Engineering Circuits Analysis (ICE2002)

Chapter 1. Circuit Variables

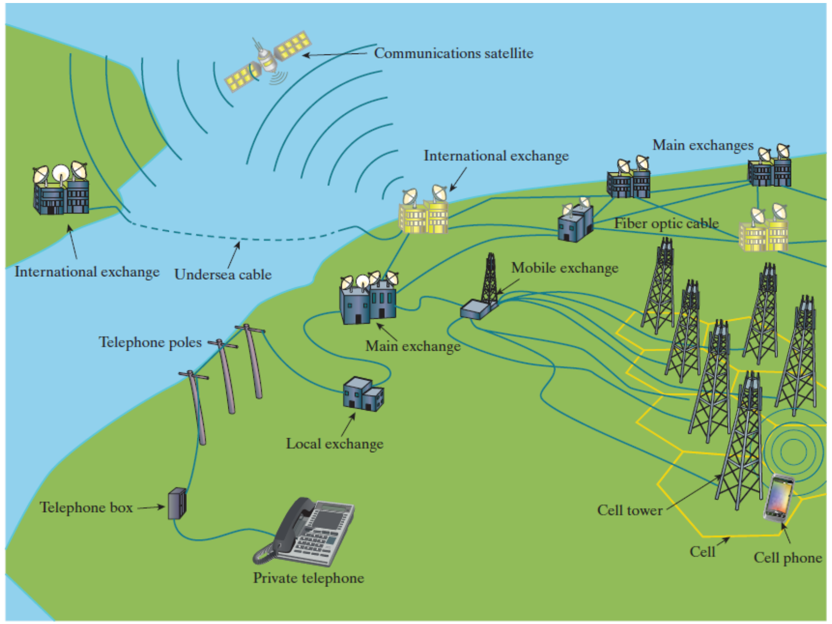
Contents

Electrical Engineering: An Overview

Electrical engineering is the profession concerned with systems that produce, transmit, and measure electric signals

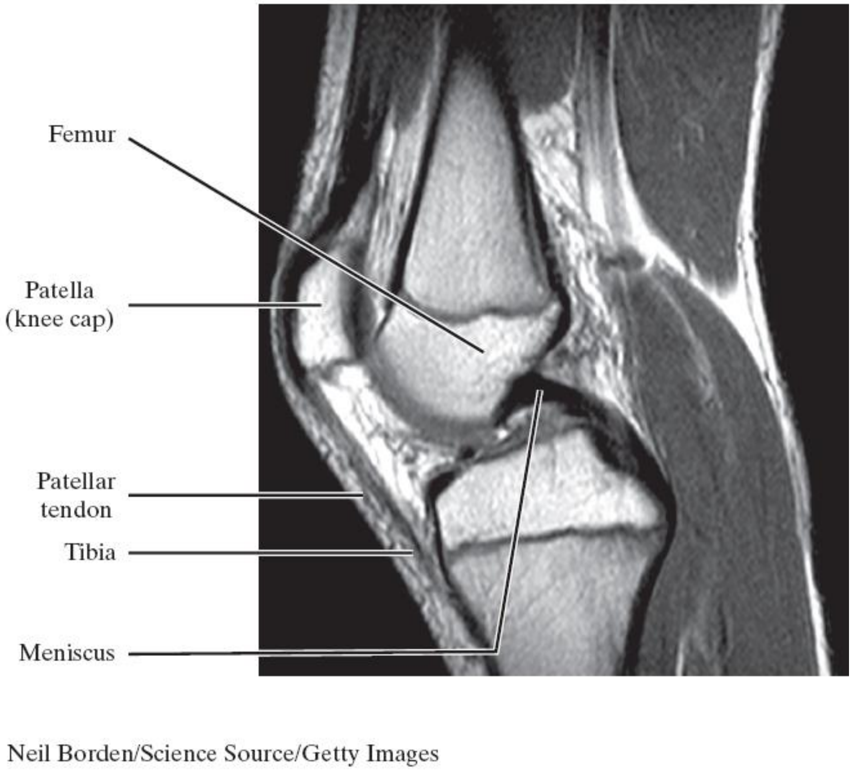
- Communication systems
- Computer systems
- Control systems
- Power systems
- Signal-processing systems

