ECE113: Basic Electronics

Lecture 1: Introductory remarks, Course information and assessments

Dr. Ram Krishna Ghosh, Assistant Professor

Office: B601, Research and Development Block

Email: rkghosh@iiitd.ac.in

INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY
DELHI

About the instructor

- **Name**: Ram Krishna Ghosh
- **Designation**: Assistant Professor
- **PhD** : Indian Institute of Science, Bangalore
- **Masters:** IIT Madras
- **Research Interest**: Computational nanoelectronics, spintronics, quantum transport simulation, device modeling, materials modeling, and multiscale modeling
- **Website**: https://www.iiitd.ac.in/rkghosh
- **Courses**:
  - Quantum Materials and Devices (Monsoon)
  - Basic Electronics (Winter), for B.Tech 1st yr. students

Teaching staffs

Teachers:

Sudhanshu S Jamuar Section A

Ram Krishna Ghosh Section B

Teaching Fellow:

Sana Ali Naqvi <sana@iiitd.ac.in>,
Khagendra Joshi <khagendra@iiitd.ac.in>

Teaching Assistants (for section A):

Justin Alex	justin21192@iiitd.ac.in
Gaurav Srivastav	gaurav21154@iiitd.ac.in
Abhinav Bajoria	abhinav21183@iiitd.ac.in
Prapti Makkar	prapti21202@iiitd.ac.in
AAKASH GUPTA	aakash21150@iiitd.ac.in
Akash Saxena	akash21185@iiitd.ac.in
Shivam Sharma	shivam21208@iiitd.ac.in

More TAs will join soon…

Teaching Assistants (section B):

Teaching Assistants:

Tarun Aggarwal	tarun21213@iiitd.ac.in
Swarnima Rawat	swarnima21176@iiitd.ac.in
Prince Kumar Rauniyar	prince21203@iiitd.ac.in
Lakshay Kumar Shringey	lakshay21195@iiitd.ac.in
Rohit Mate	rohit21155@iiitd.ac.in
Neeraj	neeraj21156@iiitd.ac.in
Sudhanshu Trivedi	sudhanshu21212@iiitd.ac.in
Shivendra Singh	shivendra21209@iiitd.ac.in
Ekta Tiwari	ekta21152@iiitd.ac.in

More TAs will join soon…

Course Outline

- Basic components of Electrical Circuits: Fundamental Electrical variables – charge, current, voltage and power; independent and dependent voltage and current sources, Ideal circuit elements – Resistor, Capacitor and Inductor. Constitutional relationship – Ohms Law;

- Basic concepts of Analysis of Resistive Networks: Nodes, Paths and Loops, Kirchoff's Voltage and Current Laws, Series and Parallel connection of Resistances and division voltage and current. Loop and Node Analysis.

- Network Theorems: Thevenin's Theorem, Norton's Theorem

Course Outline

- Superposition Theorem and Maximum Power Transfer Theorem.
- RC and RL circuits' response to Step and Direct input
- RLC circuits' response to Step and Direct input
- Concepts of impedance/admittance, Phasors and Representation
- RC, RL and RLC circuits' response to Alternating inputs (the response to alternating input will be handled only under steady state condition)

Course Outline

- Passive and Active Components: Operational Amplifier – Inverting configuration
- Operational Amplifier – Non-Inverting, Integrating and Differentiating configuration
- Diodes: Basic principle, Clipper, Clamper circuits and application
- LED, Zener Diode and Solar Cell
- Half Wave and Full Wave Rectifiers – Wave form and Ripple & its reduction.

Text books:

- William H. Hayt Jr., Jack E. Kemmerly and Steven M. Durbin, *Engineering Circuit analysis*. 8th Edition, Tata McGraw Hill
- Sedra, A. S. and Smith, K. C., *Microelectronic circuits*. 6th Edition, Oxford University Press

There are many text for Principles of Electrical Engineering.

Assessment

• Assignments	15%
• Class tests	15%
• Laboratory	20%
• Mid Semester	20%
• End Semester	30%

Course communication

- All the announcements, assignments, lectures, lab materials will be shared through **google classroom**.
- No separate commutations shall be done using email, unless necessary.
- Consult course site at **google classroom** regularly

How to Join ECE113- Basic Electronics Section B in google classroom

- Log on to **google classroom** using your IIITD credentials
- Click on the + sign at the top right corner
- Select join class
- Link: https://classroom.google.com/u/2/c/NDg1MDUxMTY4MjA1
- Enter this class code: **iqfn3vt**

Time table

Class: Monday 10 am – 11 am; Wednesday 12 pm – 1 pm, and Thursday 11 am -12 pm
Lab: Thursday 2 pm – 4 pm

B.Tech 1st Year(CSAM+CSSS+CSAI+ECE) -Section B- Winter Semester(AY2021-22)																		
Day	9.00-9.30	9.30-10	10-10.30	10.30-11	11-11.30	11.30-12	12-12.30	12.30-1	1-1.30	1.30-2	2-2.30	2.30-3	3-3.30	3.30-4	4-4.30	4.30-5	5-5.30	5.30-6
Mon			BE C201		CTRSS C21		ISA C21 IIS C201					DSA C201						
Tue	Tut P&S C02, C03, C13, C22, C24 C208, C209, C210, C211, C212, C213, C214				P&S C201		CO C201				Lab DSA - All Groups				DIPP C01 MB C11 NN C21			
Wed		IIS C201	CTRSS C21		P&S C201		ISA C21 BE C201			LUNCH	Lab BE	Tut ISA C212, C213, C214 Lab IIS			Seminar			
Thurs	Tut CO C02, C03, C13, C22, C24 C208, C209, C210, C211, C212, C213, C214				CTRSS C21 BE C201		CO C201					DSA C201			DIPP C01 MB C11 NN C21			
Fri		Tut BE C02, C03, C13, C22, C24 C208, C209, C210, C211			P&S C201							Tut DSA- All groups C02, C03, C13, C22, C24 C208, C209, C210, C211, C212, C213, C214						
Day	9.00-9.30	9.30-10	10-10.30	10.30-11	11-11.30	11.30-12	12-12.30	12.30-1	1-1.30	1.30-2	2-2.30	2.30-3	3-3.30	3.30-4	4-4.30	4.30-5	5-5.30	5.30-6

Duration of the Lectures will be 50 mins and 80 mins

Lab

- Location: We will have offline laboratory Session
- Lab materials will be provided through google classroom
- From next week onward: **prepare for the lab beforehand**

Ground rules

- Be on time
- Bring your own calculator
- Keep mobile phone in silence mode and inside your bag
- Do not contain a discussion among your peers,
- let the rest of the class know what are your concerns (may be some other students have similar concerns too!)
- IIIT Delhi plagiarism policy will be strictly followed in this class

IIITD plagiarism policy

	Misconduct/use of unfair means in assignments/projects	Penalty
1.	First misconduct/use of unfair means during the entire stay in IIIT-Delhi	Zero in the assignment (awarded by faculty) + one letter grade less in the course.
2.	Second misconduct/use of unfair means during entire stay in IIIT-Delhi	Student is assigned an F grade in the course.
3.	Third or further misconduct/use of unfair means during the entire stay in IIIT-Delhi	Student is assigned an F grade in the course and the case is reported to DAC, who may suspend the student for 1 semester to a year.

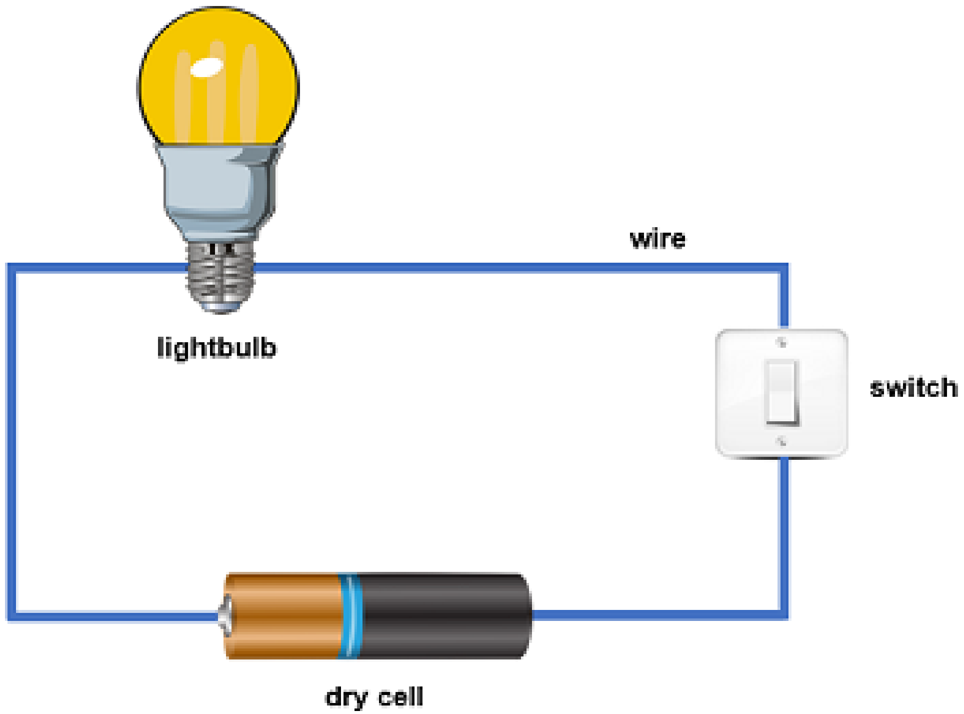
https://www.iiitd.ac.in/sites/default/files/docs/education/2017/Plagiarism%20Policy%20-%20Updated.pdf

IIITD plagiarism policy

	Misconduct/use of unfair means in quiz/midsem/endsem	Penalty
1.	First misconduct/use of unfair means during the entire stay in IIIT-Delhi	Student is assigned an F grade in the course.
2.	Second misconduct/use of unfair means during the entire stay in IIIT-Delhi	Student is assigned an F grade in the course and student may be suspended from the program for 1-2 semesters by DAC.
3.	Third misconduct/use of unfair means during the entire stay in IIIT-Delhi	Student is assigned an F grade in the course and student's program may be terminated by DAC.

