MŰEGYETEM 1782
Budapest University of Technology and Economics
Department of Electron Devices

Technology of IT Devices

Lecture 1

- Requirements
- Short introduction
- Summary of applied modern technology through an example (a smartphone)
- Refreshment of prerequisite knowledge

Minimum requirements

- Five laboratories
  - You must attend all of them
  - One midterm test
  - At the end of the semester
  - Question bank is available
- Make-up labs and tests (when you were not able to take any previous labs or tests)
- In the semester

  One lab and one midterm test
- At the end of the semester

  Make-up lab and retake midterm test
- Final grade will be calculated
  - Based on the result of the midterm test
    - (40%, 55%, 70%, 85%)

Prerequisites, required basic knowledge

- Physics – high school-level basic knowledge
- Digital Design
  - Logic gates
  - Design at higher abstraction level (system design, synthesis, simulation, IP cores, etc.)
  - Computer architectures

Administration

- The course has its own website:

http://www.eet.bme.hu/~takacs/index.php?menu_name=lecture&submenu=itdevices&language=EN&laf=dark

- Here you can find the most important information and the lecture notes
- Via Neptun messages

Goal of this course

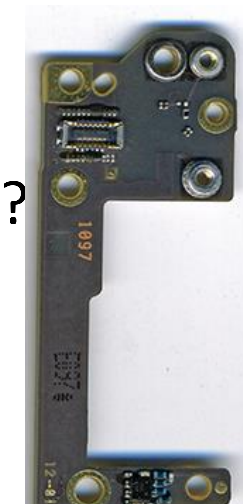
- Get some basic knowledge on the operation and technology of modern IT devices
- Possibilities, trends and limits of the modern microelectronics
- Get some knowledge on HW and SW design, tools, limits, problems

What will be discussed?

- What is inside and outside…
  - Complete computer, microprocessor, memory, co-processors
  - Sensors, display
  - ~~RF communication –~~ it won’t be discussed at all

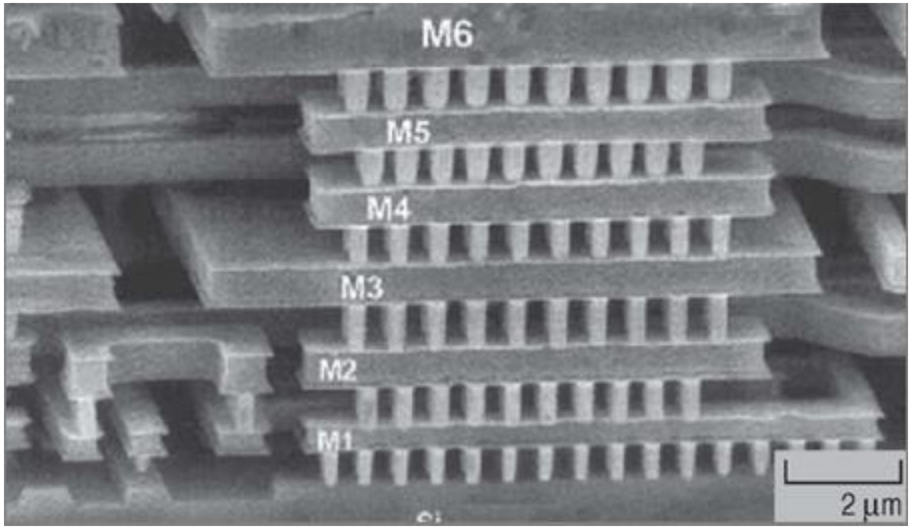
Short introduction

- What components does the system consist of?
- How to design these components?
- What are the most important viewpoints of the design?
- How they are assembled?
- What is providing the energy needed for operation?




Integrated circuits and their interconnections

- In the black cases you can find silicon chips which contain billions of integrated components
- The role of the printed circuit board is to interconnect the integrated circuits (ICs) and the other components.
- The most important component is the Metal Oxide Semiconductor (MOS) transistor which acts like a (non-ideal) switch
- The logic gates consist of these MOS transistors which are connected together by 8 to 16-level metal wires.