All systems are composed of electric circuits

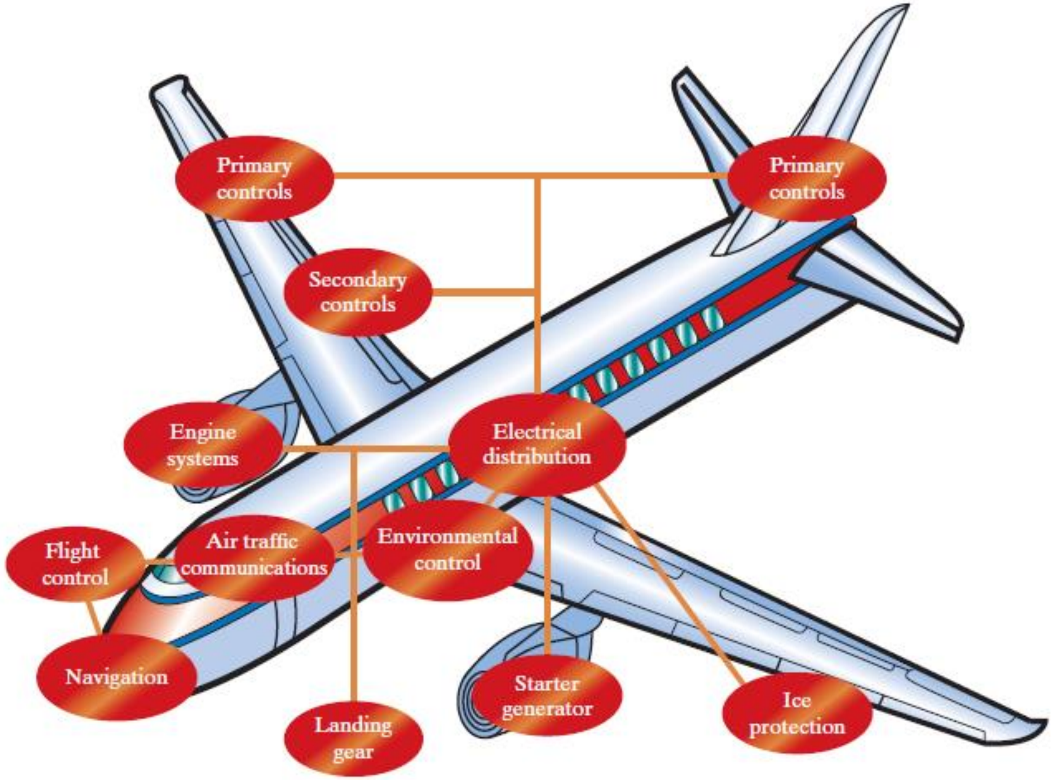


Telephone systems

Electrical Engineering: An Overview

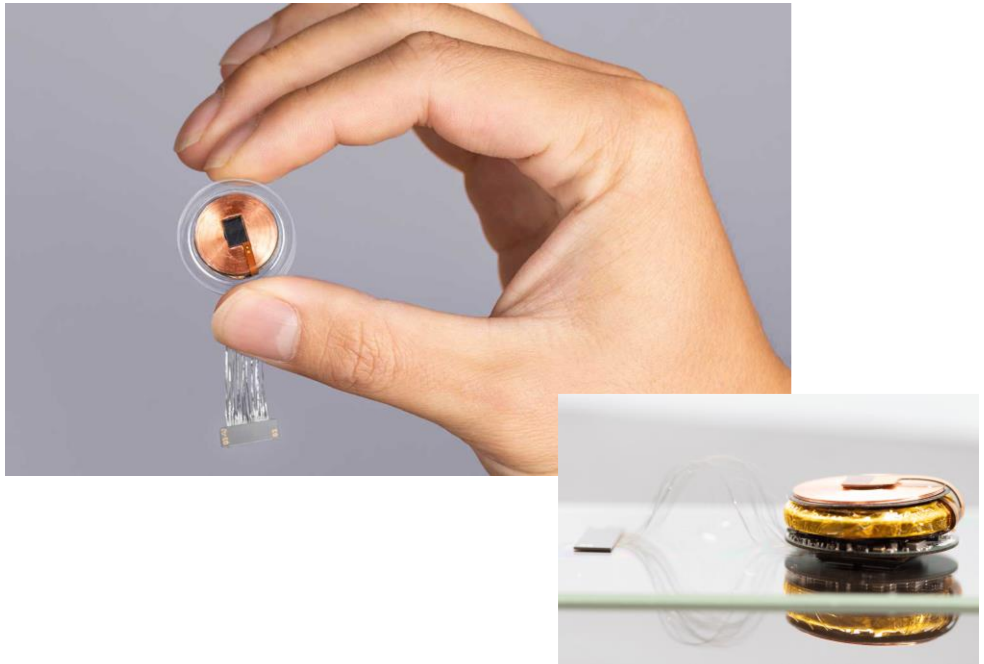


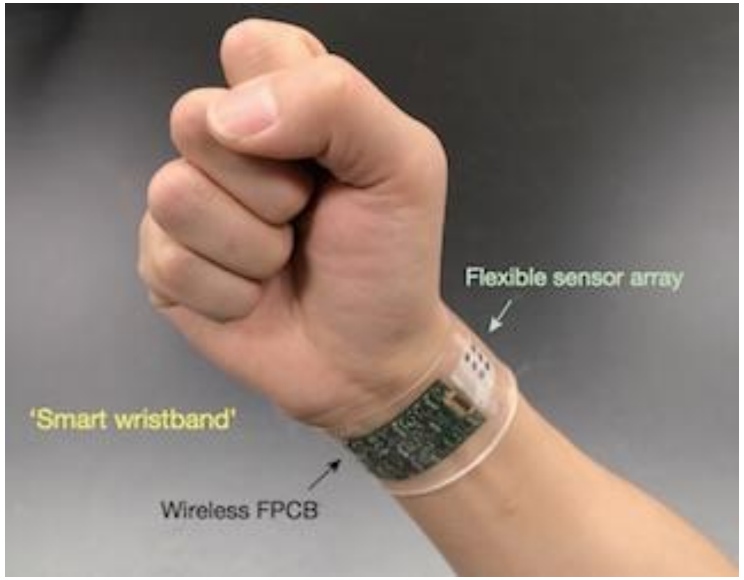
MRI scan of an adult knee joint



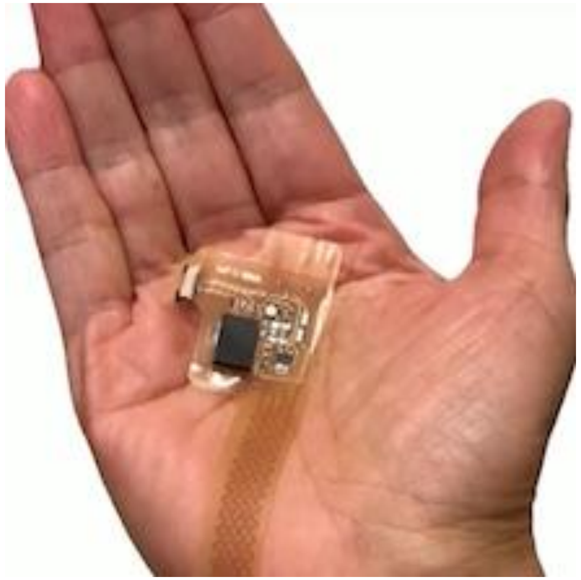
Interacting systems on a commercial aircraft

Electrical Engineering: An Overview





UC Berkeley, USA



Stanford, USA

Implantable medical devices for brain-machine interfaces (BMI), Neuralink

Wearable electronics for healthcare and medicine

Circuit Analysis

- **Electric circuits** is a **mathematical model** that approximates the behavior of an actual electrical system

- The goal of **circuit analysis** is to understand “ideal circuits” and the constraints imposed on current-voltage relationship resulting from interconnecting “ideal elements”

- The resulting interconnection (the “circuit”) will quantitatively (or approximately) predict the behaviors of the electrical system it is intended to present.