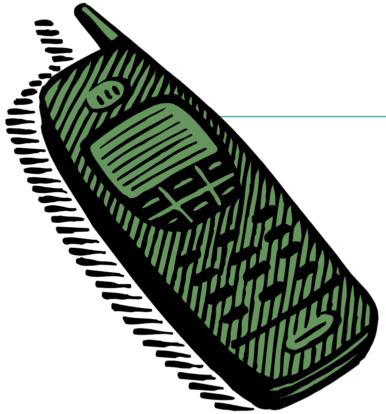
https://www.iiitd.ac.in/sites/default/files/docs/education/2017/Plagiarism%20Policy%20-%20Updated.pdf

Electronics

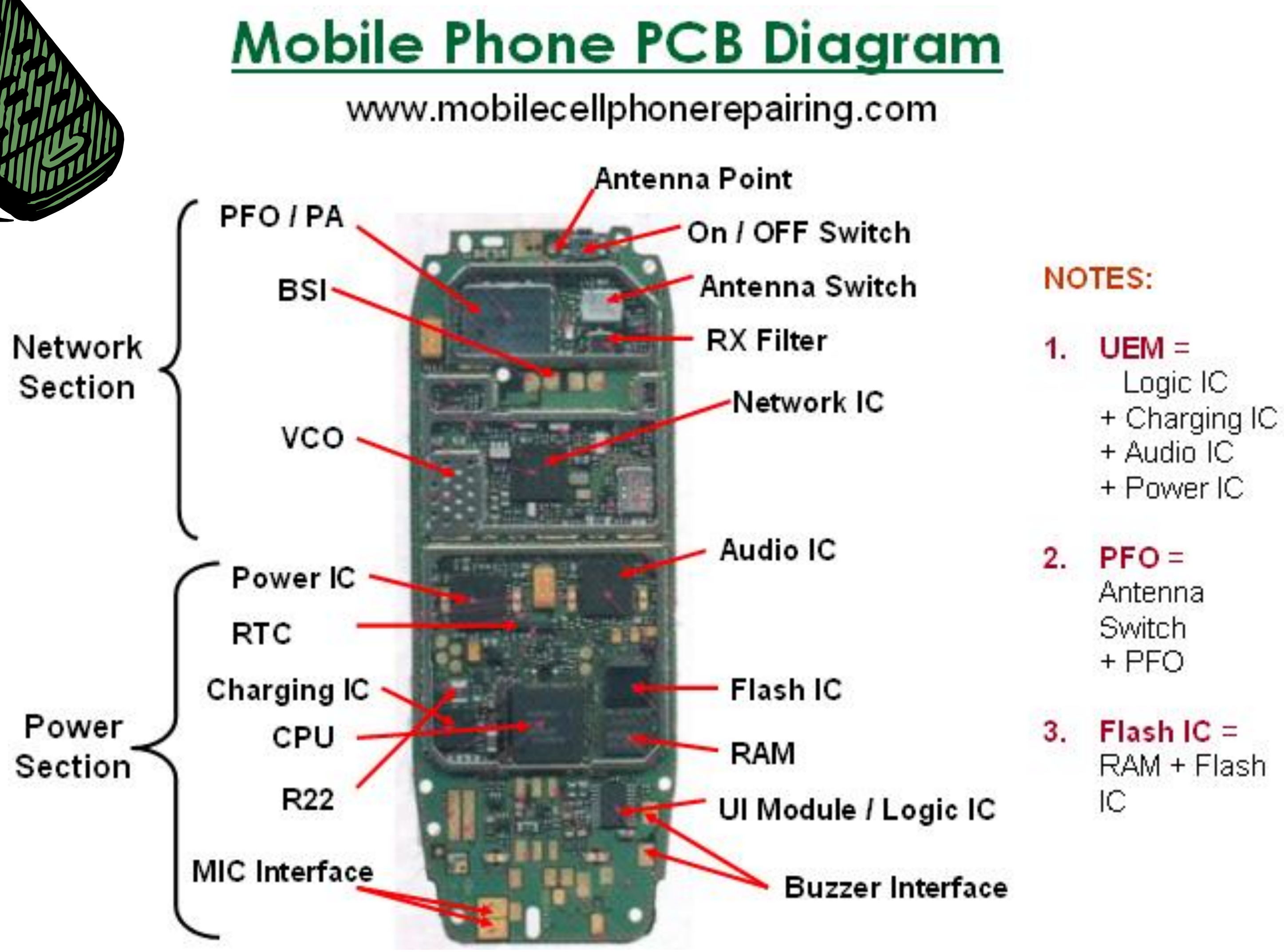


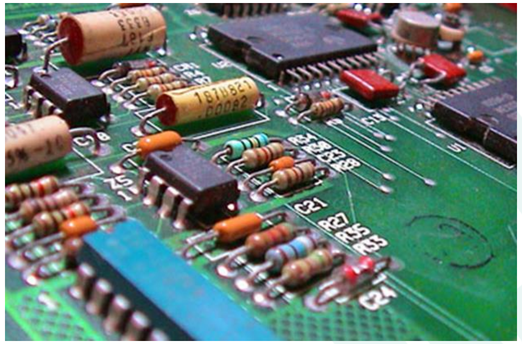
Electronics: Deals with design development and application of electron devices

Electron Devices: A device in which electron or electrical conduction takes place through vacuum, gas or semiconductor



Example electronic system: cell phone



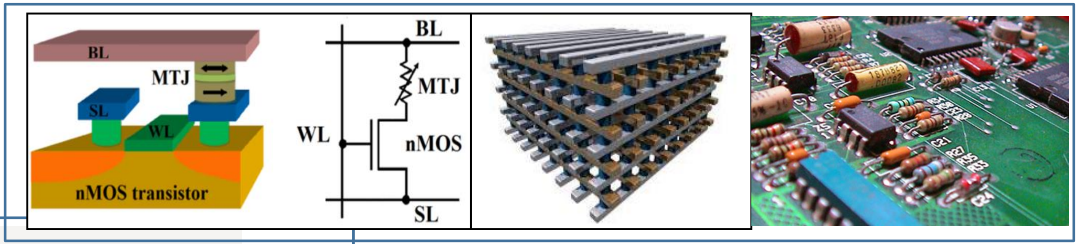


Printed circuit board: A board made for connecting electronic components together

