Introduction to Electronics
L1: Introduction

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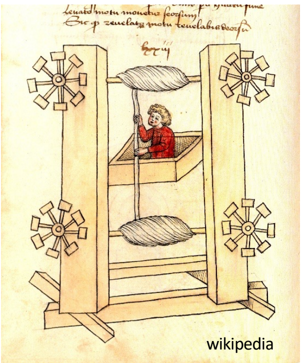
Why Electronics?

- Modern world *has been* and *is being* rapidly transformed by Electronics
- Electronics offers capabilities that can be exploited by almost all engineering branches
- Almost all systems now include an electrical subsystem

Why Electronics

- Every action requires energy



Pre-industrial era

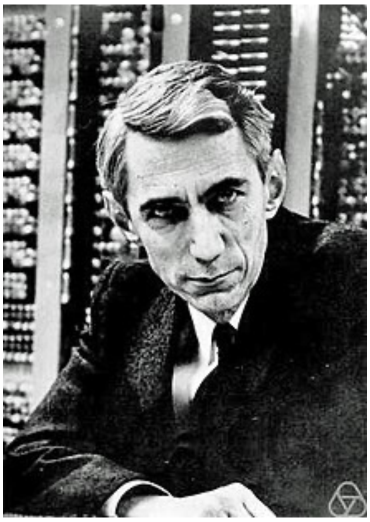
1853

Now!

- Electricity is one of the most useful forms of energy
- It is easy to generate, easy to transport, can be easily converted into other forms of energy

Why Electronics

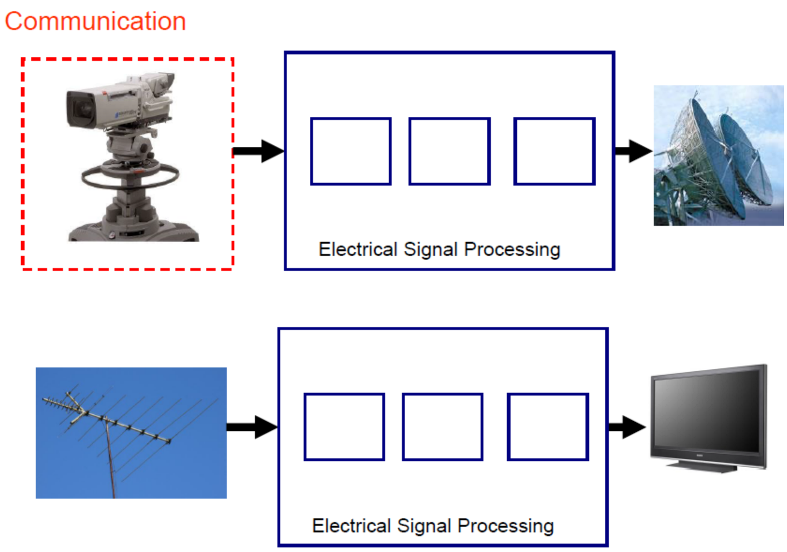
- Functionality and control
- Any functionality/logic can be represented via Boolean algebra
  - Computer programs and data consisting of 0,1s
- Claude Shannon
  - Masters thesis demonstrating that electrical applications of Boolean algebra could construct any logical numerical relationship.
  - Using this property of electrical switches to implement logic is the fundamental concept that underlies all electronic digital computers.
- Examples:
  - Add two numbers
  - Control a robotic arm under some specific conditions (if-else)



Claude Elwood Shannon
Father of Information Theory

Why Electronics

- Electro-magnetic waves: Communications and Imaging



Electrical Engineering

- Electrical Circuits
- Electronics Circuits
- Semiconductor devices
- Signal processing/ Image processing
- Communications
- Networks
- Algorithms, Data Analytics, Learning
- and much more

Relationship of Electrical Engineering with Others

Mechanical
Control for mechanical systems, robotics
Optimization

Computer Sciences
Processor and Interface Circuits (Computer Architecture),ML, Networks,

Math/Statistics
Networks, Graphs, Optimization, Machine learning

Chemical
Nano-machines, Molecular communications,
System dynamics
Instrumentation

Biological Science
Biomedical, Bio-signal processing
Imaging
DNA coding/encryption

Civil
Transportation
Remote sensing

Material Science
Device Characterization
Semiconductors
Electrical properties of materials

Aerospace
Control for devices
System Dynamics
UAVs: Control and Communication

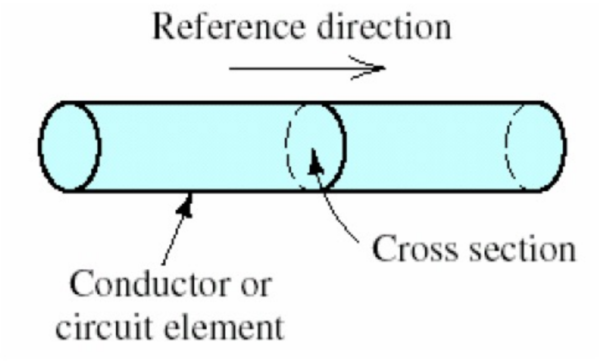
Charge

- Charge is a fundamental property of matter and is said to be conserved
  - Can neither be created nor be destroyed
- Two types of charge
  - Same types attract and opposite types repel
- Charge is designated by symbol q has unit coulombs (C)
- Negative charge carried by a single electron is $\mathbf{-1.602\times10^{-19}}$ C
  - Smallest unit of charge that exists
- Charge is the substance of which electric current is made

