Western Cape Government

Western Cape Education Department
Directorate: Curriculum FET

ELECTRICAL TECHNOLOGY
(Digital Electronics)
REVISION BOOKLET
TERM 2
2026
Grade 10

This revision booklet is designed to assist you in revising the critical content and skills that you have covered during the 2nd term. The purpose is to prepare you to understand the key concepts and to provide you with an opportunity to establish the required standard and the application of the knowledge necessary to succeed in the examination.

This revision material covers the following topics:

- Power Sources
- Electronic Components

It is important to prepare yourself by practice answering questions from past papers.

You can ask your teacher to give you some previous year question papers to use as a guide to help you prepare for your final exam:

There are also lessons on various grade 10 topics on the WCED e-Portal (https://wcedeportal.co.za/)

GENERAL

Structure of the Mid-Year Exam paper and Important point to remember:

- The paper consists of **SIX** compulsory questions.
- The weighting of the questions is as per the table below.
- It is important to remember that the paper is out of 150 MARKS, and the time given is 2,5 HOURS ie 150 marks = 150 minutes.
- It is important to ensure that you manage your time properly when writing any test or exam. You don't want to run out of time because of bad time management.
- The following rough guide will help you manage your time a bit better. 1 Mark = 1 Minute (If a question is out of 10 marks, do not spend more than 10 minutes on that question)
- Try and start with the easiest question and work your way up to the more difficult questions.
- All questions and sub questions must be kept together. DO NOT MIX QUESTIONS
- Draw a line after each completed question.
- It is important that you read all instructions slowly and carefully before you start answering any question.
- Also, please note that you must receive a formula sheet with every test or exam you write, covering at least the topics of the test or exam.
- The questions are asked in such a way that it will differentiate in terms of subject knowledge. It might start with an easy question and end off with more challenging question in the different questions per topic.

Mid-Year Examination Weighting in Digital Electronics (2,5 hours):

	Topic	Marks
1	**Multiple choice**	15
2	**Occupational Health and Safety**	10
3	**Tools and measuring instruments**	25
4	**Basic Principles of Electricity**	40
5	**Power Sources**	25
6	**Electronic Components**	35
	TOTAL	**150 Marks**

November Examination Weighting in Digital Electronics (3 hours):

	Topic	Marks
1	**Multiple choice**	15
2	**Occupational Health and Safety**	10
3	**Tools and measuring instruments**	25
4	**Basic Principles of Electricity**	40
5	**Power Sources**	25
6	**Electronic Components**	30
7	**Logics**	30
8	**Principles of Magnetism**	25
	TOTAL	**200 Marks**

2023/24 ANNUAL TEACHING PLANS: ELECTRICAL TECHNOLOGY (DIGITAL ELECTRONICS): GRADE 10 (TERM 2)

TERM 2	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11
CAPS TOPIC	**Power sources**	**Power sources**	**Power sources**	**Electronic components**	**Electronic components**	**Electronic components**	**Electronic components**	**Electronic components**	**PAT consolidation and revision**	**PAT consolidation and assessment**	**PAT consolidation and assessment**
TOPICS, CONCEPTS, SKILLS AND VALUES	**Energy** - What is energy? - Primary source of energy - Sources of energy, etc **Alternative energy** - Solar - Photovoltaic cell - Solar cell vs solar panel - Generating electricity from the sun, etc	**Potential Difference (PD)** - Understanding the concept of PD o $V=EQ$ (Volt) **Electromotive Force (EMF)** - Understanding the concept of EMF - Difference between EMF and PD o $VEMF=VPD+Vr$ (Volt)	**Internal resistance** - What is Internal Resistance? - Advantages, disadvantages of internal resistance - Internal resistance calculations o $EEMF=IR+Ir$ (Volt) o $RTOTAL=R+r(\Omega)$	**Introduction of electronic components** - What are electronic components? - Purpose of electronic components **Types of components** - Switches - SPST, SPDT, DPST, DPDT - Rotary switch - Slide switches - Magnetic switches - Key switches Application and practical in simple circuits Practical: Identify, test, components	**The capacitor** - Composition, construction, functional operation symbol, characteristics curves and values - Basic principles of electrostatic charge o $Q=VC$ (Coulomb) - Time constant o $t=RC$ (Seconds) o $T=5RC$ (Seconds)	**Charging rates and time constant including curves and calculations** $Vcapacitor=Vsupply\times0.636$ (Volt) o $Icapacitor=Imax\times0.364$ (Amp) - Graph - Application of capacitors in dc (examples of smoothing circuit and RC time constant) - Capacitors in series o $1CT=1C1+1C2...+1Cn$ (Farad) - capacitors in parallel o $CT=C1+C2+..Cn$ (Farad)	**Practical**: Calculation of charge: $Q=VC$ **Practical**: Calculation of total capacitance in series (2,3 and 4 capacitors) **Practical:** Calculation of total capacitance in parallel (2,3 and 4 capacitors) **Practical**: Charging characteristics of the capacitor Include drawing of graph from data	**Protective devices** - Fast blow and slow blow fuses **Diode** - Symbol - Diode as a polarised component - Forward biasing (concept only) - Reverse biasing (concept only) - Application as rectifier	**Simulation 2** **Design: Part 1** - Circuit description filled in - Tools list for circuitry populated - Learner's own - PCB planning, design included in the file	**Design: part 1** - Circuit description filled in - Tools list for circuitry populated - Learner's own - PCB planning, design included in the file	**Design: part 1** - Circuit description filled in - Tools list for circuitry populated - Learner's own - PCB planning, design included in the file
RESOURCES (OTHER THAN TEXTBOOK) **TO ENHANCE LEARNING**	Videos, PowerPoint presentations, additional notes, components, multimeter, breadboards, circuit boards, electronic software, tools and consumables										
INFORMAL ASSESSMENT, REMEDIATION	Classwork, case studies, worksheets, homework, theory and practical etc										
SBA (FORMAL ASSESSMENT)	**PAT simulation 2 completed** Controlled test Safe work practices are types of administrative controls that include procedures for safe and proper work used to reduce the duration, frequency, or intensity of exposure to a hazard. The section on tools and equipment must be infused when doing all PAT simulations.										

BASIC SKILLS LINKED TO THE SUBJECT:

The following skills are tested in the paper:

- Ability to follow instructions
- Identifying labels/labelling/making drawings/diagrams/schematic representations
- Plotting and interpretation of graphs/data
- Working out and interpreting calculations
- Organizing/Recording and categorizing data
- Extraction and/or manipulation and/or evaluation of data



It is important that you have your own Scientific Calculator, and that you know how to use it. NEVER BORROR A CALCULATOR FOR ANY EXAMINATION!!!!!!!

NB!!!!! The mark allocation will indicate how you much information you are required to provide in your responses/ answers to questions.

Calculations

- Always write down all the given information.
- All calculations count 3 marks (in a few instances calculations were 4 or 5 marks) 1 mark is for the correct formula, 1 mark for the correct substitution and 1 mark for the correct answer and unit. Please note if an answer does not have a unit, no marks will be given for the answer.
- Please also note that when substitutions of values are made that the correct prefixes are used with the numbers eg. 10 mA = 10 x 10^{-3} A or 0,010 A
- Mastering calculations is all about PRACTICE, PRACTICE

Prefix	Power of 10	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p

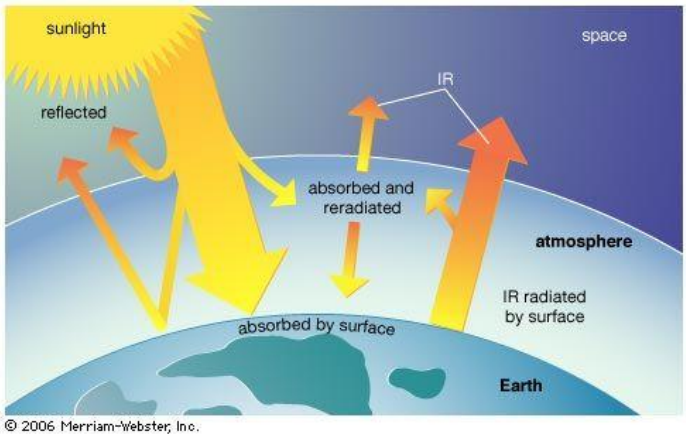
TOPIC 1: POWER SOURCES (p140-174)

This topic contains theoretical questions as well as calculations.

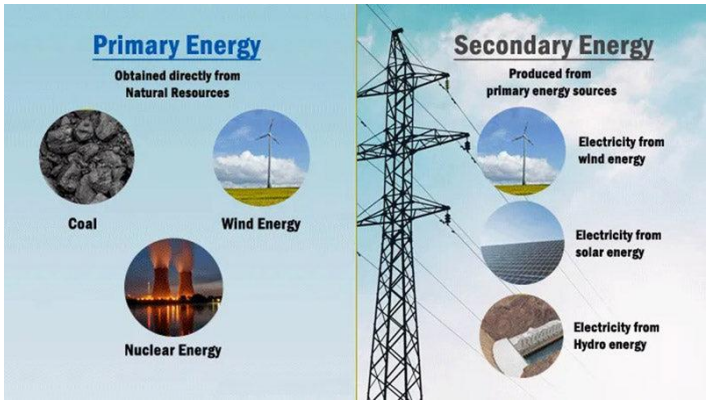
- Theoretical questions are normally a challenge, and many learners struggle to answer it properly.
- Learners must read all question with understanding before trying to answer the questions
- Theoretical answers should be short and to the point.
- The mark allocation is an indication about the number of facts that must be given.
- In this section of the work, you will learn more about different forms of energy, the electrical cell as well as the difference between primary and secondary cells
- You will also look at alternative energy in the form of solar energy.
- Concepts such as potential difference, electromotive force and internal resistance of a cell must be understood and known.

Energy (p140 – 141)

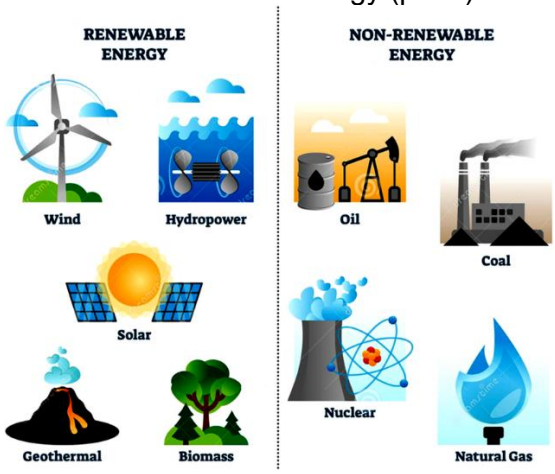
- What is energy?
  - Energy is the ability to do work
  - Kinetic Energy: Energy posessed by anything in motion
  - Potential Energy: Stored energy
  - Energy can change from one form to another
- Law of Energy*: Energy cannot be created or destroyed, it can only be converted from one form to another*
- Fundamental Source of Energy**:** The Sun is a fundamental source of energy on Earth, providing radiant energy that powers various processes, including life, weather, and climate.



- Primary and Secondary sources of energy (wind, sun, coal, nuclear, geothermal, hydro)



- Non-Renewable and Renewable sources of Energy (p141)

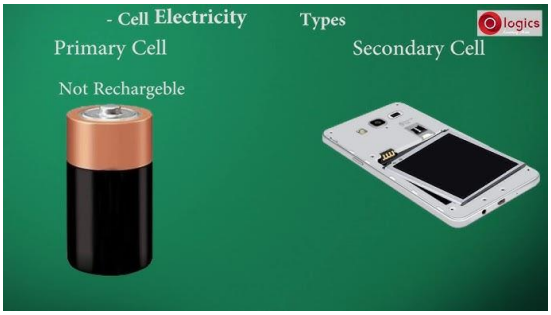


Electrical Cells (p142)

- Primary cells are non-rechargeable batteries designed for single use and disposal
- Secondary cells are rechargeable and can be used multiple times.

Key Differences:

Feature	Primary Cell	Secondary Cell
Recharging	Non-rechargeable, one-time use	Rechargeable, multiple uses
Reaction	Irreversible electrochemical reaction	Reversible electrochemical reaction
Examples	Dry cells, alkaline batteries	Lithium-ion, lead-acid, NiCd batteries
Application	Small appliances, flashlights	Mobile devices, electric vehicles
Disposal	Discarded after use	Rechargeable multiple times

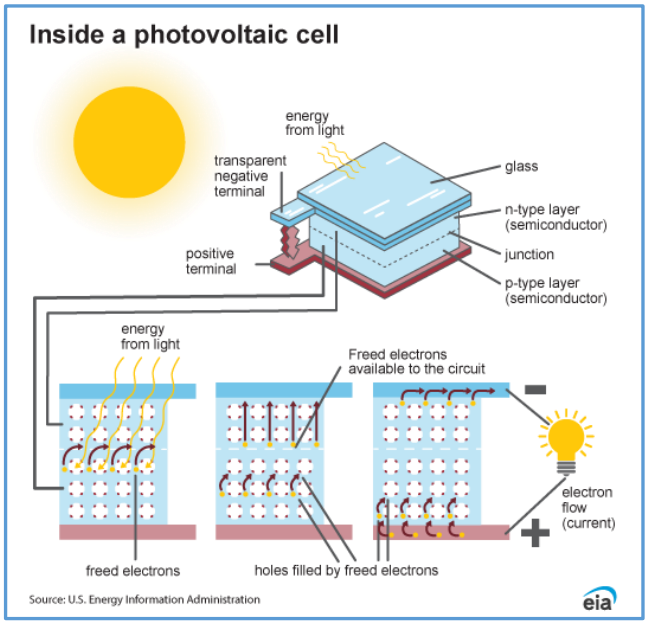


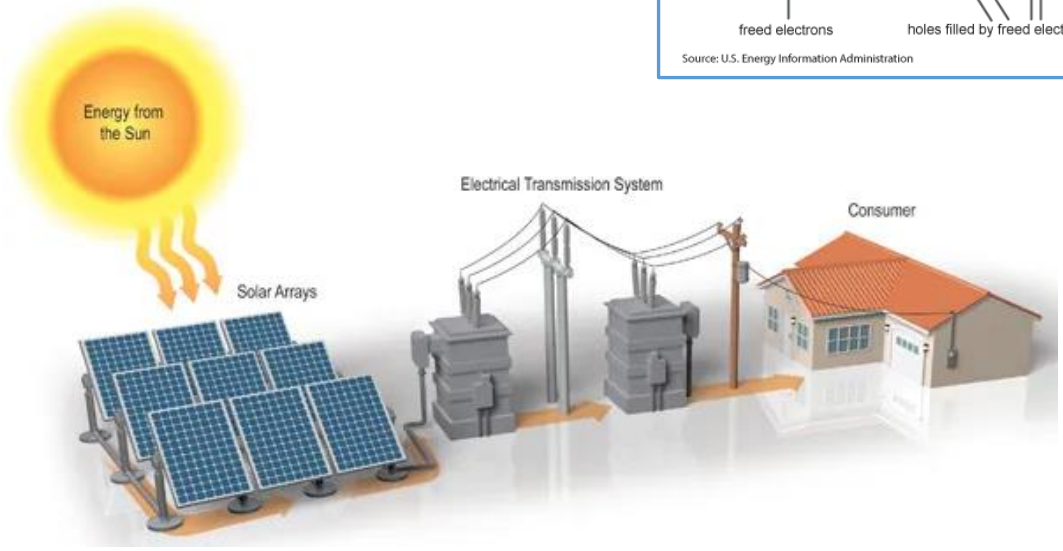
Alternative energy (p154 – 156)

- Alternative energy sources include solar power, wind power, and waterpower.
  - Most alternative energy sources are renewable, which means that, unlike fossil fuels, they are not likely to run out. Examples include the Sun, wind, rivers and oceans, heat from inside Earth, and biofuels. These energy sources can be used to generate electricity, to heat water, and, in some cases, to fuel vehicles.

