SECTION
3

AVIONICS

Avionics

Fundamentals of Avionics

INTRODUCTION

Hello learner, you are welcome to Section 3. In this section, you will explore the fundamental principles of electronics. You will delve into some basic electronics components commonly found in circuits and household appliances and discuss their primary functions. You shall also look at Ohm's law and how it is applied in circuits. This basic knowledge will then be applied to systems that enable aircraft to operate, namely, in communication, navigation and surveillance.

At the end of the section, you will be able to

- Identify basic electronics components.
- Discuss the functions of basic electronic components.
- Discuss how Ohm's law affects the flow of current in an electronic circuit.
- Discuss the various communication systems on aerospace vehicles.
- List the systems used on aerospace vehicles for navigation and explain their working principles.
- Discuss the systems used for surveillance on aerospace vehicles.

Key Ideas

- **Electronics**: Electronics form the basic building blocks of all modern digital systems. Conductors, insulators, and semiconductors are the materials used for making these electronic components. Components like capacitors, diodes, resistors, LEDs, and the like help basic appliances you use in your house like refrigerators, televisions, and microwaves as well as to work effectively and safely. They also help aerospace vehicles in their day-to-day operations for communications, navigation and surveillance.
- **Radio frequencies –** the rate of oscillation of an electric current or magnetic field.
- **Communication –** means by which aircraft crew share information between themselves and people on the ground.
- **Navigation –** means by which aircraft find their way into the air
- **Surveillance –** means by which aircraft detect objects and phenomena in their environment

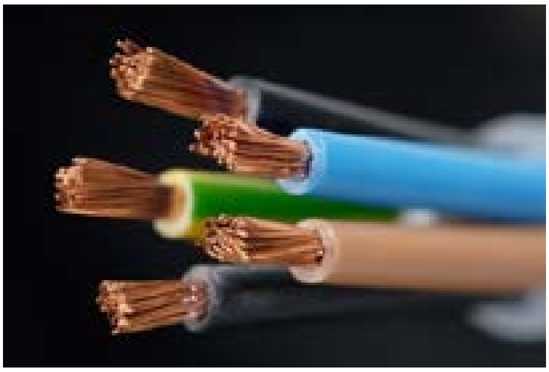
THE BASIC PRINCIPLES AND CIRCUIT COMPONENTS OF ELECTRONICS

Electronics is the study of the flow and control of electrons passing through conductors, semiconductors and vacuum. Electronics principles are applied in most household appliances, mobile phones, laptops, etc. It is the foundation of the digital age.

Materials in electronics

There are three major groups of materials that are used in electronics. They are conductors, semiconductors and insulators

Conductor: A conductor is any material that freely allows electrical current to flow through it. Examples of conductors are metals (like copper, aluminium and steel), water with dissolved minerals and graphite. Conductors are used to make wires for transmitting electricity.



https://www.sciencelearn.org.nz/images/1961-copper-wire

Fig. 3.1. Strands of copper used as electrical conductors

https://www.interwell.cn/the-complete-guide-to-graphite-pencil-lead-grade

Fig 3.2. Graphite used in pencils is a conductive material.

Insulator: An insulator is a material that does not allow electrical current to flow through it. Examples of insulators are dry wood, plastics, rubber, paper, fibreglass and foam. Insulators are used to sheath wires to prevent short-circuiting and protect humans from electrical shocks.

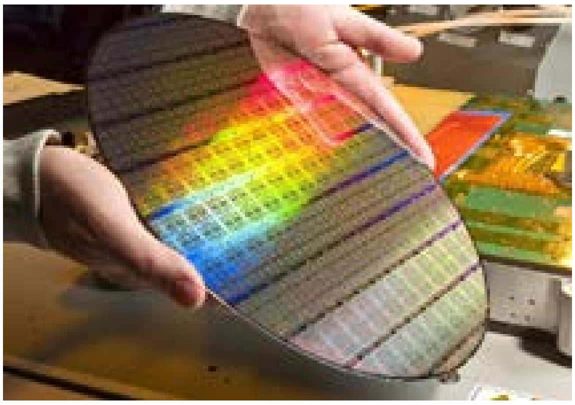
https://wesbellwireandcable.com/blog/indoor-outdoor-and-underground-copper-electrical-wire/