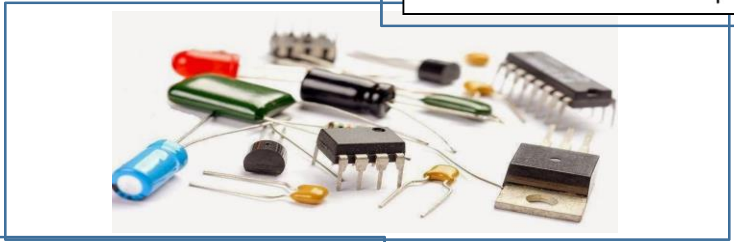
Semiconductor technology hierarchy

Application

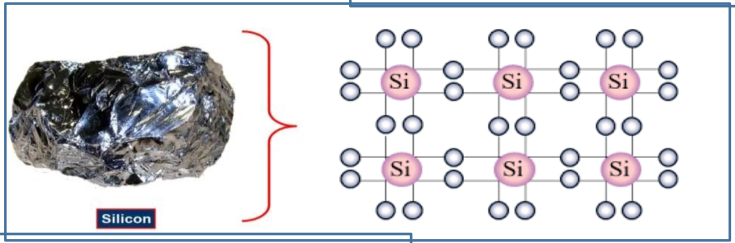
Circuit, architecture & integration



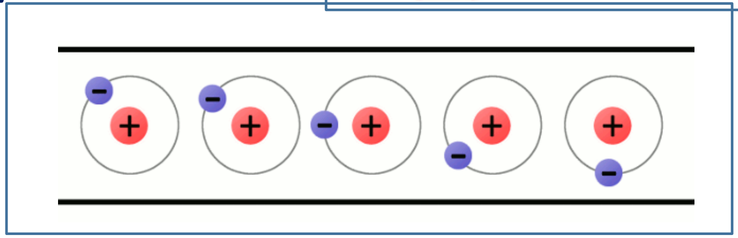
device



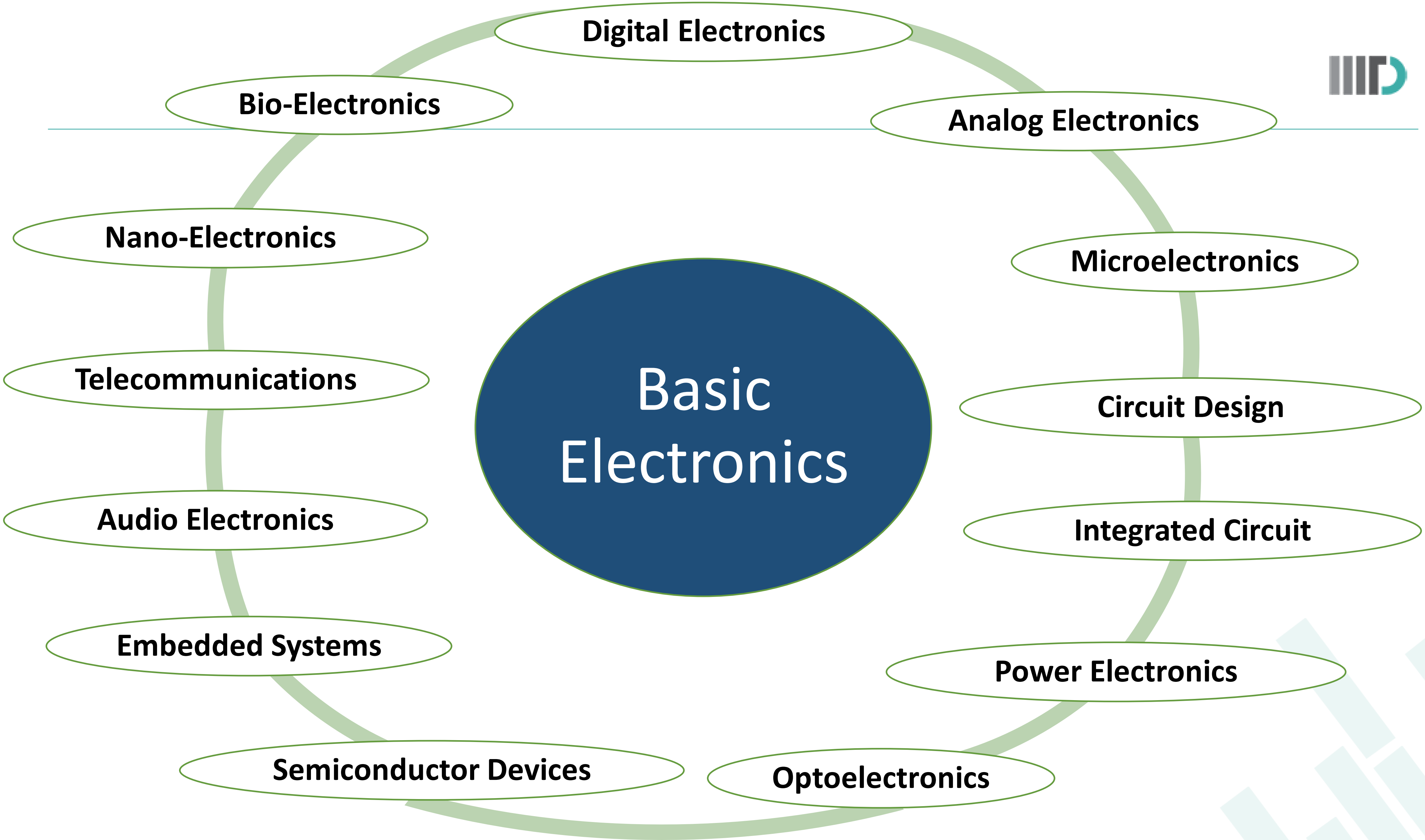
material



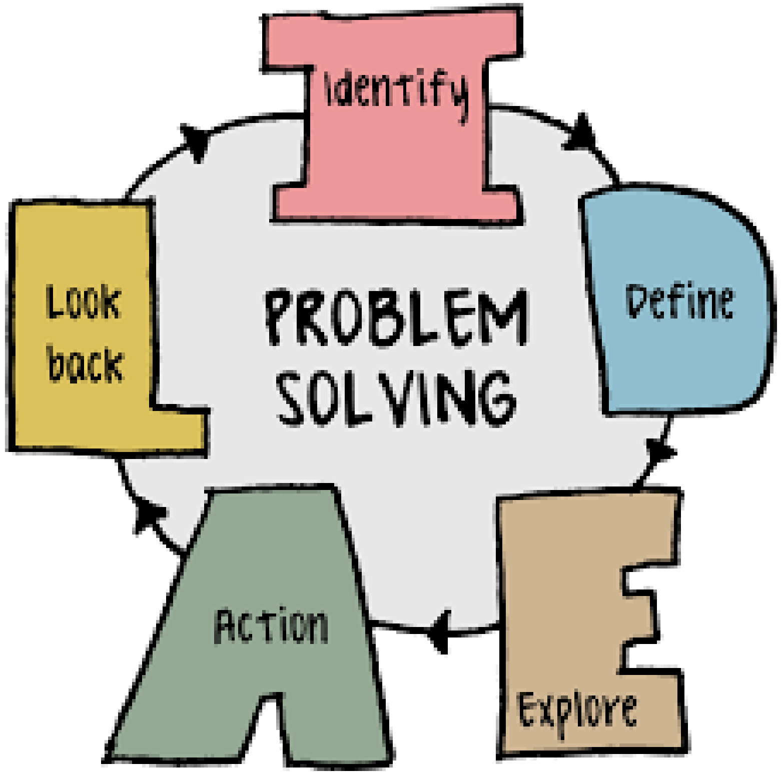
physics



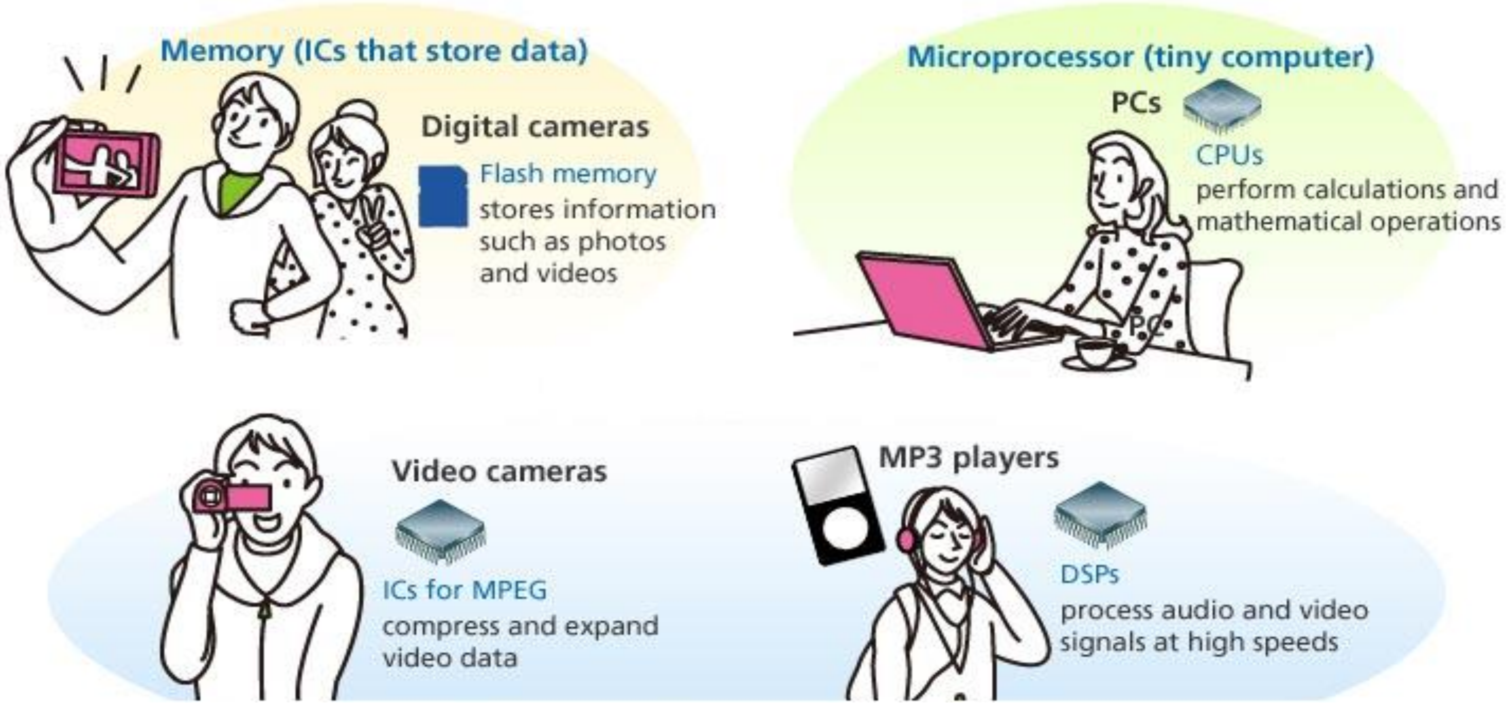
Any gadget needs the evolution of all these directions for future electronics


Digital Electronics
Bio-Electronics
Analog Electronics
Nano-Electronics
Microelectronics
Basic Electronics
Telecommunications
Circuit Design
Audio Electronics
Integrated Circuit
Embedded Systems
Power Electronics
Semiconductor Devices
Optoelectronics

Motivation



Motivation



Memory (ICs that store data)
Digital cameras
Flash memory
stores information such as photos and videos
Microprocessor (tiny computer)
PCs
CPUs
perform calculations and mathematical operations
Video cameras
ICs for MPEG
compress and expand video data
MP3 players
DSPs
process audio and video signals at high speeds

Early History of Semiconductor Devices

1940's: Vacuum-tube era

- Vacuum tubes were used for radios, television, telephone equipment, and computers

… but they were expensive, bulky, fragile, and energy-hungry

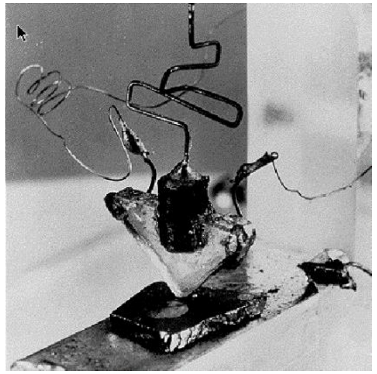
ENIAC-The first digital computer

→ Invention of the point-contact transistor

- **Walter Brattain, John Bardeen, and William Shockley, *Bell Labs*, 1947**

Nobel Prize in Physics 1956

– reproducibility was an issue, however



→ Invention of the bipolar junction transistor (BJT)

- **William Shockley, *Bell Labs*, 1950**

– more stable and reliable; easier and cheaper to make

Discrete Electronic Circuits

- In 1954, *Texas Instruments* produced the first commercial silicon transistor.