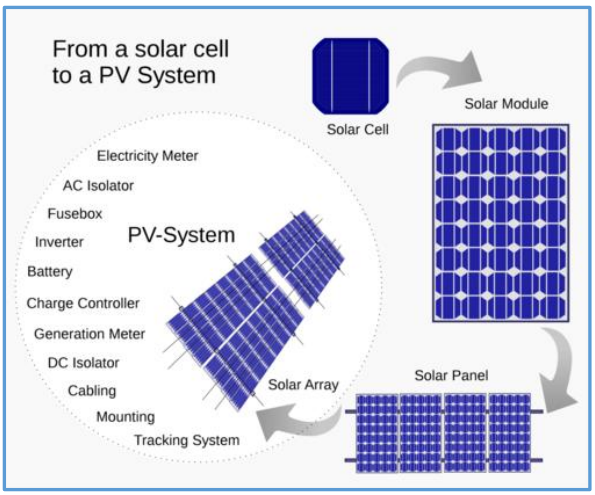
- Solar, photovoltaic cell (p154-156)
  - The heat and light produced by the Sun provide an enormous source of energy. A number of technologies, such as photovoltaic (PV) cells, have been developed to harness this energy so it can be used as a power source for generating electricity and heat (solar heating).

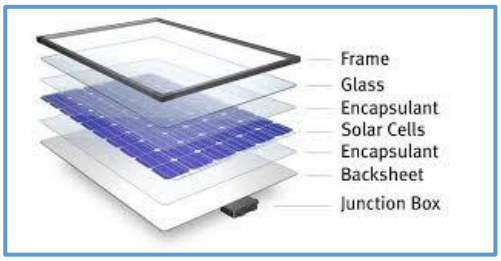
  - Generating electricity from the sun

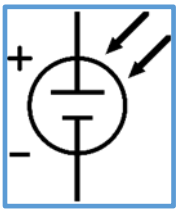


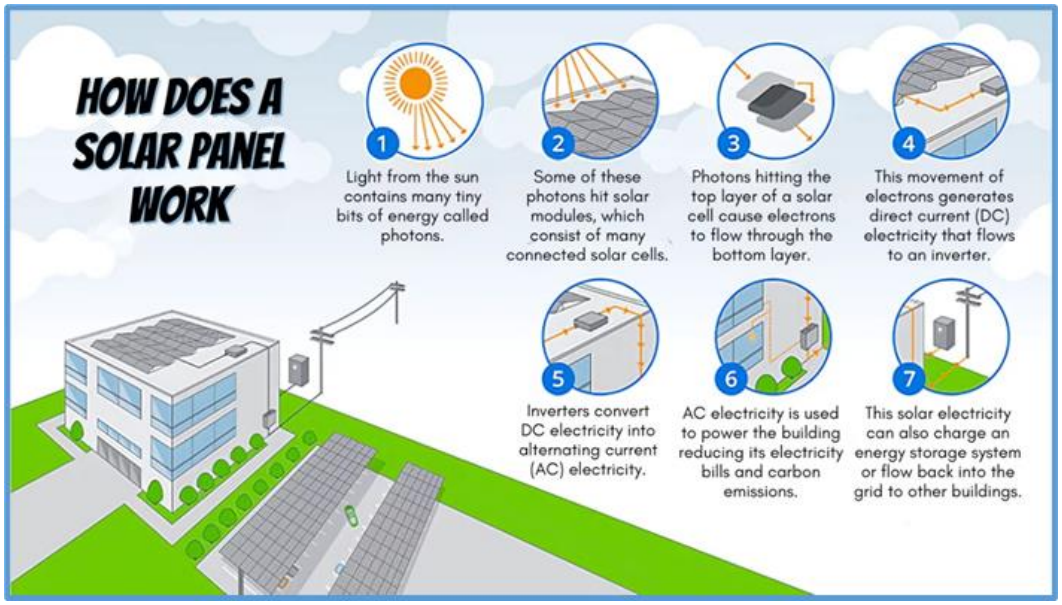


- Solar cell vs solar panel





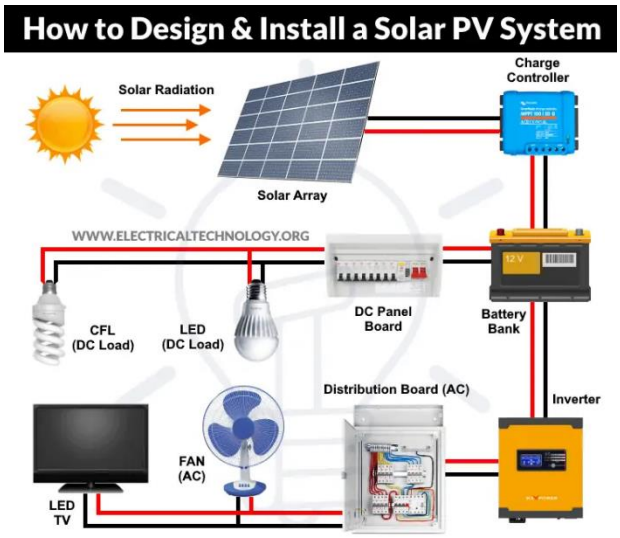


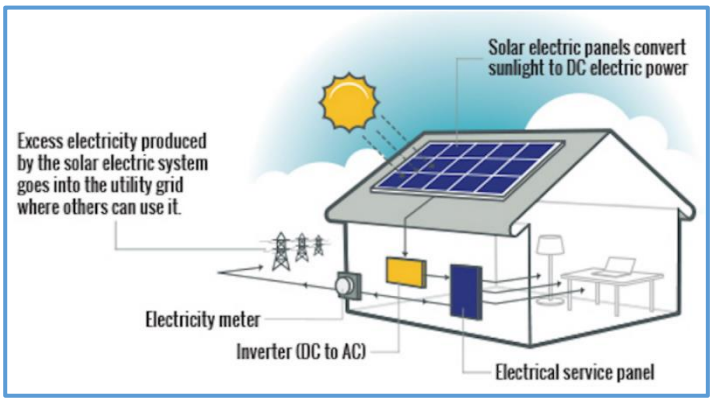


- Advantages and disadvantages
  - Reliable
  - No energy required to operate
  - Produced energy is environmentally friendly
  - Can only operate during daylight hours
  - Output depends on light intensity and varies during the day.
  - Expensive
  - Require large areas
  - Need batteries as energy reservoirs when solars panels cannot operate due to low light conditions

- Applications
  - Artificial satellites
  - Communication equipment
  - Navigational buoys
  - Pumping stations at remote locations
  - Calculators
  - Traffic lights
  - Emergency power during load shedding

- Domestic Solar Electricity Generation System





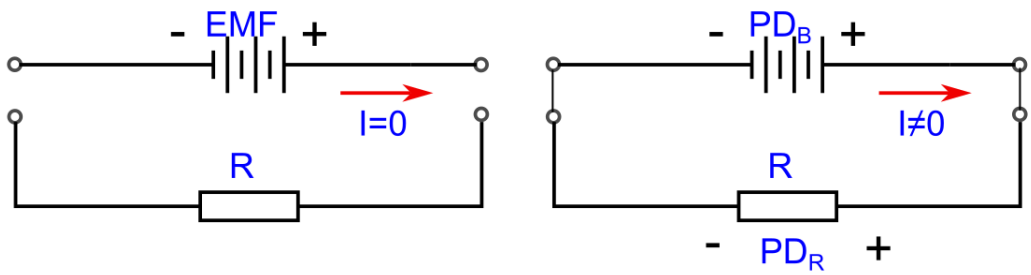
- Deep-cycle batteries: can be totally discharged without damage.
- Charge controller: contains voltage regulator to keep the charging voltage constant as well as protective devices.
- Inverter: convert battery DC voltage to AC voltage for home appliances.

Potential difference and electromotive force (p157 – 159)

- Understanding the concept of PD
  - Measured in volt (V)
  - 1V is defined as the work (W) done in moving a unit charge (q) between two points of a circuit.
  - Potential difference, $V = \frac{Work\ done}{Charge\ flow} = \frac{W}{Q} = \frac{1J}{1C}$
  - Potential Difference is the difference in voltage between two points in a circuit
  - Current flows from a high voltage to a low voltage.
  - The PD over a supply increases, and across a dissipative or storage device decreases.

- Understanding the concept of EMF
  - EMF is the potential difference created when no current is flowing in a system.
  - EMF is the amount of energy available to move 1C of charge.
  - EMF is die voltage measured between the terminals of a battery when no current is flowing.

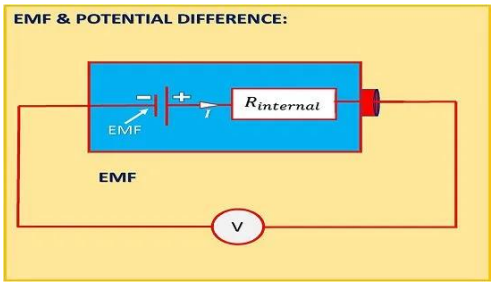
- Difference between EMF and PD



EMF represents the energy supplied by the source, while potential difference represents the energy used or transferred as charge moves through the circuit.

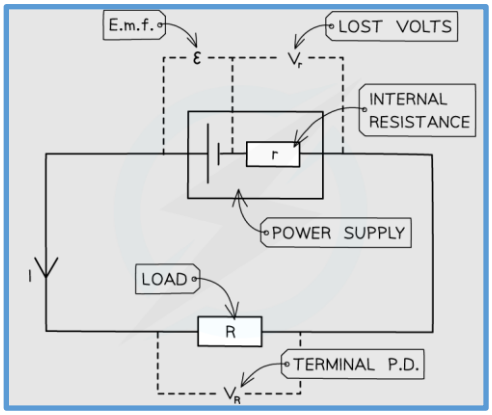
Internal resistance (p159 – 164)

- What is Internal Resistance?
  - A measure of the resistance offered by the battery's internal components, such as the electrolyte, electrodes, and separator, to the flow of electric current.
  - When current flows through the battery, it also flows through the internal resistance, causing a voltage drop. This means the voltage you measure at the battery terminals is less than the emf.

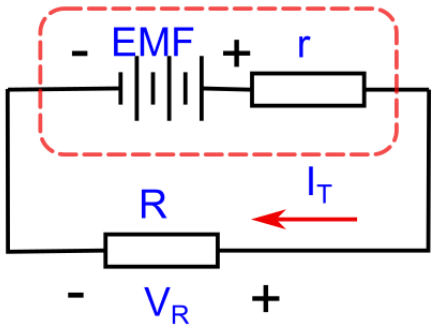


  - The current flowing through the internal resistance generates heat, which is a form of energy loss.
  - Different battery chemistries have varying internal resistances.

- Advantages, disadvantages of internal resistance.
  - Important for evaluating the health and lifespan of batteries.
  - A higher internal resistance means more energy is lost internally, resulting in less power available to the load.
  - Excessive heating due to high internal resistance can lead to battery degradation and reduced lifespan.



- Internal resistance calculations (p160-161)



$$EMF = V_r + V_R$$

$$EMF = I_T \times r + I_T \times R$$

$$R_T = r + R$$

$$I_T = \frac{EMF}{R_T}$$

$$r = \frac{EMF - V_R}{I_T}$$

Typical questions and answers

1. **Define the term energy.** (2)

   Energy can be defined as the ability to do work

2. **Explain the difference between a primary and a secondary cell and give ONE example of each.** (4)

   A primary cell is a cell that cannot be recharged and must be thrown away after use, whereas a secondary cell can be recharged when flat.
   Primary cells: Wet/dry Leclance cell/ Lithium cells, alkaline cells
   Secondary cells: Lead-acid battery, Lithium-iron battery

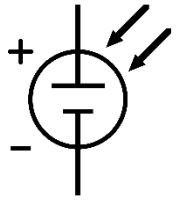
3. **Explain the difference between non-renewable and renewable energy and give ONE example of each.** (4)

   Renewable energy is all naturally replenished in a very short period and will not run out (Oil, coal, gas and Uranium) while non-renewable energy cannot be replenished in a short time and will eventually run out. (Wind, solar, hydro, biomass and geothermal)

4. **Discuss the difference between potential difference (PD) and electromotive force (EMF) with reference to a battery.** (4)

   Potential difference is the electrical pressure measured across a power source (Cell) when it is connected to a load.
   Emf is the electrical pressure measured across a power source when it is not connected to a load.

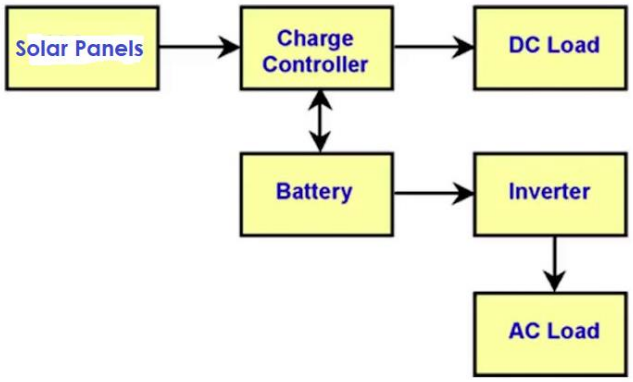
5. **Draw a labelled symbol for a Photovoltaic cell** (2)



6. **Briefly explain how a Photovoltaic cell works** (2)

   Solar Photovoltaic (PV) cells generate electricity by absorbing sunlight and using that light energy to create an electrical current.