Fig 3.3. Copper cables with various colours of PVC plastic insulation

https://cen.acs.org/materials/inorganic-chemistry/s-fiberglass-does-delicate-material/96/i3

Fig 3.4. Fibreglass material is used in electrical insulation

Semiconductor: A semiconductor is a material with its conductivity between a conductor and an insulator. The conductivity of semiconductors can be altered by introducing other materials called impurities. This method of changing the electrical properties of semiconductors through the introduction of impurities is called doping. Semiconductors are very important in electronics. Examples of semiconductors are silicon and germanium.



https://www.techpowerup.com/238785/q4-2017-300-mm-silicon-wafer-pricing-to-increase-20-yoy-in-dram-like-squeeze

Fig. 3.5. A silicon wafer used to make integrated circuits.

Important terminologies in electronics

Electronic component: An electronic component is a basic unit that forms part of an electronic circuit and performs a specific function in the circuit. Some examples of electronic components are resistors, capacitors, transistors, diodes and inductors.

Basic electronics components and their functions

Resistor: This is a two-terminal electrical component used to reduce the flow of current through components in an electric circuit. This is usually done to protect components that are currently sensitive to avoid excess current going through them in order not to destroy or damage them. The resistor's ability to reduce the current is called resistance and is measured in units of ohms(Ω). Resistors typically are made up of metals of specific resistivity and dimensions chosen to attain the desired resistance. The resistive material is then coated in an insulating material most of which are ceramic-based. They usually come in cylindrical shapes with bands of colours around them to indicate their resistance in ohms.

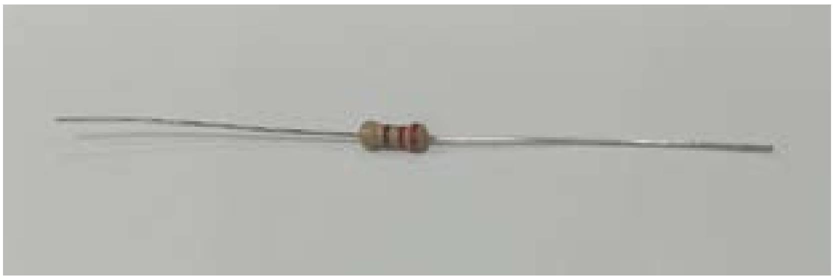


Fig. 3.6. A resistor

Capacitors: A capacitor is a two-terminal circuit component used in electronic circuits to store energy in an electric field. It is made up basically of two conductor plates facing each other with an insulator material between them. The insulator material between the plates is called a dielectric.

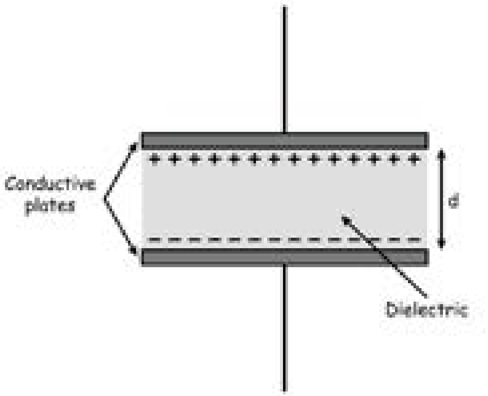


Fig. 3.7. A capacitor

The capacitance is usually indicated in farads (F). Two common types of capacitors are electrolytic capacitors and ceramic capacitors. Electrolytic capacitors are polarized, which means that one terminal is designed to be connected toward the positive terminal of a voltage source and the other terminal to be connected to the negative terminal of the voltage source. Ceramic capacitors, however, are not polarized, and the terminals can be reversed without causing changes to the circuit or damage to the capacitor. Ceramic capacitors can be used in both DC and AC. Capacitors are usually voltage-rated so one must ensure that the capacitor used in a portion of a circuit has a higher voltage rating than what the circuit can supply otherwise the capacitor may be damaged.

v

Fig. 3.8. Electrolytic capacitor

Fig. 3.9. Ceramic Capacitors

Inductors: An inductor is a two-terminal circuit component used in circuits to store energy in the form of a magnetic field. The inductance units are Henrys (H). An inductor is basically a coiled wire. When current passes through it a magnetic field is created around it. It may be used to electrically isolate parts of a circuit (as in a transformer) or to detect sudden changes in current.

