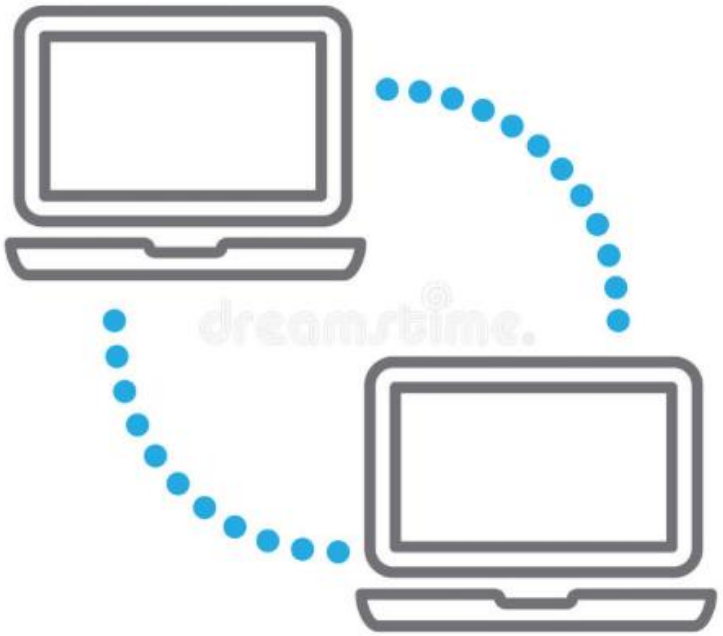
ECE 2060 Lecture 1

Intro to number systems and conversion

THE OHIO STATE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

How do computers communicate?

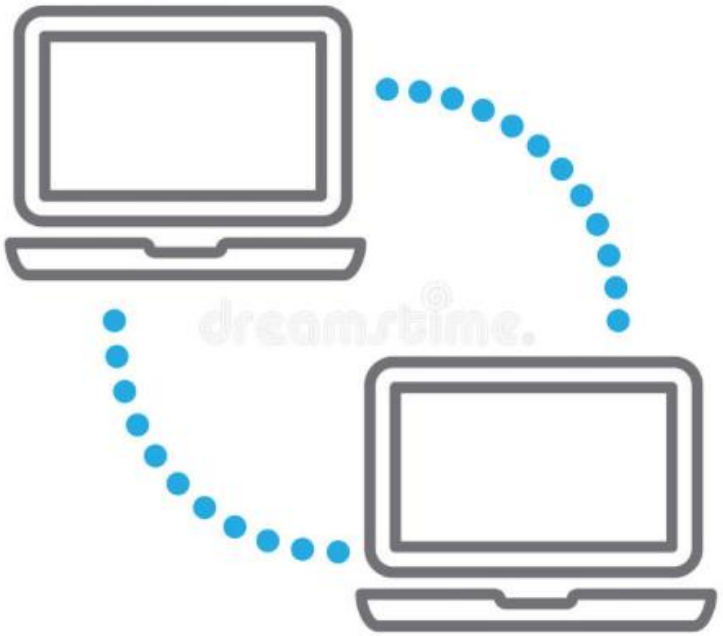
- Wire
- Wi-Fi
- Fiber Optics



https://www.dreamstime.com/

Wire

- A wire is connected between two computers
- Wire carries electricity (voltages, currents)
- Thus information is represented by electricity (we'll consider voltages)



