

# microcontrollers

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# Chapter 1

## intro

microcontrollers are small computers in a single integrated circuit.a single **integrated circuit** is a chip

# Chapter 2

## basic electronic

### 2.1 AC/DC



**Figure 2.1:** types of current

**def AC** → alternating current is an electric current that periodically reverses direction and changes its magnitude continuously with time.

**example** → used to transmit electricity in long distances. less power loss of dc in this scenario.

**def DC** → direct current is one-directional flow of electric charge.

**example** → battery

**inverter** → turns DC in AC.

**rectifier** → turns AC in DC. (in italiano raddrizzatore) (domanda 40). basically 4 diode in diamond shape see picture below.



**Figure 2.2:** Full-wave diode-bridge rectifier with parallel RC shunt filter

## 2.2 electric laws

### 2.2.1 basics

- amperes → how many electrons (1 coulomb that is  $6.24150910^{18}$  electrons) are passing through a point in a second
- volts → the electric potential between two points. many electrons in negative side, few electrons on positive side of battery. when the battery is exhausted there are equal number of electrons in each side.
- watt → the power.  $W = V \cdot A$
- resistance → how difficult is it to pass for the electrons through a specific material

### OHMS LAW

**def** → electric current is proportional to voltage and inversely proportional to resistance.

$$V = I \cdot R$$

$$R = \frac{V}{I}$$

$$I = \frac{V}{R}$$

- $V$  is the voltage (in volts  $V$ )
- $I$  is the current (in amperes  $A$ )
- $R$  is the resistance (in ohms  $\Omega$ )

# Chapter 3

## components and circuits

### 3.1 categories

**passive** → incapable of power gain. example capacitor, resistance

**active** → capable of power gain. example transistor

**electromechanical** → can carry out electrical operations by using moving parts or by using electrical connections. example relay, solenoids

**note** → diodes can be both active and passive.

**active diodes** → zener diode, led

**passive diodes** → normal diodes

### 3.2 impedances - impedenze

**def** → L'impedenza, in elettrotecnica e elettronica, è una grandezza fisica che rappresenta la resistenza di opposizione al passaggio della corrente elettrica alternata o corrente variabile, in un circuito. Il concetto di impedenza generalizza la legge di Ohm estendendola ai circuiti funzionanti in regime sinusoidale (comunemente detta corrente alternata); in regime di corrente continua rappresenta infatti la resistenza elettrica.

### 3.3 voltage divider - partitore di tensione

**def** → passive linear circuit that produces an output voltage that is a fraction of its input voltage.



**Figure 3.1:**  $Z_1$  and  $Z_2$  are impedances

$$\text{formulas} \rightarrow V_{out} = \frac{Z_2}{Z_1 + Z_2} \cdot V_{in}$$

### 3.4 semiconductors

**def** → Silicon is a semiconductor, which means it's neither really a conductor (something like a metal that lets electricity flow) nor an insulator (something like plastic that stops electricity flowing). If we treat silicon with impurities (a process known as doping), we can make it behave in a different way. If we dope silicon with the chemical elements arsenic, phosphorus, or antimony, the silicon gains some extra "free" electrons—ones that can carry an electric current—so electrons will flow out of it more naturally. Because electrons have a negative charge, silicon treated this way is called n-type (negative type). We can also dope silicon with other impurities such as boron, gallium, and aluminum. Silicon treated this way has fewer of those "free" electrons, so the electrons in nearby materials will tend to flow into it. We call this sort of silicon p-type (positive type). Quickly, in passing, it's important to note that neither n-type or p-type silicon actually has a charge in itself: both are electrically neutral. It's true that n-type silicon has extra "free" electrons that increase its conductivity, while p-type silicon has fewer of those free electrons, which helps to increase its conductivity in the opposite way. In each case, the extra conductivity comes from having added neutral (uncharged) atoms of impurities to silicon that was neutral to start with—and we can't create electrical charges out of thin air! A more detailed explanation would need me to introduce an idea called band theory, which is a little bit beyond the scope of this article. All we need to remember is that "extra electrons" means extra free electrons—ones that can freely move about and help to carry an electric current. Suppose we join a piece of n-type silicon to a piece of p-type silicon and put electrical contacts on either side. Exciting and useful things start to happen at the junction between the two materials. If we turn on the current, we can make electrons flow through the junction from the n-type side to the p-type side and out through the circuit. This happens because the lack of electrons on the p-type side of the junction pulls electrons over from the n-type side and vice-versa. But if we reverse the current, the electrons won't flow at all. What we've made here is called a diode (or rectifier). It's an electronic component that lets current flow through it in only one direction. It's useful if you want to turn alternating (two-way) electric current into direct (one-way) current. Diodes can also be made so they give off light when electricity flows through them. You might have seen these light-emitting diodes (LEDs) on pocket calculators

and electronic displays on hi-fi stereo equipment.

### 3.5 resistori

**def** → informalmente chiamati resistenza (in realtà essa è la grandezza fisica che quantifica il valore ohmico). Basically, a resistor limits the flow of charge in a circuit and is an ohmic device where  $V=IR$ .