Electrical Current

- Current is simply a measure of how much charge is moved per unit of time

– Units are amperes (A), which are equivalent to coulombs per second (*C/s)*

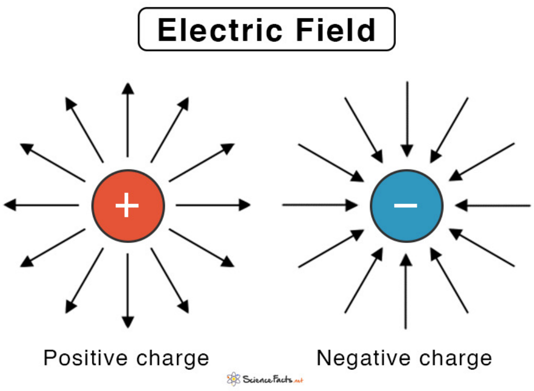


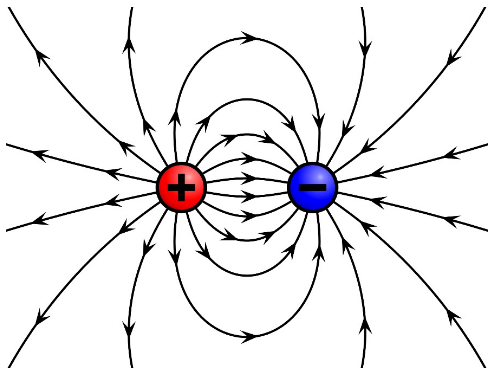
$$i(t) = \frac{dq(t)}{dt}$$

André-Marie Ampère
1775-1836

Electric Field

- Electric field surrounds charges
- Exerts force on charged particles and responsible to move them in its direction: current
- Generates potential difference between two points: Voltage

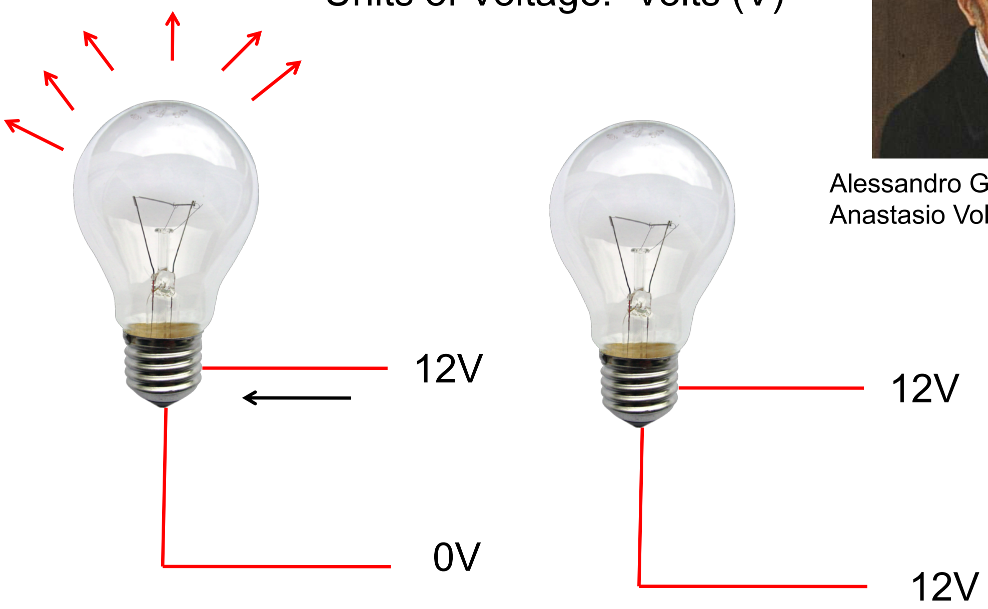




Voltage

Voltage difference acts a source of current flow

Units of Voltage: Volts (V)



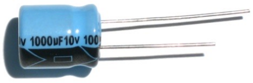
Alessandro Giuseppe Antonio Anastasio Volta 1745-1827

Voltage Sources

Electrical elements

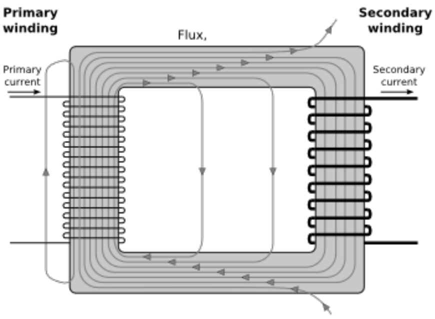
Electrical Systems are made of Voltage sources, wires and a variety of electrical elements