7. **Draw a neat block diagram of a home solar electricity system.** (6)

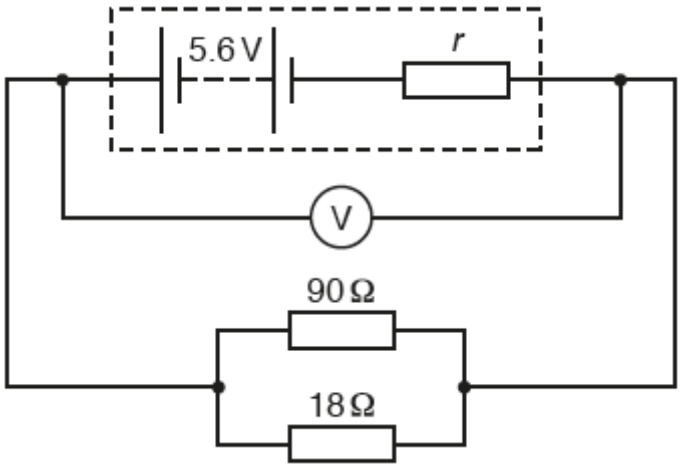


8. Give ONE advantage and ONE disadvantage of a solar system

Advantage:
- Solar cells are reliable / long lasting
- They use free energy
- No pollution (Any 1)

Disadvantage:
- They rely on sunlight- no sun no energy
- Power output depends on intensity of sunlight
- They are expensive
- Take up lots of space (Any 1)

9. A battery with an electromotive force (EMF) of 5.6V having an internal resistance *r* is connected to two external resistors as shown in the circuit diagram below. The reading on the voltmeter is 4.8V.



a) Calculate the combined resistance of the two resistors connected in parallel.

$$R_T = \frac{R_1 R_2}{R_1 + R_2} = \frac{90 \times 18}{90 + 18} = 15\Omega$$

b) Calculate the battery current.

$$I_T = \frac{V_{meter}}{R_T} = \frac{4.8}{15} = 320mA$$

c) Show that the internal resistance of the battery is 2,5Ω.

$$r = \frac{V_r}{I_T} = \frac{EMF - V_{meter}}{I_T} = \frac{5.6 - 4.8}{320 \times 10^{-3}} = 2.5\Omega$$

d) Calculate the power produced by the battery.

$$P_T = EMF \times I_T = 5.6 \times 320 \times 10^{-3} = 1{,}79W$$

e) Calculate the power dissipated in the resistor combination.

$$P_R = V_{meter} \times I_T = 4.8 \times 320 \times 10^{-3} = 1{,}54W$$

f) Calculate the power wasted in the internal resistor.

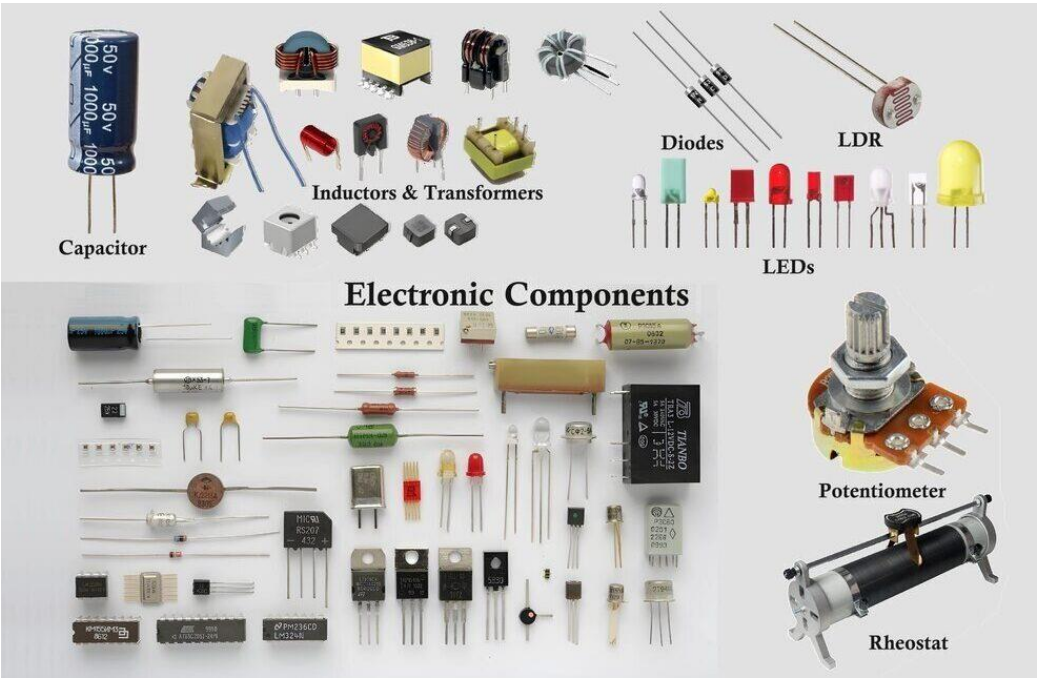
$$P_r = P_T - P_R = 1{,}79 - 1{,}54 = 250mW$$

TOPIC 2: Electronic Components (p175-227)

This topic contains theoretical questions as well as calculations.

- Theoretical questions are normally a challenge, and many learners struggle to answer it properly.
- Learners must read all question with understanding before trying to answer the questions
- Theoretical answers should be short and to the point.
- The mark allocation is an indication about the number of facts that must be given.
- In this section of the work, you will learn more about all the basic electronic components, their symbols, and their uses.
- You will learn more about the following components: switches, capacitors, fuses, diodes, and LED's

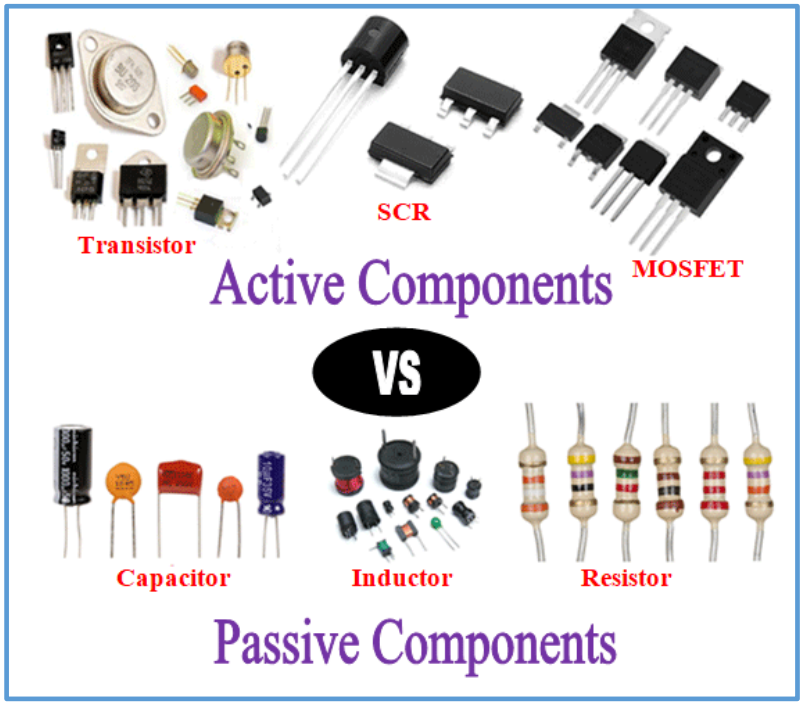
Introduction to electronic components (p175 – 176)



- What are electronic components?
  - Electronic components are the elements of the circuit which help in its functioning the electrical circuit. Electronic components are the basic building blocks of an electronic circuit any electronic system or any electronic device. They can control the flow of electrons in an electronic system or electronic circuit.

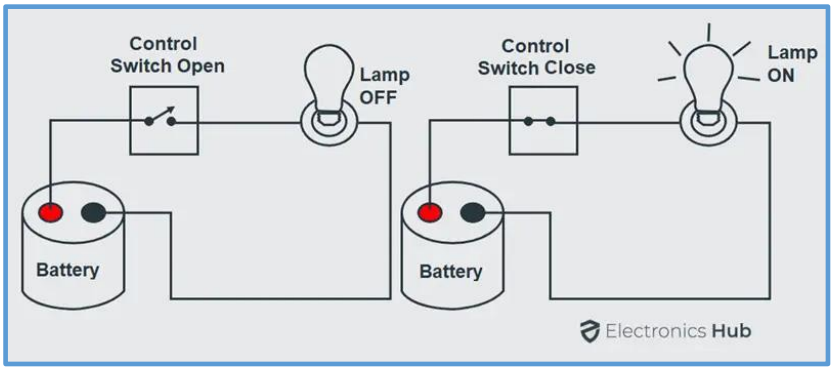
- Active components
  - Active components can introduce energy into a circuit and can amplify or process electrical signals. They are key to control and contain electrical power and information in a circuit.
  - Active components enable functions such as amplification and signal processing.
  - Transistors, Diodes, Integrated Circuits (ICs), Microprocessors, Microcontrollers, Operational Amplifiers (Op-Amps)

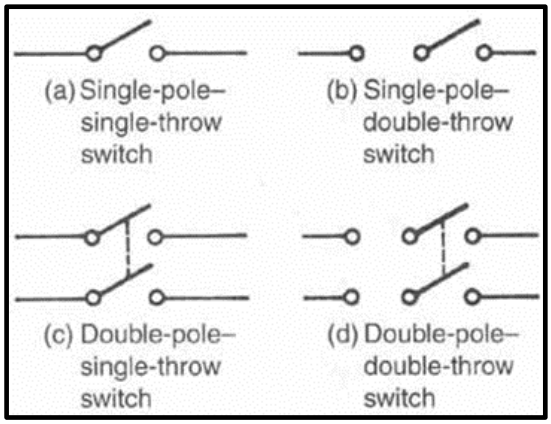
- Passive Components
  - Passive electronic components cannot introduce energy into the circuit. They only consume or store energy.
  - Passive components control, stabilize, and facilitate the flow of electricity in a circuit.
  - Resistors, Capacitors, Inductors, Transformers, Potentiometers



Types of components (p176 – 180)

- Switches
  - Switches can make or break an electrical circuit.
  - A switch can perform two functions, namely fully ON (by closing its contacts) or fully OFF (by opening its contacts).
  - Make: Closes a contact
  - Break: Opens a contact
  - Normally open (N/O): Makes a contact when operated
  - Normally close (N/C): Closes a contact when operated
  - SPST, SPDT, DPST, DPDT
    - P(oles): the number of separate circuits that can be controlled at the same time. A poles represents a contact.
    - T(hrows): the number of positions each pole can be switched to. A throw represents a contact-to-contact position.

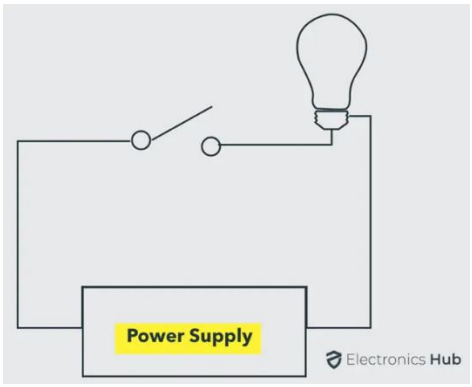




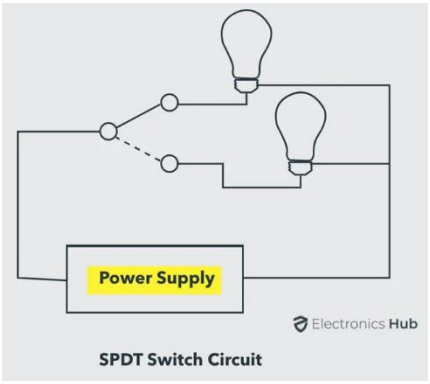
SYMBOLS



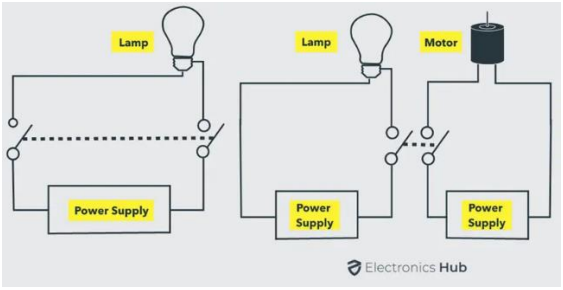
TOGGLE SWITCH



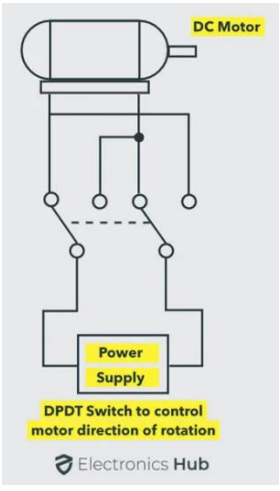
SPST



SPDT



DPST

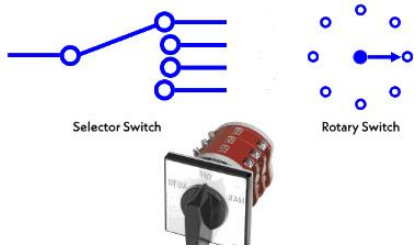


DPDT

TYPES OF SWITCHES (p177-180)



ROCKER SWITCH



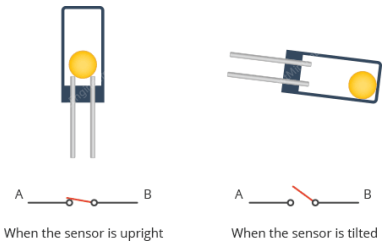


ROTARY SWITCH



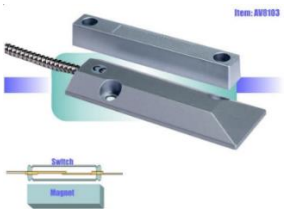


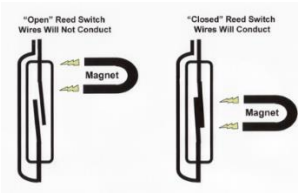
SLIDE SWITCH





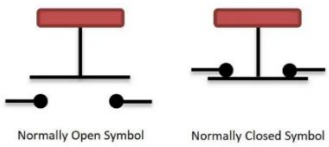
TILT SWITCH



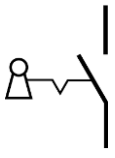


MAGNETIC SWITCH





PUSH BUTTON SWITCH





KEY SWITCH

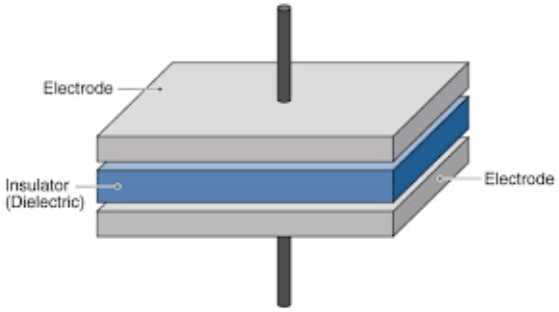
THE CAPACITOR (P184 – 200)

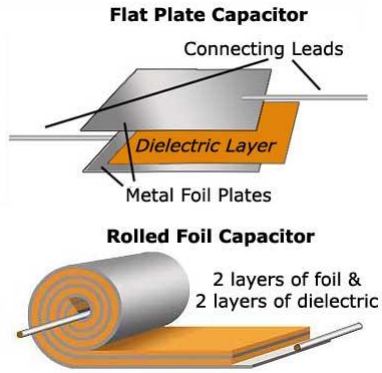


A capacitor is a device that stores electrical energy in an electric field by accumulating an internal imbalance of electric charge.