#### caratteristiche

- resistenza → in  $\Omega$ .  $R = \rho \frac{l}{S}$ 
  - $\rho$  → resistività del materiale. dipende dalla temperatura  $T$
  - $l$  → lunghezza del materiale
  - $S$  → sezione del materiale
- massima potenza → in  $W$ . threshold che se superata distrugge/deteriora il resistore

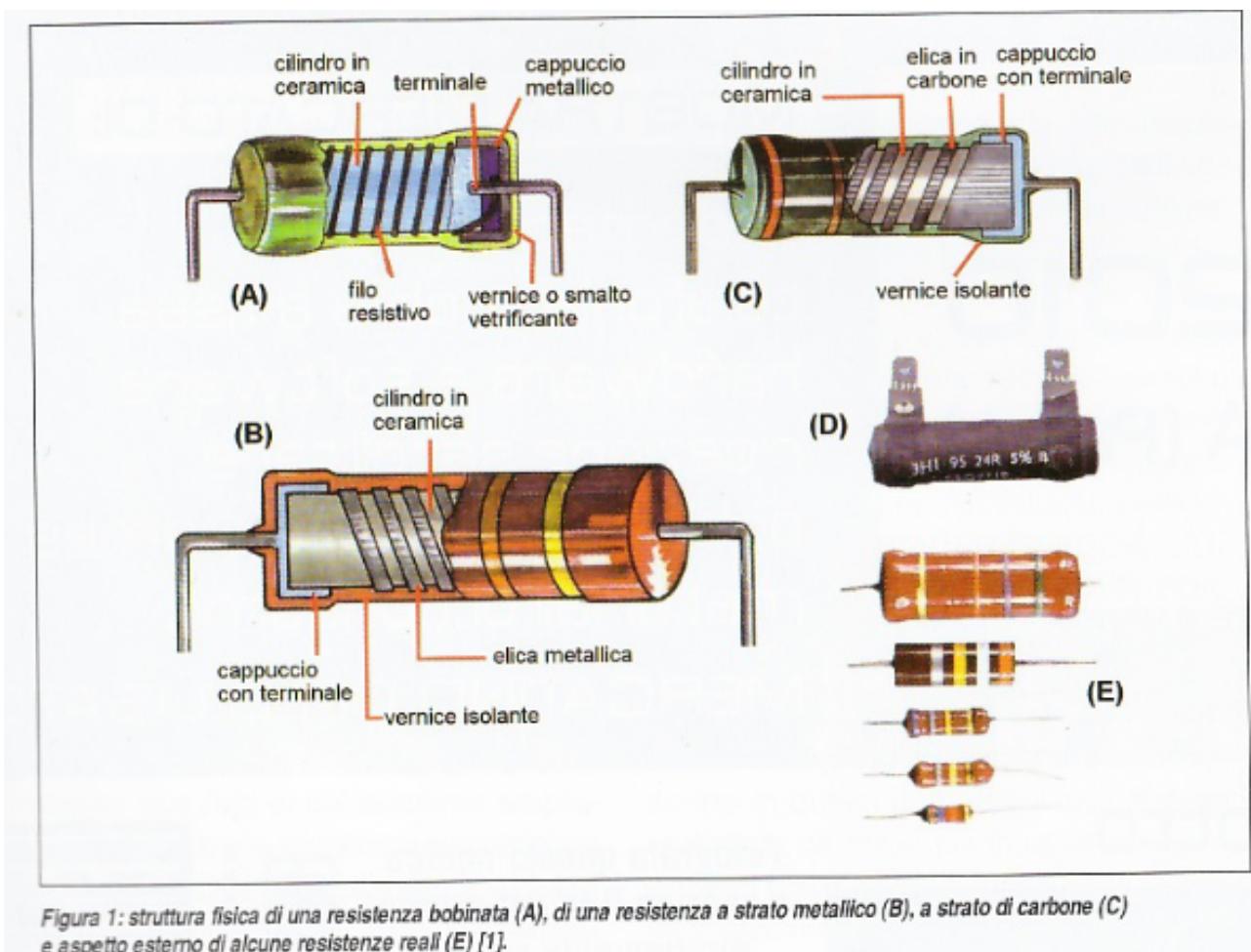


Figura 1: struttura fisica di una resistenza bobinata (A), di una resistenza a strato metallico (B), a strato di carbone (C) e aspetto esterno di alcune resistenze reali (E) [1].

### 3.5.1 series and parallel



(a) Resistors connected in series



(b) Resistors connected in parallel

**Figure 3.2:** (a) For a series connection of resistors, the current is the same in each resistor. (b) For a parallel connection of resistors, the voltage is the same across each resistor.

#### series

resistors are in series when the current flow through them sequentially.



(a) Original circuit

(b) Equivalent circuit

**Figure 3.3:** (a) Three resistors connected in series to a voltage source. (b) The original circuit is reduced to an equivalent resistance and a voltage source.

$$\text{formulas} \rightarrow R_{eq} = R_1 + R_2 + R_3 = \sum_{i=1}^n R_i$$

#### parallel

Resistors are in parallel when one end of all the resistors are connected by a continuous wire of negligible resistance and the other end of all the resistors are also connected to one another through a continuous wire of negligible resistance. The potential drop across each resistor is the same. Current through each resistor can be found using Ohm's law  $I=V/R$ , where the voltage is constant across each resistor.



**Figure 3.4:** (a) Two resistors connected in parallel to a voltage source. (b) The original circuit is reduced to an equivalent resistance and a voltage source.

$$\text{formulas} \rightarrow R_{eq} = \left( \frac{1}{R_1} + \frac{1}{R_2} \right)^{-1} = \left( \sum_{i=1}^n \frac{1}{R_i} \right)^{-1}$$

## 3.6 condensatore - capacitor

**def** → device that stores electrical energy by accumulating electric charges on two closely spaces surfaces that are insulated from each other. it is the equivalent of a dam (diga) in the hydraulic analogy. ha una threshold di tensione massima in volt. la capacita e l abilita di un oggetto di immagazzinare carica elettrica.