Integrated Circuits in IPHONE 6S

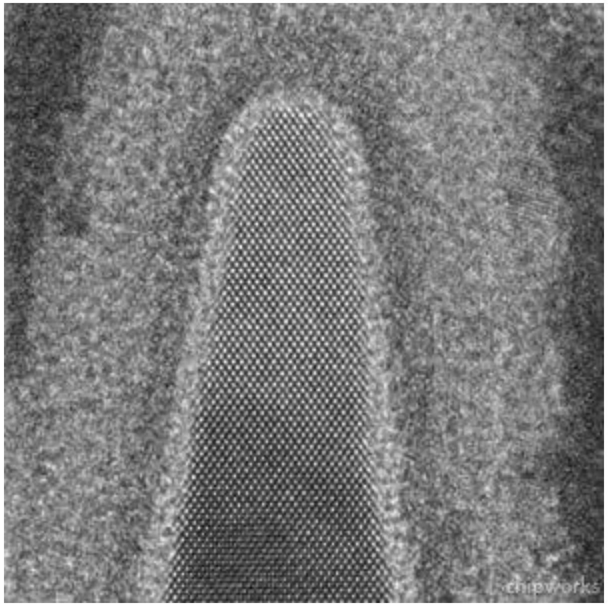
- 3 x Knowles KSM2 microphones
- 2 x Apple/Cirrus Logic 338S1285 Audio
- **Apple 343S00014 3D Touch Controller**
- **Apple A9 APL0898 application processor**
- Apple/Dialog 338S00120 Power Management IC
- Avago ACPM 7714 Multimode Power Amplifier
- Avago AFEM-8030 Power Amplifier Module
- Bosch Sensortec 367 LA 3-axis Accelerometer
- Bosch Sensortec barometric pressure sensor
- Goertek GWM1 microphone
- InvenSense MP67B 6-axis Gyroscope and Accelerometer Combo
- **Micron D9SND 2 GB LPDDR4 SDRAM**
- Murata 240 Front-End Module
- Murata Ne G98 RF Front-End Module
- Murata(Yd G54 RF Front-End Module
- NXP 66V10 NFC Controller
- Qorvo/RFMD RF1347 Antenna Switch Module
- Qorvo/TriQuint TQF6405 Power Amplifier Module
- Qualcomm MDM9635M LTE Cat. 6 Modem
- Qualcomm PMD9635 Power Management IC
- Qualcomm Envelope Tracking IC
- Qualcomm Radio Frequency Transceiver
- RF Micro Devices RF5150 Antenna Switch
- **SK Hynix H23QDG8UD1ACS Dual Die Package (DDP) 64Gb NAND Flash**
- Skyworks SKY77357 Power Amplifier Module
- Skyworks SKY77812 Power Amplifier Module
- Texas Instruments 3539 LED backlight Retina display driver
- Texas Instruments 6BB27 Power Management IC
- Texas Instruments Texas Instruments SN2400AB0 Charger IC
- Universal Scientific Industrial 339S00043 Wi-Fi Module

Sensor	Mobil/RF	Computer	Display	PS*	Audio	Wireless

*power supply

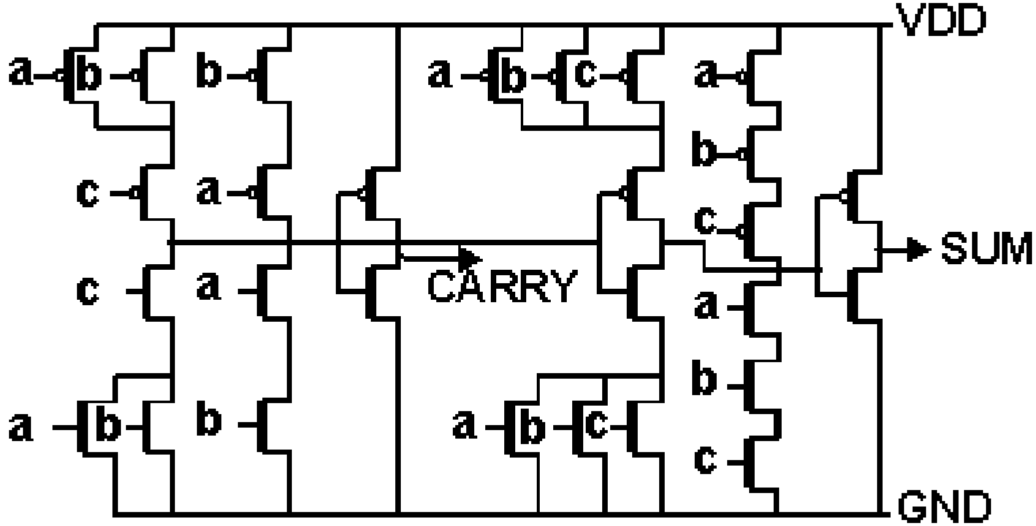
ICs and MOS transistors – Lecture 2

- What does semiconductor mean?
- What material are transistors made of?
- How does it work?
- Why is it suitable to create a logic gate?
- In this picture the cross section view of a modern FIN-FET transistor can be seen
  - The texture is caused by the electric field of the atoms.
  - Details are coming later