Fig. 3.10. Inductors

Diodes: Diodes are two-terminal semiconductor circuit components that allow current to flow through them in only one direction. It has low resistance in one direction and high resistance in the other direction. A common application of diodes is in rectifier circuits (circuits that convert AC voltages to DC voltages) like in phone chargers

Fig. 3.11. Diodes

Light Emitting Diodes (LEDs): These are diodes that give off light when current passes through them. They come in different sizes and colours. They usually serve as visual indicators in a circuit. For example, one may integrate a light-emitting diode into a circuit to indicate if there is power in the circuit. LEDs, just like typical diodes, allow current to pass through in only one direction, only then will they light. They can be found in televisions, headlights of cars, backlights of keyboards, flashlights etc.

Fig 3.12. An image of a light-emitting diode

Transistors: These are three-terminal semiconductor devices. Transistors form the building blocks of most modern digital systems. They serve as amplifiers and switches in electronic circuits. They can be combined to create logic circuits which can then be used to build more complex systems like microprocessors and processors for computers.

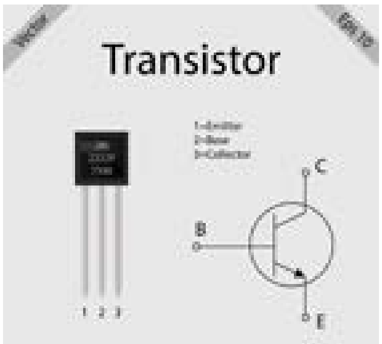


Fig. 3.13. Image of a transistor

Integrated Circuits: An integrated circuit is a small device consisting of several electronic components like transistors, resistors and capacitors inscribed on a single small piece of semiconductor wafer, usually silicon. They are used in several electronic devices like computers, phones, and calculators. Integrated circuits allowed the miniaturization (constructed in small size) of computers since processors and other system components can be made much smaller. They are mounted on circuits using two main methods. There is the Through-Hole-Technology (THT) and Surface-Mount Technology (SMT).

Fig. 3.14. THT Integrated Circuits. Image ID: **FNG0GX**

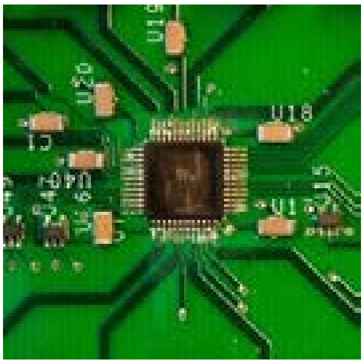


Fig. 3.15. SMT integrated circuit

Microcontrollers: A microcontroller is a small computer on a single integrated circuit programmed to control a specific task. It usually has input and output ports through which it receives and sends signals to communicate with other components in an electronic circuit. Modern microcontrollers can be purchased off-the-shelf and programmed on a personal computer (PC) to control sensors and other devices. Microcontrollers find themselves in most modern systems like washing machines, automatic teller machines and fight controller boards for UAVs (Unmanned Aerial Vehicles). They may come in readily programmable packages like the Arduino and Raspberry Pi boards.

Fig. 3.16. Arduino microcontroller board based on the ATMEGA328p chip. Image ID: **D7756M**