### 3.6.1 series and parallel

**series**

$$C_{eq} = \left( \sum_{i=1}^n \frac{1}{C_i} \right)^{-1}$$

**parallel**

$$C_{eq} = \sum_{i=1}^n C_i$$

**NOTE THAT IS THE OPPOSITE OF RESISTORS**

### 3.6.2 questions

Perché talvolta si collega un condensatore in parallelo ai contatti di un pulsante?

Un interruttore, così come un microswitch, lo scambio di un relè o più in generale un qualsiasi contatto meccanico sono detti "sporchi". Questo perché quando avviene la commutazione (sia in apertura che in chiusura) la variazione di tensione prodotta non è netta ma affetta da una moltitudine di disturbi causati dalla non perfetta aderenza delle parti meccaniche che realizzano il contatto. Questi disturbi si traducono elettricamente in picchi e

vuoti di tensione che per il primo istante della commutazione (circa 50 ms) generano un segnale dall' andamento imprevedibile.

Per eliminare tale problema si può ricorrere all' uso di un condensatore in parallelo ai contatti , tale componente avrà il compito di assorbire le "impurità" dal segnale generato rendendolo pulito.

## 3.7 circuito rc

**def** → un circuito rc e un circuito elettrico del primo ordine basato su un resistore e su un condensatore.  
 $\tau$  → time required for the voltage to fall to  $\frac{V_0}{e}$ .

$$\tau = R \cdot C$$

**PAY ATTENTION TO TIME UNITS. TIP USE  $10^X$  NOTATION WHEN DOING MULTIPLICATION**

dopo  $5 \cdot \tau$  il condensatore è scarico/carico.

### 3.7.1 questions

A che cosa serve una rete RC formata da una resistenza e un condensatore in serie.

Se viene preso l output agli estremi del condensatore vengono attenuate le frequenze alte, cioe low-pass filter.  
Se viene preso l output agli estremi del resistore vengono attenuate le frequenze basse, cioe high-pass filter.

## 3.8 potentiometer

**def** → three terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.

21. Un potenziometro è collegato a +5V :



0V (GND)

Calcolare la tensione presente sul cursore rispetto a GND quando il cursore è posizionato a in (A) e in (B), dove (A) è a  $\frac{1}{4}$  del potenziometro e (B) è a  $\frac{3}{4}$ .

22. Un potenziometro è collegato a +5V :



0V (GND)

Si vuole ottenere una tensione di 4 V tra il cursore e massa (GND). Il potenziometro andrà messo in (A) o in (B) ?

Figure 3.5: es

$$C = \text{cursor\_position\_ratio}$$
$$V_{out} = V_{in} \cdot C$$

## 3.9 leds

def → semiconductor device that emits light when current flows through it.

### 3.9.1 questions

27. Un diodo LED rosso ( $V_F = 1.8$  V) viene collegato a un pin di Arduino alimentato a 3.3 V. Immaginando una corrente di 10 mA, calcolare la resistenza serie.

$$R = \frac{\Delta V}{I} = \frac{V_{in} - V_F}{I} = \frac{3.3V - 1.8V}{10mA} = \frac{1.5V}{10 \cdot 10^{-3}A} = 150\Omega$$

<https://www.build-electronic-circuits.com/how-to-find-voltage-and-current-of-led/>

## 3.10 opto isolator

**def** → electronic component that transfers electrical signals between two isolated circuits by using light.

### 3.10.1 questions

34. A cosa serve utilizzare un optoisolatore collegato a un pin di uscita digitale di un microcontrollore? a isolare arduino da un circuito con voltaggio maggiore, per evitare di friggere il microcontrollore.

## 3.11 transistors

**def** → semiconductor device used to amplify or switch electrical signals and power. a voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals.

### 3.11.1 Bipolar Junction Transistor

**pin names** → base collector emitter

**hFE** → rapporto tra la corrente diretta ( $I$ ) del collector e tra la corrente diretta ( $I$ ) della base nella forward active region.

### 3.11.2 Field Effect Transistor

**pin names** → source gain drain

## 3.12 circuits

### 3.12.1 questions

33. Come fare a collegare un carico di potenza (es. una lampada a 24 V 2 A) ad un microcontrollore? To control devices, such as motors, lamps, coffee makers, toasters, etc. that require more voltage and/or current than can be handled directly by the Arduino pins, we need to place a device between the Arduino and those higher requirement devices. Three popular “in-between” devices that allow us to control relatively high voltage and/or current with relatively low voltage and current are relays designed for Arduinos, and two transistors: BJT and MOSFETS. **TL;DR Relays, transistor BJT e transistor MOSFETS**

## 3.13 misc

### 3.13.1 sinking and sourcing

**def** → Current sourcing and sinking refers to the way that an external load is connected to a circuit, system, microcontroller or other electronic device.

When a load is connected to a device so that the device supplies current to the load (sources current) then the configuration is said to be current sourcing.

When a load is connected to a device so that current flows from the power supply through the load and into the device, then the configuration is said to be current sinking. When current flows into the device, it is said to be sinking current.