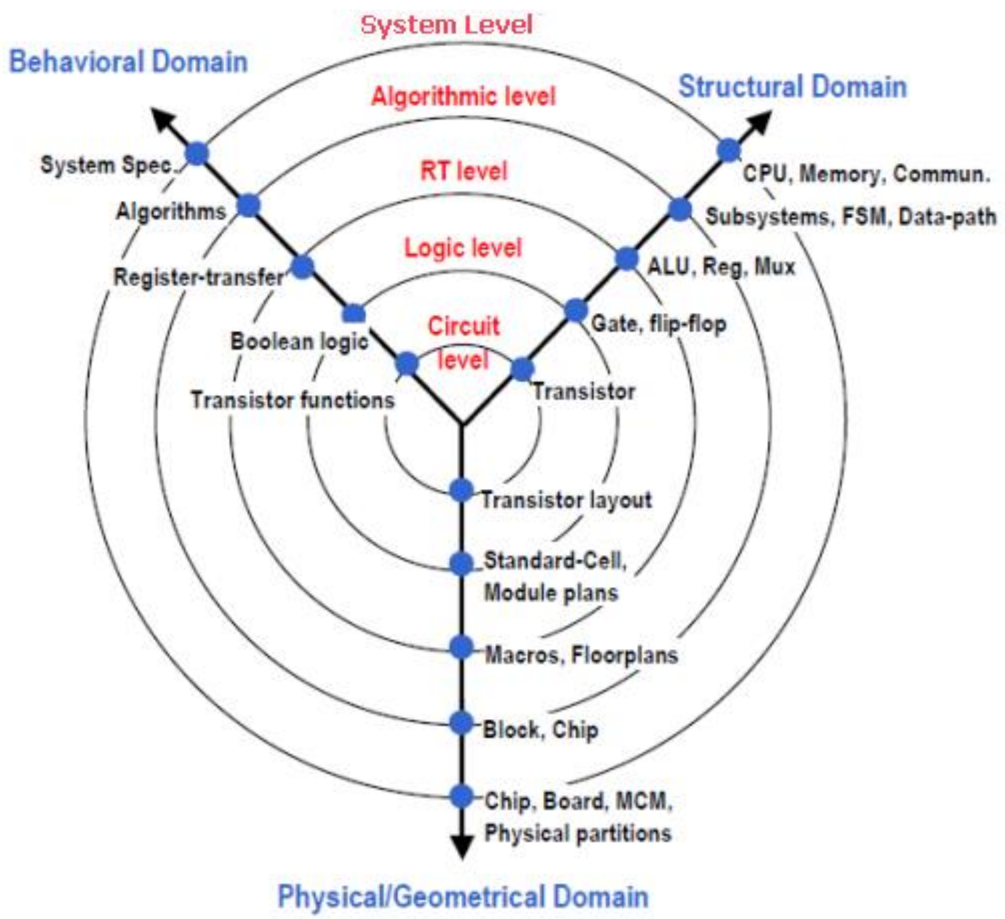
Realization of the digital gates – Lecture 3 & 4

- Logic circuits
  - Inverter and logic gates, NOR and NAND gates
- And the difficulties:
  - Power consumption, delay, and its correlation
- Realization of combinational and sequential logic networks
  - Complex gates, multi-level logic, latches
  - What is in the picture below?



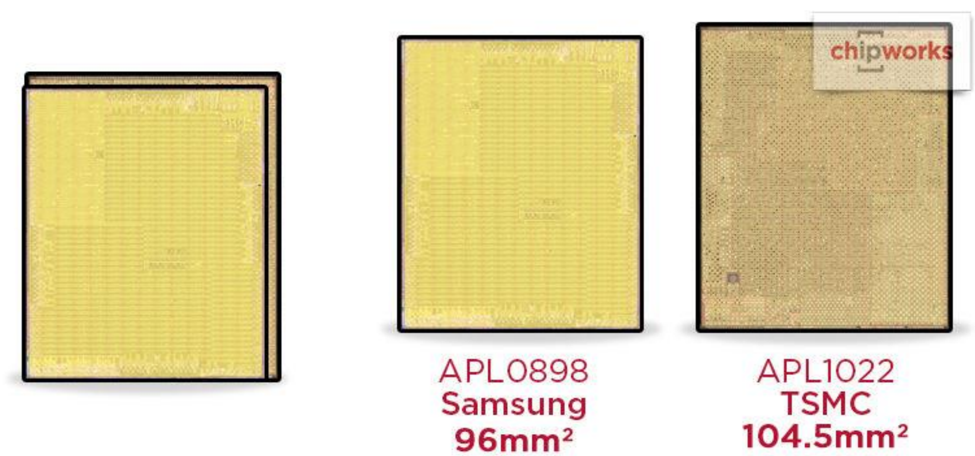
Digital system design – Lecture 5 & 6

- The process of digital design
- Hardware desciption languages
- Logical and physical synthesis