Fig 3.17. Image of a Raspberry Pi Pico

Circuit components and their symbols

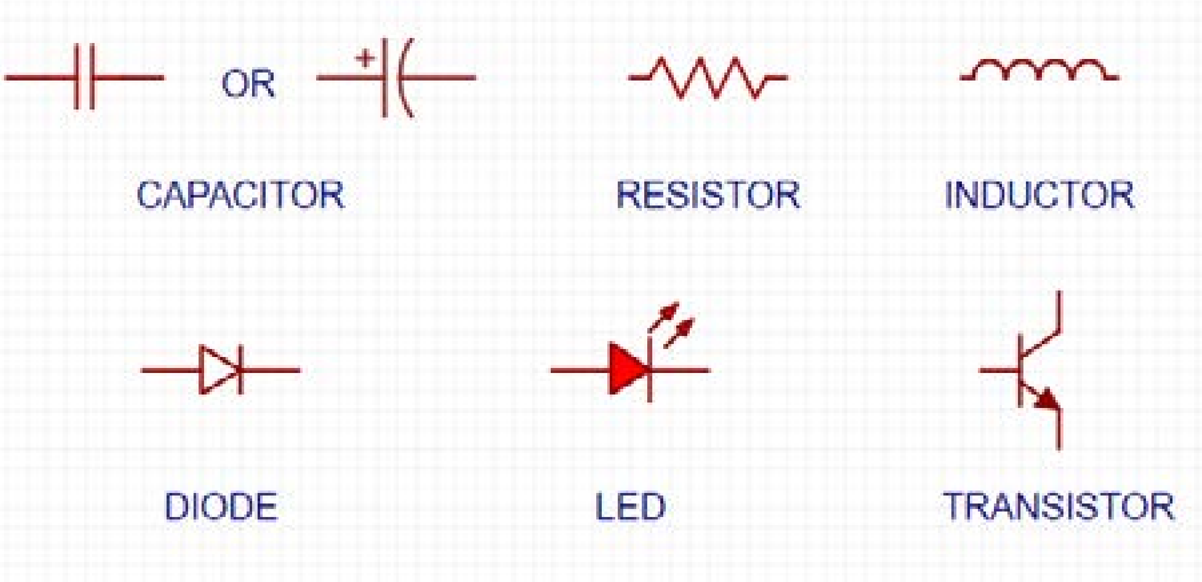


Fig. 3.18. Symbols of Electronic Components

Activity 3.1

1. Take a gallery walk around the classroom to observe and identify displayed electronic components on walls and on tables.
2. Make a list of the basic electronic components you observed on your walk.

E.g. Capacitors
1.
2.
3.
4.
5.
6.
7.
8.

3. Pair with peers and discuss the functions of each of the basic electronic components listed above
4. Make a poster outlining the functions of the basic electronic components

Self-Assessment

How do the basic electronic components contribute to the operations in a circuit?

Ohm's Law

Ohm's Law is a fundamental principle in electronics that forms the basis for understanding how voltage, current, and resistance are interrelated in an electrical circuit.

Whether you're an aspiring hobbyist, a student, or just curious about the world of electronics, grasping Ohm's Law is crucial. You will unravel the mysteries of Ohm's Law in simple terms, empowering you to navigate through basic electrical calculations with confidence.

What is Ohm's Law?

Ohm's Law, named after the German physicist Georg Ohm, *states that the current passing through a conductor between two points is directly proportional to the voltage across the two points, given a constant temperature.* It can be used to calculate voltage, current or resistance.

You must know two of these values to calculate the third.

Ohm's Law:

Voltage (V) = Current (I) × Resistance (R)

$$\mathbf{V = I \times R}$$

As you can see from the above formula, the Greek letter omega (Ω) is used to represent ohms (Resistance). The letter **I** is used for current, which stands for current *intensity*. The letter **V** is used for voltage. To calculate current, you need to re-arrange the formula so that it becomes:

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

To calculate resistance, you need to re-arrange the formula so that it becomes:

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

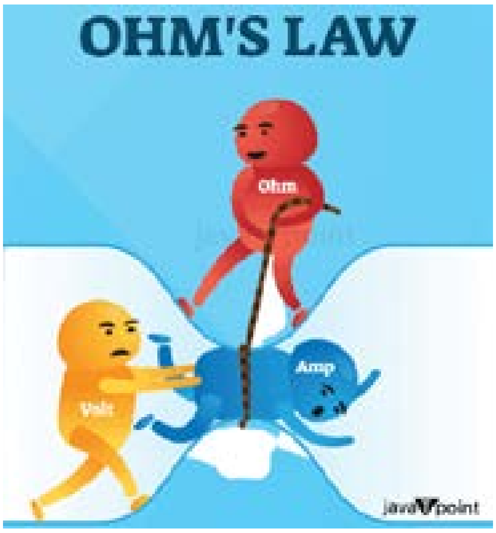


Fig. 3.19. Ohms Law diagram

Understanding the Components of Ohm’s Law

Voltage (V): Voltage is the potential difference between two points in an electrical circuit. It is what pushes electric charges, causing them to flow through a conductor. In simpler terms, voltage is the ‘pressure’ that drives current.

Current (I): Current is the flow of electric charge through a conductor. It is measured in amperes (A) and represents the rate at which electric charges pass through a given point in a circuit. Think of it as the ‘flow’ of electricity.

Resistance (R): Resistance is the opposition to the flow of electric current. It is measured in ohms (Ω) and is determined by the material, length, and cross-sectional area of the conductor. Resistance ‘resists’ the flow of current, converting electrical energy into heat.

