage
  - A measure of pressure
  - Unit: volts
  - Can be negative or positive (direction of pressure)
  - Handy for encoding (discussed later)
- Current
  - A measure of flow
  - Unit: Amperes
- Wattage
  - A measure of work
  - Unit: watts



Ohm's Law:

`V = IR`

`I = V/R`

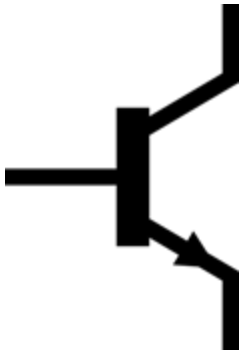
`R = V/I`

Electrical Computers - Vacuum Tubes

- Alternatives to relays:
  - Vacuum tubes
    - Low pressure tubes with anode and a heated cathode
    - Photoelectric effect causes electrons to flow only in one direction
    - ENIAC, Colossus
    - Expensive, energy waste, often fail
  - Transistors

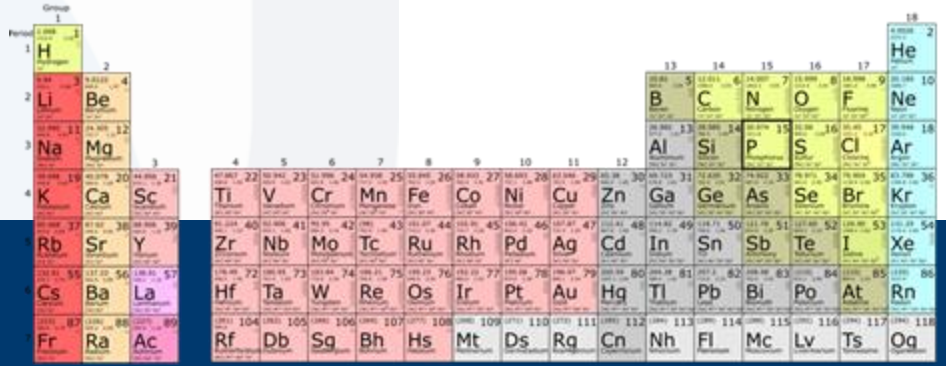
Electrical Computers - Transistors

- Alternatives to relays:
  - Vacuum tubes
  - Transistors
    - Devices made in silicon
    - Developed in the 1950s and 1960s
    - Popularized in the 1970s
    - Energy efficient, small, rarely break down
    - Primary component of very large scale integration (VLSI) circuits



Electrical Computers

- Chemistry review:
  - Atoms can share electrons in their outermost shells (co-valent bonds)
  - Pure silicon crystal has 4/8 electrons in its outer shell, so it can bond with 4 other silicon atoms



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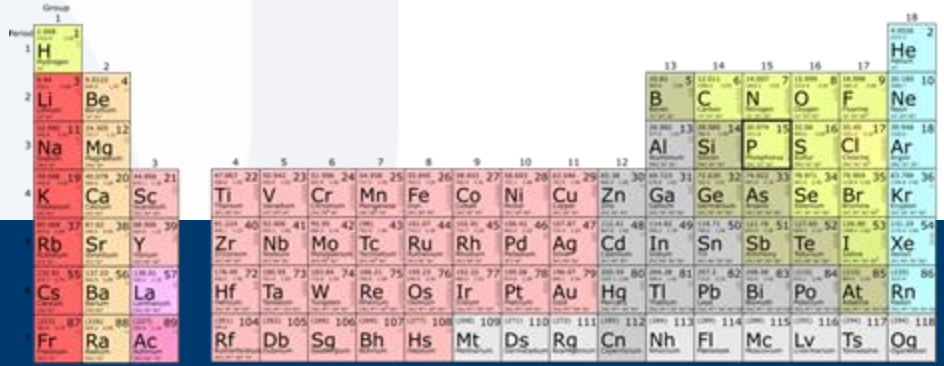
      - Phosphorus - has 5 electrons in its outer shell (one extra electron; N-type)



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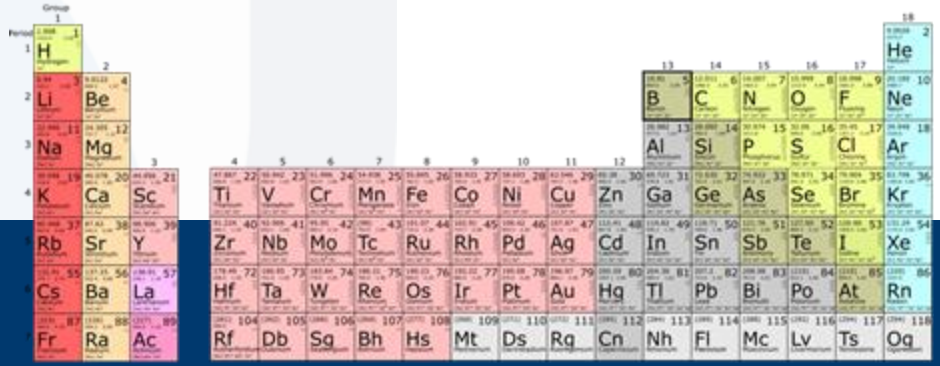
      - Phosphorus - has 5 electrons in its outer shell (one extra electron; N-type)
      - Boron - has 3 electrons in its outer shell (one extra hole; P-type)