Apple A9 application processor

- This is a SoC (System-on-a-chip)
- 1,85GHz 2 core ARM processor + GT7600 6-core graphic accelerator + three-level cache + “motion coprocessor”
  - Instruction set: ARM (UK)
  - Microarchitecture: Apple (US)
  - Graphic accelerator: Imagination Technologies (UK)
  - Production
    - Samsung (ROK), 14nm, 96mm^2
    - TSMC (TW), 16nm, 104mm^2



Memory devices – Lecture 7 & 8

- RAM memory
  - Operational memory→ Dynamic RAM
  - Cache memory → Static RAM (?)
- ROM memory
  - Program memory, data memory, hard disk drive – they are the same but with different features.
- CAM (Content Addressable Memory)

What’s wrong with this picture below?

ASIC and programmable logic devices – Lecture 9.

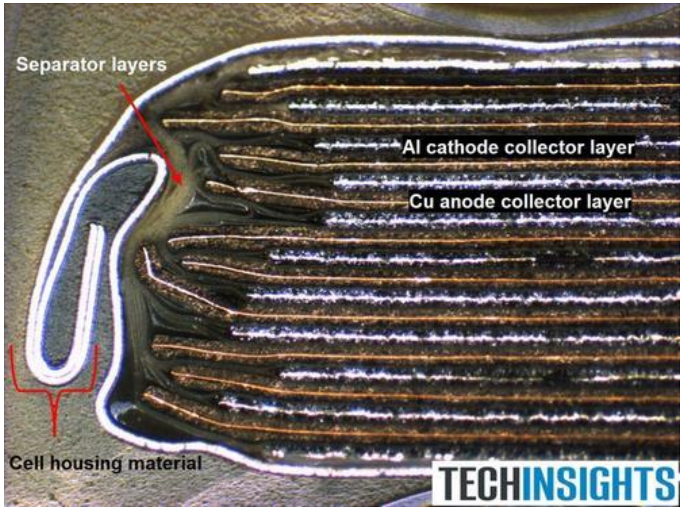
- What can we do when the commercially available ICs cannot fulfill our special requirements, or we need a special IC?
  - For example A9 in iPhone!
- How do programmable logic devices work?
- What are the advantages and disadvantages of different solutions? Why does a processor company purchase an FPGA company?

How to embed a digital IC into a system – Lecture 10

- What do these words mean? 5VT, pull-up resistor, open-drain output?
- Why should you not touch ICs with bare hands?
- How to generate clock signal?
- What kind of external components are needed for a system?

Power supply and battery operation – Lecture 11

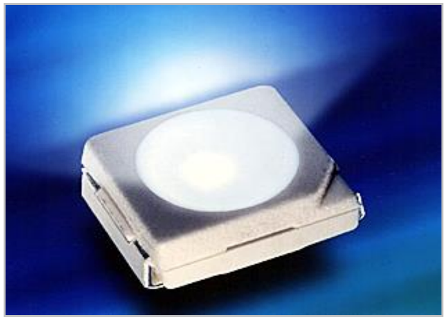
- How to provide power supply?
  - From the electric power distribution network (230V in EU and 110V in US)
  - From direct current.
  - With high efficiency!
  - Primary and secondary batteries

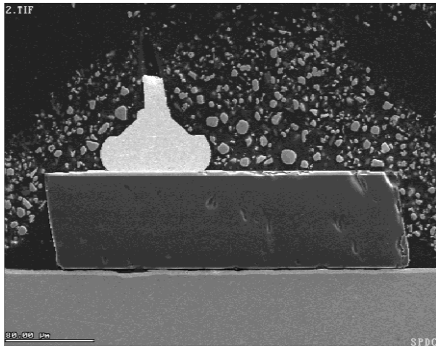


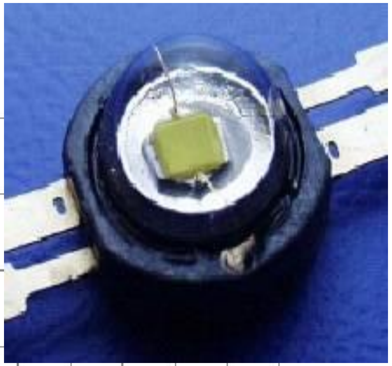
Primary batteries irreversibly transform chemical energy to electrical energy. When the supply of reactants is exhausted, energy cannot be readily restored to the battery.
Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by supplying electrical energy to the cell, approximately restoring their original composition.