Figure 3.6: sourcin and sinkin



Figure 3.7: sourcin and sinkin

### 3.14 questions

- 35. Cosa si intende per “debouncing” (o antirimbombo) di un interruttore collegato a un ingresso digitale? Per bouncing si intende il rimbalzo al momento di switch tra i due contatti di un interruttore che provoca differenze di tensione imprevedibili in un circuito. Per debouncing si intende mitigare questo effetto e si puo farlo con un condensatore collegato in parallelo ai contatti del pulsante.
- 36. Perche bisogna usare un transistor per pilotare un relè da parte di un pin I/O di un microcontrollore? The average microcontroller like on your Arduino has only limited ‘strength’ on the port pins. Typically it might be 2..20mA. Your relay might require 60mA at a guess so you require some means of amplifying the port pin. A transistor or mosfet is commonly used.

- 37. Nel circuito allegato, a cosa serve il diodo collegato in parallelo alla bobina del relè?

When a small voltage typically above 0.6V is applied across the base emitter junction of the transistor, it enters into an active state. This activation is crucial as it enables the transistor to conduct current between its collector and emitter terminals. The activated transistor serves as a switch for the relay. With the transistor conducting current flows through the relay coil. The magnetic field generated by this current causes the relay's internal switch to close allowing a larger load to be connected or disconnected. Upon deactivation of the relay or when the input voltage is removed a back electromotive force EMF is generated across the relay coil. The freewheeling diode connected in parallel with the relay coil provides a path for this back EMF to circulate preventing it from damaging the transistor. Essentially, it ensures a safe discharge path for the stored energy in the relay coil. The base resistor is introduced to control the current flowing into the base of the transistor. Proper base current is essential to keep the transistor in its active region without overloading it. This information is critical for sizing components and ensuring the relay operates within its specified parameters. **TL;DR Il diodo serve per non danneggiare il transistor con i campi elettromagnetici generati dall'utilizzatore.**

- 39. Come è fatto un diodo a semiconduttore e a cosa serve.

Un diodo a semiconduttore è formato da una giunzione p-n connessa a due terminali elettrici (la maggior parte dei diodi è fatta di silicone). Serve a far circolare la corrente in una sola direzione.

- 41. Come è fatto un transistor BJT? Un transistor BJT è formato da due giunzioni p-n e usa sia gli elettroni che gli electron holes come portatori di carica. Le pn junctions possono essere di tipo PNP oppure di tipo NPN.

- 42. Devo usare un BJT per controllare un carico di potenza. Perché devo andare a guardare e valutare il guadagno ( $hFE$ ) del transistor? Se il guadagno del transistor è troppo basso il carico di potenza non funziona e se invece è troppo alto rischio di danneggiare il componente.

- 87. Che differenze ci sono tra la RS232 e la RS-485? La RS-232 e la RS-485 sono due standard di comunicazione seriale utilizzati per la trasmissione di dati, ma presentano differenze significative in termini di architettura, applicazioni e prestazioni. Ecco un confronto tra i due:

Caratteristica	RS-232	RS-485
Architettura e Topologia	Punto-a-punto (2 dispositivi)	Multi-punto (fino a 32 trasmettitori e 32 ricevitori)
Distanza di Trasmissione	Fino a 15 metri (50 piedi)	Fino a 1200 metri (4000 piedi)
Velocità di Trasmissione	Fino a 115200 bps	Simile o superiore a RS-232
Immunità al Rumore	Maggiore suscettibilità al rumore	Maggiore resistenza al rumore grazie alla trasmissione differenziale
Applicazioni	Collegamenti a corto raggio (modem, stampanti)	Applicazioni industriali (controllo automazione, reti di sensori)

**Table 3.1:** Confronto tra RS-232 e RS-485

# Chapter 4

## protocols

- 1 WIRE PROTOCOL:

**def** → wired half-duplex serial bus designed by Dallas Semiconductor that provides low-speed (16.3 kbit/s) data communication and supply voltage over a single conductor.

- wired → on a physical cable
- half-plex → only a device at a time can send data
- serial → data is transmitted one bit at a time
- bus → communication system that encompasses both hardware (wires) and software (communication protocol)
- synchronous → it uses a clock signal

- components

- bus master with controlling software (a "server")
- wiring
- devices

# **Chapter 5**

## **Sources**

- [https://phys.libretexts.org/Bookshelves/University\\_Physics/University\\_Physics\\_\(OpenStax\)/University\\_Physics\\_II\\_-\\_Thermodynamics\\_Electricity\\_and\\_Magnetism\\_\(OpenStax\)/10%3A\\_Direct-Current\\_Circuits/10.03%3A\\_Resistors\\_in\\_Series\\_and\\_Parallel](https://phys.libretexts.org/Bookshelves/University_Physics/University_Physics_(OpenStax)/University_Physics_II_-_Thermodynamics_Electricity_and_Magnetism_(OpenStax)/10%3A_Direct-Current_Circuits/10.03%3A_Resistors_in_Series_and_Parallel)

## FORMULAS

OHM'S LAW

RC NETWORK TIME

$$\tau = R C$$

$$V = R I$$

POTENTIELLE

$$V_{\text{OUT}} = V_{\text{IN}} \cdot \frac{\text{POSITION}}{\text{RATIO POSITION}}$$