Electrical Computers

- Diodes
  - A component that restricts the flow of electrons to a single direction
- How do they work?
  - Place an N-type semiconductor adjacent to a P-type semiconductor
  - The extra electrons in the N-type semiconductor occupy the holes in the P-type semiconductor for a small space near the junction (depletion zone)

Electrical Computers - Diodes

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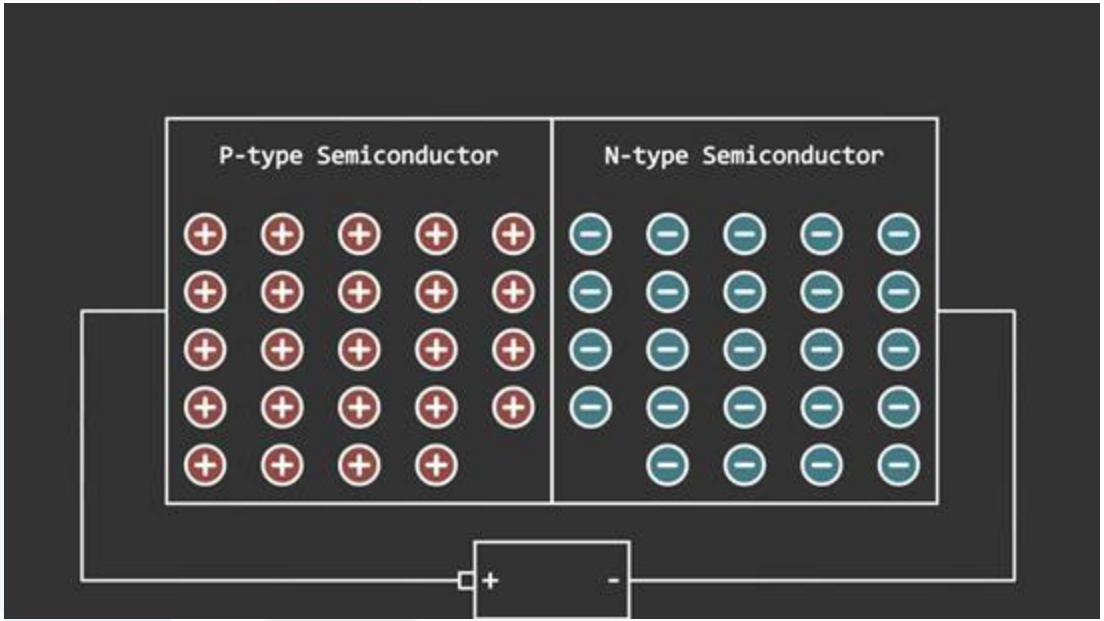
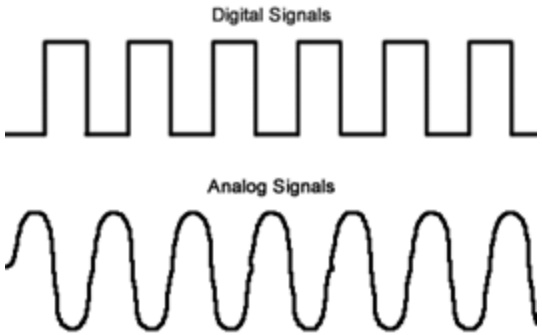


Electrical Computers - Transistors

Analog vs. Digital

- Digital
  - Represent only discrete values
  - e.g. 0-10% of the population voted → +0.5v
- Analog
  - Represent any continuous value
  - e.g. 71.3% of the population voted → +0.713v



Digital Logic Gates

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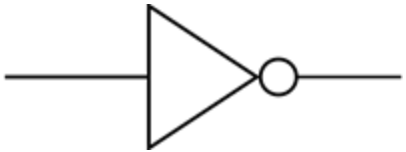
Basic Circuit Diagrams

- Inverter:

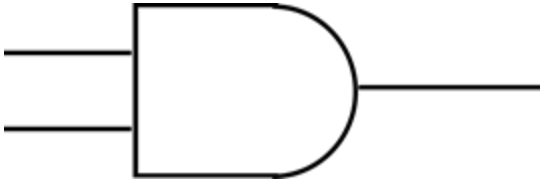


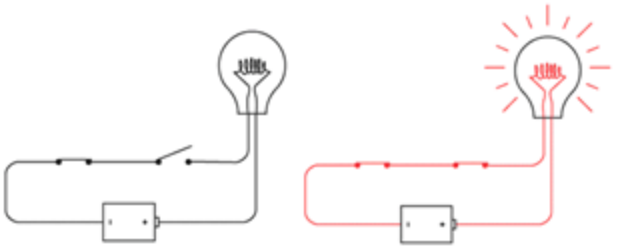
A	***NOT A (A′)***
0	1
1	0

Basic Circuit Diagrams

- AND:

A	***B***	***A AND B (AB)***
0	0	0
0	1	0
1	0	0
1	1	1

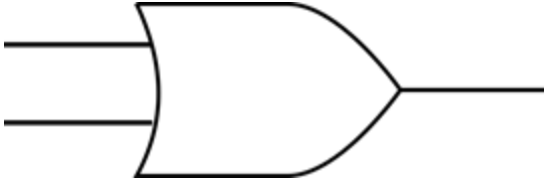


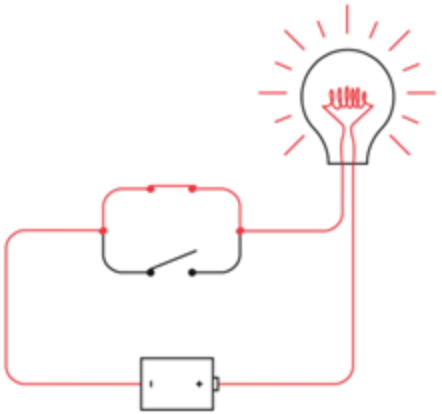


Basic Circuit Diagrams

- OR:

A	***B***	***A OR B (A+B)***
0	0	0
0	1	1
1	0	1
1	1	1

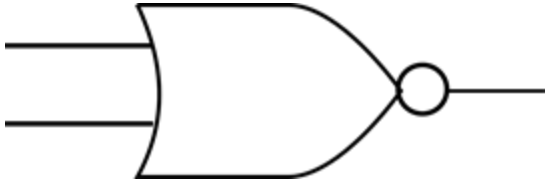




Basic Circuit Diagrams

- NOR:

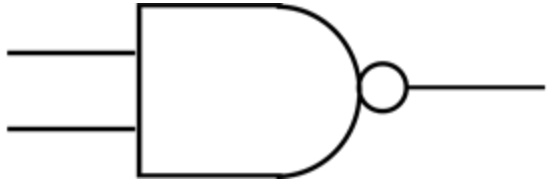
A	***B***	***A NOR B***
0	0	1
0	1	0
1	0	0
1	1	0



Basic Circuit Diagrams

- NAND:

A	***B***	***A NAND B***
0	0	1
0	1	1
1	0	1
1	1	0



Universal Gates

- NAND and NOR are both considered universal gates
  - Any circuit that can be built with AND, OR, and NOT can also be built exclusively with NAND gates (or NOR gates)

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- NOT:

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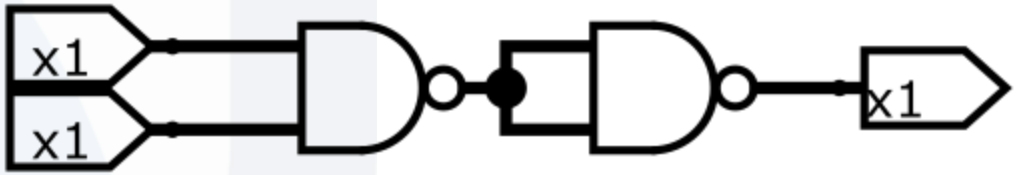

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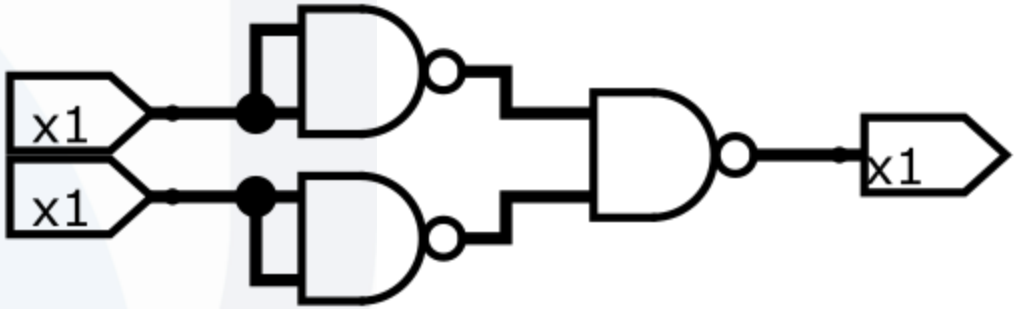

Homework

- Install the following digital circuit design package before our next lecture:
  - LogiSim Evolution - https://github.com/reds-heig/logisim-evolution
  - Instructions are provided on Canvas, under Assignments

Wrap-up

- Basic electronics
  - mechanical → electromechanical → electrical
  - relays → vacuum tubes → transistors
  - basic electronics
  - digital vs. analog
- Basic logic gates

What is next?

- Binary addition
- Half adder
- Full adder
- Ripple carry adder
- Fast carry adder