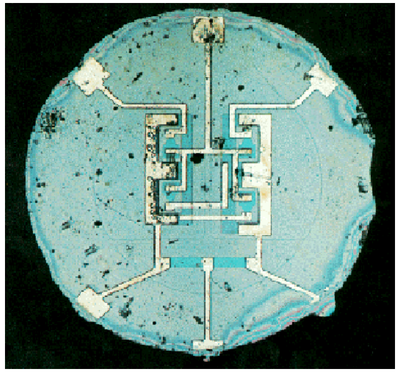
~$2.50 each

- Before the invention of the integrated circuit, electronic equipment was composed of discrete components such as transistors, resistors, and capacitors. These components, often simply called "discretes", were manufactured separately and were wired or soldered together onto circuit boards. Discretes took up a lot of room and were expensive and cumbersome to assemble, so engineers began, in the mid-1950s, to search for a simpler approach…

The Integrated Circuit (IC)

- An IC consists of interconnected electronic components in a single piece ("chip") of semiconductor material.
  - In 1958, Jack S. Kilby (Texas Instruments) showed that it was possible to fabricate a simple IC in germanium.
  - In 1959, Robert Noyce (Fairchild Semiconductor) demonstrated an IC made in silicon using SiO_2 as the insulator and Al for the metallic interconnects.

Kilby's first integrated circuit in germanium.

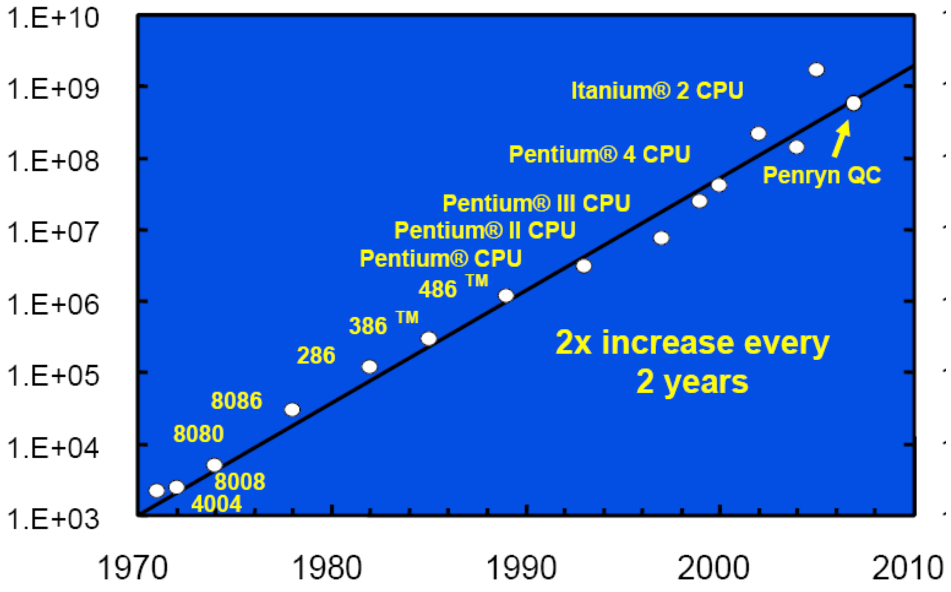


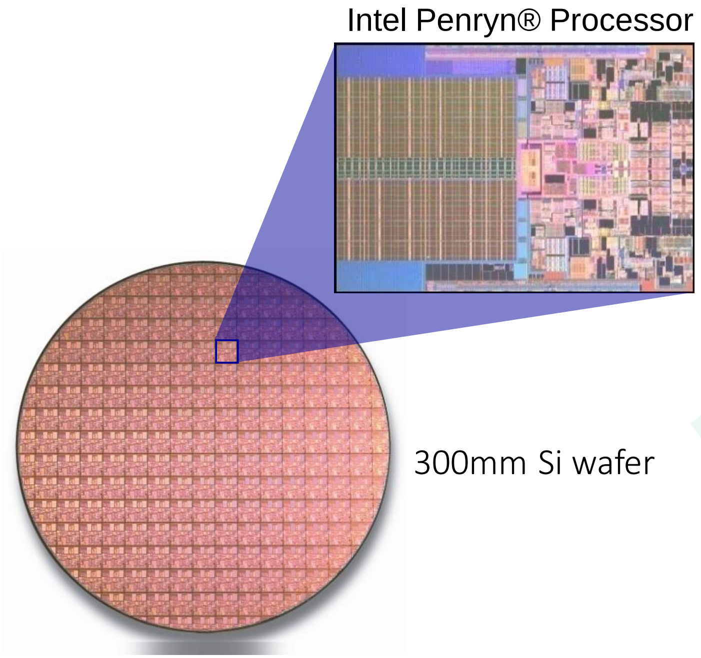
The first planar IC
(actual size: ~1.5mm diameter)

From a Few, to Billions of Components

- By connecting a large number of components, each performing simple operations, an IC that performs complex tasks can be built.
- The degree of integration has increased at an exponential pace over the past ~40 years.
  - The number of devices on a chip doubles every ~2 years, for the same price.

"Moore's Law" still holds today.





The Silicon Revolution

- Steady progress in integrated-circuit technology over 40+ years has had dramatic impact on the way people live, work, and play.

- The semiconductor industry is approaching $300B/yr in sales:

Military
2%

Computers
42%

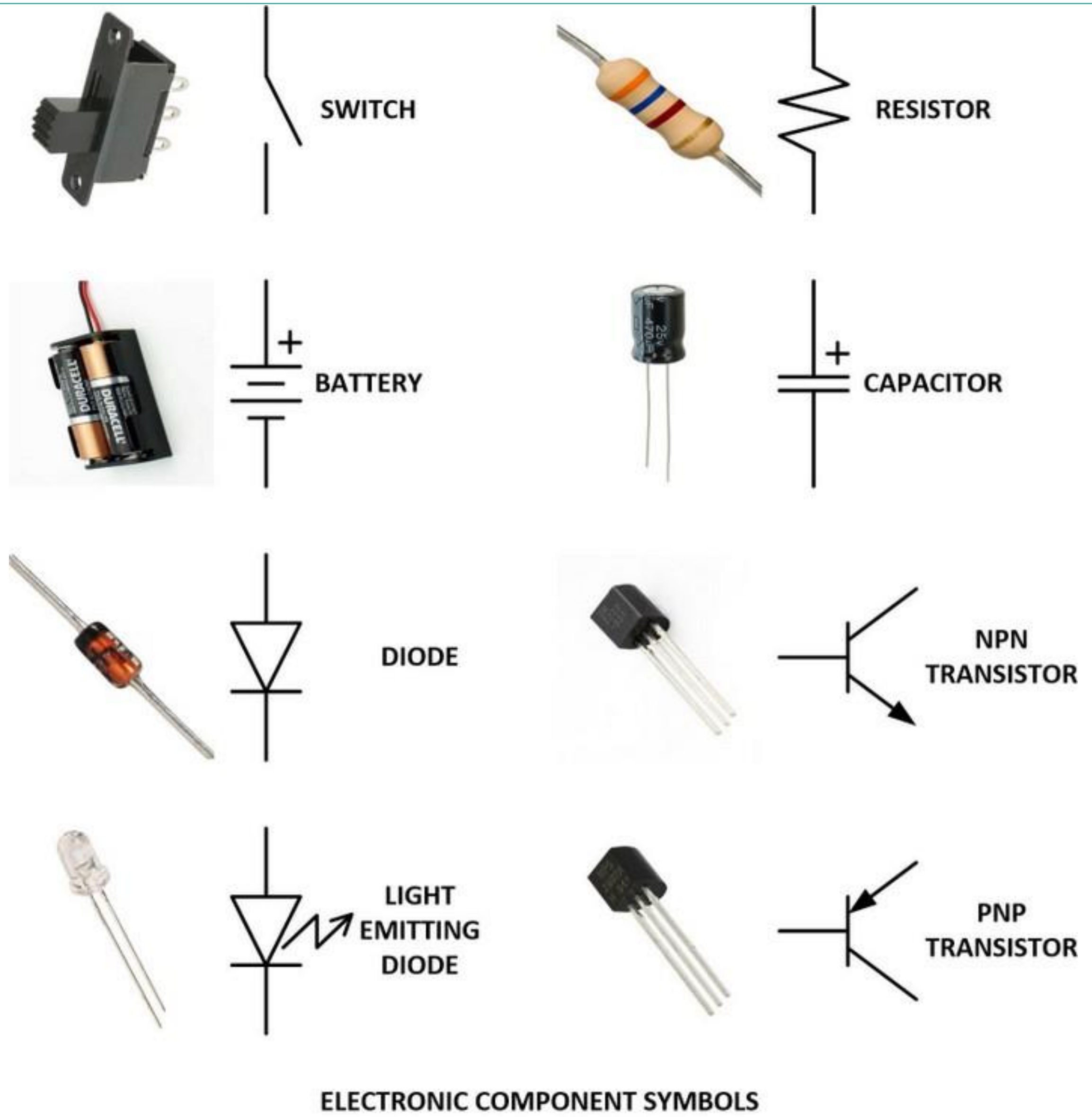
Communications
24%

Industrial
8%

Transportation
8%

Consumer Electronics
16%

Electronic components



Electrical quantities

- Charge: unit - Coulomb
- Current: unit - Ampere
- Voltage: unit - Volt
- Power: unit – Watt
- Resistance: unit - Ohm