Resistor

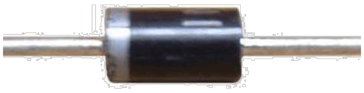


Capacitor

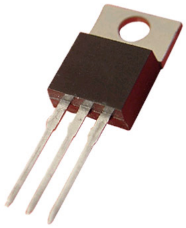
Inductor



Transformer



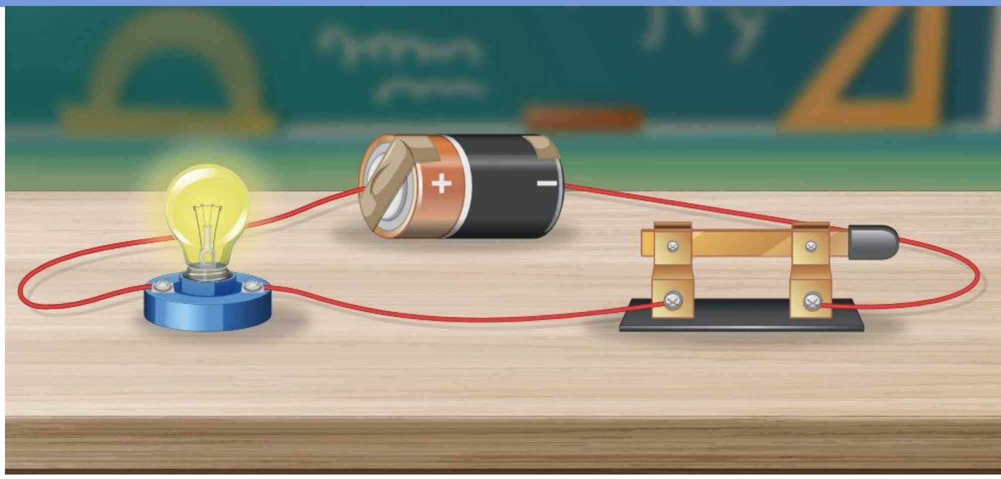
Diode



Transistor

Electrical Circuit

Analyze circuit

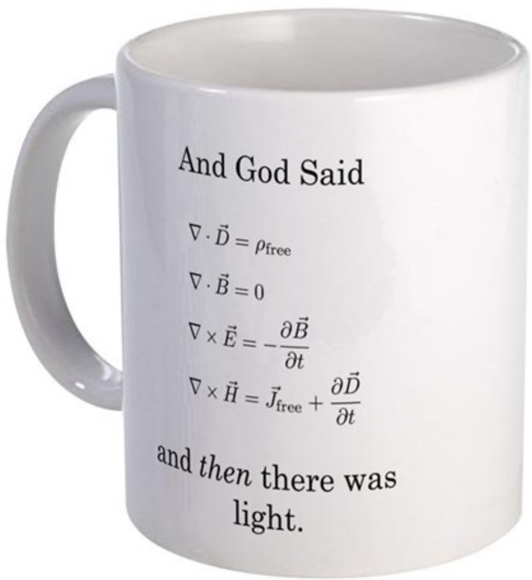


Questions
Compute current given voltage
Compute light intensity generated from bulb

How to solve these questions?

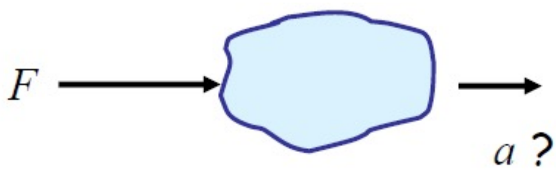
Back to Maxwell's Equations

- Should we write Maxwell's equations everytime
- Gainful employment of Maxwell's equations to build interesting systems
- Create an abstraction layer
  - Avoid dealing with Maxwell's eq



Abstraction

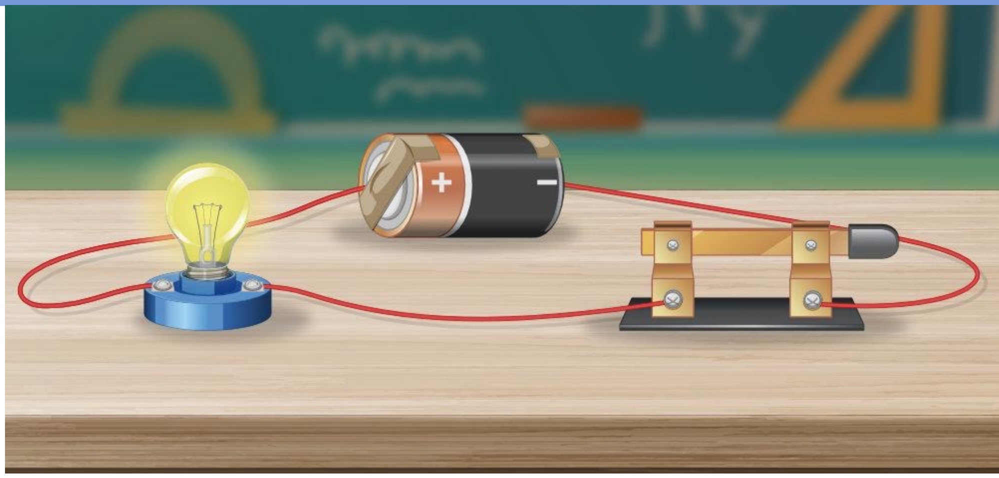
- Example: point mass abstraction



- What is the acceleration? $a = F/m$
- Ignoring the object's shape, rigidity, temperature
- Point-mass discretization or *lumping*
- Useful at all levels

Electrical Circuit

Analyze circuit



Questions

Compute current given voltage

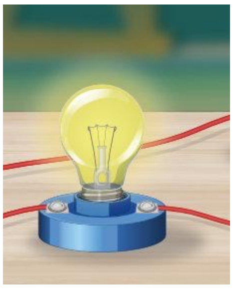
Compute light intensity generated from bulb

How to solve these questions?