Wi-fi

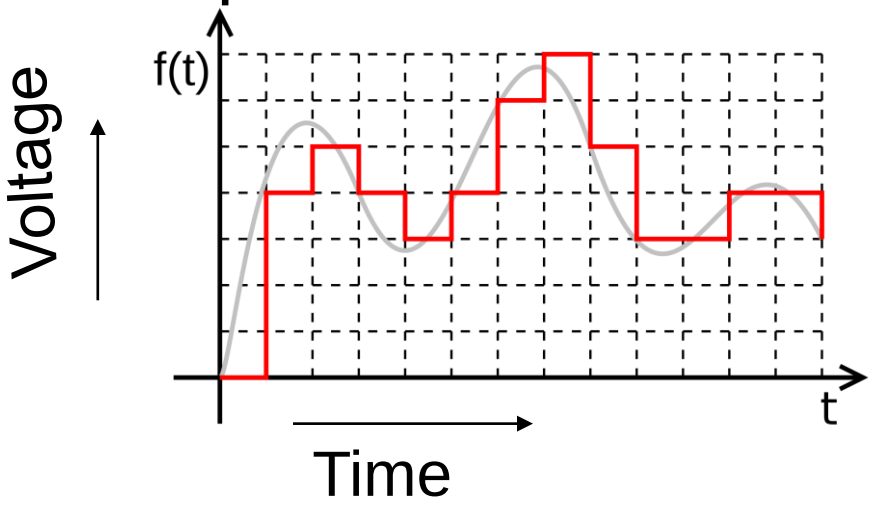
- Computer 1 sends electrical signal representing the information to an antenna by radio wave
- A router receives the radio wave, converts it back into a voltage
  - Uses internal digital circuits to figure out what to do with it
- Router transmits the message to its antenna
- Computer 2 receives the signal on its antenna, converts it back to a (digital) signal

Fiber optics

- Computer 1 converts the electrical signal to an optical signal
- Transmitted via fiber to next computer (or router)
- Receiving device converts light back to electricity
- *Thus all inter-device communication is fundamentally based on electrical signals*

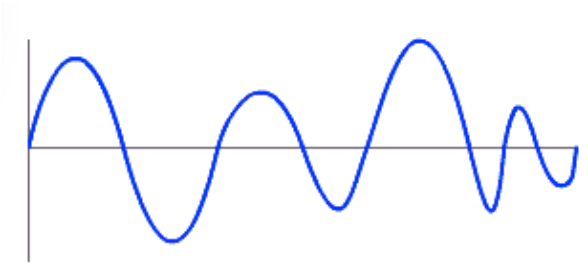
Digital vs Analog

- Digital: Voltage can be one of a fixed number of voltage quantities:



https://www.elprocus.com/differences-between-analog-signal-and-digital-signal/

- Analog: Voltage can be any voltage in a range
  - Say, -10V to 10V



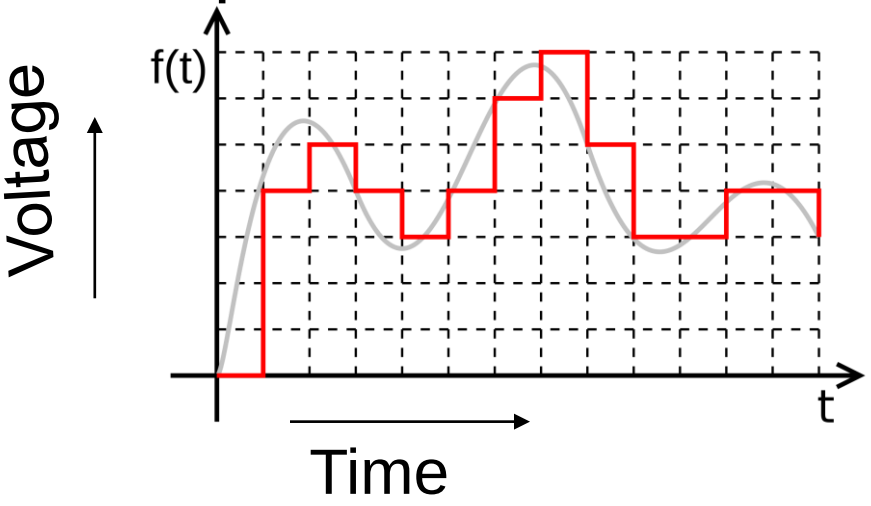
https://www.technologyuk.net/telecommunications/telecom-principles/analogue-signals.shtml

Analog

- The voltage is an “analog” for the information
  - E.g. temperature probe
  - The voltage is proportional to the temperature measured
    - Or some other representation, for example the output could be proportional to the temperature squared- but it contains the information; you can get the temperature from the voltage if you know the representation

Digital

- Digital: Voltage can be one of a fixed number of voltage quantities:



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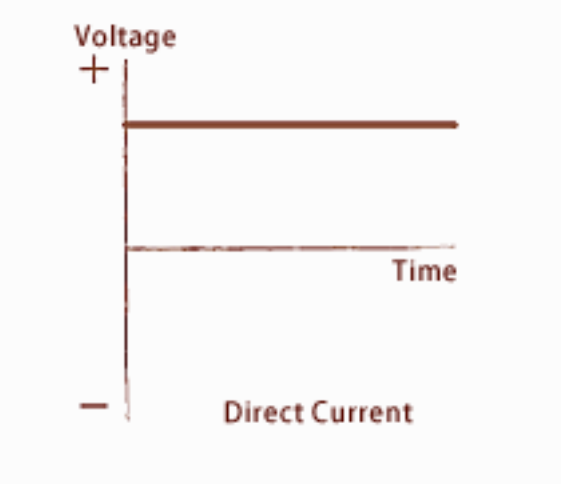
- This one has 8 distinct levels
- In computers, is always 2 levels (binary)

https://www.technologyuk.net/telecommunications/telecom-principles/analogue-signals.shtml

How do you represent a number with electricity?

- Suppose you want to send the number “6”
- In analog system, you could send a voltage of 6 volts
  - Or, if you want to send “600” you could agree that whatever voltage you send, multiply it by 100, then send 6 V

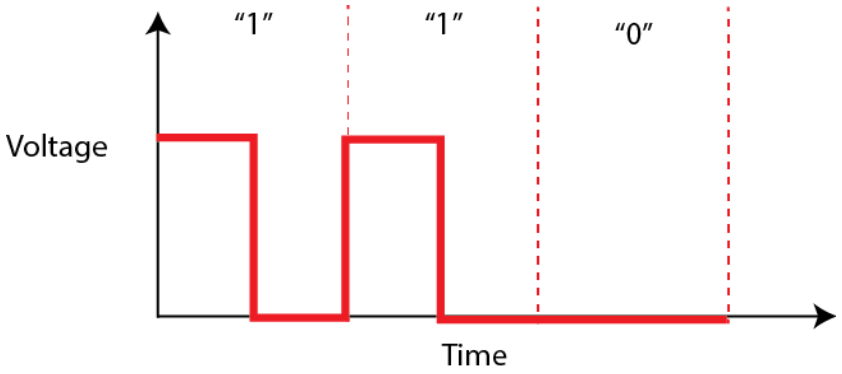


http://footprintz.in/tutorial/electronicles.html

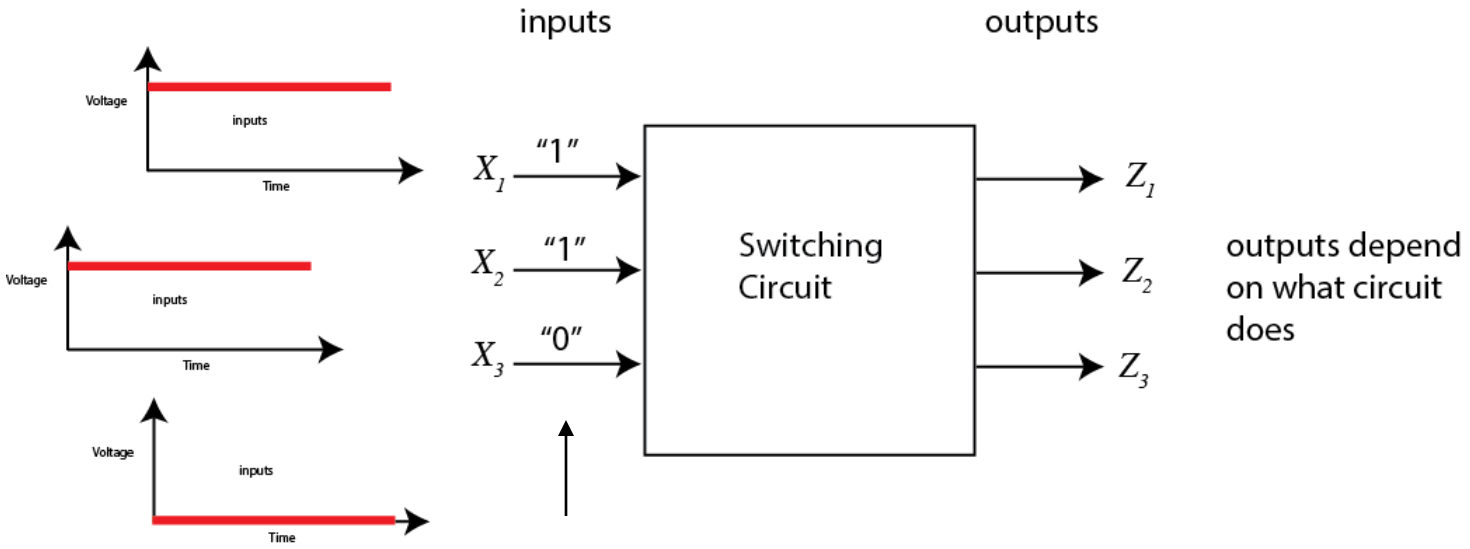
In digital (binary), can only send one of two voltages