Charge

- A physical property of matter which interacts with electromagnetic field
  - Experiences a force due to a electromagnetic field
  - Responsible for creating electric field
- The force can be calculated using Coulomb's Law:

$$F = \frac{Kq_1q_2}{d^2}$$

Notice the similarity with Newton's Law of Gravitation

- Two types of charges: +ve and –ve
- Same types of charges repel and unlike types attract
- Convention: charge of a proton is +ve and that of an electron is –ve

Charge

- Unit : Coulomb (C)
- -ve charge of an electron = 1.602×10^{-19} C

Notation convention:

Constant charge is represented as Q and time varying charge is represented as q(t)

Current

- Electric/ electronic circuits' function depends on flow of charge
- Current is defined as the instantaneous rate at which net positive charge move past a specific point/ cross-section at a specific direction:

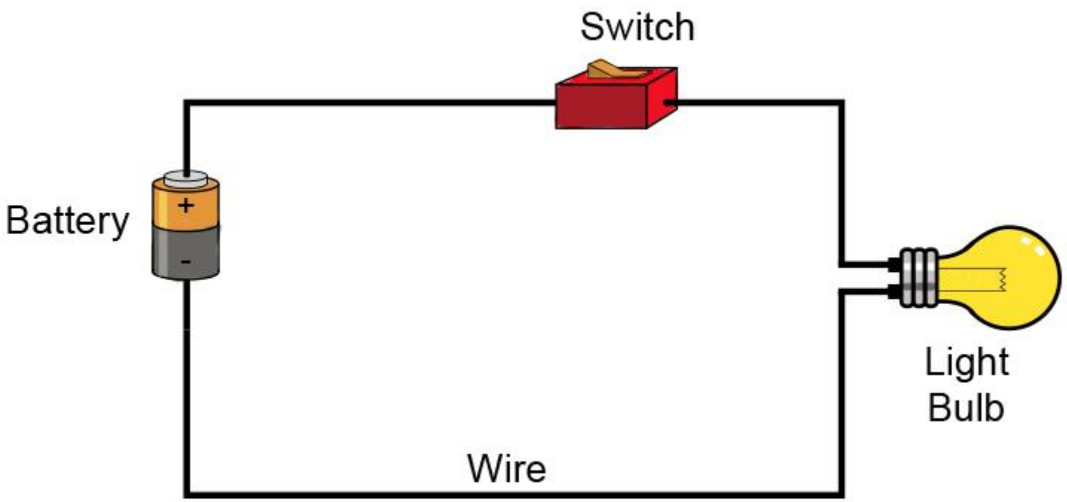
$$i = \frac{dq}{dt}$$

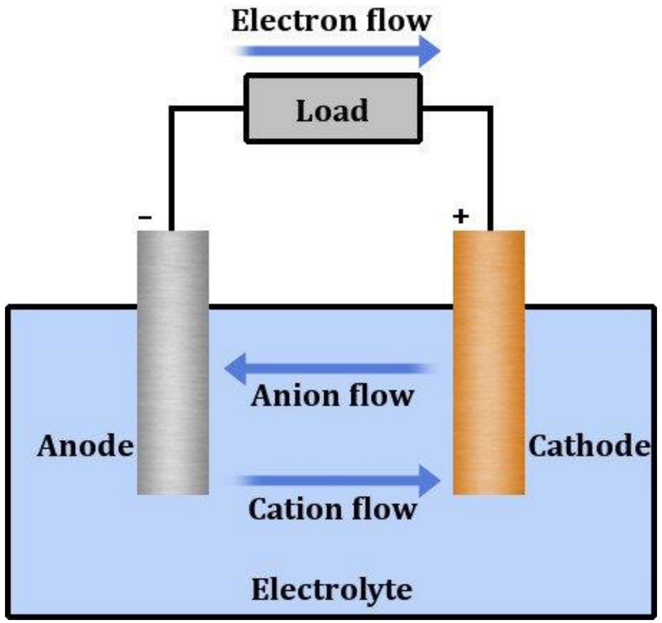
- Unit: Ampere (A): 1 C/s
- Can vary with time (unless DC, in ideal case)

A current of 5 A flows for 2 minutes in a circuit, find the quantity of electricity transferred.

Quantity of electricity $Q = It$ coulombs
$I = 5$ A, $t = 2 \times 60 = 120$ s
Hence $Q = 5 \times 120 =$ **600 C**

Conservation of charge



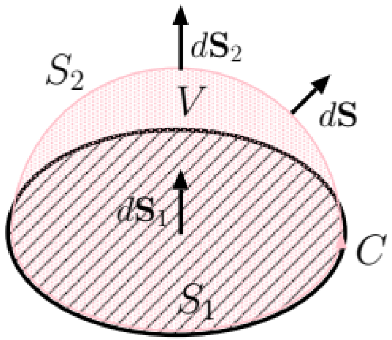


- **Total electric charge** is ***conserved*** in nature in the following sense: if a process generates (or eliminates) a positive charge, it always does so as accompanied by a negative charge of equal magnitude.

Continuity equation

- Consider two distinct surfaces S_1 and S_2 bounded by the same closed loop C (as shown in the margin) such that a volume V is contained between the two surfaces.
  - Let
    $$I_1 = \int_{S_1} \mathbf{J} \cdot d\mathbf{S}_1$$
    and
    $$I_2 = \int_{S_2} \mathbf{J} \cdot d\mathbf{S}_2$$
    denote currents flowing through surfaces S_1 and S_2, respectively.
  - Note that current I_1 through surface S_1 enters volume V, while current I_2 through surface S_2 exits volume V (with the directions assigned to $d\mathbf{S}_1$ and $d\mathbf{S}_2$).
  - If $I_1 \neq I_2$, then **current out** is not matched by the **current in**, and as a result, the net charge Q_V contained in volume V increases with time at a rate $I_1 - I_2$ provided that charge is *conserved* in the sense discussed above. In that case, we have
    $$\frac{dQ_V}{dt} = I_1 - I_2.$$
    This relationship can be expressed as
    $$\frac{d}{dt}\int_V \rho dV = \int_{S_1} \mathbf{J} \cdot d\mathbf{S}_1 - \int_{S_2} \mathbf{J} \cdot d\mathbf{S}_2$$

Current I out of a volume is equal to rate of decrease of charge Q contained in that volume:



since, in terms of charge density ρ, charge in volume V is

$$Q_V = \int_V \rho dV.$$

The expression can also be cast as

$$\int_V \frac{\partial \rho}{\partial t} dV = -\oint_S \mathbf{J} \cdot d\mathbf{S}$$

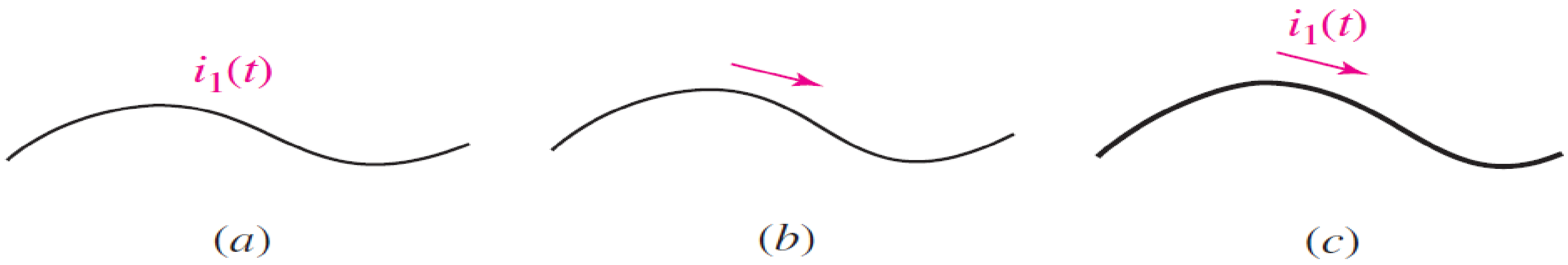
where S is the union of surfaces S_1 and S_2 enclosing V, and $d\mathbf{S}$ is an outward area element of S (see margin). This relationship is known as **continuity equation**. Its *differential form* is