Circuit: A circuit is the arrangement of electronics components to form a complete loop.

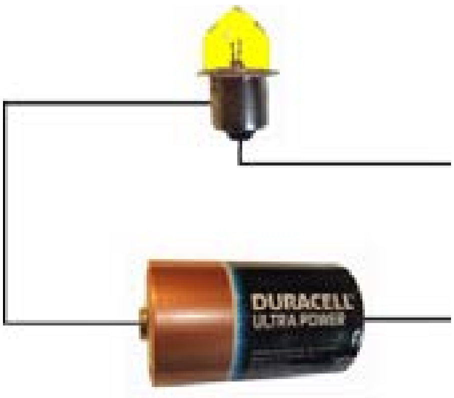


Fig. 3.20. Picture of a simple circuit

Closed circuit: In a closed circuit, there is no break in the network and current is able to flow through all the circuit components.

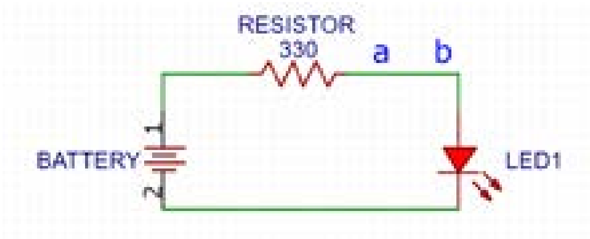


Fig. 3.21. A closed circuit consisting of a battery, resistor and light-emitting diode connected by wires.

Open circuit: This is a circuit that has a break between the components so that the loop is not closed. In an open circuit, current will not be able to flow to all components in the circuit.

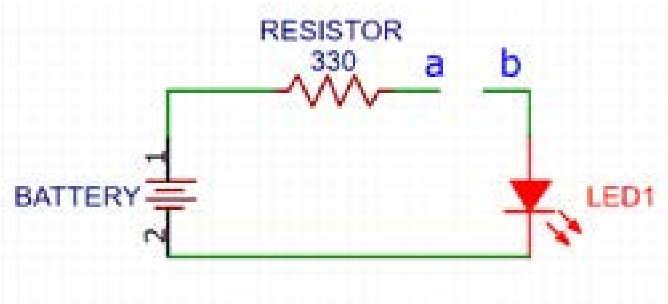


Fig. 3.22. An open circuit. Notice the break in the connection between points **a** and **b**.

Direct Current (DC): This is an electric signal whose magnitude stays constant over time. Batteries, phone chargers and solar cells supply DC power.

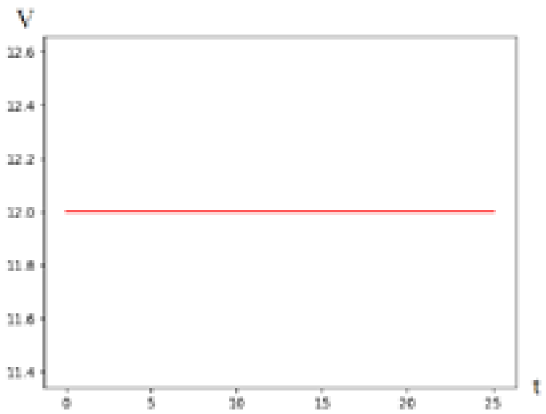


Fig. 3.23. DC voltage stays constant over time

Alternating Current (AC): AC signals are constantly changing magnitude and polarity. Wall sockets and generators supply AC power.

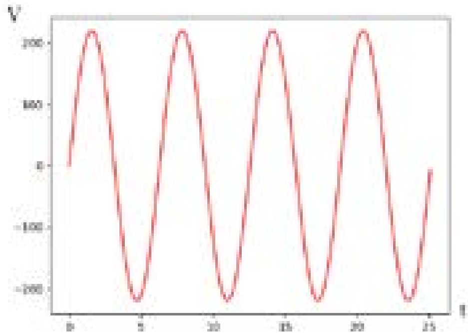


Fig. 3.24: An AC voltage as a function of time.

Activity 3.2

Let us apply Ohm's Law to simple circuit examples:

Example 1.

A circuit has a current of 2 amperes (A) flowing through a resistor with a resistance of 5 ohms (Ω). What is the voltage across the resistor?