VOLTAGE DIVIDER

$$V_{\text{OUT}} = \frac{R_2}{R_1 + R_2} \cdot V_{\text{IN}}$$

RESISTORS

SERIES

$$R_{\text{EQ}} = \sum_{i=1}^n R_i$$

PARALLEL

$$R_{\text{EQ}} = \left( \sum_{i=1}^n \frac{1}{R_i} \right)^{-1}$$

CAPACITORS

SERIES

$$C_{\text{EQ}} = \left( \sum_{i=1}^n \frac{1}{R_i} \right)^{-1}$$

PARALLEL

$$C_{\text{EQ}} = \sum_{i=1}^n C_i$$

C = CAPACITANCE Fara

I = INTENSITÉ DU A

R = RESISTANCE

V = TENSION VA

METRIC PREFIXES

GIGA  $10^9$

MEGA  $10^6$

KILO  $10^3$

ILLI  $10^{-3}$

MICRO  $10^{-6}$

NANO  $10^{-9}$

PICO  $10^{-12}$

CONTROLLATI  
DAL  
VOLTAGEGIC

MOSFET

VS

BJT

CONTROLLATI DALLA  
CORRENTE

GATE  
DRAIN  
SOURCE

NON HANNO UN GRANDE  
GADDAENO

SONO PIÙ UTILI PER  
SWITCHING

ALTA IMPEDANZA

PIÙ SENSIBILI AI SEGNALE

POINT IN  
PERPETUALLY

ACROSS

NEVER POINT  
IN

PNP

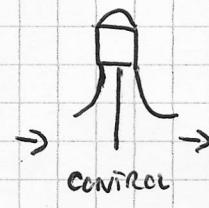
NPN



BASE  
COLLECTOR  
EMITTER

PIÙ ADATTI PER AMPLIFICARE  
SEGNALE → HIGHER GAIN

IMPEDENZA VARIABILE



SILICIO DROCATO

POSITIVAMENTE OPPURE  
NEGATIVAMENTE



CROSS  
SECTION



DARLINGTON

PNP



NPN



TWO BJTS CONNECTED  
TOGETHER EVEN MORE  
TO AMPLIFY GA

# OPAMP

INGRESS  
NON INVERTING



INGRESS  
INVERTING

## VOLTAGE FOLLOWER



- VERY HIGH INPUT IMPEDANCE

- VERY LOW OUTPUT IMPEDANCE

## INVERTING AMPLIFIER



+ → NON INVERTING INPUT

IF + > -

- → INVERTING INPUT

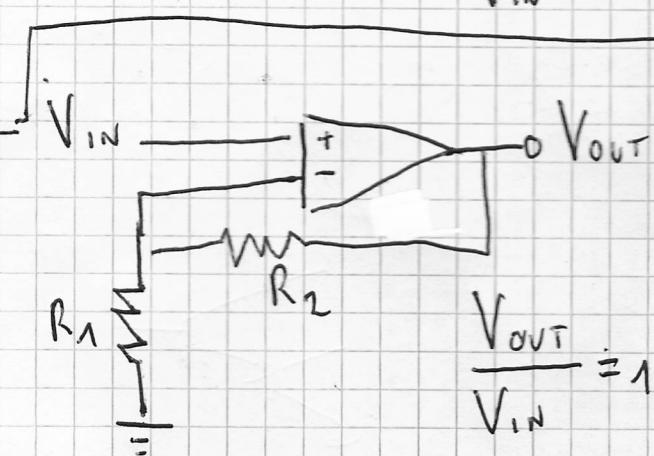
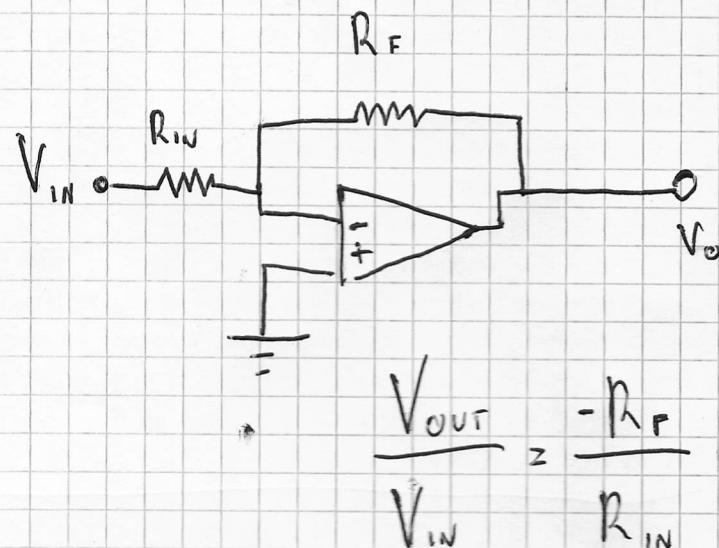
RETURN +