- Can send 0V and +5V (for example)
  - Call it “low” and “high”
  - “False” or “true”
  - “No” or “yes”
  - “0” or “1”
- Need to represent “6” as a sequence of voltage values

- Suppose we agree that the sequence “110” means the number “6”
- Could send three pulses



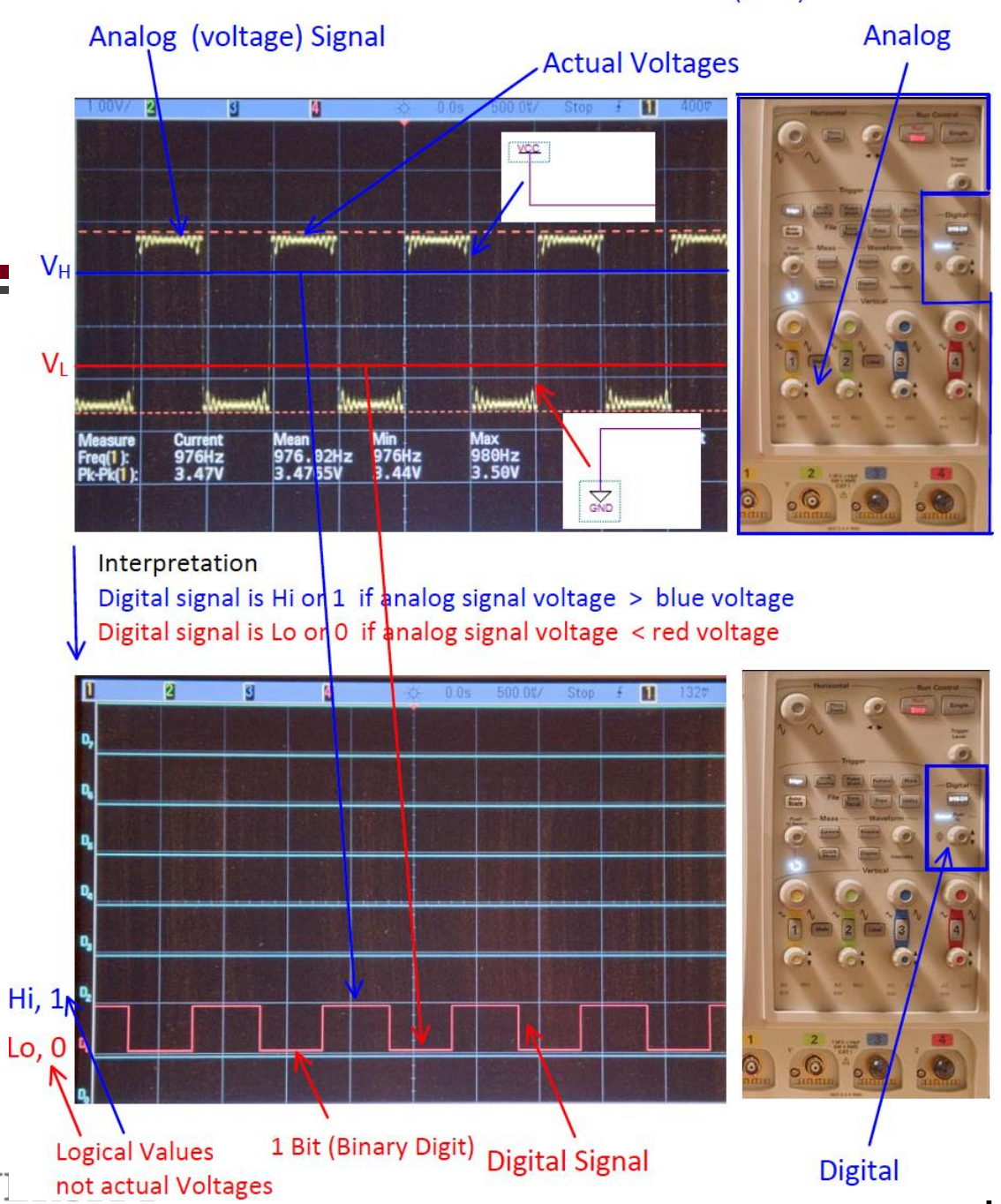
Or you could have parallel wires