Circuit Analysis

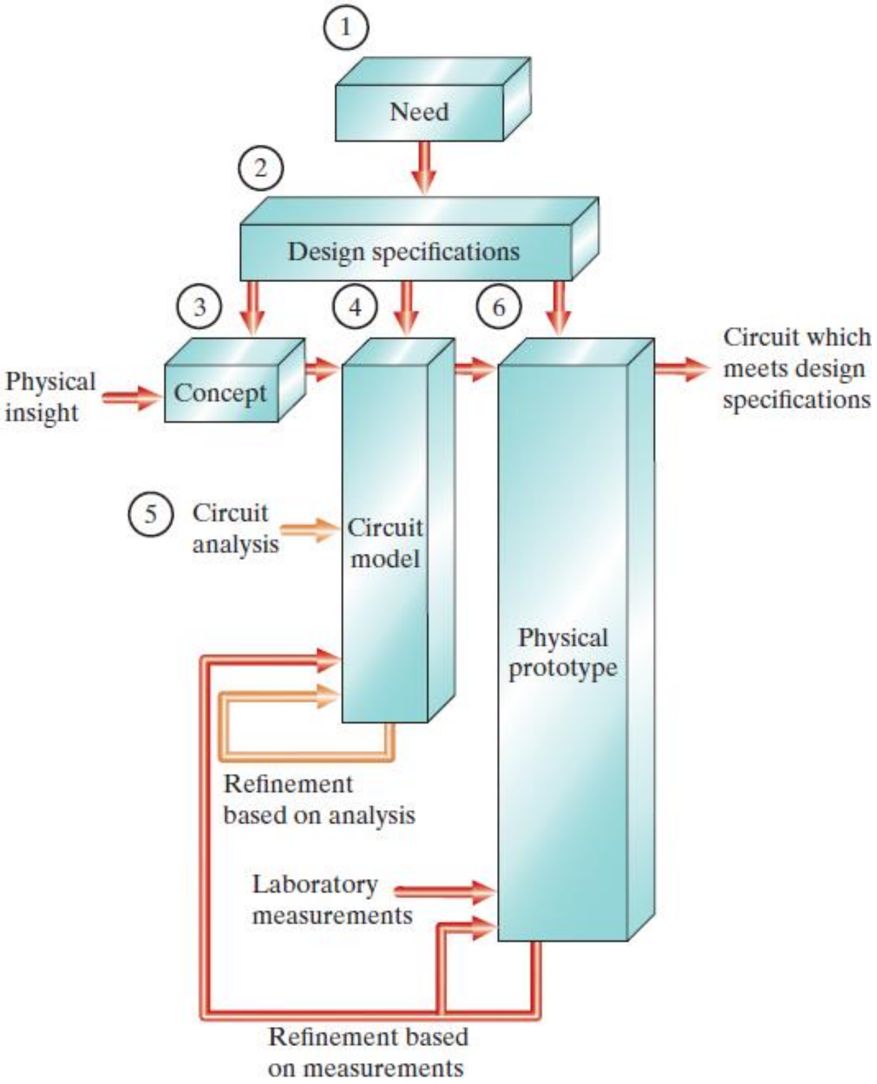
- **Three basic assumptions**

  1. Electrical effects happen instantaneously throughout a system.

  2. The net charge on every components in the system is always zero.

  3. There is no magnetic coupling between the components in a system.

Circuit Analysis



- **Circuit model:** mathematical model for electrical systems
- **Circuit analysis** is based on mathematical techniques and is used to predict the behavior of the circuit model and its ideal circuit components.
  It is based on the variables of voltage and current.
- **Physical prototype:** actual electrical system constructed from actual electrical components.