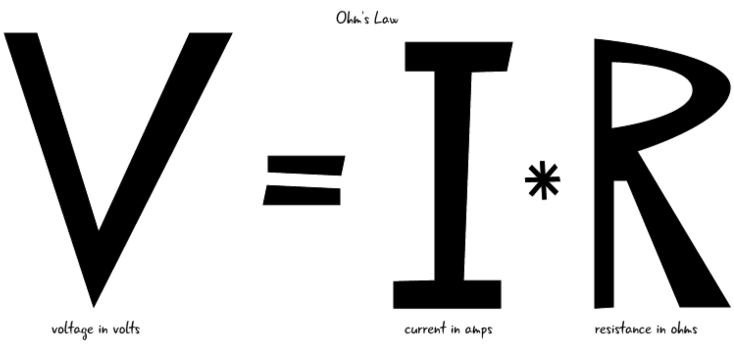
Need to understand each element's behavior? Characterization

Lumped Circuit Abstraction

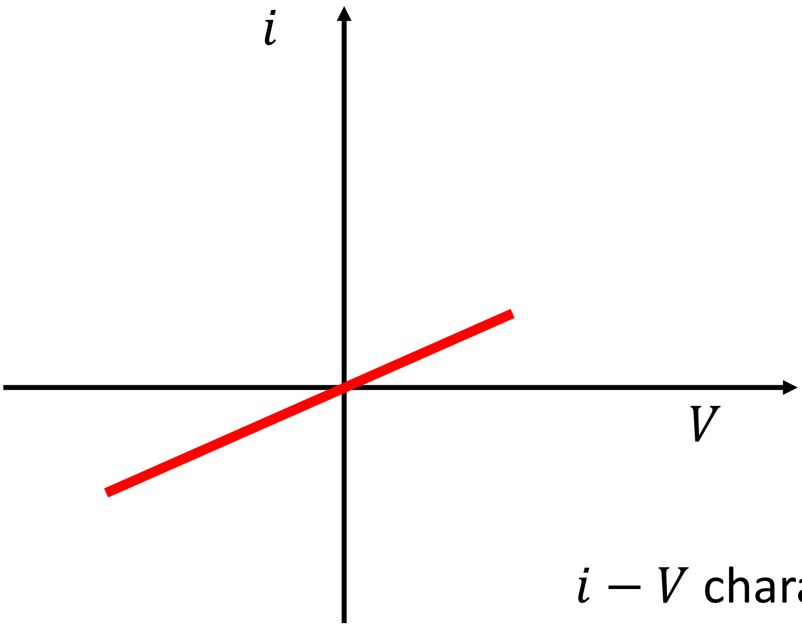
1. $\nabla \cdot \mathbf{D} = \rho_V$
2. $\nabla \cdot \mathbf{B} = 0$
3. $\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$
4. $\nabla \times \mathbf{H} = \dfrac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$



V	I
3	1
6	2
9	3
12	4



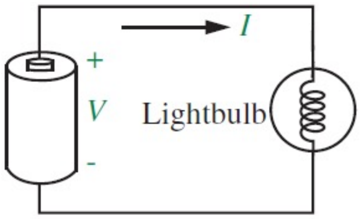
Bulb's behavior

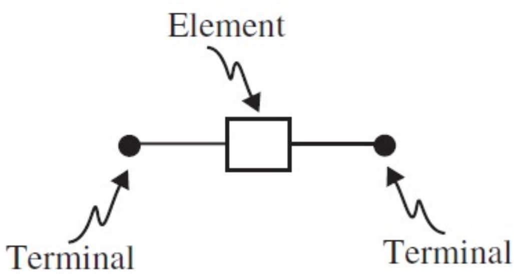


$i - V$ characteristics

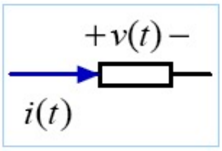
Lumped circuit abstraction

- Ignore:
  - Temperature
  - Orientation
  - How current flows inside the filament





Resistor



$$v(t) = R \times i(t)$$

Ohm's law

The constant, *R, is called the resistance of the component and is* measured in units of Ohm (Ω)

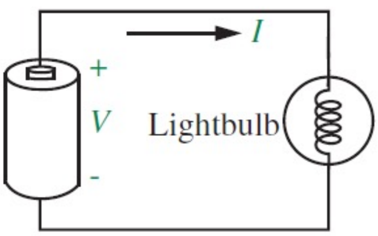
Standard Multiples of Ohm

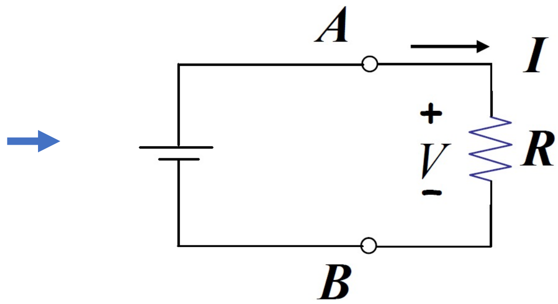
$M\Omega$	Mega Ohm ($10^6\,\Omega$)
$k\Omega$	Kilo Ohm ($10^3\,\Omega$)

Georg Simon Ohm
1789-1854

Resistor Symbol: 