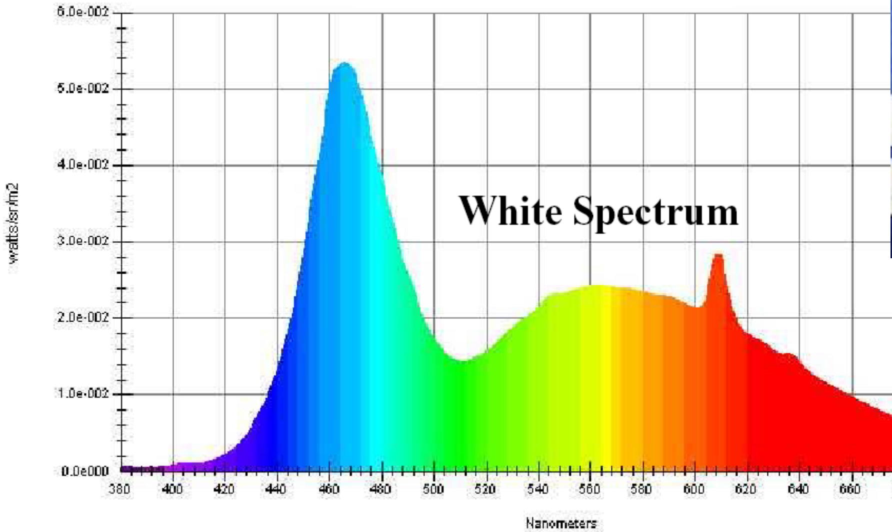
Power supply and battery operation – Lecture 12

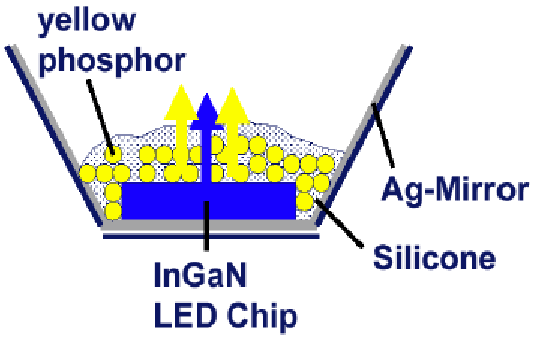
- Light emitting diodes
- LED semiconductor materials
- LASER diode
- Electrical characteristics
- Packaging