Answer

To find the voltage (V) across the resistor, use Ohm's Law

V= I × R

Given Current (I) = 2 Amperes

Resistance (R) = 5 Ohms

Substitute the given values in the Equation

V= I × R

$V = 2 \times 5 = 10$ volts

The voltage across the resistor is 10 volts

Now try your hands another example

Example 2.

A Refrigerator operates on a voltage of 220 volts and a current of 2.5ampers flowing through it. What is the resistance of the refrigerator?

Exercise

Now go through the following examples with your peers and present your findings for a whole classroom discussion

You have three different household appliances: a kettle, an air conditioner, and a washing machine. Use the information given about each appliance to find the missing parameter using Ohm's Law.

Hint

1. Read the given parameters for each appliance carefully.
2. Identify which parameter you need to find (current, resistance, or voltage).
3. Use the appropriate form of Ohm's Law to calculate the missing parameter.
4. Show your calculations step by step and discuss them with peers

a. *Kettle*:

- Voltage: 240 volts (V)
- Resistance: 48 ohms (Ω)
- Find the current (I) flowing through the kettle.

b. *Air Conditioner:*

- Voltage: 220 volts (V)
- Current: 10 amperes (A)
- Find the resistance (R) of the air conditioner.

c. *Washing Machine:*

- Current: 5 amperes (A)
- Resistance: 44 ohms (Ω)
- Find the voltage (V) across the washing machine.

Activity 3.3

1. Watch the videos below

https://www.youtube.com/watch?v=xR1lVvYbfd0

https://www.youtube.com/watch?v=BS9IgyAp3I0

2. Make a simple circuit to light an LED

Materials needed:

- A breadboard
- Breadboard wire links
- 9V battery (nine-volt battery)
- Battery clip
- Resistor
- LED

Steps

1. Bend the LED and plug the long lead to the positive rail of the breadboard and the shorter lead to the main part of the breadboard.
2. Plug one of the resistors leads into the hole directly below the shorter lead of the LED and the other into a hole below the middle channel of the breadboard
3. Insert a wire link into the hole directly below the resistor lead into the negative rail of the breadboard beneath it.
4. Plug the red wire of the battery clip into the top rail(positive) of the breadboard and the black wire of the battery clip to the bottom rail(negative) of the breadboard.
5. Plug the batteries into the battery clip

Caution: After building the circuit, have the lab technician inspect it before you power it up

Now use your observation in the activity above to answer the following:

What happened after you plugged your batteries into the battery clip? Share your findings with a peer.

What is the purpose of the resistor?

Parallel and Series Connections of Circuits

Series connections

In series connections, circuit components are arranged one after another on the same circuit path. The same current, I, passes through all the circuit components but the voltage across each component is generally different.

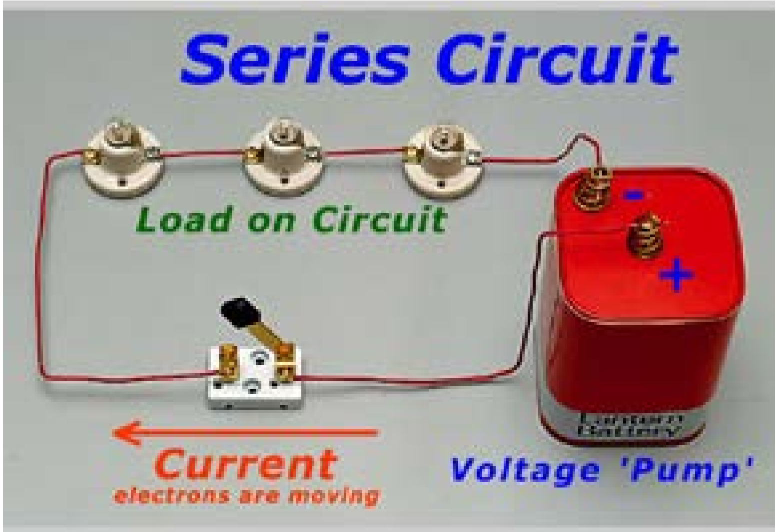


Fig. 3.25 A picture of a series circuit

Parallel Connections

In parallel connections, circuit components are arranged adjacent to one another such that they share the same voltage across their terminals but the current passing through them is generally different.