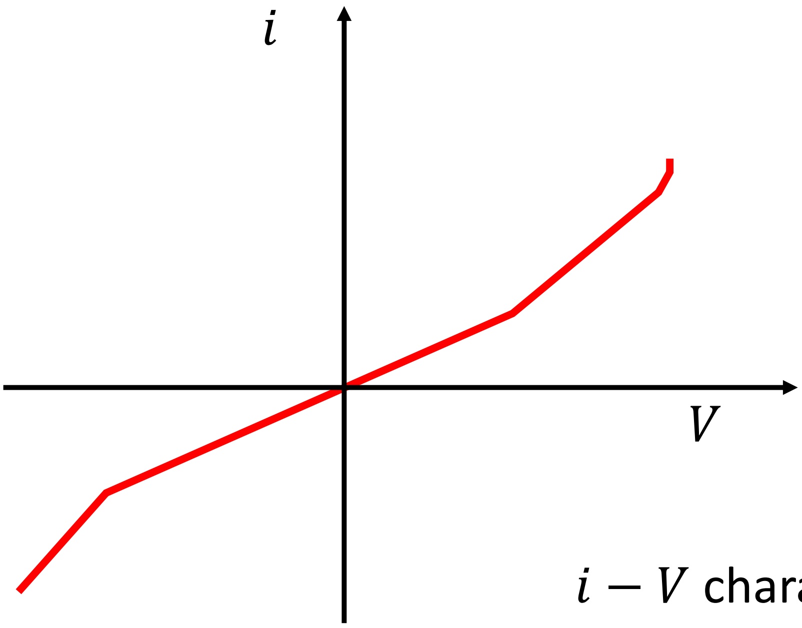
The easy way





- For the purpose of calculating the current, R is enough!
- R is a lumped element abstraction for the bulb
- $$I = \frac{V}{R}$$

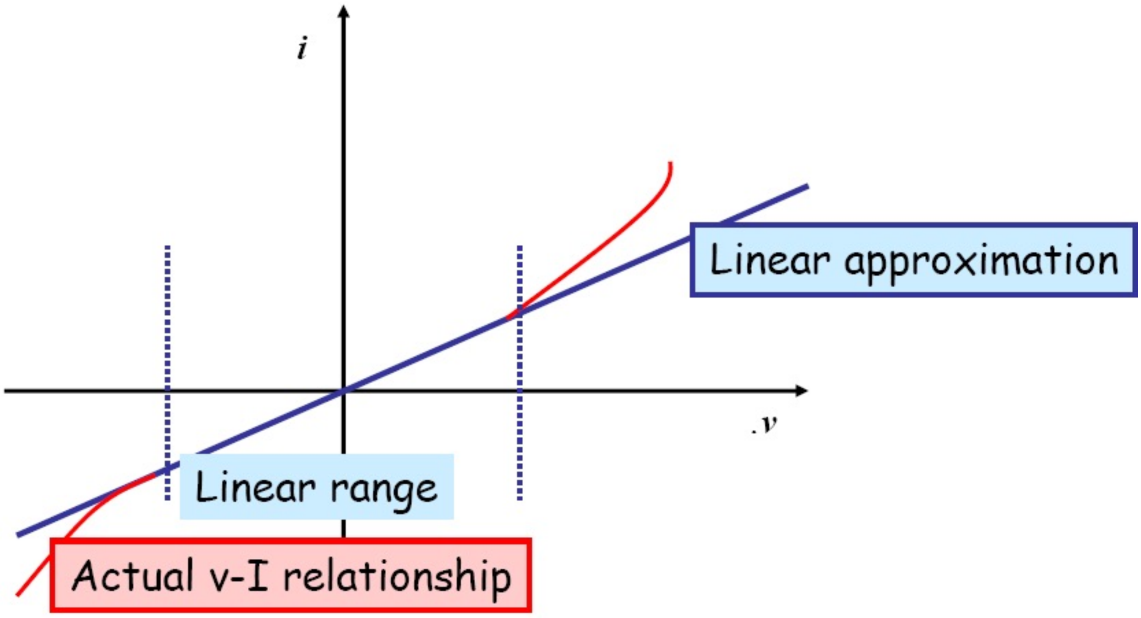
Bulb's behavior



$i - V$ characteristics

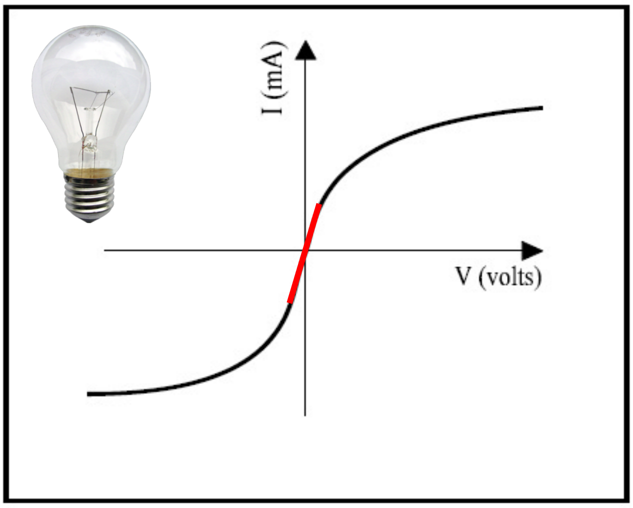
Bulb's behavior

Any electrical element which obeys ohms law can be modeled as a resistor



Can we model an electric bulb as a resistor?