It is a passive electronic component with two terminals.

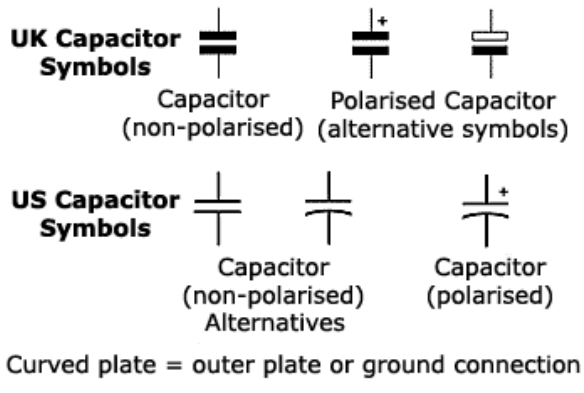
CONSTRUCTION (p184)

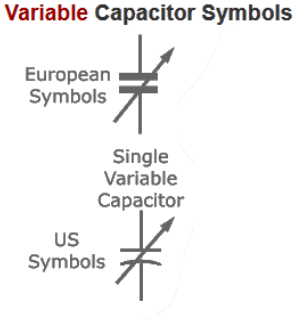




A capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but are electrically separated either by air or by some form of a good insulating material. This insulating material could be waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between a capacitors plates is commonly called the dielectric.

SYMBOLS (p184)





BASIC OPERATION (p185)

When voltage is applied to the capacitor a large number of electrons start moving from the negative terminal to the right side plate of the capacitor. The right side plate of the capacitor becomes negatively charged.

The electrons on the left side plate experience a strong attractive force from the positive terminal of the battery and electrons leave the left side plate and moves towards the positive terminal of the battery. The left side plate of the capacitor becomes positively charged.

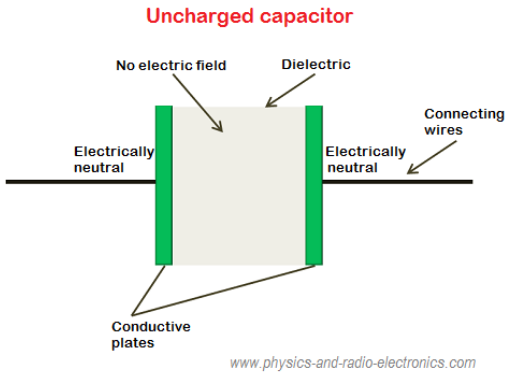
Because of the excess number of electrons on one plate and shortage of electrons on another plate, a potential difference or voltage is established between the plates. As the capacitor continues to charge, the voltage produced between the plates increases.

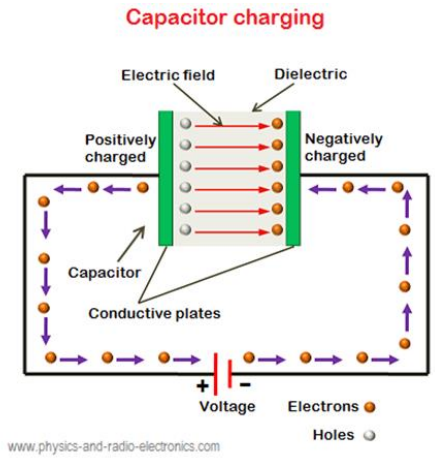
The voltage produced between the plates opposes the source voltage. As a result, when the capacitor is fully charged (voltage between the plates is equal to the source voltage), the capacitor stops charging.

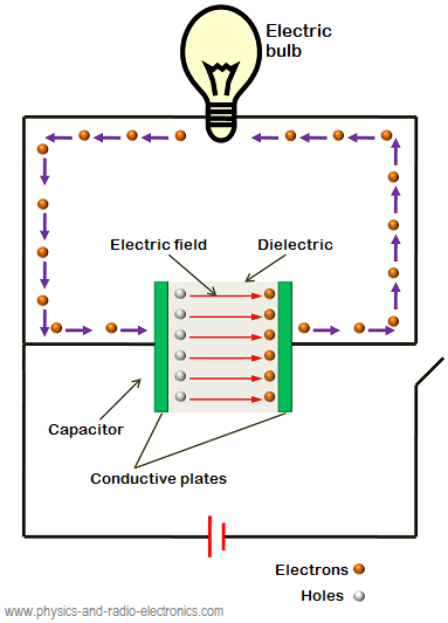
The stationary charges on these plates create an electrical field, which influences potential energy and voltage. When charges group together on a capacitor like this, the capacitor stores electric energy

To further charge the capacitor, we need to increase the voltage to a higher level.

When the charged capacitor is connected to an electric bulb through a conductive wire, the electrons trapped on the right side plate starts flowing through the circuit. The charge on the left side plate and right side plate decreases.







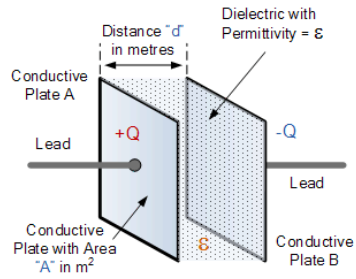
CHARGE EQUATIONS

CAPACITANCE (p191-192)

Capacitance, C is the electrical property of a capacitor and is a measure of its ability to store an electrical charge on its two plates. The unit of capacitance is the Farad (F).

The capacitance of a parallel plate capacitor is proportional to the area, A in m^2 of the plates and inversely proportional to the distance, d (i.e. the dielectric thickness) given in metres (m) between these two conductive plates.

The generalised equation for the capacitance of a parallel plate capacitor is given as: $C = \varepsilon\left(\frac{A}{d}\right) = \varepsilon_0\epsilon_r\left(\frac{A}{d}\right)$ where ε represents the absolute permittivity of the dielectric material being used, ϵ_r is the relative permittivity of the material and ε_0 is the permittivity of a vacuum.



Standard Units of Capacitance

$1\mu F = 1/1{,}000{,}000 = 0.000001 = 10^{-6}\,F$

$1nF = 1/1{,}000{,}000{,}000 = 0.000000001 = 10^{-9}F$

$1pF = \frac{1}{1{,}000{,}000{,}000{,}000} = 0.000000000001 = 10^{-12}\text{F}$

$1nF = 1000pF$

$1\mu F = 1000nF$

CURRENT SOURCE CHARGING (p191)

A current source provides a constant current to the capacitor, which allows for a controlled charging rate. This is particularly useful in applications where the charging speed needs to be regulated to prevent damage to sensitive components or to achieve a specific time constant.

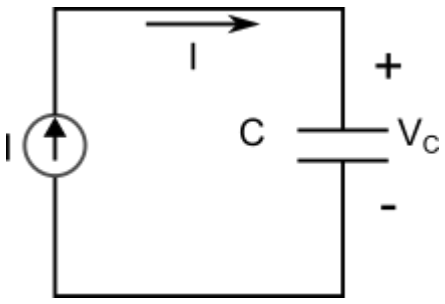
Current is the flow of electrons past a point in the circuit within a set amount of time. The unit of measurement is the ampere (A) where 1A is equal to 1 coulomb of charge per second.

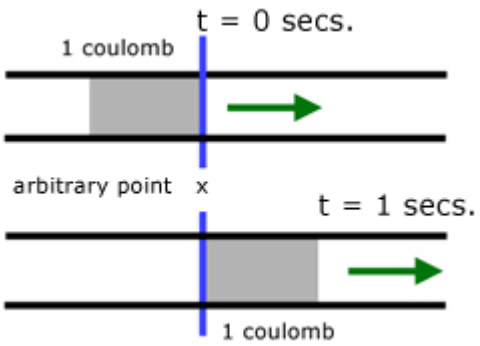
Each electron carries a charge of $q = 1.602\,x\,10^{-19}\,C$, thus 1A consists of $6{,}24 \times 10^{18}$ electrons per second passing a point.

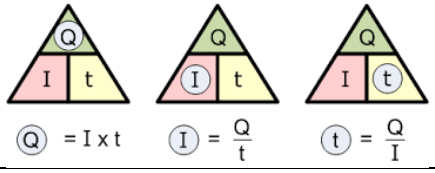
Thus, if a current of 200mA is used to charge a capacitor for 30ms, the charge accumulated on the capacitor will be:

$Q = I \times t = 200 \times 10^{-3} \times 30 \times 10^{-3} = 0{,}006C$

And it will increase linearly with time.







VOLTAGE ACROSS CAPACITOR (p191)

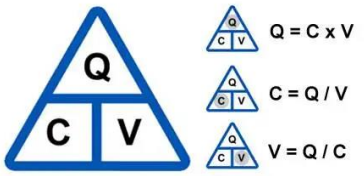
The charges on the capacitor plates creates tension between them – if nothing keeps them apart they will move back to where they were removed from until the system is neutral again, In other words, a potential or voltage will exist between the two plates. This amount of charge, Q is directly proportional to the voltage, V where C is the proportionality constant:

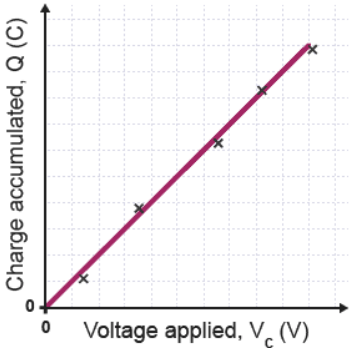
$$Q = C \times V$$

If in the example above, the capacitance, C of the capacitor is 47μF:

$$V = \frac{Q}{C} = \frac{0{,}006}{47 \times 10^{-6}} = 127{,}66V$$

(The higher the capacitance, the more charge is required to increase the voltage across the capacitor)





CAPACITOR CHARGED BY A VOLTAGE SOURCE (p189-194)

A voltage source should not be connected directly to a capacitor, as it will try to charge instantly to the voltage of the power supply. The energy added to the capacitor and dissipated by the internal resistance of the supply, will cause both to heat up and damage may occur. A series resistance is thus used to limit the charging current.

As the capacitor charge, its voltage, V_C will increase, the charging current, I determined by the resistor,R will thus decrease. When the voltage across the capacitor is equal to the supply voltage,V_B the charging stops.

Intitally when the switch is closed, the voltage across the capacitor is zero, thus the charging current will be a maximum of

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

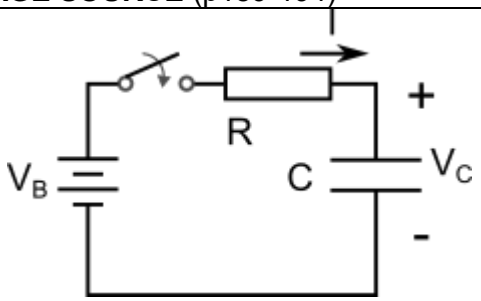
When the capacitor is fully charged, the voltage across the resistor will be zero, and

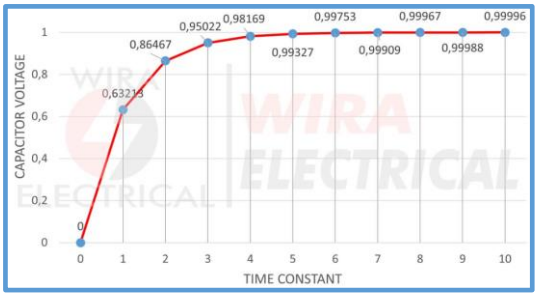
$$I = 0$$

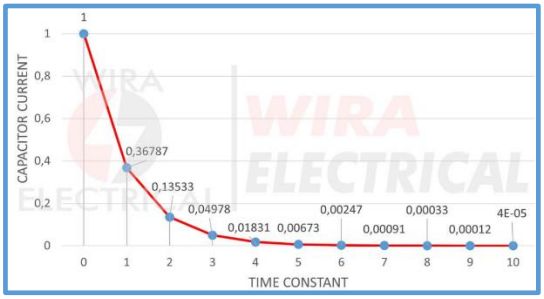
In-between,

$$I = \frac{V_B - V_C}{R}$$

As time progresses, the charging current thus become less and less and the capacitor voltage







increases slower and slower. This charging curve is typical of physical processes and is represented by an exponential graph, in this case:

$$I = \frac{V_B}{R} e^{\frac{-t}{RC}}$$

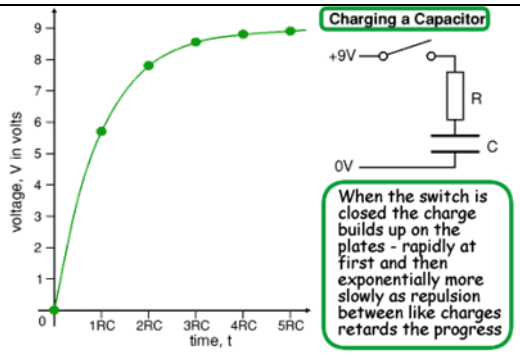
Or

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

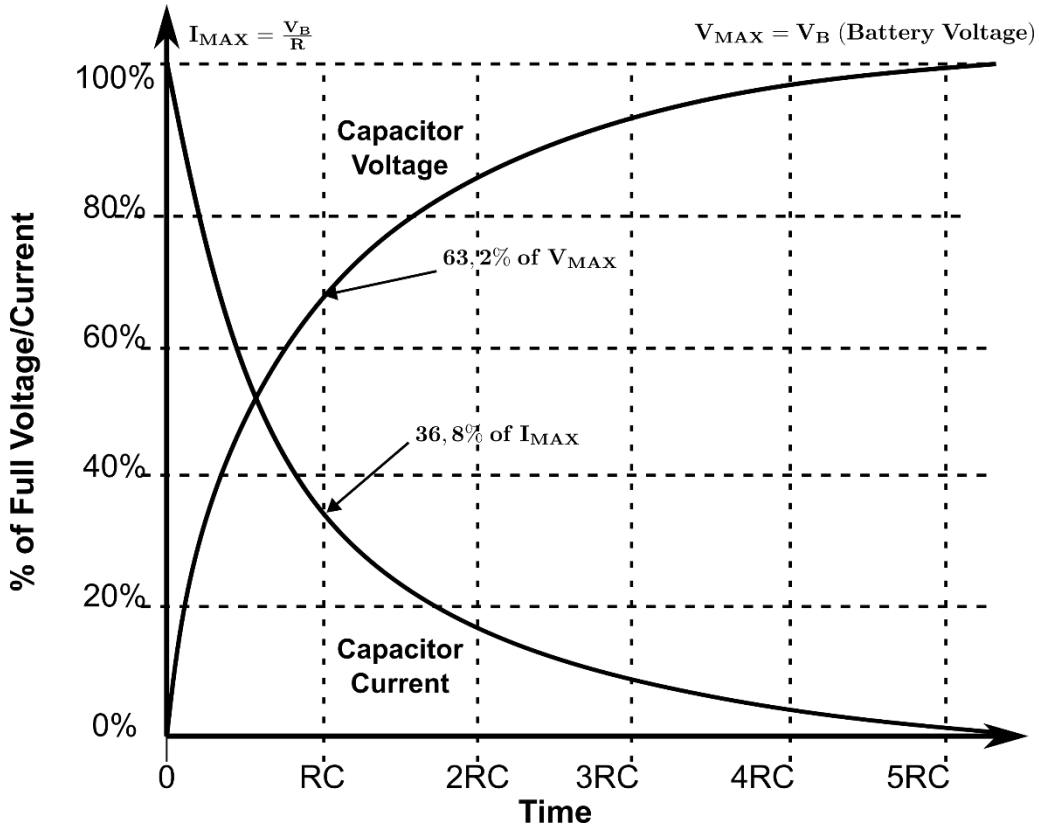
The quantity RC is called the time constant of the circuit

$$\tau = RC$$

As can be see from the table, after 5 time constants, the capacitor voltage has charged to more than 99% of the final voltage of V_B and the charging current is less than 1% of its initial charging current $\frac{V_B}{R}$.