The International System of Units

- The International System of Units (SI) enables engineers to communicate in a meaningful way about quantitative results.

	SI UNIT	
QUANTITY	NAME	SYMBOL
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

The International System of Units

Derived units in SI

QUANTITY	UNIT NAME	FORMULA	SYMBOL
Acceleration — linear	meter per second per second	m/s^2	
Velocity — linear	meter per second	m/s	
Frequency	hertz	s^{-1}	Hz
Force	newton	$kg \cdot m/s^2$	N
Pressure or stress	pascal	N/m^2	Pa
Density	kilogram per cubic meter	kg/m^3	
Energy or work	joule	$N \cdot m$	J
Power	watt	J/s	W
Electric charge	coulomb	$A \cdot s$	C
Electric potential	volt	W/A	V
Electric resistance	ohm	V/A	Ω
Electric conductance	siemens	A/V	S
Electric capacitance	farad	C/V	F
Magnetic flux	weber	$V \cdot s$	Wb
Inductance	henry	Wb/A	H

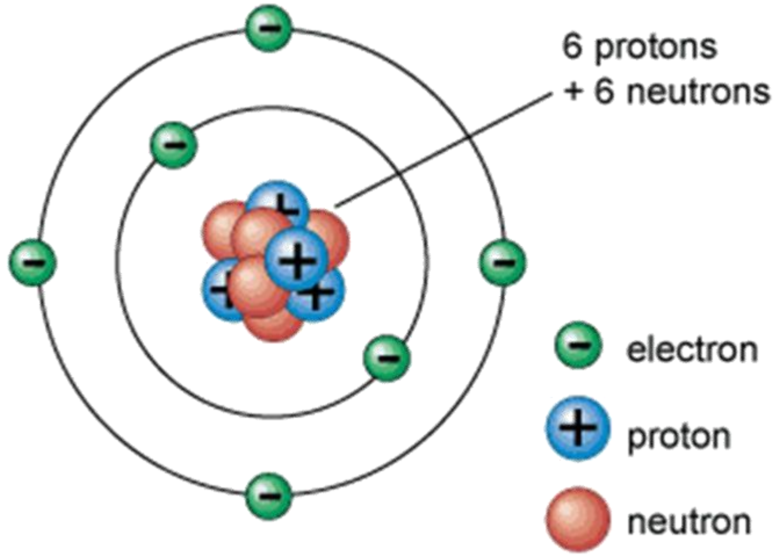
The International System of Units

Standardized prefixes to signify power of 10

MULTIPLE	PREFIX	SYMBOL
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Voltage and Current

- **Electric charge**
  - Basis for describing all electrical phenomena
  - Described in positive and negative charges
  - Exists in discrete quantities, which are integral multiples of the electronic charge, 1.6022×10^{-19} [C]



  - Electrical effects are attributed to both the
    separation of charge >> electric force (voltage)
    charges in motion >> electric fluid (current)

Voltage and Current

- **Voltage**
  - Whenever positive and negative charges are separated, energy is expended.
  - Voltage is the energy per unit charge created by charge separation.

$$v = \frac{dw}{dq}$$

where
v = the voltage in volts,
w = the energy in joules,
q = the charge in coulombs.

Voltage and Current

- **Current**

  - Current is the rate of charge flow.

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

where
i = the current in amperes,
q = the charge in coulombs,
t = the time in seconds.

Power and Energy

- **Power**
  - Power is energy per unit of time; the rate of energy flow.
  - If $p>0$, power is being delivered to the circuit components.
  - If $p<0$, power is being extracted from the circuit components.

$$p = \frac{dw}{dt}$$

where
p = the power in watts,
w = the energy in joules,
t = the time in seconds.

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i$$

Power and Energy

- **Energy**
  - Energy is the integral of power over time.
  - If w>0, energy is being stored.
  - If w<0, power is being dissipated.