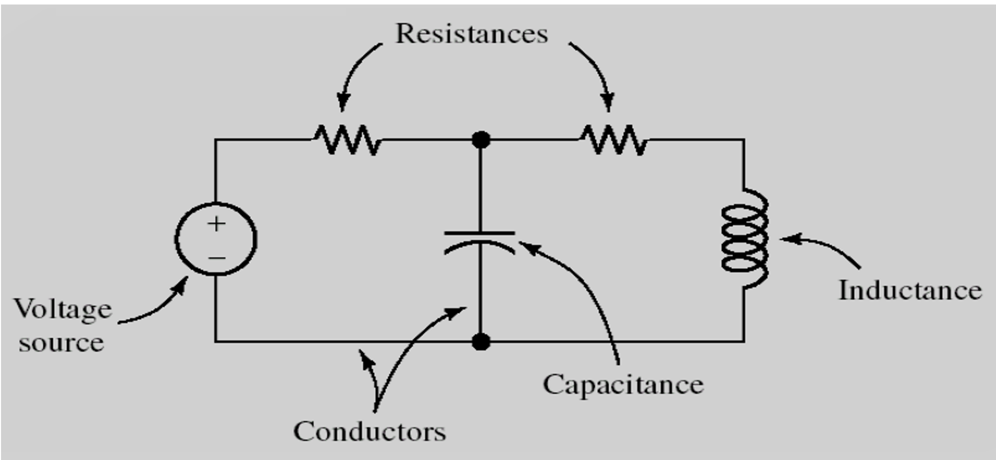
Bulb's behavior



Even though characteristics are non-linear, over a certain range, the bulb can be thought of as a resistor

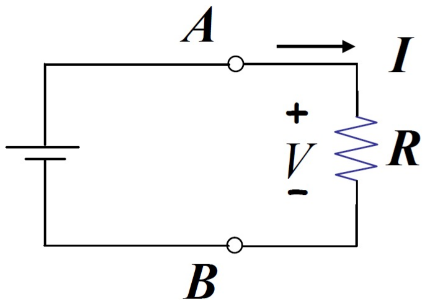
Lumped Circuit Abstractions

Connection of several circuit elements in closed paths by conductors



Before we learn how to analyze and design circuits, we must become familiar with some basic circuit elements.

The easy way

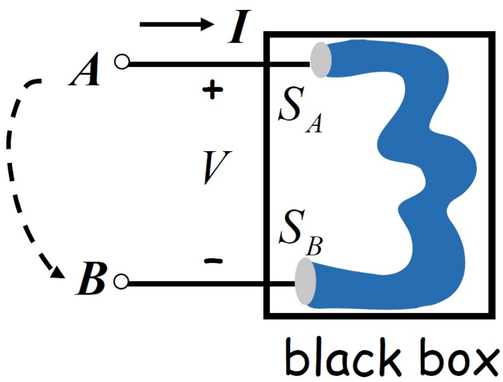


$$I = \frac{V}{R}$$

- For the purpose of calculating the current, R is enough!
- R is a lumped element abstraction for the bulb

- Q: Is it reasonable?
- We need to understand what is going on behind the scenes

Is it reasonable?



$\boxed{V}$ $\boxed{I}$

must be defined for the element

- Current in = current out $\frac{\partial q}{\partial t} = 0$

- Voltage across A and B should be unique $\frac{\partial \phi_B}{\partial t} = 0$

"Maxwell's equations and the lumped matter discipline" in Agarwal, Anant, and Jeffrey H. Lang. *Foundations of Analog and Digital Electronic Circuits*. San Mateo, CA: Morgan Kaufmann Publishers, Elsevier, July 2005. ISBN: 9781558607354.

Caution

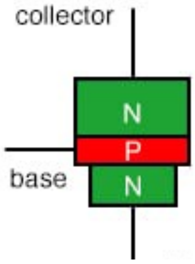
- The abstraction $V = IR$ is valid under certain constraints
  - E.g., V, I, R must be defined for the element (bulb)
- What if they are not?
  - Open the abstraction and go to details at the lower level

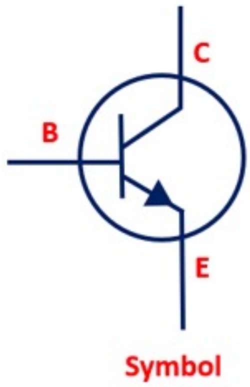
Abstraction

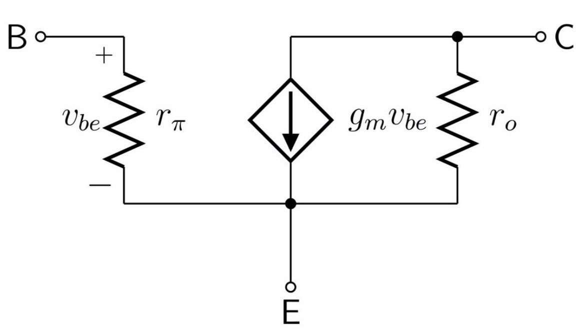
- Layers of abstraction
- Useful at all levels