IF - > +

RETURN -

## Non Inverting Amplifier

### AMPLIFIER



## INTEGRATOR



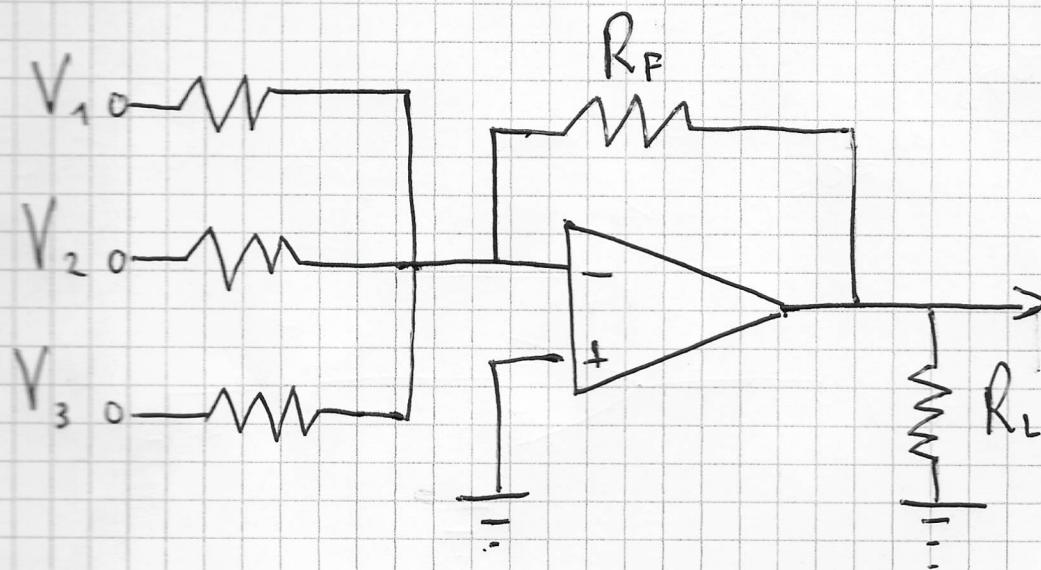
## DIFFERENTIATOR



# WHEATSTONE BRIDGE WITH OPAMP

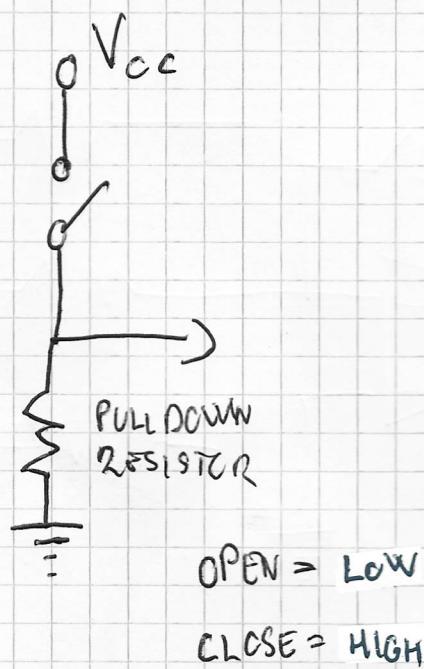


SUM VOLTAGES OPAMP





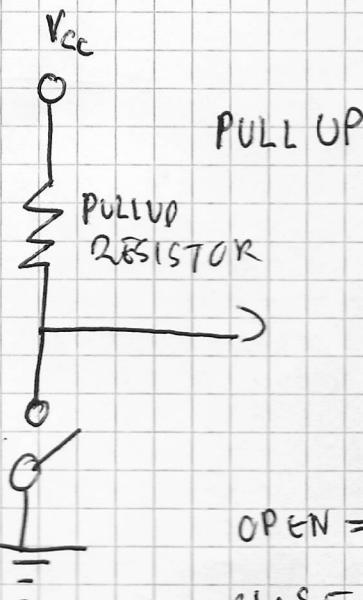
PULLDOWN



PULLDOWN  
RESISTOR

OPEN = LOW

CLOSE = HIGH

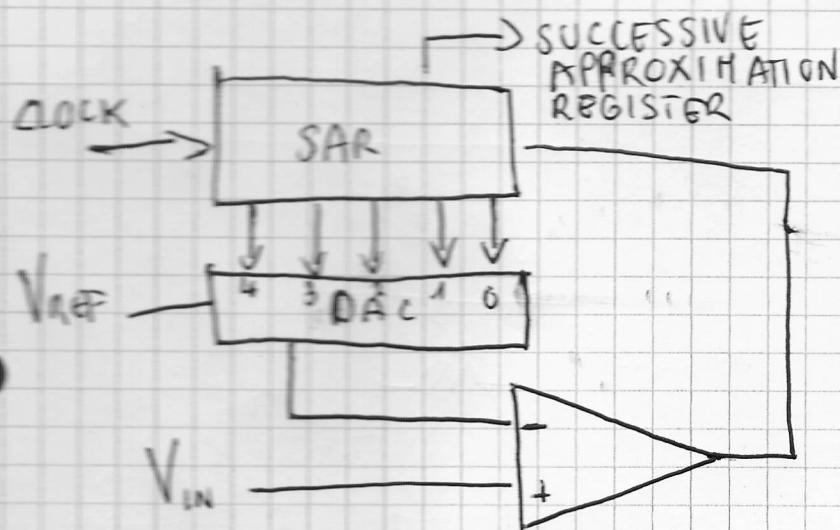


PULLUP  
RESISTOR

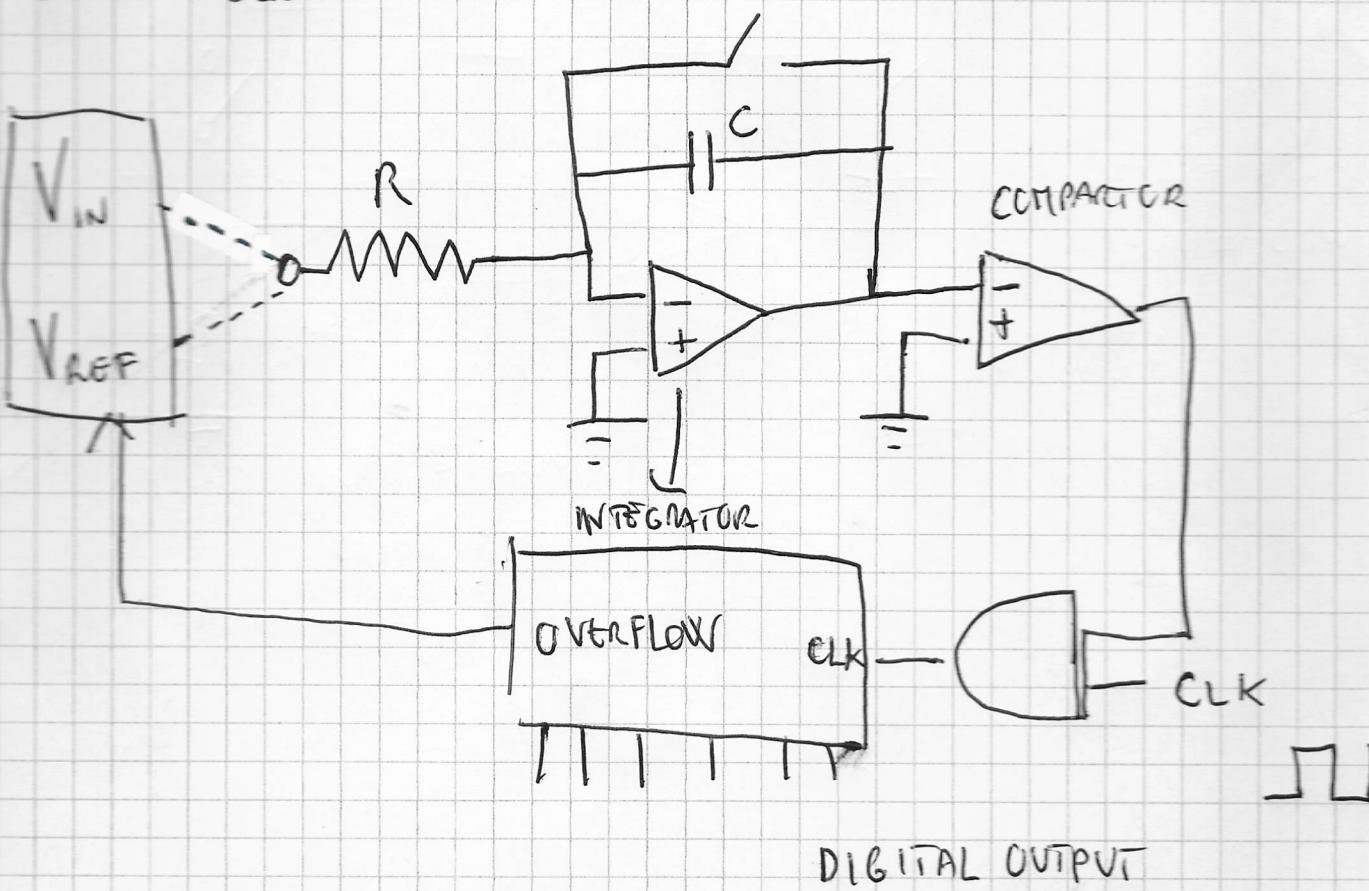
OPEN = HIGH  
CLOSE = LOW

ADC

APPROXIMAZIONI      SUCCESSIVE → BINARY SEARCH