Continuity equation

$$\frac{\partial \rho}{\partial t} = -\nabla \cdot \mathbf{J},$$

Current representation

- Direction is important



c) Is the correct representation

Current representation

Both are same

Types of current

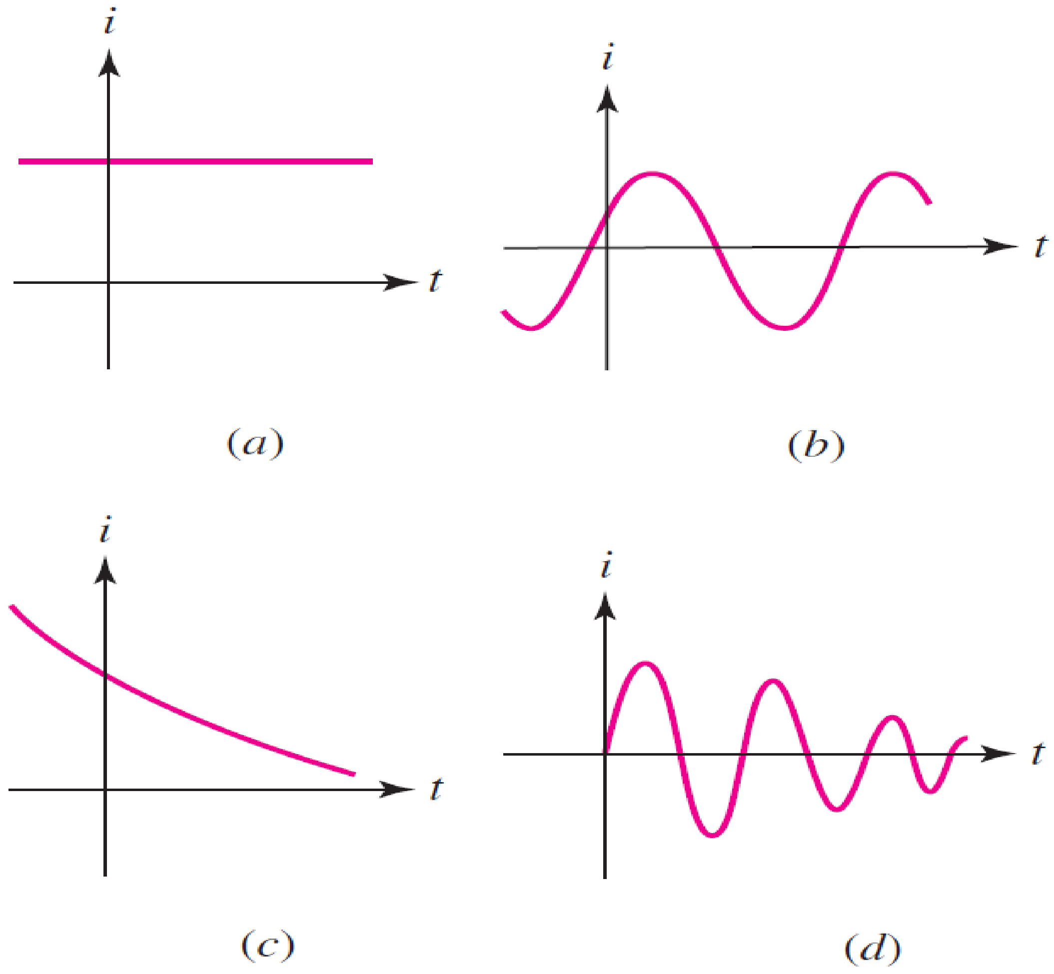


FIGURE 2.4 Several types of current: (*a*) Direct current (dc). (*b*) Sinusoidal current (ac). (*c*) Exponential current. (*d*) Damped sinusoidal current.

Voltage

To describe the rigorous definition of voltage, we must define Electric Potential

- **Electric Potential:** -ve of line integral of electric field over a path
- **Voltage :** Difference in potential between two points
- Essentially this is the work required to move an unit charge from one point to another
- **Unit :** Volt (V) – Work required is 1 Jule to move 1 C charge

Voltage

The unit of electric potential is the volt (V), where one volt is one joule per coulomb. One volt is defined as the difference in potential between two points in a conductor which, when carrying a current of one ampere, dissipates a power of one watt, i.e.

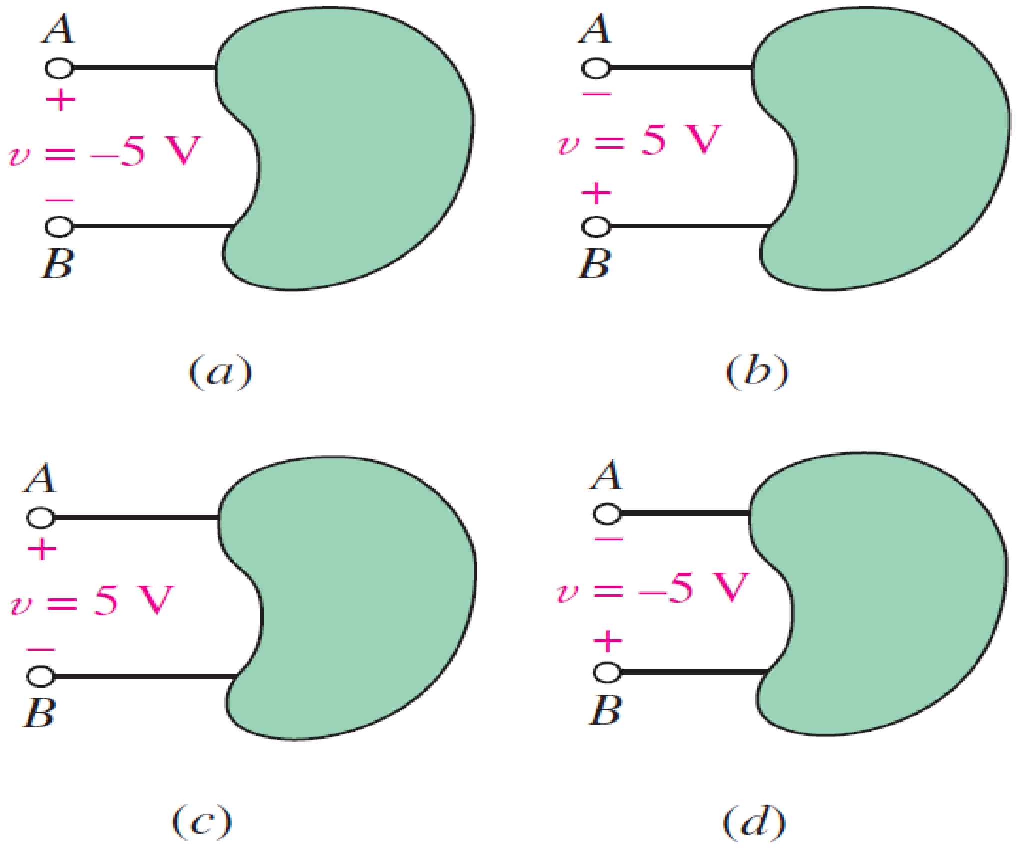
$$\text{volts} = \frac{Watt}{amperes} = \frac{\frac{joules}{second}}{ampere}$$

$$= \frac{joules}{amperes\ seconds} = \frac{joules}{coulombs}$$

A change in electric potential between two points in an electric circuit is called a potential difference and its unit is Volt.

The electromotive force (e.m.f.) provided by a source of energy such as a battery or a generator is measured in volts.

Voltage representation



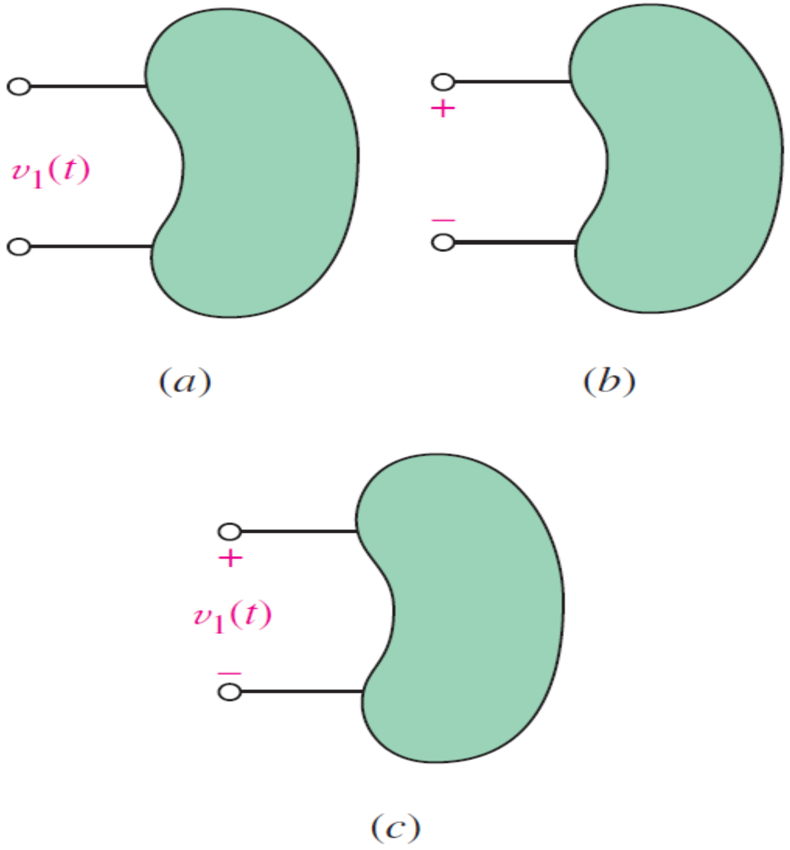


FIGURE 2.10 (*a, b*) These are inadequate definitions of a voltage. (*c*) A correct definition includes both a symbol for the variable and a plus-minus symbol pair.