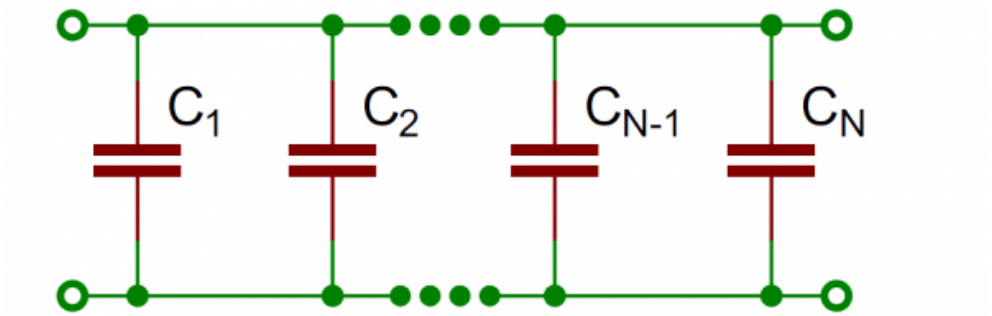
t	V	I
0	0	$\frac{V_B}{R}$
τ	$0{,}632V_B$	$0{,}368\frac{V_B}{R}$
2τ	$0{,}865V_B$	$0{,}135\frac{V_B}{R}$
3τ	$0{,}950V_B$	$0{,}050\frac{V_B}{R}$
4τ	$0{,}982V_B$	$0{,}018\frac{V_B}{R}$
5τ	$0{,}993V_B$	$0{,}007\frac{V_B}{R}$



CHARGING CHARACTERISTICS OF CAPACITOR

CONNECTING CAPACITORS TOGETHER (p195-198)

PARALLEL



$$C_{Tot} = C_1 + C_2 + \ldots + C_{N-1} + C_N$$

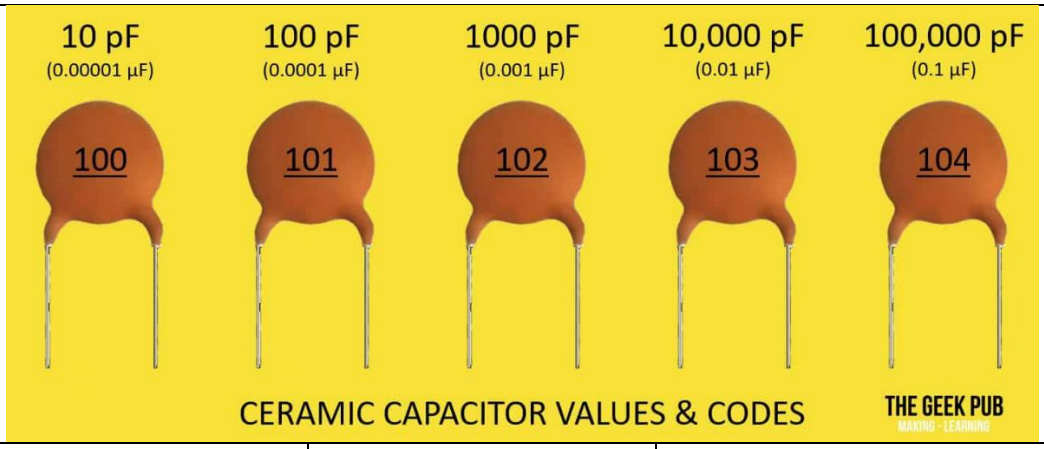
SERIES

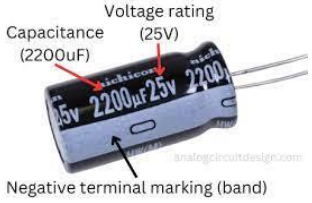


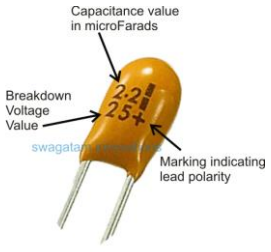
$$\frac{1}{C_{Tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_{N-1}} + \frac{1}{C_N}$$

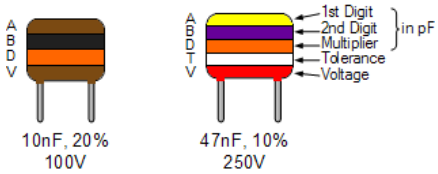
TYPES OF CAPACITORS (p198-200)

SPECIFICATION AND VALUES











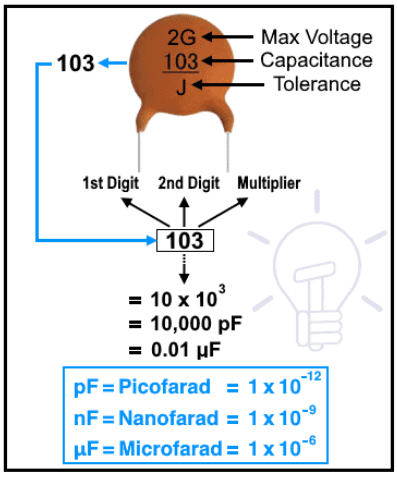
Capacitor Conversion Values & Marking Codes

µF - Microfarad	nF - Nanofarad	pF - Picofarad	Code
0.000001 µF	0.001 nF	1 pF	
0.00001 µF	0.01 nF	10 pF	100
0.0001 µF	0.1 nF	100 pF	101
0.001 µF	1 nF	1,000 pF	102
0.01 µF	10 nF	10,000 pF	103
0.1 µF	100 nF	100,000 pF	104
1 µF	1,000 nF	1,000,000 pF	105
10 µF	10,000 nF	10,000,000 pF	106
100 µF	100,000 nF	100,000,000 pF	107



Max Operating Voltage

Code	Max Voltage
1A	10V
1H	50V
2A	100V
2T	150V
2D	200V
2E	250V
2G	400V
2J	630V
3A	1000V



Tolerance

Code	Percentage %
B	±0.1 pF
D	±0.5 pF
F	±1%
G	±2%
H	±3%
J	±5%
K	±10%
M	±20%
Z	±80%, -20%

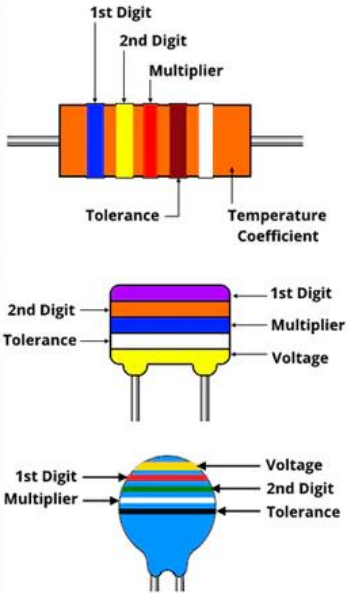
EXAMPLE If the Capacitor Marking Code is **105.** It means **= 10 + 5 Zeros.**
= 1,000,000 pF = 1000 nF = 1 µF WWW.ELECTRICALTECHNOLOGY.ORG

SMD Aluminum Electrolytic Capacitor

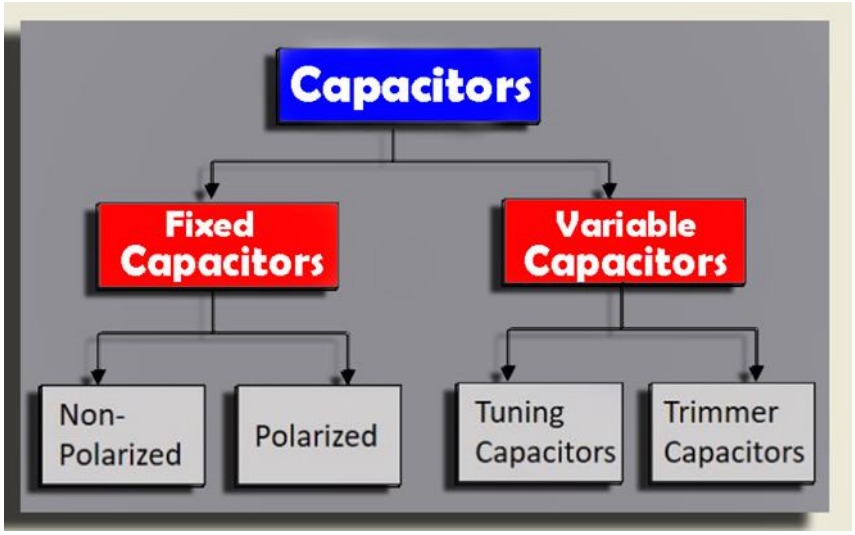


LETTER	VOLTAGE
e	2.5 V
G	4 V
j	6.3 V
A	10 V
C	16 V
E	25 V
V	35 V
H	50 V
J	63 V
K	80 V
2A	100 V

Band Colour	Digit A	Digit B	Multiplier D	Tolerance (T) > 10pf	Tolerance (T) < 10pf	Temperature Coefficient (TC)
Black	0	0	x1	± 20%	± 2.0pF	
Brown	1	1	x10	± 1%	± 0.1pF	-33×10^{-6}
Red	2	2	x100	± 2%	± 0.25pF	-75×10^{-6}
Orange	3	3	x1,000	± 3%		-150×10^{-6}
Yellow	4	4	x10,000	± 4%		-220×10^{-6}
Green	5	5	x100,000	± 5%	± 0.5pF	-330×10^{-6}
Blue	6	6	x1,000,000			-470×10^{-6}
Violet	7	7				-750×10^{-6}
Grey	8	8	x0.01	+80%,-20%		
White	9	9	x0.1	± 10%	± 1.0pF	
Gold			x0.1	± 5%		
Silver			x0.01	± 10%		



CLASSIFICATION



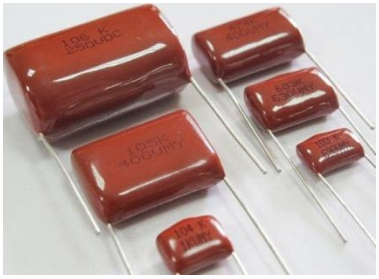
NON-POLARISED	POLARISED
• **No Polarity:** These capacitors do not have a defined positive or negative terminal and can be connected in either direction. • **AC and DC Applications:** They can be used in both AC and DC circuits. • **Versatility:** They are suitable for applications where the direction of current flow may change. • **Examples:** Ceramic, film, polyester, mylar	• **Defined Polarity:** These capacitors have a marked positive (+) and negative (-) terminal. • **DC Applications:** They are typically used in DC power supplies for filtering and smoothing voltage. • **Reverse Voltage:** Connecting them with incorrect polarity can cause damage or even failure. • **Examples:** Electrolytic capacitors, tantalum



Ceramic



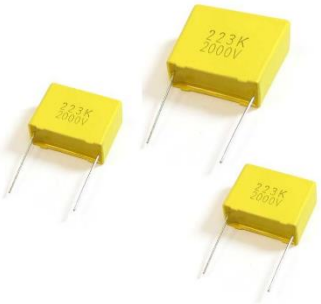
Electrolytic - Radial



Polyester



Electrolytic – Axial



Polyester



Tantalum

VARIABLE CAPACITORS



Variable Capacitors

www.powerelectronicstalks.com

APPLICATIONS

Filtering - main elements in frequency selective filters. The capacitor is used to pass or reject certain frequencies.

LPF: Low pass filters - only frequencies below a certain value are passed to a load.

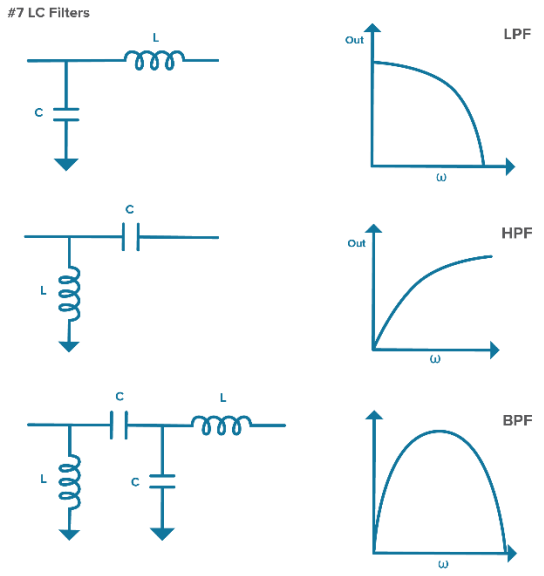
HPF: High Pass Filters – only frequencies above a certain value are passed to a load.

BPF: Band Pass Filters – a range of frequencies is passed to a load.

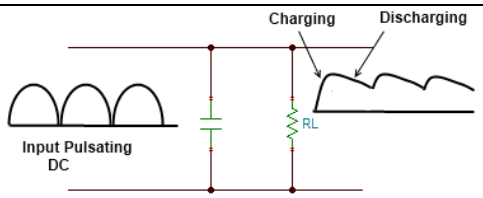
BSF: Band Stop Filter – a range of frequencies is prevented from reaching a load.