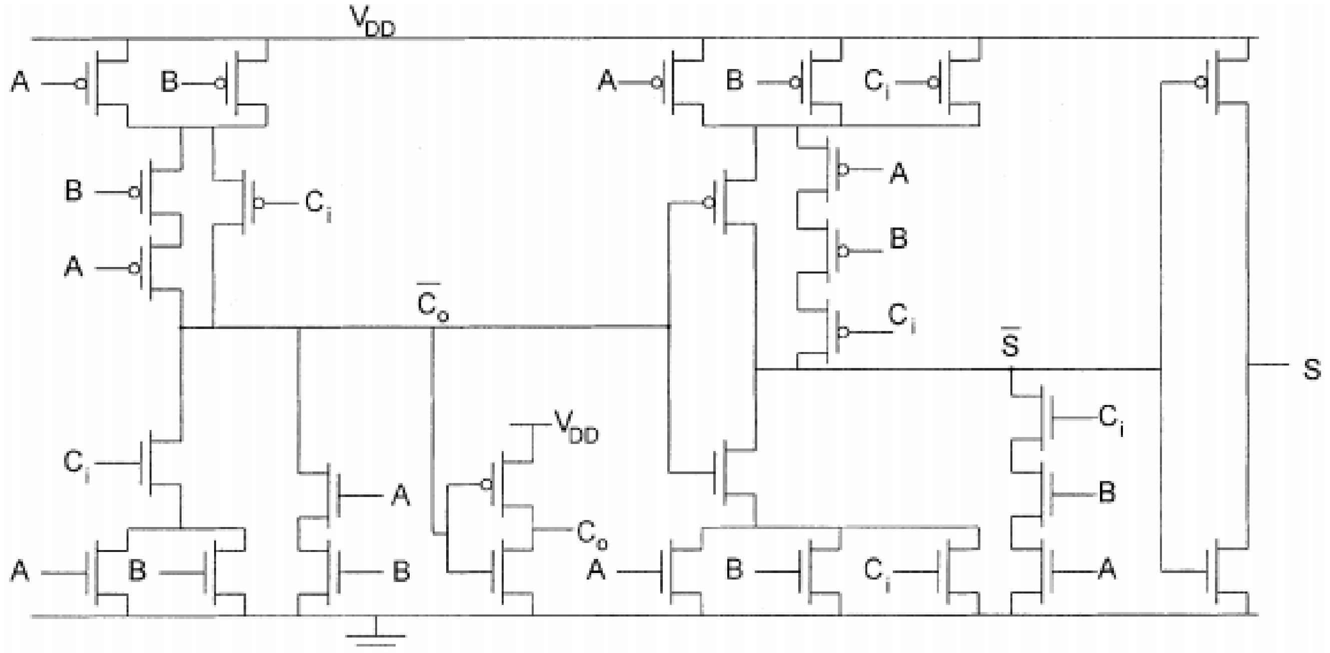




Digital circuits

- Digital logic is realized by circuits
  - The most frequent is the so-called voltage logic
  - Full power supply voltage is the “high” state and zero voltage is the “low” state
  - The common power supply voltages are: 5V, 3.3V, 2.5V, 1.8V or less.
  - Digital networks consist of logic gates.
  - (in the high speed circuits there are current logic or differential voltage logic circuits)

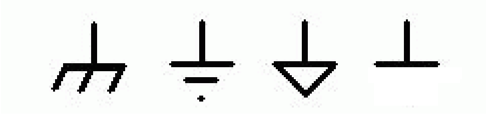
Schematic



- The „electrical engineer view” differs from the „physical view”
- The voltage sources are replaced with circles or lines
- The source voltages are denoted with circles or arrows and are multiplied to save on wires.
- The source voltage is usually called VCC or VDD or it is denoted with its value (e.g. +5 V)

Ground

Ground symbols



- Every circuit contains a reference point: the ground.
- Voltages are measured/given with respect to the ground.
- The reference potential is not necessarily equivalent to the real ground potential.
- In physics, when a voltage is given with respect to the ground it is called potential
- But in the electrical engineering practice it is often called ”voltage”

Passive components (resistor, inductor, capacitor)

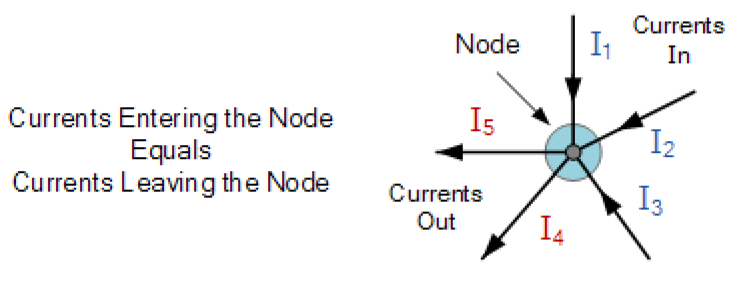
- The units are usually not shown – the symbol of the element together with the value give all the information needed
- The prefixes are compliant with the SI standard – sometimes (usually on elements) they appear at the position of the decimal point: e.g. 5k1 corresponds to 5100.

M, mega	10^{6}
k, kilo	10^{3}
m,milli	10^{-3}
µ, mikro	10^{-6}
n, nano	10^{-9}
p, piko	10^{-12}
f, femto	10^{-15}

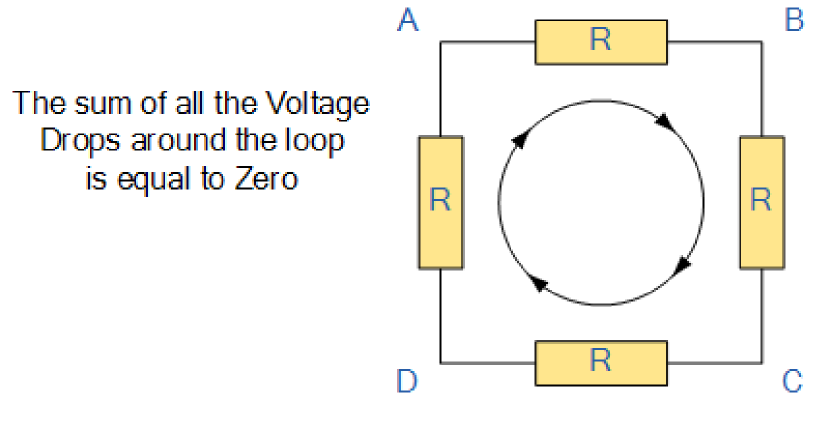
Kirchhoff's laws

- Kirchhoff's current law (KCL): the sum of currents in any given node is zero.
- Kirchhoff's voltage law (KVL): the sum of voltages in any given loop is zero.