Power

- Power: rate of work done (transferring energy)

$$P = \frac{W}{t} = \frac{W}{q}.\frac{q}{t} = vi$$

- Unit: Watt – 1 J/s

Electrical energy = Power × time

= $V \ I \ X \ t$

joules

Although the unit of energy is the joule, when dealing with large amounts of energy the unit used is the **kilowatt hour (kWh)**

where 1kWh = 1000 watt hour

= 1000×3600 watt seconds (joules) = 3600 000 J

Passive sign convention

Power absorbed by the element p = v i
We can also be say that element generates
or supplies a power of – v i

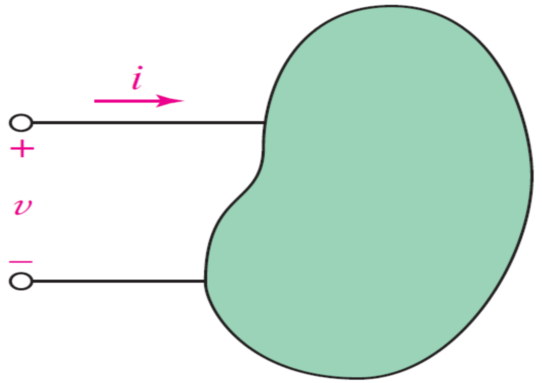
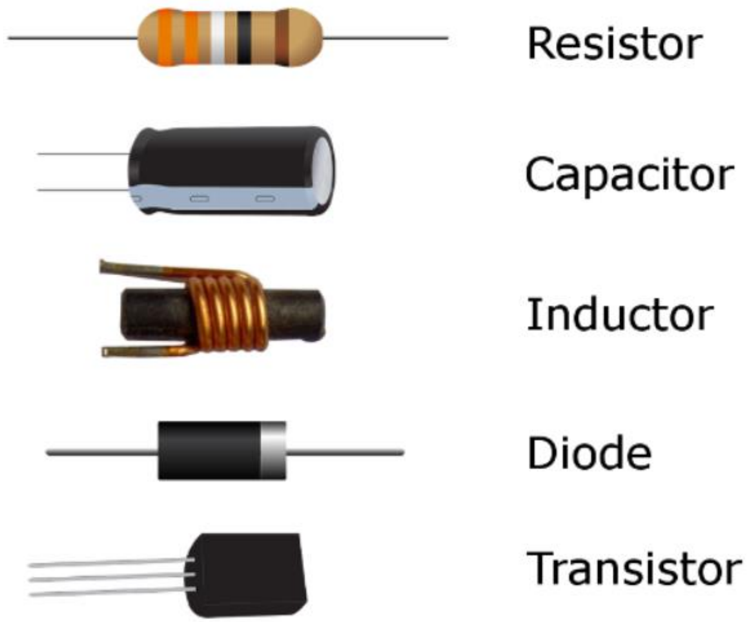


FIGURE 2.12 The power absorbed by the element is given by the product $p = vi$. Alternatively, we can say that the element generates or supplies a power $-vi$.

- When the current arrow is directed into the element at the plus-marked terminal, we satisfy the passive sign convention.
- If the current arrow is directed into the "+" marked terminal of an element, then $p = vi$ yields the *absorbed* power. A negative value indicates that power is actually being generated by the element.
- If the current arrow is directed out of the "+" terminal of an element, then $p = vi$ yields the *supplied* power. A negative value in this case indicates that power is being absorbed.

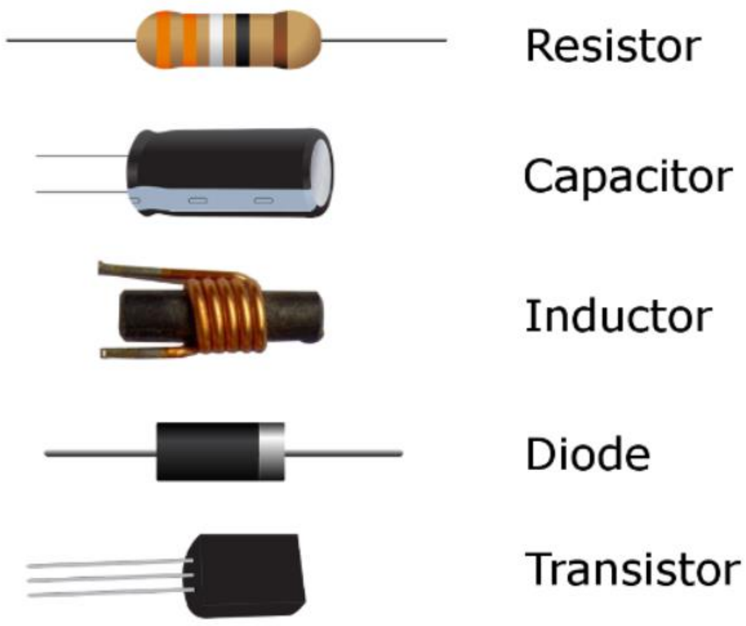
Circuit Elements

- Passive elements – compoment that does not generate power / cannot amplify or rectify a.c. power
- Active Elements – capable of generating electrical energy / can amplify or rectify a.c. power



Circuit Elements

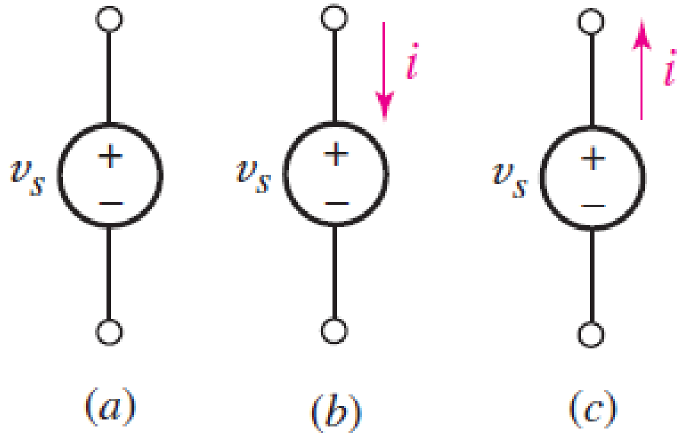
- **Linear circuit elements** – Resistor, capacitors, and inductors are called linear circuit elements as the current –voltage relationship is linear in these elements
- **Nonlinear circuit elements**– In diodes and transistors, the current –voltage relationship is not linear and they called nonlinear circuit elements.



Ohm’s law, Kirchhoff’s laws are not applicable to circuits involving nonlinear elements. However, in many electronic circuits under certain operating conditions the nonlinear elements are replaced by some linear but equivalent circuits and then are analyzed by the known laws of electrical circuits.

Independent Voltage Source

- Terminal voltage is completely independent of the current
- + sign is a reference, does not necessarily mean that upper terminal is numerically +ve
- This is a theoretical notion, a mathematical model that can be used for further analysis



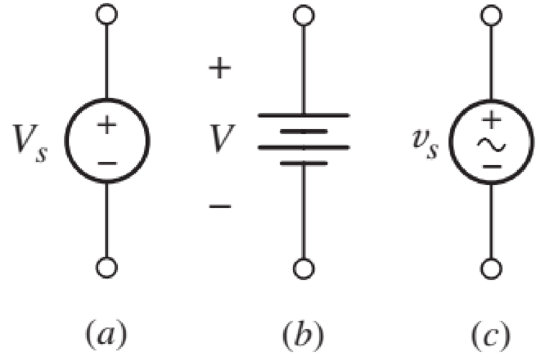
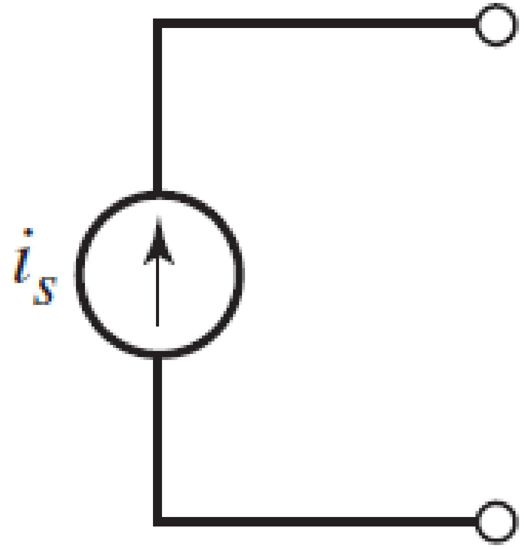


FIGURE 2.16 (*a*) DC voltage source symbol; (*b*) battery symbol; (*c*) ac voltage source symbol.