Group of lines representing a quantity is called a “bus”

Analog: what you actually send
The voltage is an "analog" to the message you want to send

Digital: for us in this class, the information we want to send

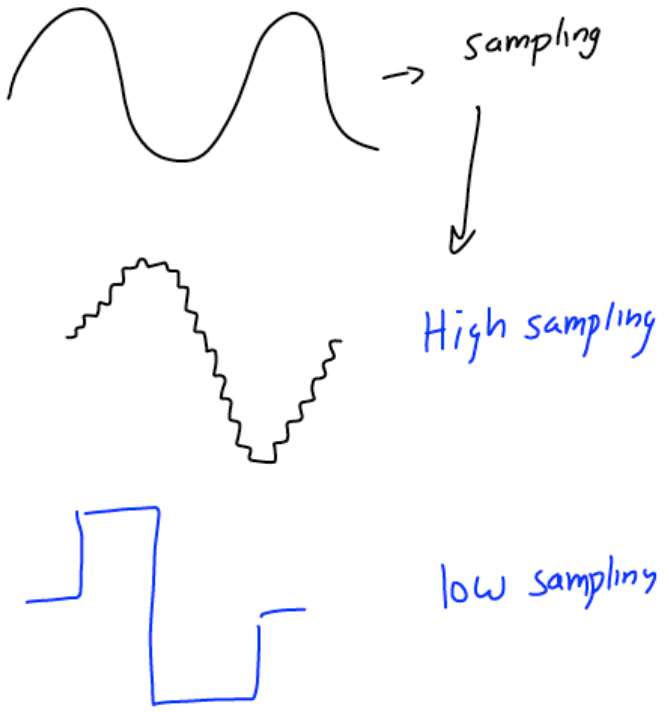


More about analog vs digital

Analog (continuous)

Digital (discrete)

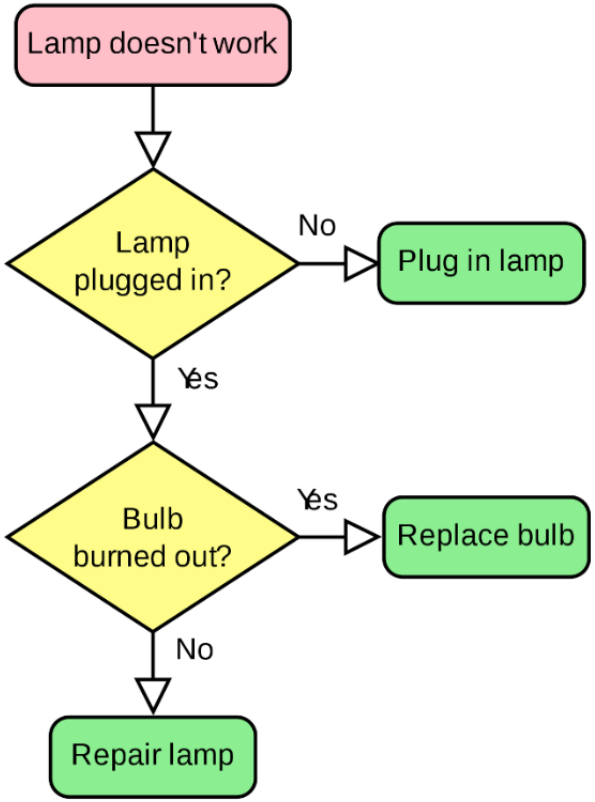
Digital (discrete)