Transistor Level

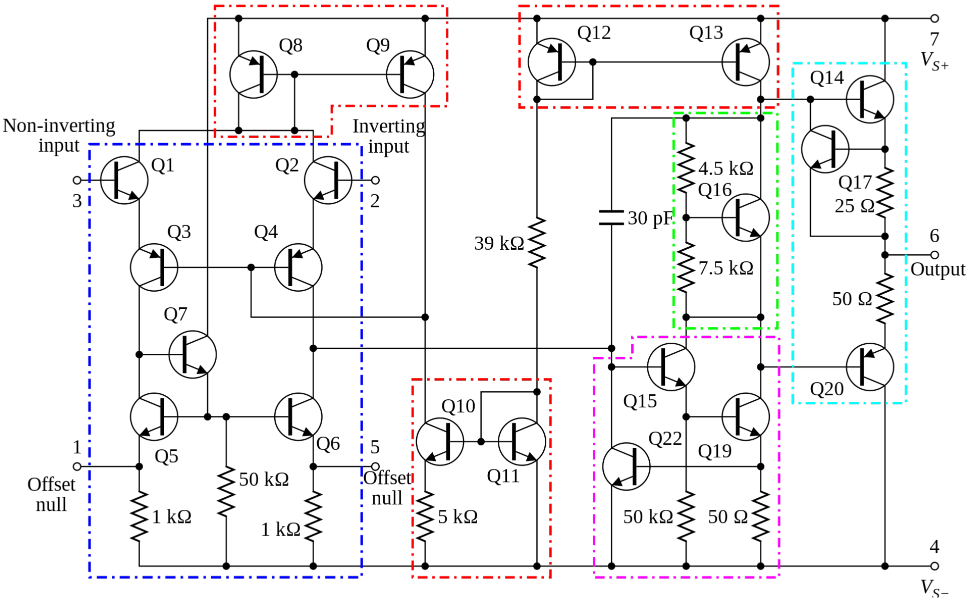
- Semiconductor transistor

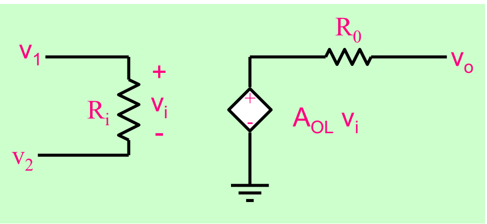


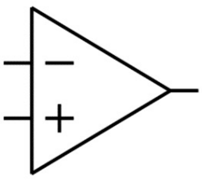




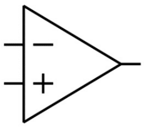
OpAmp

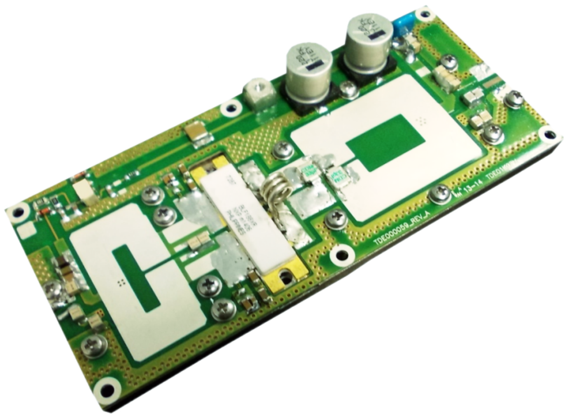


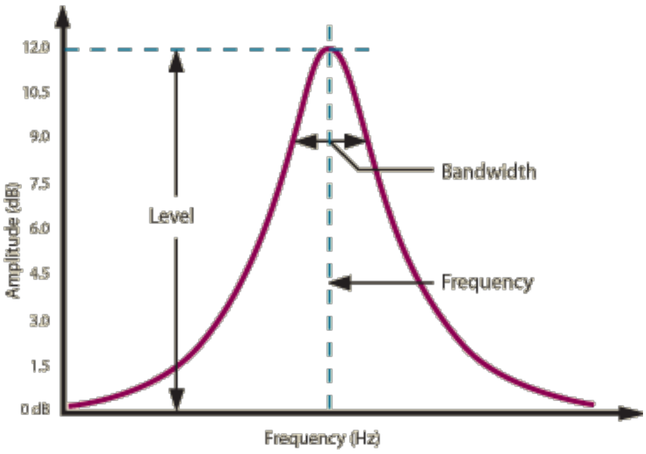




OpAmp Abstraction



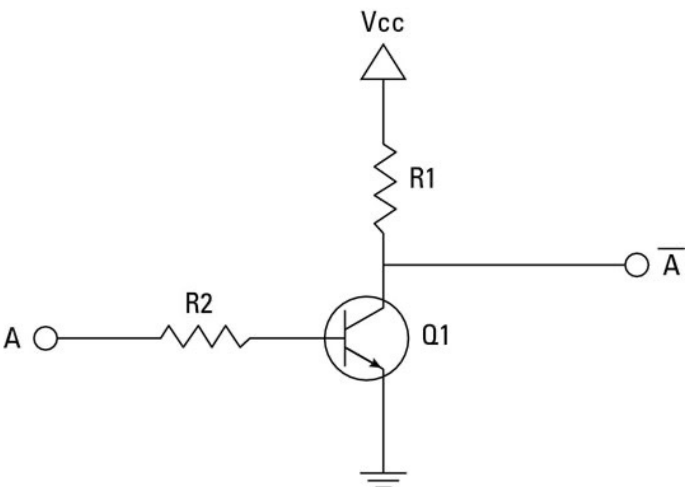


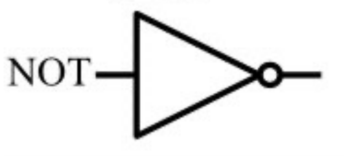


Power supplies
Oscillators
Modulators
RF Amplifiers

Gate Level

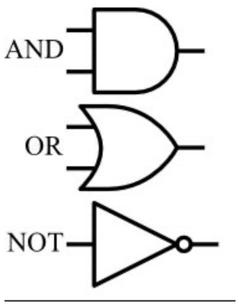
- Transistors form logical gates

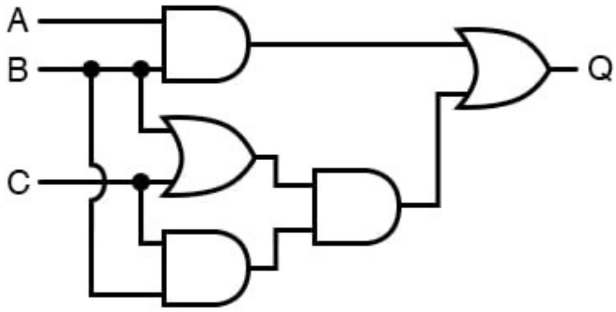




I	O
T	F
F	T

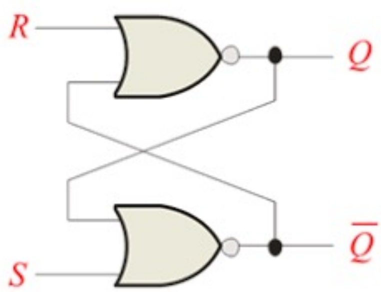
Digital Abstraction





I1	I2	O
T	T	F
T	F	T
F	T	F
F	F	T

Digital Abstraction



registers
- memory

Register transfer level (RTL)

```
at clock-edge
    change    Q by R
    Increase D by 1
```