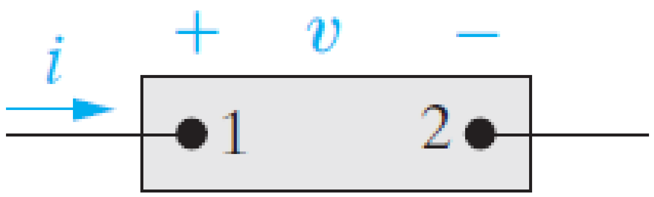
$$p = \frac{dw}{dt}$$

$$w = \int_{-\infty}^{t} p \, d\tau$$

where
p = the power in watts,
w = the energy in joules,
t = the time in seconds.

Ideal Basic Circuit Element

- **Attributes**
  - Two terminals,
    which are points of connection to other circuit components
  - Described mathematically in terms of current and/or voltage
  - Cannot be subdivided into other elements



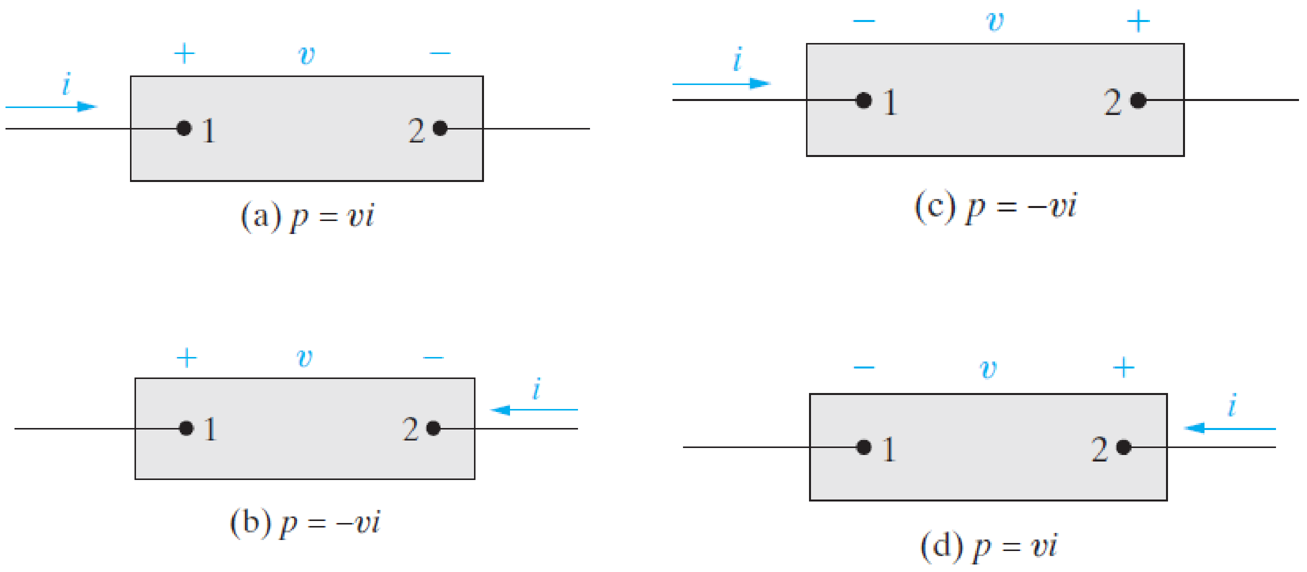
Ideal basic circuit element

Voltage: Polarity reference for voltage can be indicated by plus (+) and minus (-) signs

Current: reference direction for the current is indicated by an arrow

Sign Convention

- **Passive sign convention**
  - Reference direction for current through the element is in the direction of the reference voltage drop across the element



If p>0, power is being delivered to the box

If p<0, power is being Extracted from the box (battery)

Summary

- **Electric charge**
  separation of charge >> electric force (voltage)
  charges in motion >> electric flow (current)

- **Current** = rate of charge flow
- **Voltage** = energy per unit charge created by charge separation

- **Power** = energy per unit time

- Ideal basic circuit element
- Passive sign convention