Series Resonant Filter – an RLC circuit that passes a very narrow range of frequencies

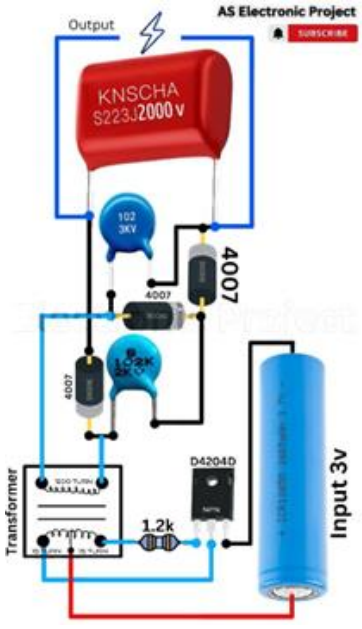
Parallel resonant Filter – an RLC circuit that stops a very narrow range of frequencies.



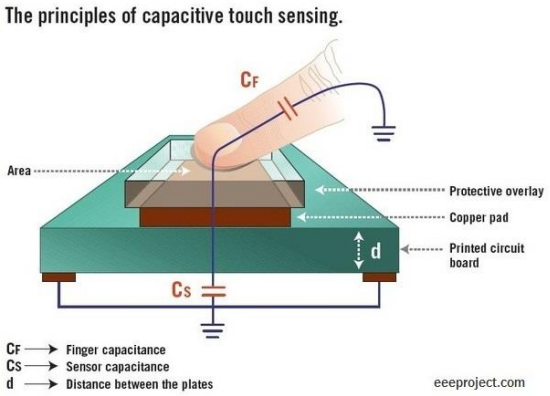
Smoothing – Used in power supplies to prevent voltages fluctuations.



Pulsed Power – Supplies a large amount of power in a short time. Tazers, rail guns, defibrillators.



Capacitive Sensing – Using a change in capitance to detect objects. Smartphone touchscreens, capacitive proximity sensors.

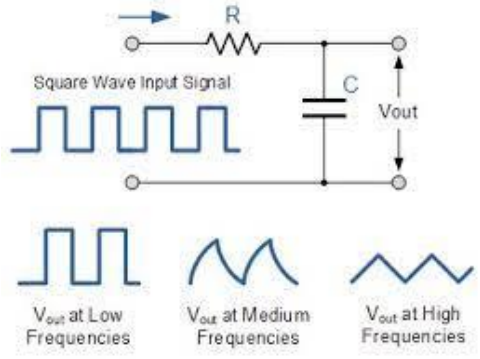


Timing - used in conjunction with a resistor (forming an RC circuit) to create a predictable delay or time-based signal.

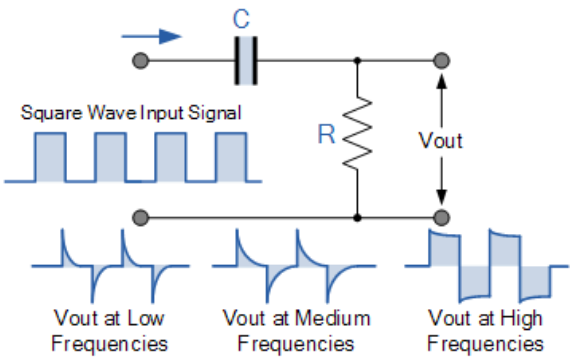
Coupling – Block DC and pass AC signals between circuits

Bypass – Short-circuits high frequency noise signals to ground

Wave-Shaping



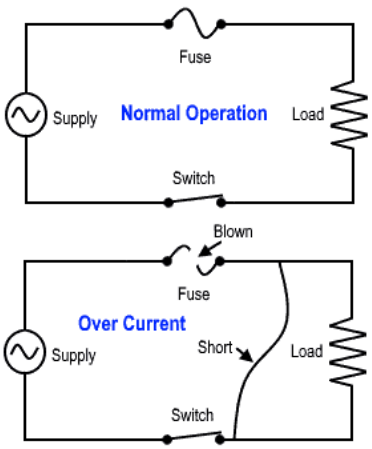
Wave-Shaping



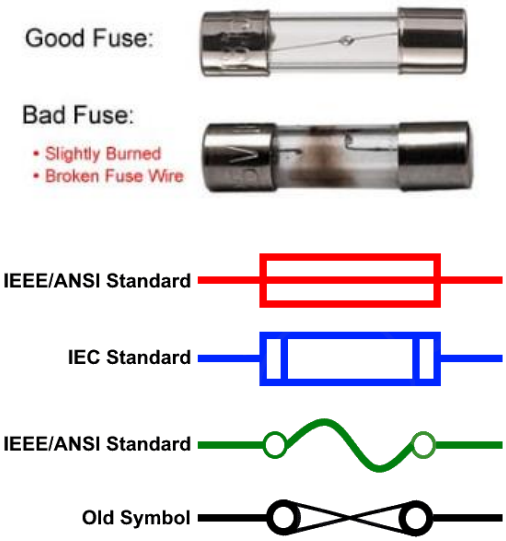
PROTECTIVE DEVICES (p201-203)

FUSES (p201)

A fuse is an electrical / electronic or mechanical safety device designed to protect circuits from overcurrent and overload conditions to safeguard electrical systems during electrical faults.



Working of a Fuse



Different Symbols of Fuse

SYMBOLS

FUSE HOLDERS (p202)





TYPES (p202)

Fast Acting fuses are designed to protect sensitive components and are also used to protect cabling from melting or catching fire when an overload occurs. Fast acting fuses are the most common type of fuse.

Slow acting fuses feature a built-in delay that allows temporary and harmless inrush currents to pass without opening the fuse, but the fuse will open on sustained overloads and short circuits. These fuses are designed to accommodate short surges caused for example by motor start-ups

FUSE RATINGS (p203)	
Fuse ratings, typically in amps (A), indicate the maximum current a fuse can safely handle before it blows, protecting the circuit and equipment from damage. A fuse's rating should be slightly higher than the circuit's normal operating current.	The following basic formula can guide you in selecting the right fuse size for typical applications. Fuse Rating = (Power ÷ Voltage) x 1.25

THE DIODE (p204-215)

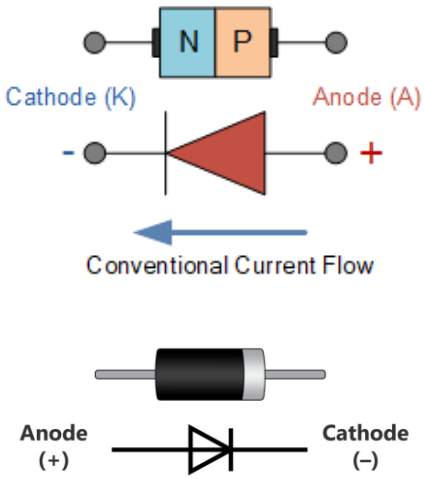
A diode is a two terminal polarised electronic component that allows electric current to flow in one direction while blocking current from flowing in the opposite direction.

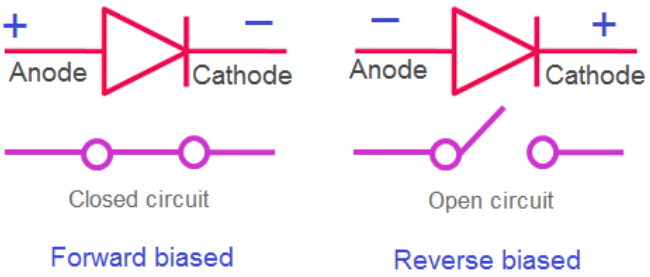
A diode can be considered to be a voltage controlled switch. When it is forward biased, it allows current to flow; when it is reversed biased, current cannot flow.

Forward biased: The anode is at a higher voltage than the cathode.

Reverse bias: The cathode is at a higher voltage than the anode.

Diodes are manufactured from a semiconductor material such as silicon.

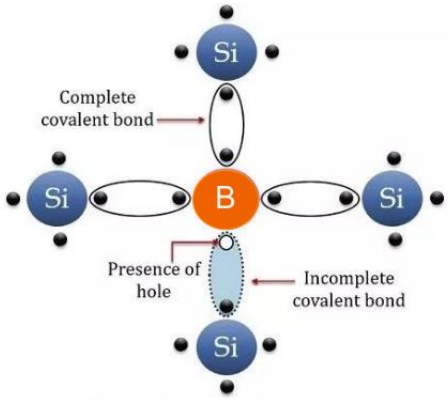


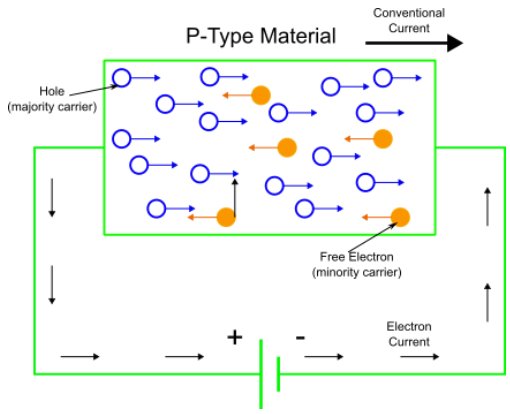


CONSTRUCTION OF A DIODE (p205)

A semiconductor diode, also called a pn-junction diode, is formed when two parts of semiconductor material, such as silicon, is doped with impurities so that one part has an excess amount of free negative charge carriers (electrons), the n-type, and the other has an excess amount of free positive charge carriers (holes), the p-type. These p- and n-type silicon materials are formed when impurities are diffused into the silicon lattice thereby increasing its conductivity.

P-TYPE SEMICONDUCTOR	**N-TYPE SEMICONDUCTOR**
A hole is formed when silicon and the introduced impurity atom make an incomplete covalent bond. Boron is commonly used. Material with a majority of holes is called p-type.	An electron is freed when the silicon and impurity atom have one electron too many when they form a covalent bond. Phosphorous is commonly used. Material with a majority of electrons is called n-type.



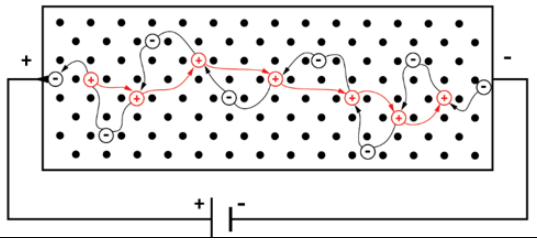


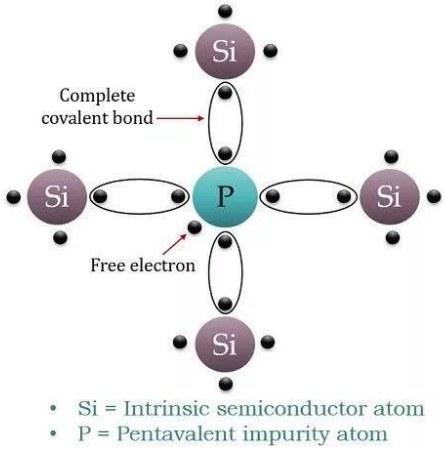
Holes only exist inside the semicondutor material, only electrons flows through the external circuit.

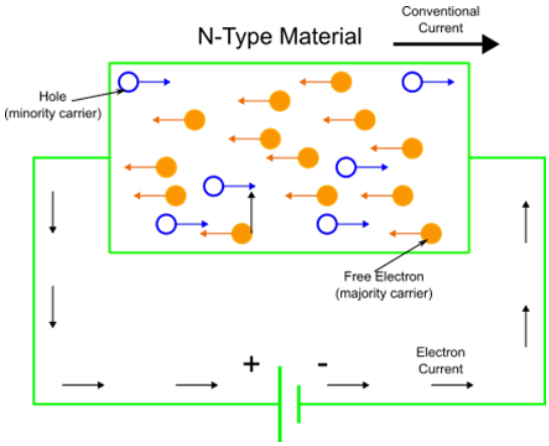
When a battery is connected, electrons are pushed from the negative battery terminal into the p-type material where it combines with a hole forming a complete covalent bond. It will seem as if the hole moved out of the material towards the negative battery terminal.

At the other end, electrons are attracted to the positive terminal of the battery through the breaking of covalent bonds, forming new holes. As electrons are removed from a bond, a hole is available for another electron to combine with. It seems as if the holes are moving to the right and electrons to the left.

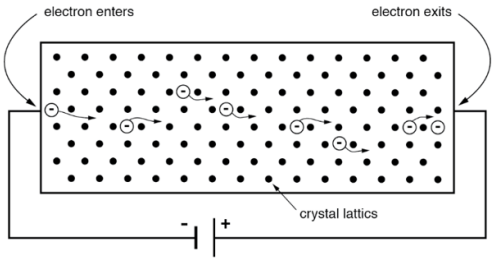
An electron current thus flows in the external circuit.

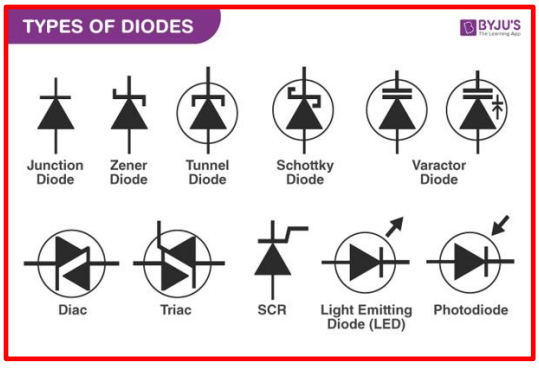




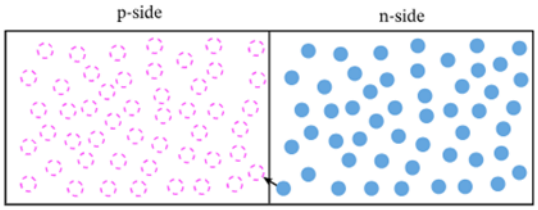


The majority charge carrier in n-type silicon is the electron. Current flow through the material due to electrons is similar to electrons moving in a wire.

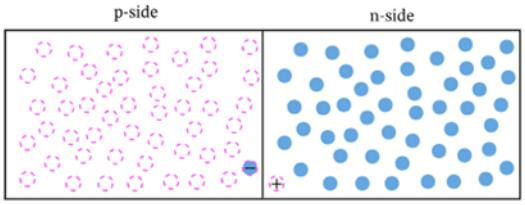




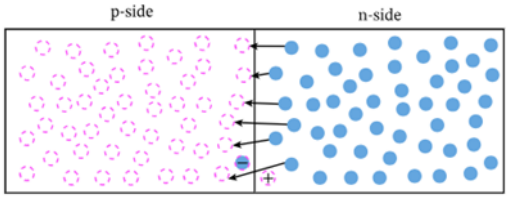
THE PN-JUNCTION



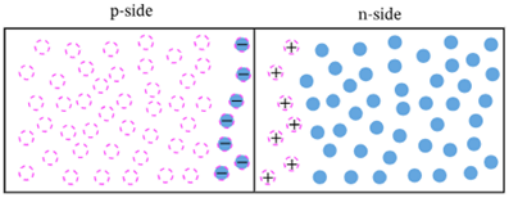
A pn-junction is formed when a p-type and n-type material is formed next to each other.



