AS Systems & Control Study Notes
Part 2: Electronic Materials

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Part 1 Learning Objectives

- Know the properties of
  - Conductors
  - Insulators
  - Semiconductors.
- Know the properties and functions of:
  - Resistors
  - Capacitors

Materials

There are three main types of materials used in electronic and electrical systems:

- Conductors
- Insulators
- Semiconductors

Each of these materials has its own properties and applications.

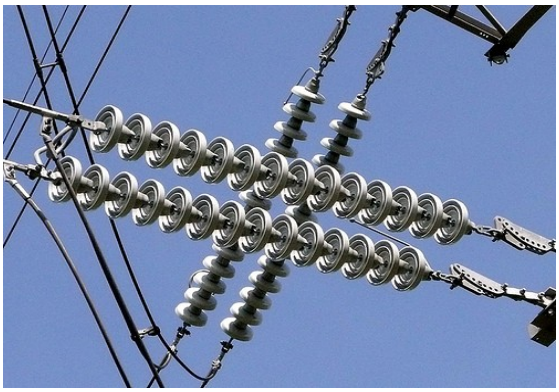
Insulators

An insulator is a material with negligible electrical conductivity. Examples of insulating materials are:

- Ceramics
- Glass
- Rubber
- Plastics

Some applications of insulators are:

- PVC insulation on electrical wires
- Ceramic insulation on electricity pylons
  Fibreglass circuit board substrate



Electricity pylon ceramic insulators

Conductors

A conductor is a material that allows electricity to flow through it. Examples of conductive materials are:

- All metals
- Carbon
- Ionised water (e.g. tap water)

Some applications of conductors are:

- Copper wires
- Aluminium alloy electrical pylon wires

Electrical cable

Resistance

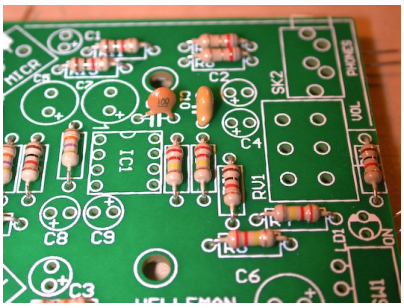
All conducting materials have varying levels of conductivity, in other words some conductors conduct better than others. The opposition to current flow of a material is known as the resistance. The unit of measurement of resistance is the Ohm (Ω.) The amount of current flowing through a material is inversely proportional to its resistance, this is known as Ohm's law:

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

The property of resistance is utilised in every electronic circuit in order to control the flow of current. The most common component that utilises resistance is known as a Resistor.

Resistors

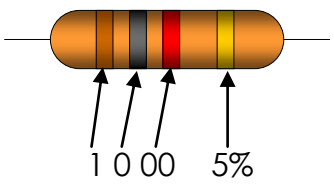
A resistor is a component used to control the flow of current through circuits.



Resistors mounted on a PCB

Resistors come in a range of different values. The resistor value is identified by coloured bands printed on their bodies. The resistance can be determined using the following colour chart:

Colour	First Band	Second Band	Third Band (Multiplier)	Fourth Band (Tolerance)
Silver				10%
Gold				5%
Black	0	0		
Brown	1	1	0	
Red	2	2	00	1%
Orange	3	3	000	
Yellow	4	4	0 000	
Green	5	5	00 000	
Blue	6	6	000 000	
Violet	7	7	0 000 000	
Grey	8	8		
White	9	9		



Resistance = 1K

Tolerance

Although the colour code identifies the resistor as having a particular value, the actual resistor is never bang on that figure. The tolerance describes how accurate the resistance value actually is.

For example a 100 Ohm resistor with a ±5% tolerance would have a resistance of somewhere between -5% and +5% of the stated value. The resistance would therefore range from between 95 Ohms and 105 Ohms.

Therefore it stands to reason that a 1% resistor has a more precise value than 5% or 10% resistors.

Other types of resistors have five band and have much tighter tolerances. These resistors are used in situations where exact values are desirable.

Resistor Series

Resistors are only manufactured in certain values. There are two main series of resistors that you will come across: E12 & E24. E12 has 12 basic values, and the E24 has 24 basic values. It is therefore clear that the E24 series is the most accurate. E24 is the most common.

E12 Resistor values (Silver band 10% tolerance:)

10	100	1K	10K	100K	1M	10M
12	120	1K2	12K	120K	1M2	12M
15	150	1K5	15K	150K	1M5	15M
18	180	1K8	18K	180K	1M8	18M
22	220	2K2	22K	220K	2M2	22M
27	270	2K7	27K	270K	2M7	27M
33	330	3K3	33K	330K	3M3	33M
39	390	3K9	39K	390K	3M9	39M
47	470	4K7	47K	470K	4M7	47M
56	560	5K6	56K	560K	5M6	56M
68	680	6K8	68K	680K	6M8	68M
82	820	8K2	82K	820K	8M2	82M

Tolerance continued

E24 Resistor values (5% tolerance:)

