

The very first idea is to make this document a learning tool for git, latex and, of course, of Electronics. I will be very proud of ourselves if we reach to maintain English as its primary language.

Introduction to Electronics

Formulas and utilities

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1 Semiconductors

Semiconductors are material with an electrical conductivity value falling between that of a conductor and an insulator. An important property of semiconductors is that, during a temperature increment, their resistance decreases. Common semiconductors material are:

- Silicon, Si. Z (i.e. atomic number) = 14. IV (14^{th}) group.
- Germanium, Ge. Atomic number = 32. IV (14^{th}) group
- Gallium Arsenide, GaAs, a compound of Gallium and Arsenic.

1.1 Semiconductors: a nuclear approach

A neutral Silicon atom possesses 14 protons and many electrons.

- the first 10 of them lies in the first energy level: they fit perfectly around the nucleus and are not involved in chemical reactions or anything (because very high energy is necessary to interact with them).
- the remaining 4 electrons are called *valence electrons* and are at higher energy levels. They are involved in the *covalent bond*.

When temperature is near at the absolute zero ($-273^{\circ}C$) the Silicon atoms assume a crystal form in which every *valence electron* is shared with the nearest 4 atoms of Silicon, with a covalent bond: in this circumstance Silicon act as an **insulator**. At higher temperatures, the atoms get energy from the outside: **1 eV** is the energy amount necessary for breaking a covalent bond.

1.1.1 Electrons and Holes

When the break happens, an electron *jumps* to valence band and a hole is generated (note that the semiconductor remains neutral). Remember that the hole is in fact the absence of an electron, and it may be referred to as a **cation**, an atom with positive charge.

1.1.2 Valence and conduction bands

Without the necessary energy, electrons remain under the *Fermi level*, in a zone called *Valence Band*; when the *jump* occurs, electrons step over the *Fermi level* and stay in the *conduction band*. In the conduction band charge carrier have less constraints and can easily move in the crystalline lattice, depending on the intensity of the electro-magnetic field.

1.1.3 Silicon properties

- To complete
- It is compatible with SiO_2 and Al

1.2 Doping

The doping process consists in significantly change the number of *electrons* or *holes* in a semiconductor. This result is achieved inserting atoms of the doping element in the crystalline arrangement of the doped.

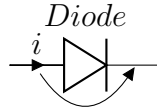
1.2.1 Utilities and numbers

- $N_d \cong 10^{12} : 10^{20} cm^{-3}$ number of donors
- $p[\frac{electrons}{cm^3}]$ number of holes

- $n[\frac{electrons}{cm^3}]$ number of electrons

TO ADD: the part regarding mobility and resistance.

2 Diodes



Diodes are defined as a p-n junction. Is is made by two parts: the left part (according to the figure) is a p-doped semiconductor in which there are holes left. The other part, on the contrary, is n-doped in which there are electrons left.

3 FORMULAS

3.1 Electric field and semiconductors

Electrostatic force between two charges q_1q_2 at a distance r :

$$F = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2} \quad (1)$$

The Electric field (as the force which a charge q is subjected to in a point of the space divided by the charge q) =

$$E = \frac{F}{q} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \quad (2)$$

Note that the Electric field is a **CONSERVATIVE FIELD**

A conservative field is a field in which the *Work* done for placing an element from a point a to a point b depends only from the different location of a and b and not by the route done.

The *Work* in a conservative field is defined as follows:

$$W_{a \rightarrow b} = \int_a^b \vec{F}(x) dx = q(V_b - V_a) \quad (3)$$

4 Engineer's corner

Question 1: How much is $1C$?

At first attempt we can say that 1 *Coulomb* is *very* approximately 10^{19} times the fundamental charge unit (the electron). However it is a bit difficult rendering the idea of 10^{19} electrons. Thinking about batteries, a common *AAA* battery has a capacity of 540 *mAh*, which are equivalent to 1944 *C*.

A common *AA* battery has a charge of 9 *kC*.

In everyday terms, a Coulomb is $\frac{1}{2000}$ times the charge occurring to empty a normal *AAA* battery.

Problem 6. a) Suppose an entire function f is bounded by M along $|z| = R$. Show that the coefficients C_k in its power series expansion about 0 satisfy

$$|C_k| \leq \frac{M}{R^k}.$$

b) Suppose a polynomial is bounded by 1 in the unit disc. Show that all its coefficients are bounded by 1.

Solution Part a): Since f is an entire function it can be expressed as an infinite power series, i.e.

$$f(z) = \sum_{k=0}^{\infty} \frac{f^{(k)}(0)}{k!} z^k = \sum_{k=0}^{\infty} C_k z^k.$$

If we recall Cauchy's Integral we have

$$f(z) = \frac{1}{2\pi i} \int_{\gamma} \frac{f(w)}{w - z} dw,$$

carefully notice that $\frac{1}{w-z} = \frac{1}{w} \cdot \frac{1}{1-\frac{z}{w}}$ can be written as a geometric series. We have

$$\begin{aligned} \frac{1}{2\pi i} \int_{\gamma} \frac{f(w)}{w - z} dw &= \frac{1}{2\pi i} \int_{\gamma} \left\{ \frac{f(w)}{w} \cdot \left(\frac{1}{1 - \frac{z}{w}} \right) \right\} dw \\ &= \frac{1}{2\pi i} \int_{\gamma} \left\{ \frac{f(w)}{w} \cdot \left(1 + \frac{z}{w} + \frac{z^2}{w^2} + \frac{z^3}{w^3} + \dots \right) \right\} dw \\ &= \left(\frac{1}{2\pi i} \int_{\gamma} \frac{f(w)}{w} dw \right) z^0 + \left(\frac{1}{2\pi i} \int_{\gamma} \frac{f(w)}{w^2} dw \right) z^1 + \left(\frac{1}{2\pi i} \int_{\gamma} \frac{f(w)}{w^3} dw \right) z^2 \dots \end{aligned}$$

Now take the modulus of C_k to get

$$|C_k| = \left| \frac{1}{2\pi i} \int_{\gamma} \frac{f(w)}{w^{k+1}} dw \right| \leq \frac{1}{2\pi} \int_{\gamma} \frac{|f(w)|}{|w^{k+1}|} |dw| \leq \frac{M}{2\pi} \int_{\gamma} \frac{|dw|}{|w^{k+1}|}$$

Then integrate along $\gamma(\theta) = Re^{i\theta}$ for $\theta \in [0, 2\pi]$ to get

$$|C_k| \leq \frac{M}{2\pi} \int_0^{2\pi} \frac{|iRe^{i\theta} d\theta|}{|R^{k+1}e^{ik\theta}|} = \frac{M}{2\pi \cdot R^k} \int_0^{2\pi} d\theta = \frac{M}{R^k}.$$

Hence, $|C_k| \leq \frac{M}{R^k}$.

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