There is a lot of holes on the left-hand side of the junction and electrons on the right-hand side.

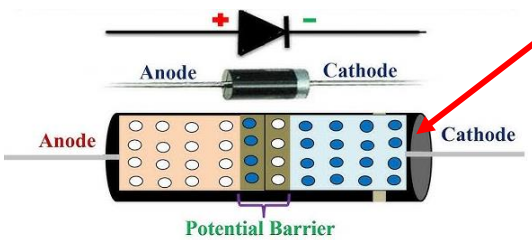


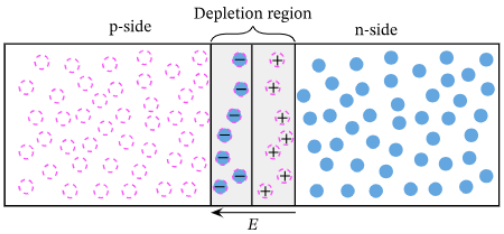
To correct the imbalance, diffusion takes place and electrons diffuses across the junction.



As electrons diffuses across the junction, they recombines with holes on the left-hand side. This forms a negatively charged ion.

On the right-hand side, due to the loss of an electron, a positively charged ion remains.





After the initial surge of free electrons across the PN junction, the depletion region expands to a point where equilibrium is established and there is no further diffusion of electrons across the junction.

This process occurs because, as electrons continue to diffuse across the junction, more and more positive and negative charges are created near the junction and the depletion region forms.

A point is reached where the total negative charge in the depletion region repels any further diffusion of electrons into the p-region and the diffusion stops.

These two layers of positive and negative charges form the depletion region. This depletion region is depleted of charge carriers (electrons and holes).

The depletion region has many positive charges and many negative charges on opposite sides of the PN junction. The force between the positive and the negative charges form an electric field.

The electric field acts as a barrier to the free electrons in the n region, and external energy must be applied to move these electrons across the depletion region.

A DIODE HAS NOW BEEN FORMED.

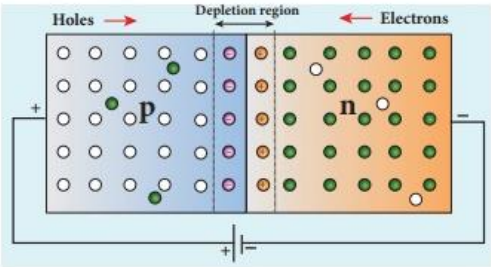
The situation is now similar to a fully charged capacitor – there is no current in the circuit. To allow current to flow, a potential larger than the charged voltage must be applied. In this case, the voltage is built into the junction, called the barrier potential. For silicon this is approximately 0,7V which must be overcome to allow conduction.

DIODE BIASING

Biasing means providing external energy to charge carriers to overcome the barrier potential and make them move in a particular direction. The charge carriers can either move towards the junction or away from the junction. The external voltage applied to the p-n junction is called bias voltage. Depending on the polarity of the external source to the p-n junction we have two types of biasing: 1. Forward bias; 2. Reverse bias

FORWARD BIAS

If the positive terminal of the external voltage source is connected to the p-side and the negative terminal to the n-side, it is called forward biased.



The application of a forward bias potential (approximately 0,7V for silicon) makes the electrons move into the n-side and the holes into the p-side from the battery terminals. This initiates the recombination with the ions near the junction which in turn reduces the width of the depletion region and hence the barrier potential.

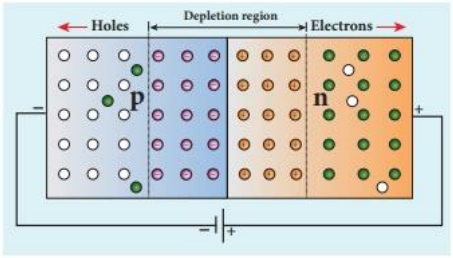
The electrons from the n-side is now accelerated towards the p-side as it experiences a reduced barrier potential at the junction. In addition, the accelerated electrons experience a strong attraction by the positive potential applied to the p-side. This results in the movement of electrons towards the p-side where they recombine with holes and in turn, holes towards the n-side where they recombine with electrons.

During recombination, the recombining holes and electrons releases heat and light. Light is emitted as phonons (the process is called electroluminescence), which is maximised using special semiconductor materials, also to produce different colours.

When the applied voltage is increased, the width of the depletion region and hence the barrier potential are further reduced. This results in a large number of electrons passing through the junction resulting in an exponential rise in current through the junction.

REVERSE BIAS

If the positive terminal of the battery is connected to the n-side and the negative potential to the p-side, the junction is said to be reverse biased.

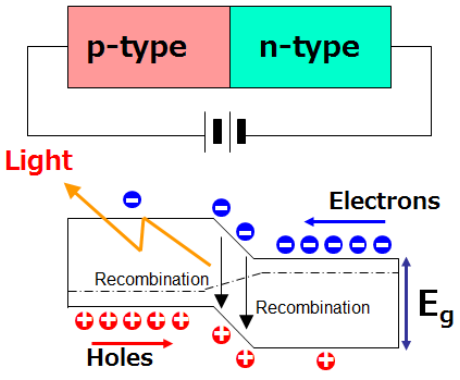


As the positive potential is connected to the n-type material, the electrons in the n-type material are attracted towards the positive terminal in turn, the holes in the p-type material move towards the negative terminal (both away from the junction). It increases the immobile ions at the junction.

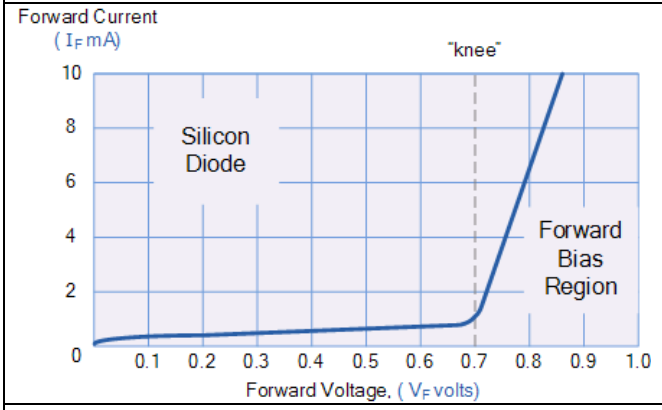
The net effect is the widening of the depletion region. This leads to an increase in the barrier potential.

Consequently, the majority charge carriers from both sides experience a great barrier to cross the junction.

This prevents the diffusion current across the junction effectively.



CHARACTERISTIC CURVE AND CURRENT FLOW



A silicon diode only starts to conduct current once the forward bias voltage increases above 0,7V. Below that, the current is close to zero.

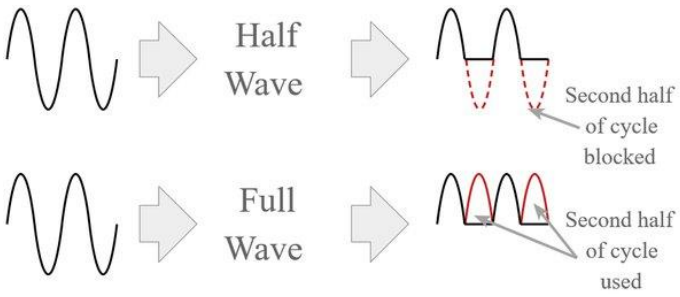
As the voltage increase, the current increases rapidly at an exponetial rate. Resistors are normally used in series with a diode to prevent excess current from damaging it.

THE DIODE AS A RECTIFIER (p212)

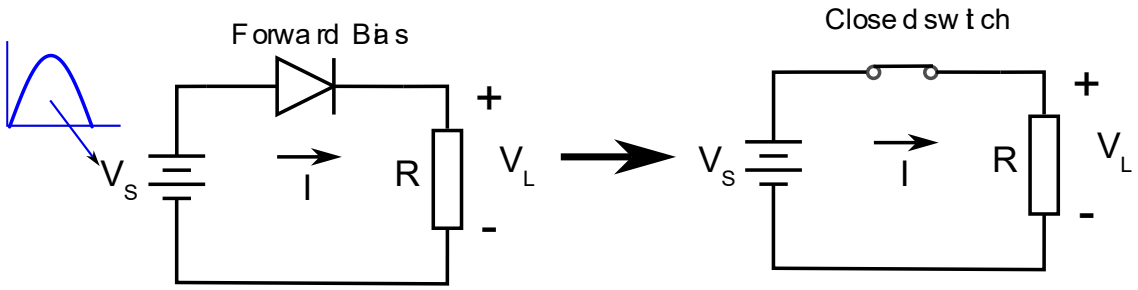
One of its main applications is the rectification of AC power to DC power.

Half-wave: The positive half of the AC signal is passed and the negative half is cut off.

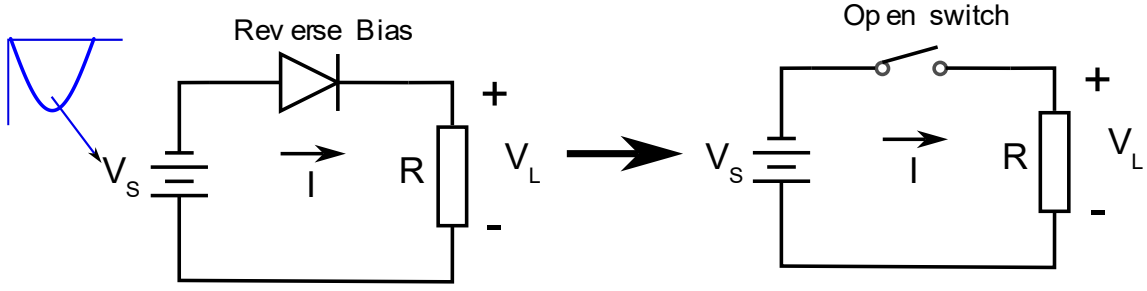
Full-wave: Both halves of the AC signal is used to create a postive signal.



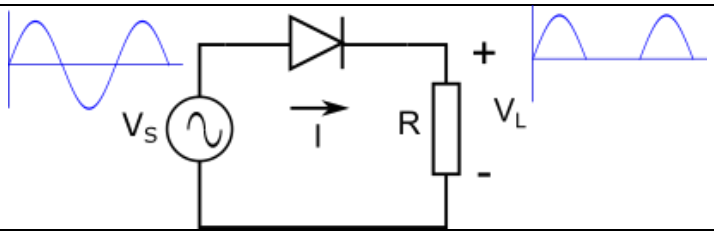
HALF-WAVE RECTIFICATION (p213)



The positive part of the AC signal can be represented by a battery with a value that change from zero to some maximum positive value. A current flows in the circuit.

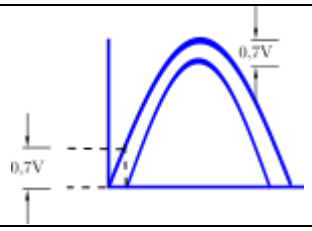


The negative part of the AC signal can be represented by a battery with a value that change from zero to some maximum negative value. No current flows in the circuit and $V_L = 0$.



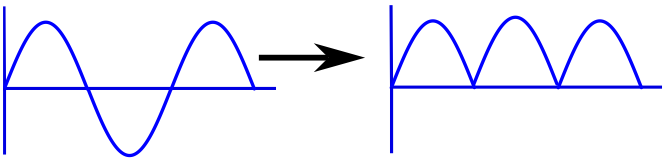
The result is a DC signal that pulsates between 0V and the maximum value of the AC signal. Half of the power applied by V_S is thus supplied to the load, V_L.

Note that the diode will only start to conduct once the AC signal voltage is above 0,7V. Note also that the load voltage will be 0,7V lower than the maximum AC voltage due to the voltage drop across the diode.

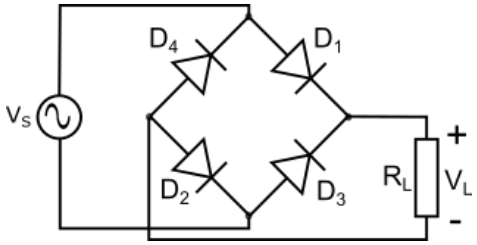


FULL-WAVE BRIDGE RECTIFIER (p214-215)

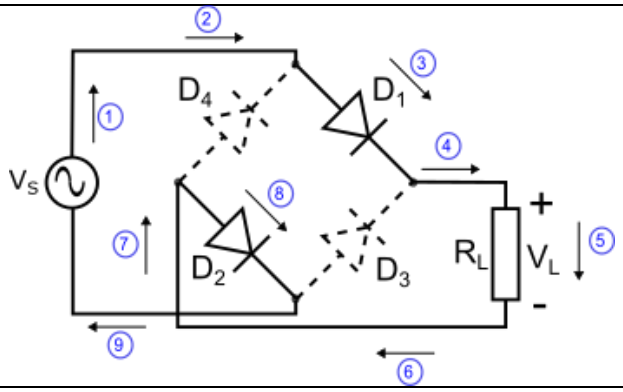
The full-wave rectifier converts both halves of the AC signal into a pulsating DC voltage and thus most of the applied power is available to the load.



The bridge rectifier is the most commonly use circuit.

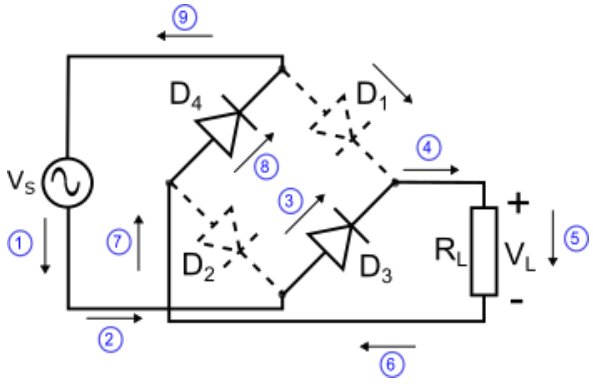


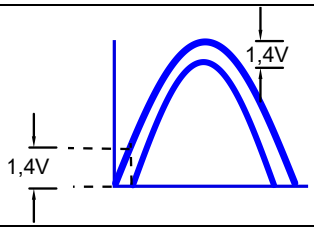
When the AC signal is positive, the current follows the path indicated by 1 to 9. Diodes D_1 and D_2 are conducting, while D_3 and D_4 are reverse biased and off.