Every circuit can be solved using the Kirchhoff laws and the characteristic equations of the elements.



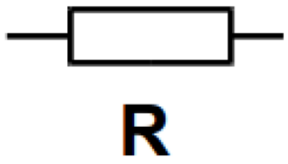
$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$



$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$

Passive linear electrical elements

- **Dissipative element:**
  - **resistor**



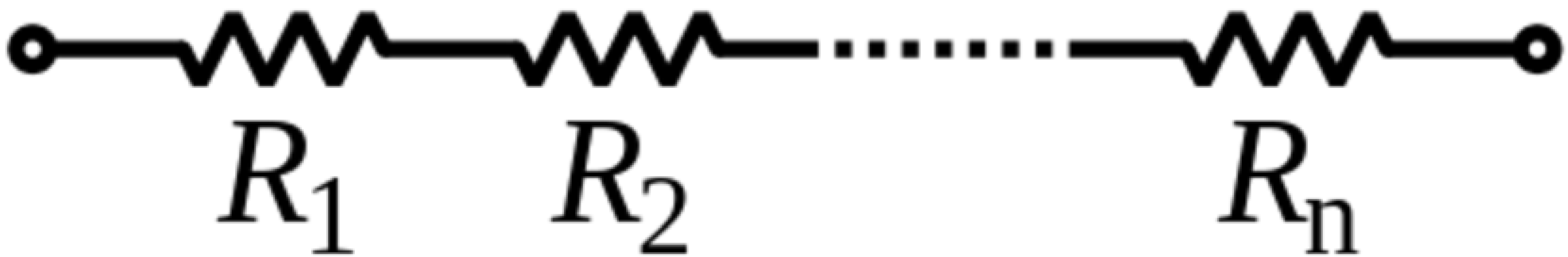
    - The power P dissipated by a resistor is calculated as:
      $P = VI = I^2R = V^2/R$
    - The current through a resistor is in direct proportion to the voltage across its terminals:

$$I = V/R$$

- R is the resistance – it is measured in Ohm (Ω).
- The inverse quantity of resistance is conductance (G), which is measured in S (Siemens). ($1S = 1\Omega^{-1}$)

Series configuration of resistors

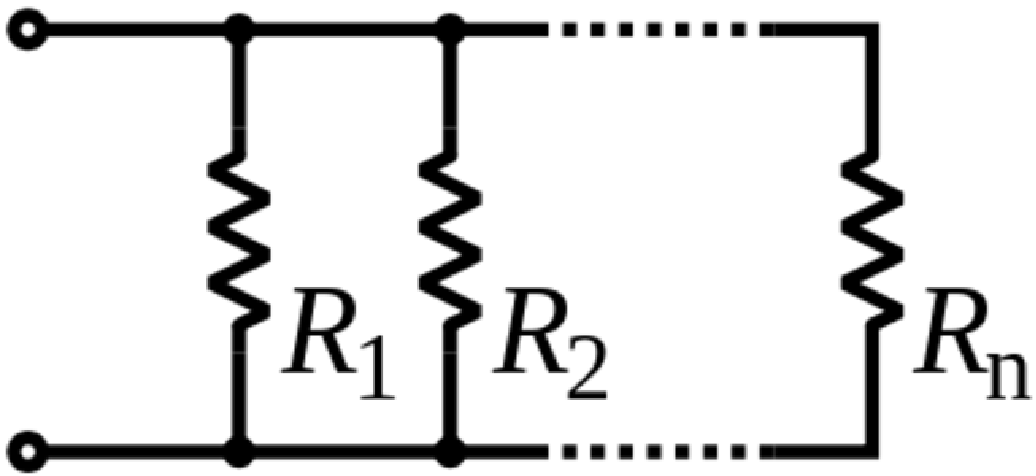
- In series configuration, the **current** is equal for all resistors



$$R_{eq} = R_1 + R_2 + \cdots + R_n .$$

Parallel configuration of resistors

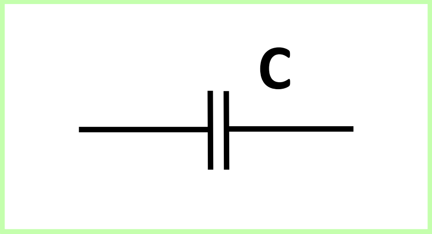
- In parallel configuration, the **voltage** is equal for all resistors



