# Analog Electronics

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## 0.1 Introduction

- mail: philippe.velha@unitn.it
- exam
  - written: mandatory, 0-30
  - lab reports: mandatory, pass-no pass
  - spice project: optional but is extra credit
  - assignements: design and spice simulations (optional but gives extra credit)
- main arguments
  - course introduction
  - rectification block
  - regulation block
  - transistor block
  - opamp block
  - protection and integration
- books:
  - art of electronics
  - ...

# Chapter 1

# foundamentals

## 1.1 theory introduction

### 1.1.1 Voltage

- intended as potential difference between two points
- the voltage difference between two points is the work required in Joules to move one Coulomb of charge from A to B
- $1V = 1\frac{J}{C}$
- voltage is expressed in Volts

### 1.1.2 Current

- is the rate of flow of electric charges past a point around a closed circuit
  - *point* is not precise $->$ we will define a point as an average through said checkpoint
  - rate implies an average over time: $I = \frac{N \cdot q}{\Delta t} = \frac{Q}{t}$
- Current is measured in Amperes [A]
- corresponds to the flow of 1 Coulomb of charge per second
- definiton of current density=J , $I = \int \int J \cdot dA$

### 1.1.3 sources of Voltage and Current

- Independent voltage sources
- real voltage sources
- independent current sources
- real current sources

### 1.1.4 Power

- Power is energy per unit time
- $P = V \cdot I$
- $\frac{energy}{charge} \cdot \frac{charge}{time}$
- expressed in watts [W]= $1\frac{J}{s}$
- power is sometimes dissipated in heat or in mechanical work of some type

## 1.2 Fundeamental Laws

### 1.2.1 Mawell Equations

- $\nabla \cdot E = \frac{\rho}{\epsilon}$ : Gauss'law
- Gauss' law for magnetism
- Faraday's law of induction
- Ampere's Law

### 1.2.2 kirchoff

**KCL**

- $\Omega$: a volume containing a node
- S; surface boundary of $\Omega$
- $S_K$: intersection between and wire k
- $n_K$: normal of surface $S_K$

$$\int\int_{\Omega}\int \nabla \cdot J dV = \int\int_{S} J \cdot n dS = \sum_{k=1}^{N}\int\int J \cdot n dS + \int\int_{S/\cup_{k=1}^{N}}$$

**KVL**

## 1.3 Elementary linear components

### 1.3.1 Capacitor

### 1.3.2 Inductance

### 1.3.3 Resistorns

## 1.4 types of signals

## 1.5 Thevenin theorem

any two-terminal network whose internal circuitry consists solely of resistors, batteries, and current sources, interconnected in any manner whatsoever, is equivalent (and indistinguishable) from the two-terminal network consisting of a single battery $V_{TH}$ in series with a single resistor $R_{TH}$

## 1.6 Amplifiers

### 1.6.1 models of the amplifiers

- Voltage Amplifier
  - Gain parameter
    - Open circuit voltage gain
    - $A_{v_0} \equiv \frac{v_0}{v_i} |_{i_0=0} \quad (V/V)$
  - Ideal Characteristics
    - $R_i = \infty$
    - $R_0 = 0$
- current amplifier
  - Gain parameter
    - Short-circuit Current gain

        - $A_{is} \equiv \frac{i_0}{i_i}|_{v_0=0} \quad (A/A)$
    - Ideal Characteristics
        - $R_i = 0$
        - $R_0 = \infty$

- Transconduttance amplifier
    - Gain parameter
        - short-circuit transconductance
        - $G_m \equiv \frac{i_0}{v_i}|_{v_0=0} \quad (A/V)$
    - Ideal Characteristics
        - $R_i = \infty$
        - $R_0 = \infty$

- transresistance amplifier
    - Gain parameter
        - Open circuit transresistance
        - $R_m \equiv \frac{v_0}{i_i}|_{i_0=0} \quad (V/A)$
    - Ideal Characteristics
        - $R_i = 0$
        - $R_0 = 0$

### 1.6.2 unilateral amplifier

- signal flows in only one direction
- it is a model used sometimes to indicate that input and output are totally isolated
- this for the sake of modelling simplifies greatly but might not be always true

### 1.6.3 Frequency response

- a sinewave applied to a linear circuit is transformed in another sinewave with a different amplitude and some phase shift.

### 1.6.4 Single time constant networks (STC)

- minimum STC network is a resistor and reactive load (capacitor or inductor)
- usually classified in 2 categories LP(low pass) and HP(high pass)
- an STC circuit formed of an inductance L and a resistance R has a time constant $\tau$ =L/R
- the time constant $\tau$ of an STC circuit composed of a capacitance C and a resistance R is given by $\tau$=RC
- time constant evaluation
    - The first step in the analysis of an STC circuit is to evaluate its time constant $\tau$ (unit: seconds)
    - in many instances, it will be important to be able to evaluate rapidly the time constant $\tau$ of a given STC circuit.
    - A simple method for accomplishing this goal consists first of reducing the excitation to zero; that is, if the excitation is by a voltage source, short it, and if by a current source open it!

#### classification of STCs

- Low-Pass
- High-Pass