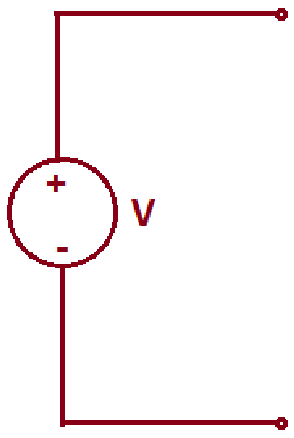
Independent Current Source

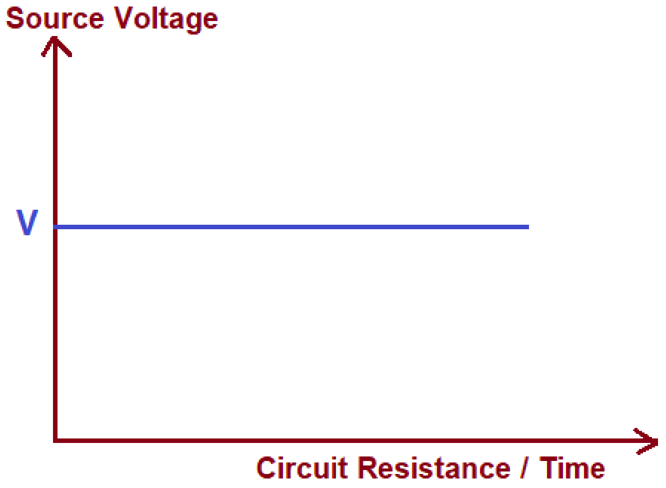
- Current is completely independent of the terminal voltage
- Again a theoretical notion
- Arrow denotes the direction
- Does not necessarily mean that terminal voltage difference will be 0
- Direction: +ve to –ve is +
- Direction: -ve to +ve is -



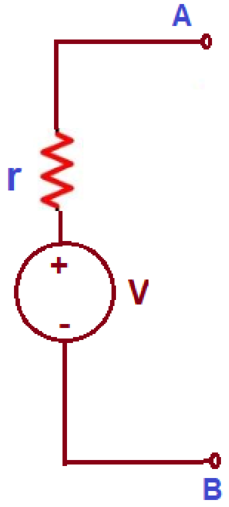
Practical voltage source

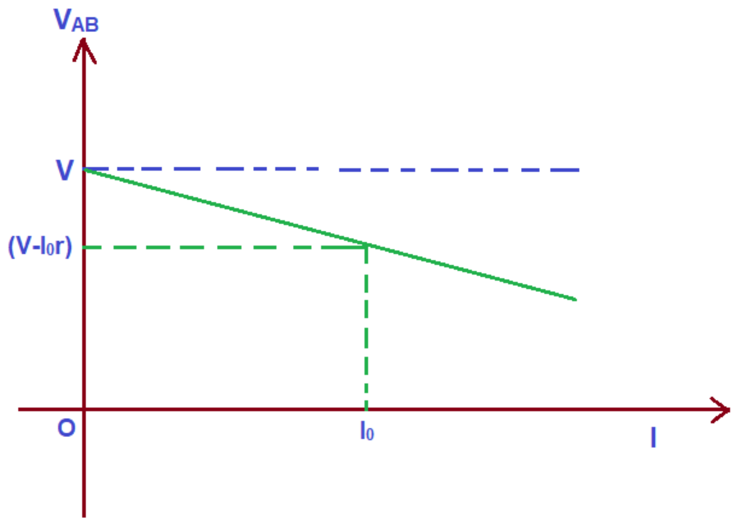
Ideal





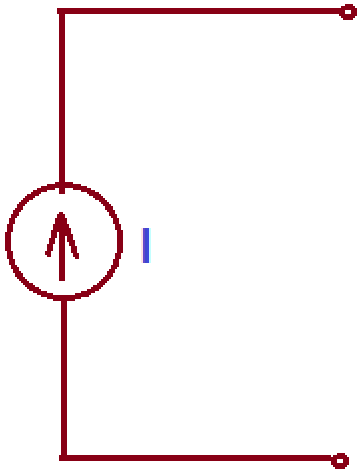
Practical

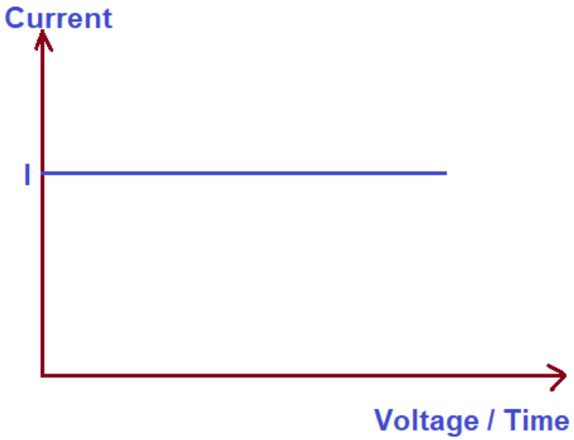




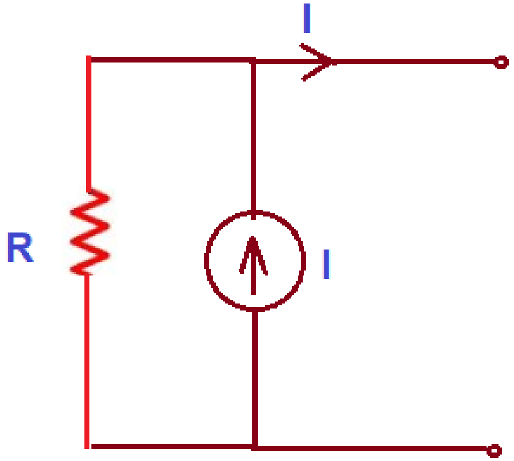
Practical current source

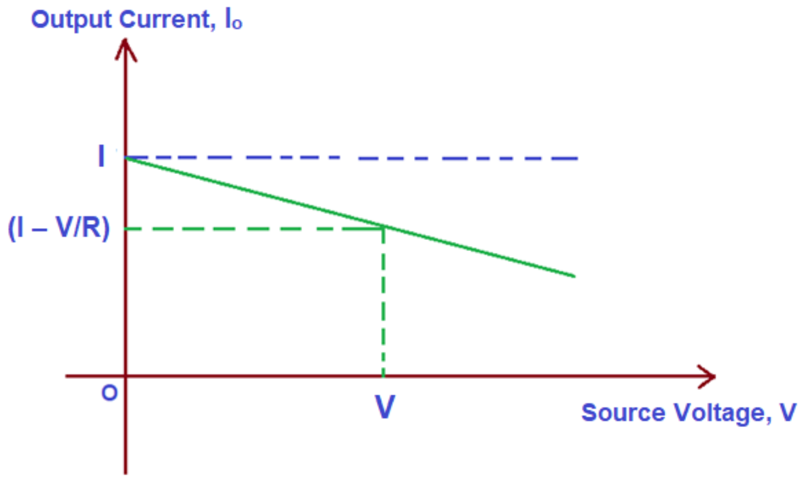
Ideal





Practical





Dependent Sources

- These are also ideal sources
- Dependent on current or voltage at some other area of the circuit
- Again independent of terminal voltage/current

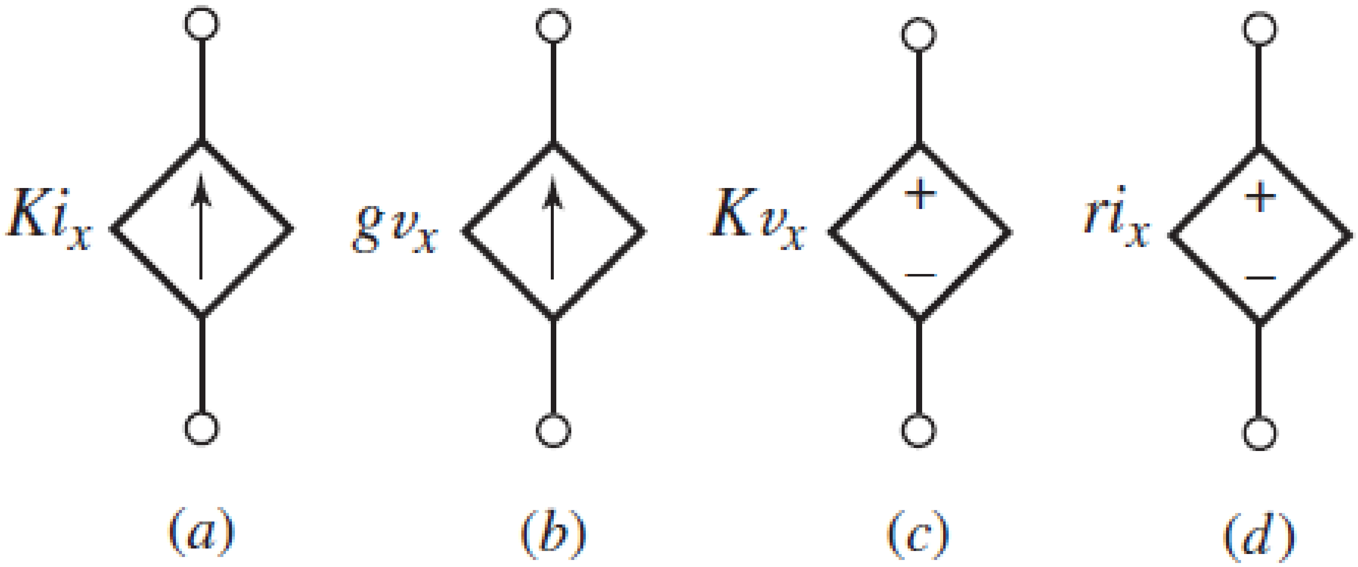


FIGURE 2.18 The four different types of dependent sources: (*a*) current-controlled current source; (*b*) voltage-controlled current source; (*c*) voltage-controlled voltage source; (*d*) current-controlled voltage source.

K is a dimensionless scaling const. g is a scaling factor with units of A/V and r is a scaling factor with units of V/A