This course

- Digital systems
  - Data processing, controls, communication
- Our systems will be binary
  - Digital systems don’t have to be binary

Digital logic



Digital system design

- System Design
- Logic Design
- Circuit Design

System Design: example microwave controller

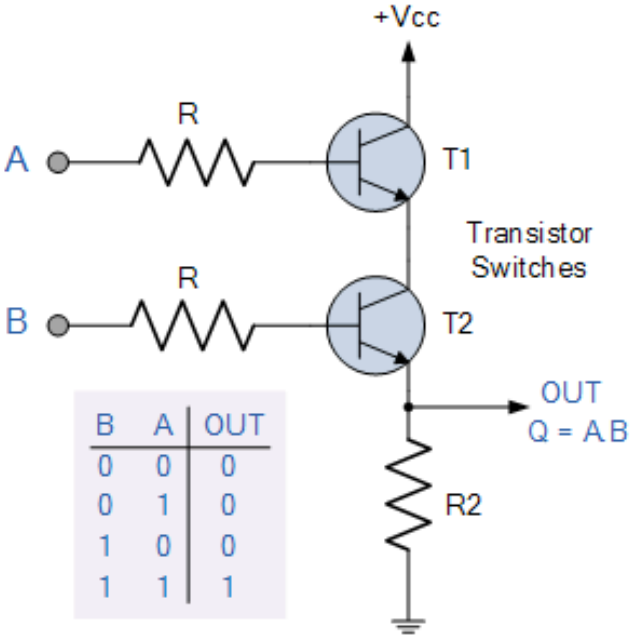
- Break the system down into subsystems
  - Clock
  - Keypad input
  - Control power level
  - Control plate rotation
  - etc

Logic design

- Design of how logic gates and flip-flops are connected to perform a logical function
  - E.g., IF the power level is set AND the time is set AND the door is closed, start the microwaves and start the plate rotating
  - IF the power level is set AND the time is NOT set, display an error message (state of door=don't care)

Circuit Design

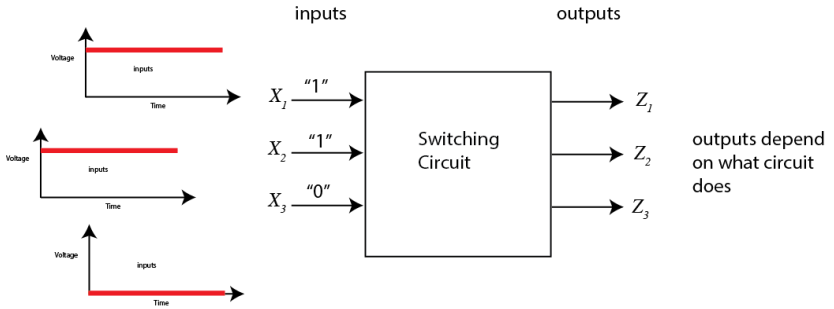
- Transistors, diodes, etc that make up the logic gates and flipflops



https://www.electronics-tutorials.ws/logic/logic_2.html

We will focus on logic design

- We will study switching circuits
  - Combinational: outputs depend only on the current state of the inputs



  - Sequential: outputs depends on current inputs and also previous values
    - Has to have some “memory” to know what has happened before
    - In general is a combinational circuit combined with some memory elements

Combinational Circuits

- For a given problem, start with a table or some equations to describe what we want the circuit to do
  - Given a set of inputs, for each possible combination of states (voltages) at those input, what should the output(s) be?
- Figure out the most efficient way to implement that logic (fewest circuits)
- Then implement using various kinds of circuits (logic gates)

Sequential Circuits

- Basic memory element is a flip-flop
- Second half of course we'll look at these
- We'll create tables or graphs to show what system should do
- Then convert to circuits using flip-flops and logic gates
- Learn Hardware Description Language (VHDL) to simulate digital hardware (you'll do this in the lab)

All of our circuits will be binary

- Inputs and outputs can only assume one of two states: 0 or 1, true or false, high or low, blue or slippery, whatever you want to call them…
- So we need to talk about how to represent numbers/ information with binary signals

Start with number systems and conversion

Section 1.2 coming right up