When the AC signal is negative, the current follows the path indicated by 1 to 9. Diodes D_1 and D_2 are reversed biased and off, while D_3 and D_4 are conducting.

Note that the current is directed by the diodes to flow in the same direction through the load R_L than when the AC signal is positive. The AC signal is thus flipped vertically during the negative half signal.

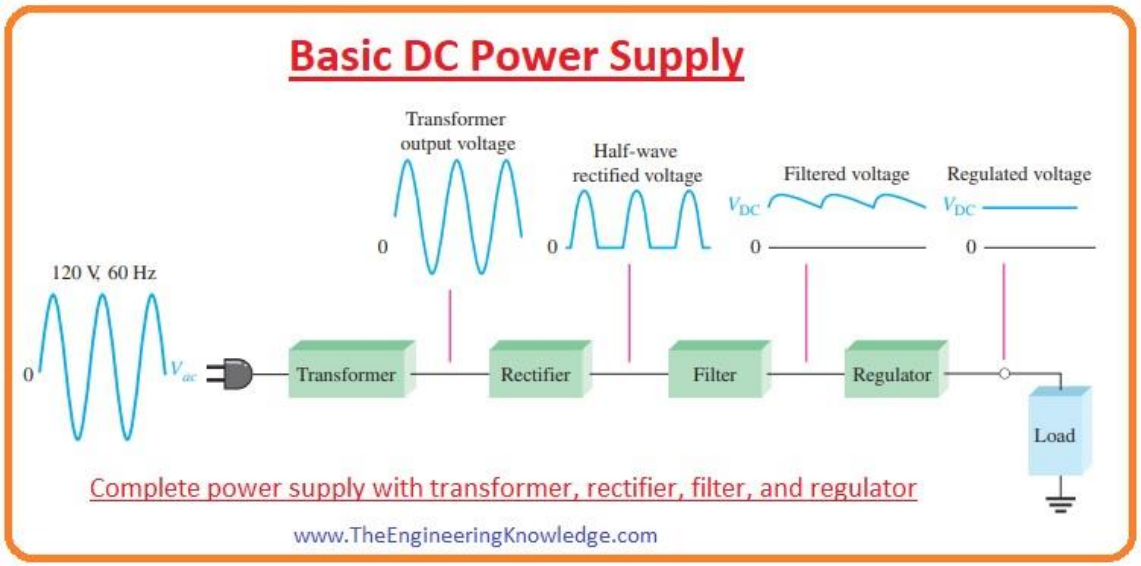


Due to the rectifier having 2 diodes in the conduction path, the output signal is now 1,4V lower than the AC signal, and conduction only takes place once the AC signal is higher than 1,4V.	
The bridge rectifier can be implemented as an integrated circuit instead of four discrete diodes.	

RECTIFIER APPLICATION

Rectifiers are commonly used in linear power supplies which is used to convert AC voltage to a constant DC voltage.:

AC Supply: 230V supplies power to the power supply
Transformer: Steps the 230V AC Supply down to an AC voltage with an amplitude slightly higher than the required DC output voltage.
Rectifier: The rectifier changes the AC voltage into a pulsating DC voltage
Filter: The filter consisting of a capacitor smoothes the pulsating DC voltage to a smoother voltage
Regulator: Adjusts the voltage to the required constant output DC voltage.

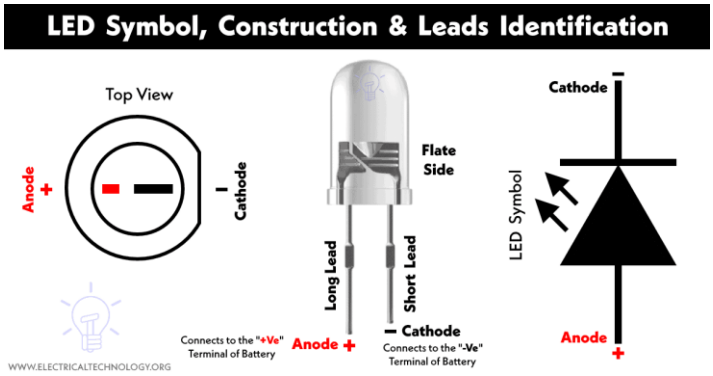


THE LIGHT EMITTING DIODE (p222-224)

An LED is a special diode that is designed to emit light at a specific colour when forward biased.

Applications of LEDs :

- Picture phones and digital watches
- Camera flashes and automotive heat lamps
- Aviation lighting
- Digital computers and calculators
- Traffic signals and Burglar alarms systems
- Microprocessors and multiplexers
- Optical Communication
- Indicator lamps in electric equipment
- LED televisions and monitors
- Vehicle head lamps, domestic and decorative illumination, street lighting.



CONSTRUCTION (p222)

Manipulation of the interaction between electrons and holes at the p-n junction is fundamental in the design of all semiconductor devices, and for light emitting diodes, the primary design goal is the efficient generation of light

The basic structure of a light emitting diode consists of the semiconductor material (the die), a lead frame on which the die is placed, and the encapsulation epoxy surrounding the assembly. The LED chip is supported in a reflector cup coined into the end of one electrode (the cathode), and top face of the chip is connected with a gold bonding wire to a second electrode (anode).

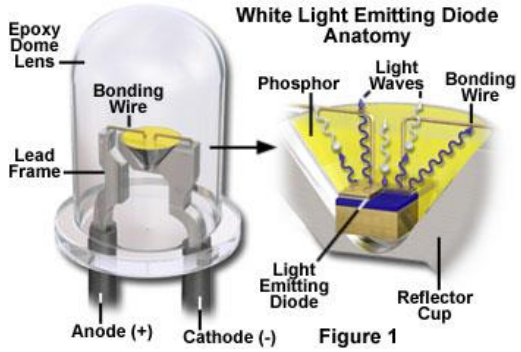


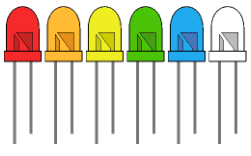
Figure 1

Several junction structure designs require two bonding wires, one to each electrode.

COLOURS (p222-223)

The color of an LED is determined by the specific semiconductor material and the way it is manipulated through doping and other manufacturing processes to control the energy gap and, ultimately, the wavelength of light emitted.

The color of the light emitted by an LED is not determined by the color of the plastic body enclosing the LED. The choice of the semiconductor material used in manufacturing the LED will determine the wavelength of the photon emissions and the resulting color of the emitted light.



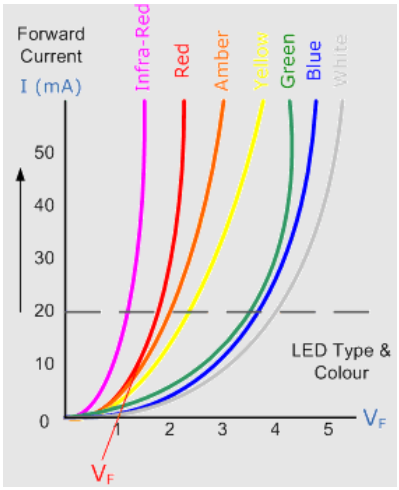
- Gallium Phosphide (GaP) – red, yellow and green
- Aluminium Gallium Phosphide (AlGaP) – green
- Gallium Nitride (GaN) – green, emerald green
- Gallium Arsenide (GaAs) – infrared
- Gallium Arsenide Phosphide (GaAsP) – red to infrared, orange
- Aluminium Gallium Arsenide Phosphide (AlGaAsP) – high-brightness red, orange-red, orange, and yellow
- Gallium Indium Nitride (GaInN) – near ultraviolet, bluish-green and blue
- Silicon Carbide (SiC) – blue as a substrate
- Zinc Selenide (ZnSe) – blue

Typical LED Characteristics			
Semiconductor Material	Wavelength	Colour	V_F @ 20mA
GaAs	850-940nm	Infra-Red	1.2v
GaAsP	630-660nm	Red	1.8v
GaAsP	605-620nm	Amber	2.0v
GaAsP:N	585-595nm	Yellow	2.2v
AlGaP	550-570nm	Green	3.5v
SiC	430-505nm	Blue	3.6v
GaInN	450nm	White	4.0v

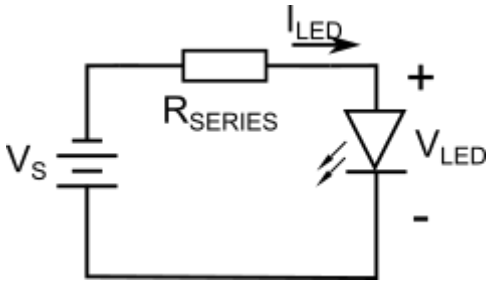
CHARACTERISTIC CURVE (p223)

Color LED	Name Color	Wavelength nm = $1x10^{-9}$	Voltage Drop (Forward Voltage)
	White	395 - 530 nm	3 - 5 V
	Ultraviolet	< 400 nm	3.1 - 4.4 V
	Violet	400 - 450 nm	2.8 - 4.0 V
	Blue	450 - 500 nm	2.5 - 3.7 V
	Green	500 - 570 nm	1.9 - 4.0 V
	Yellow	570 - 590 nm	2.1 - 2.2 V
	Orange	590 - 610 nm	2.0 - 2.1 V
	Red	610 - 760 nm	1.6 - 2.0 V
	Infrared	> 760 nm	< 1.9 V

The forward voltage across the LED depends on the colour as shown in the table above.



CONNECTING AN LED (p223-224)



A green LED with a on voltage of $V_{LED(ON)} = 3{,}5V$ and a current $I_{LED(ON)} = 15mA$ is connected through a resistor to a battery with $V_S = 12V$. Calculate the value of the resistor required and give a practical value for this resistor.

$$\begin{aligned} R_{SERIES} &= \frac{V_R}{I_{LED}} \\ &= \frac{V_S - V_{LED}}{I_{LED}} \\ &= \frac{12 - 3{,}5}{15 \times 10^{-3}} \\ &= 566{,}67\ \Omega \end{aligned}$$

A practical value for the resistor will thus be 560Ω (normal best practice is to select a resistor slightly larger than the theoretical value, but this is sufficiently close).

Typical questions and answers

1. **Electronic components can be divided into two main groups, name them.** (2)
   Passive Components and Active components

2. **Discuss the difference between passive components and active components and give ONE example of each.** (4)

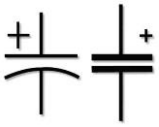
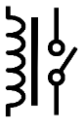
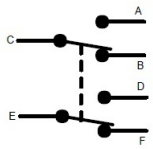
   Active components need to be powered in some way to make them work eg. a transistor or Integrated Circuit (IC)

   Passive components can work on their own in simple circuits, they do not need any applied voltage to work eg. Resistors, capacitors etc

3. **What does the following abbreviation stand for with regards to switches? SPDT** (1)

   Single-pole Double-throw

4. **With reference to electronic components, complete the table 1 below.** (5)

Component Symbol	Component Name
	(a) Diode
(b) 	Polarised Capacitor
	(c) Relay
(d) 	Double pole - Double throw switch

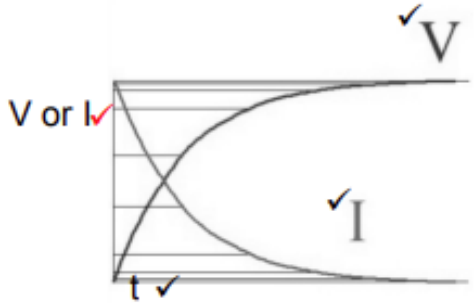
5. **Explain the operating principle of a rotary switch.** (2)

   It's a switch madeup of disks, each disk can have up to 8 switching positions, and they are selected by turning the control shaft.

6. **Briefly explain the function of a capacitor, and give ONE application for a capacitor** (3)

   A capacitor is a capacitive component that can store electric energy in the form of an electrostatic field. A capacitor can be used as a smoothing device in a power supply.

7. Draw the graph of voltage and current versus time for a charging capacitor. (4)



8. You are given two capacitors, 1000nF and 2000nF respectively. Calculate the total capacitance value when they are connected:

(a) In Series (3)

(b) In Parallel (3)

(a) $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$

$\frac{1}{C_T} = \frac{1}{1000x10^{-9}} + \frac{1}{2000x\ 10^{-9}}$

$C_T = 6.667x10^{-7}\ F\ or\ 0.667x10^{-6} F\ or\ 0.667\mu F$

(b) $C_T = C_1 + C_2$

= 1000 nF + 2000 nF

= 3000 nF

NB

Capactors in parallel- the total capacitance will increase

Capacitors in series – the total capacitance will decrease

9. Complete the following conversions with respect to capacitor values. (3)

(a) 1µF = ……. F

(b) 20000 pF =……µF

(c) 1000 nF = …… pF

(a) 0.000001 F

(b) 0.020 µF

(c) 1000000 pF

It is important that you know these prefixes and how to convert from one to the other.

10. A 100uF capacitor is charged through a 560Ω resistor. Calculate the Following:

(a) The time constant. (3)

(b) The time it will take for the capacitor to fully charge. (3)

(a) $\tau = RC\ =\ 560\ x\ 100x10^{-6}\ =\ 0.056\ s$

(b) $T\ =\ 5\ x\ \tau\ =\ 5\ x\ 0.056\ =\ 0.28\ s$

11. Briefly discuss the different between a slow blow and a fast blow fuse (4)

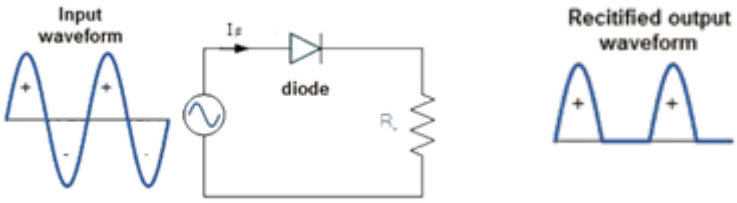
Fast blow fuse: a fuse that will blow the instant the current rises above thet rated value

Slow blow fuse: a fuse that will be a ble to withstand current far higher than its rated value for a short period of time befor it blows.

12. Explain the term forward biasing with reference to diode. (2)

When the positive of the supply is connected to the P-Type material (Anode) and the negative connected to the N-Type material (Cathode).

13. With reference to the circuit diagram given below, make a neat drawing of the output waveform. (3)



14. A blue LED must be driven by a 12V DC power supply. The maximum operating current of the LED is ID(max) =35mA at a diode voltage VLED=2,1V.

(a) Calculate the value of the resistor that needs to be put in series with the LED to prevent it from being damaged. (3)

(b) Calculate the power dissipated by the LED under maximum operating conditions.

(3)