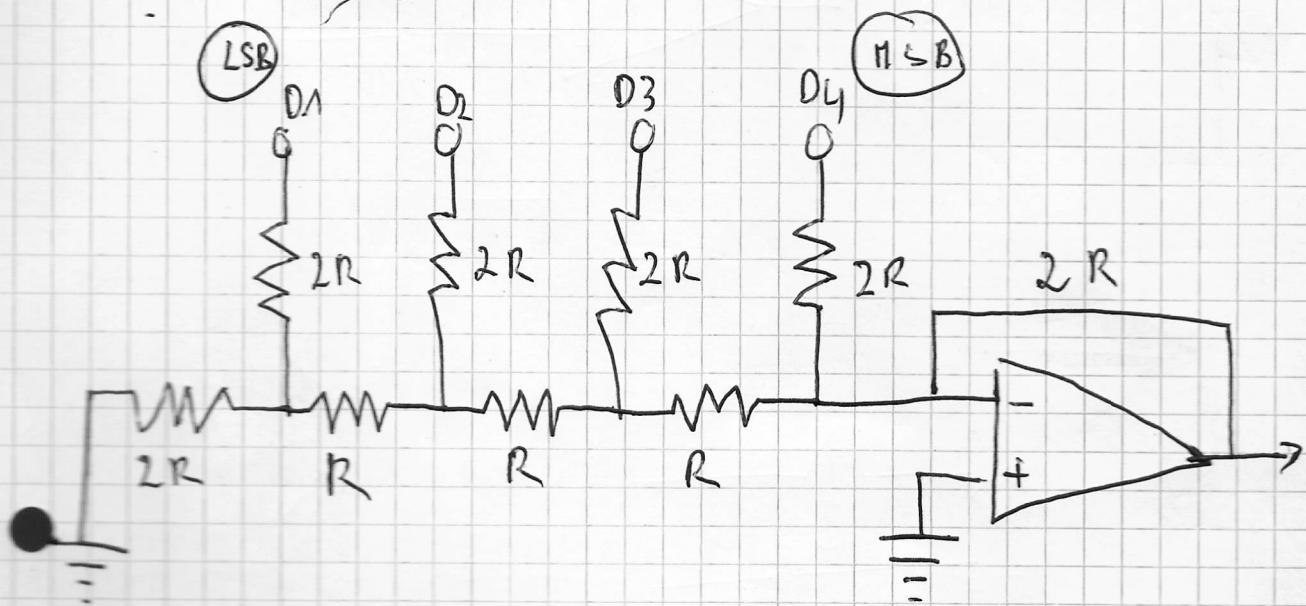


DUAL SLOPES



D<sub>AC</sub>

LADDER



RESISTORS MUST BE PRECISE

# PROTOCOLS

RS232

VS

RS 485

SINGLE ENDED  
SIGNALING

DIFFERENTIAL  
SIGNALING

SIGNAL TYPE

15 M

1200 M

DISTANCES

1MS, 2 KBPS

10 MBPS

DATA RATE

MIN 3  
TX  
RX  
GND

MIN 2  
A  
B

WIRING

POINT TO  
POINT  
A TRANSMITTER  
A RECEIVER

MULTI-POINT

TOPOLOGY

UP TO 32  
DEVICES

LESS RESISTANT  
TO NOISE

MORE RESISTANCE  
TO NOISE

NOISE IMMUNITY

COMPUTER  
PERIPHERALS  
(DEPRECATE)