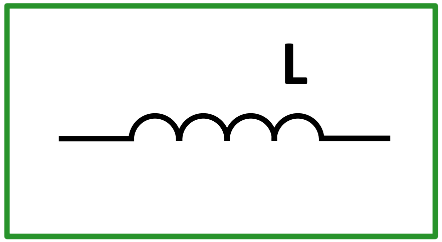
$$\frac{1}{R_{\mathrm{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}.$$

Capacitor

- A capacitor comprises at least two conductors placed very close to each other and separated by an insulator.
- Charges (Q) accumulate on the plates of the capacitors: $Q = CU$
- where C is the capacitance measured in Farad (As/V).
- The current of the capacitor: $I = \frac{dQ}{dt} \rightarrow I = C\frac{dU}{dt}$
- Thus in a DC case, when the voltage is constant: the current is zero (for ideal capacitors).
- In non-ideal capacitors a parallel resistance is always present and there is a so-called leakage current.



Inductor



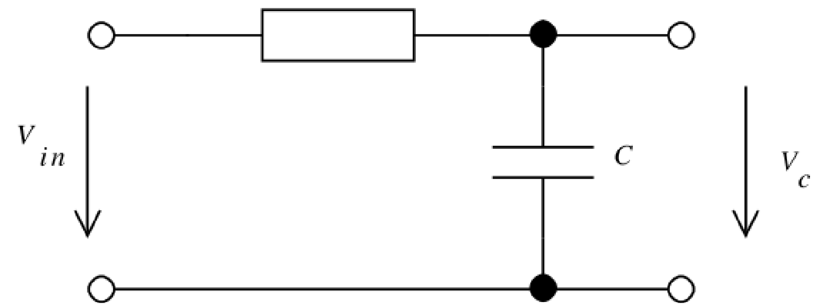
- An inductor is a coil made of a conducting wire.
- It stores energy in a magnetic field that is created by the current flowing through the wire.
- A change in the current of the inductor results in a voltage between its terminals:

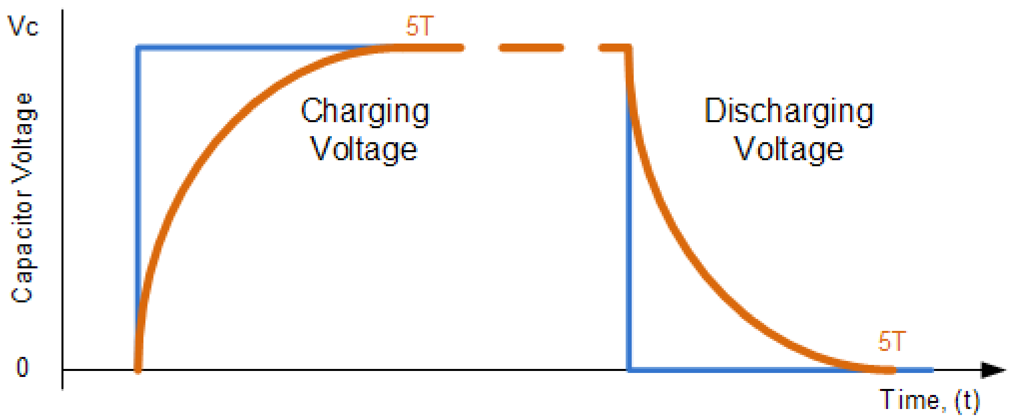
$$V = L\frac{dI}{dt}$$

- where *L* is the inductance, which is measured in Henry
- If the current flowing through an inductor is constant, then the voltage across it is zero.
- In non-ideal inductors there is always a series resistance (and a parallel capacitance) present which cause(s) losses.

Calculation of RC networks

$$\frac{V_{in} - V_C}{R} = C \cdot \frac{dV_C}{dt}$$





(a) **Switch-on event:**

$$V_C(t) = V_0 \cdot \left(1 - e^{-\frac{t}{RC}}\right)$$

(b) **Switch-off event:**

$$V_C(t) = V_0 \cdot \left(e^{-\frac{t}{RC}}\right)$$

- time constant (τ): the time it takes for the step response to reach 1 – 1/e (63.2%) of its final value.

The time constant can be calculated easily:

$$\tau = RC$$