10	100	1K	10K	100K	1M	10M
11	110	1K1	11K	110K	1M1	11M
12	120	1K2	12K	120K	1M2	12M
13	130	1K3	13K	130K	1M3	13M
15	150	1K5	15K	150K	1M5	15M
16	160	1K6	16K	160K	1M6	16M
18	180	1K8	18K	180K	1M8	18M
20	200	2K	20K	200K	2M	20M
22	220	2K2	22K	220K	2M2	22M
24	240	2K4	24K	240K	2M4	24M
27	270	2K7	27K	270K	2M7	27M
30	300	3K	30K	300K	3M	30M
33	330	3K3	33K	330K	3M3	33M
36	360	3K6	36K	360K	3M6	36M
39	390	3K9	39K	390K	3M9	39M
43	430	4K3	43K	430K	4M3	43M
47	470	4K7	47K	470K	4M7	47M
51	510	5K1	51K	510K	5M1	51M
56	560	5K6	56K	560K	5M6	56M
62	620	6K2	62K	620K	6M2	62M
68	680	6K8	68K	680K	6M8	68M
75	750	7K5	75K	750K	7M5	75M
82	820	8K2	82K	820K	8M2	82M
91	910	9K1	91K	910K	9M1	91M

Potentiometers

A potentiometer is a component whose resistance can be altered by the position of a metal wiper on a carbon track. The further the distance between one terminal and the central wiper the larger the resistance. They are generally used to produce an adjustable voltage level.

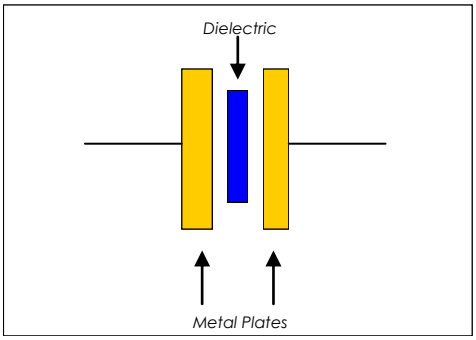
Preset Potentiometer

Control Potentiometer

Capacitors

A capacitor is a component that can store electrical charge (electrons.)

Put simply a capacitor consists of two metal plates separated by an insulating material known as a dielectric. Applying a voltage to the two plates the dielectric will charge up with static electricity.



Physical structure of a capacitor

Capacitance is measured in Farads. A Farad is a very large unit therefore capacitors are generally measured in terms of a fraction of a Farad, such as:

- pF ($1x10^{-12}$)
- nF ($1x10^{-9}$)
- µF ($1x10^{-6}$)

Various types of capacitor are available with different dielectrics, commonly polyester, ceramic and tantalum; each with their own properties. Capacitors made out of these dielectrics generally have a low capacitance range (pF to nF.)

Polyester Capacitor

Tantalum Capacitor

Ceramic Capacitor

Electrolytic Capacitors

Electrolytic capacitors are a different type that allows much higher capacitance values in the range of several uF and more

Electrolytic capacitors are polarised, this means that they must be connected the correct way around. The negative terminal is identified by the shorter lead and a stripe on the body.

Polyester Capacitor

10F Capacitor
Used as backup power supply for computer memories

Massive 350F Capacitor
Used in new hybrid cars for providing quick boosts of power to improve acceleration

Applications of Capacitors

Coupling

A capacitor can conduct alternating current but blocks direct current. They are therefore used where it is required to prevent the passage of DC currents. A common situation is at the output of an amplifier, as DC currents would damage the speaker.

Decoupling

Capacitors can be used to smooth the voltage levels on power supply rails. When the current load of a circuit changes, the voltage on the supply rails will fluctuate, causing undesired effects. This is minimised by placing small capacitors across the power supply rails which short the AC signals introduced on to them down to ground.

Smoothing

Capacitors can be used as a temporary supply of electricity in many applications – particularly power supplies. In most electronic systems the mains supply is rectified (changed from AC to DC.) However the output from a rectifier is not smooth, it is said to be pulsing DC. To smooth out the voltage levels a large capacitor is placed across the rails. (See Rectification)

Timing

If a resistor is connected in series with a capacitor it can be used to create time delays. The length of the delay is dependent on the size of the capacitor (capacitance) and the size of the resistor: the larger the capacitor and resistor the larger the delay.

Semiconductors

Silicon rectifier diode

A semiconductor is an engineered material whose conductivity can be controlled by a variety of different methods.

Semiconductors a usually based on two main materials: Germanium, and most commonly; Silicon

Germanium signal diode

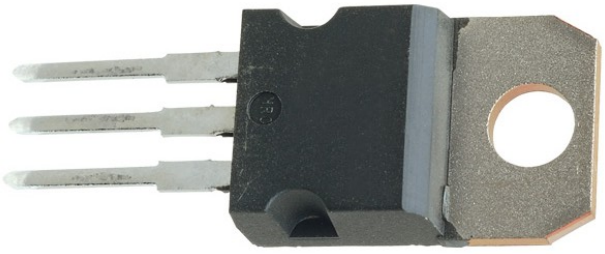
All electronic systems rely on semiconductors. Semiconductor based components are:

- Diodes
- Transistors
- Field Effect Transistors (FETs)
- Thyristors
- Light Emitting Diodes (LEDs)
- Integrated Circuits (ICs or Silicon Chips)

Integrated circuits are tiny circuits consisting of miniaturised components that are found on circuit boards. It is now possible to integrate hundreds of millions of transistors on to a single silicon chip, especially those found in modern computers.

Transistor

PIC Microcontroller witch window showing internal integrated circuit



MOSFET Transistor