Instruction Sets
X86, Pentium, MIPS

Software systems
OS, Browser

Schedule

- Class
  - Monday, Wednesday, Friday – 8-9 am
- Tutorial
  - Thursday 8-9 am
  - No tutorial first week
- Lab
  - One Lab session each week out of five days. 2-5 pm
  - No Lab first week

The Instructor

- Course Instructor:
  - Prof. Abhishek Gupta
  - Email: gkrabhi@iitk.ac.in
  - Assistant professor, Electrical Engineering
  - Research areas:

    Wireless communications

    5G and Beyond

    Probability theory

Lab Instructor

- Lab Coordination
  - Prof. K.S. Venkatesh venkats@iitk.ac.in

Sections: Section Tutors

Course Objective

- The course offers an introduction to the basic principles of electrical circuit analysis and exposes students to electronic devices and analog and digital electronic circuits
- To provide a panoramic view of the mutual relevance and dependence between other branches of engineering and sciences with concepts encountered in electronics
- Mathematical modeling methods useful across disciplines

Course Content

Circuits	– Circuit Analysis (Nodal, Mesh, Superposition, Thevenin's and Norton's Theorem) – Elements with memory- inductors/capacitors – Transient analysis and sinusoidal steady state analysis circuits – Transfer function and frequency response
Diodes/Transistors	– Non-linear circuits- Diode/transistors/BJT - Semi-conductor evolution – Circuit analysis- Large/small scale signals – Applications- Rectifiers/amplifiers – Opamps (Operational amplifier) circuits
Digital Circuits	– Logic gates, logic minimization – Combinational circuits – Sequential circuits, Flip flops, Counters, shift registers – Data convertors (ADC, DAC)

Additional Side-objectives

- Learn tools which are applicable to other engineering applications
  - Linear systems
    - Most of engineering systems. How to make them linear.
  - Transfer function and frequency domain analysis
    - Applicable to any linear system e.g. robotics, chemical systems
  - Abstraction

References

- Most of these books are available online as well as in the Library (check both circulation and reference sections). You may use whichever book you prefer.
  - Foundations of Analog and Digital Electronic Circuits by Agarwal, Lang, Elsevier
  - Engineering Circuit Analysis by W. Hayt, J. E. Kemmerly and S. M. Durbin, TATA McGraw Hill
  - Electronic Devices and Circuit Theory by R. Boylestad and L. Nashelsky, Prentice Hall of India
  - Microelectronics Circuits, by Sedra/Smith, 5th edition, Oxford University Press
  - Digital Design by Mano, Ciletti, 4th edition, Pearson
  - Digital Principles and Applications, by Leach, Malvino, 5th edition, Tata McGraw Hilll
  - Essential of Electrical and Computer Engineering, Kerns and Irvin, Pearson, Prentice Hall, 2004.

Tutorial Plan

- Tutorials are for clarifying any doubts regarding lectures and assignments
- Homework Assignment sheets will be given every week
- For proper learning it is expected that you would attempt to solve all the problems prior to tutorial
- You are not required to submit homework solutions
- Solutions to homework assignments will be discussed in tutorials
- A Mini-Quiz in the starting of every tutorial

Grading Scheme

• Lab component	15%
• Mini-Quizzes	15%
• 2 Major Quizzes (Dates 31 Aug, 2 Nov)	20%
• Midsem Exam	20%
• Final Exam	30%

Attendance policies
Attending classes strongly recommended
Missing more than 25 lectures → automatic drop/F
First week is not included

Academic honesty policy
Any cheating/academic dishonesty: automatic F

Policy regarding missed exams/labs:

- If you miss an examination due to approved medical leave or you have your leave approved by the competent authority at IIT Kanpur, following policy will be applied.

1. *Missed Quiz-1/Quiz-II/Mid-semester examination*: No make up examination.
2. Missed Endsem: You will be allowed to sit in a make-up examination if approved by DoAA. It is your responsibility to apply to DoAA for it.
3. Missed Laboratory sessions: You will be allowed to complete the experiment in the designated make-up laboratory sessions. However, if you do not appear in the makeup laboratory sessions, you will be awarded zero marks for that experiment.
4. Missed tutorial 10 minutes mini-quiz: No make-up examination will be allowed for missed tutorial quiz. (Best n-1 out of n quizzes)

Acknowledgements

- Prof. Baquer Mazhari,
- Prof. A. R. Harish
- Prof. S.S.K. Iyer
- Prof. Yogesh S Chauhan
- Prof. Adrish Banerjee
- Prof. K. V. Srivastava
- Prof. Pradeep Kumar
- Prof. Shilpi Gupta
- Prof. Ketan Rajawat
- Prof. Vipul Arora