INDUSTRIAL AND BUILDING  
AUTOMATION APPLICATIONS

THINGS IN COMMON

FULL-DUPLEX (RS485 HAS THE OPTION)

ASYNCHRONOUS

THEY USE START AND STOP BITS TO FRAME THE DATA

# SPI

SERIAL PERIPHERAL  
INTERFACE

3+1 CAVI

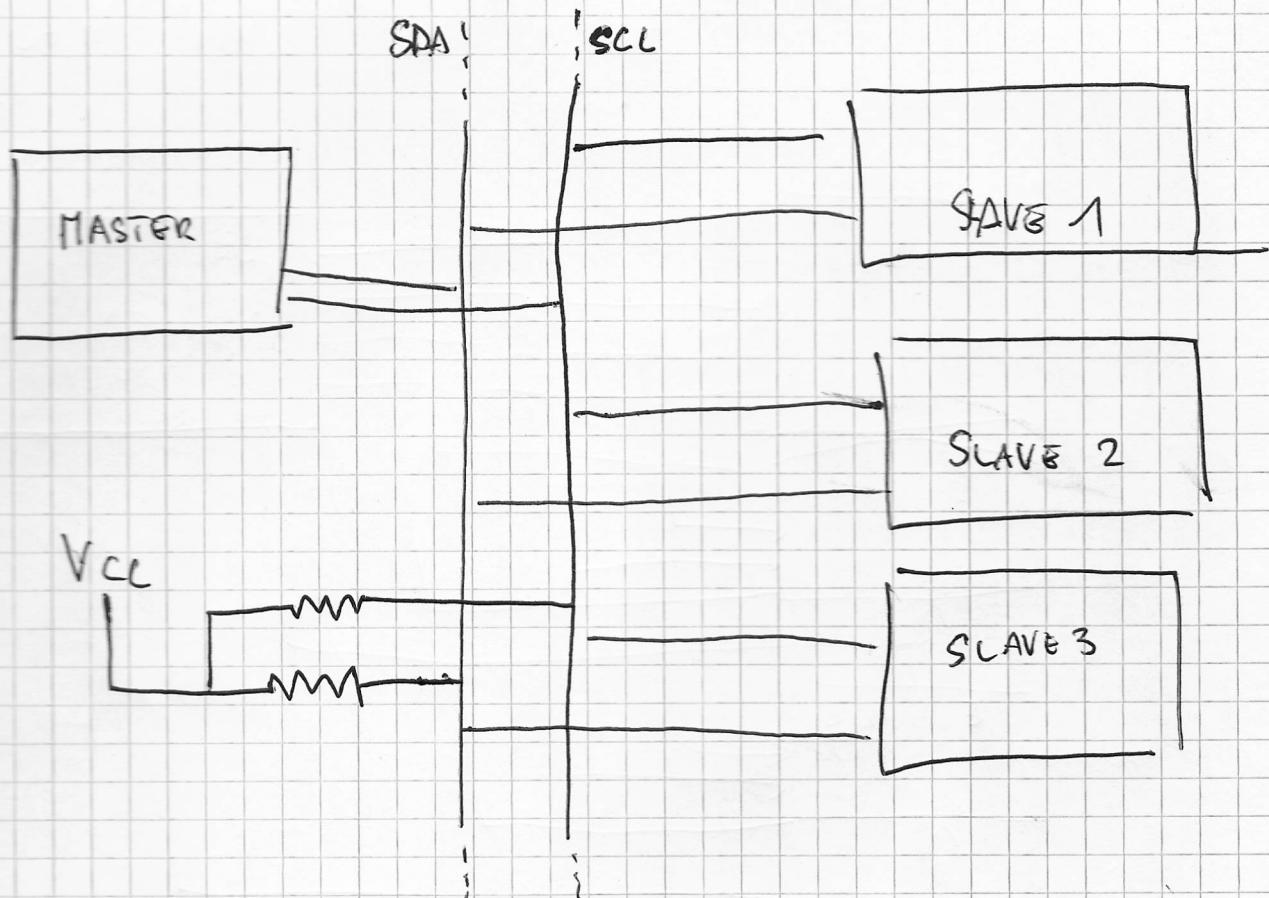


-MASTER SLAVE ARCHITECTURE

-SYNCHROUNOUS (HAS A CLOCK SIGNAL)

-FULL DUPLEX

-SLAVE SELECT TELLS WHICH SLAVE THE MASTER WANTS TO COMMUNICATE WITH: THE SLAVES THAT DO NOT OPERATE PUT HIGH IMPEDANCE ON THE WIRE.



- BUS TOPOLOGY
- MULTI MASTER / MULTI SLAVE
- SYNCHRONOUS
- SERIAL
- HALF-DUPLEX
- ARBITRATION FOR COLLISION . DEVICE MONITOR THE BUS AND IF DATA ON THE BUS DOES NOT MATCH DATA TRANSMITTED IT SLEEPS AND WAIT FOR TRYING AGAIN