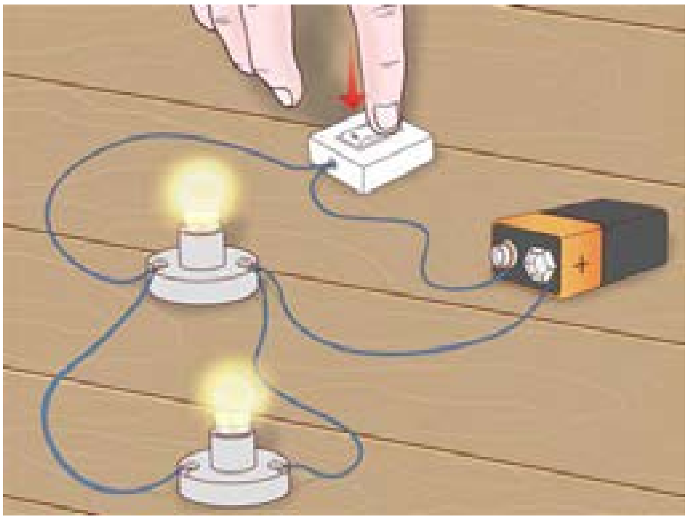


Fig. 3.26 A picture of parallel circuit

Basic Skill: Soldering

How to solder electronic components

A breadboard enables you to prototype electronic circuits without the need to solder components in place. With a breadboard, you can insert a component into position and then remove it and put it somewhere else. Beneath the holes are a series of internally connected rows and columns that enable components to be connected by jumper wires. To supply power to the breadboard you normally use a battery.

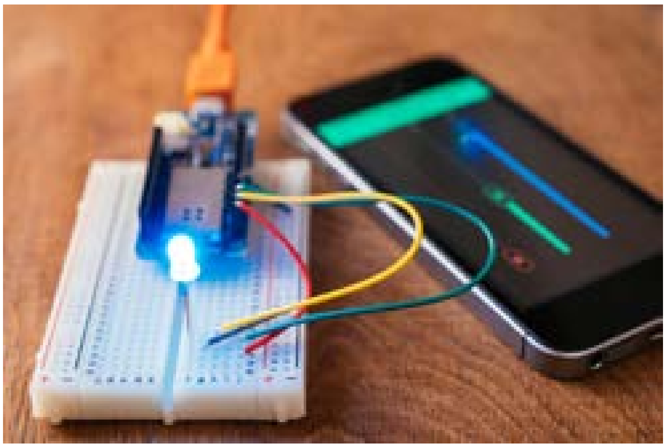


Fig. 3.27. Components arranged on a breadboard.

Printed Circuit Board (PCB) prototyping and soldering

Usually, once a circuit has been designed and tested on a breadboard, we go on to build the circuit on a more permanent platform. Printed circuit boards are fiberglass-based boards on which circuit components are mounted. The components are soldered onto the PCB, whether they are surface-mount devices (SMDs) or through-hole devices. Soldering is done with a heated soldering iron and soldering lead. The soldering lead has a low melting point, which is easily melted by the heated soldering to join components together on the PCB.

Fig 3.28. A soldering iron.

Fig. 3.29. Soldering lead

Fig. 3.30 An image showing the proper way to solder.

Activity 3.4

1. Watch the videos below

https://youtu.be/AqvHogekDI4

https://youtu.be/3jAw41LRBxU

2. Follow the steps on how to solder an LED on a PCB board

Materials needed

- Soldering irons
- Solder lead
- Safety goggles
- Heat-resistant mats
- Sponge or brass wool for cleaning soldering iron tips
- PCB boards
- LED

Steps

1. Clean the soldering iron tip and apply a small amount of solder to promote heat transfer.
2. Position the LED on the PCB and hold it in place with a small clamp or tape
3. Heat the soldering iron to the recommended temperature.
   Caution: Do not touch the tip of the soldering iron when heated
4. Bring the heated tip in contact with the joint where the LED lead meats the PCB pad and apply gentle pressure
5. Allow the solder to melt and flow around the joint, ensuring s solid bond
6. Remove the iron and let the joint cool before moving the PCB

Self-Assessment

Your task is to solder the following electronic components on a Printed circuit board

1. Resistor
2. Capacitor
3. Transistor

AVIONICS COMMUNICATION SYSTEM

Communication System in Aircraft Avionics

Now that you have seen the basics of electronic circuits and components, it is time to know how knowledge in that field has been applied to build devices that enable communication, navigation and surveillance in aircraft. You will know how people on the ground are able to speak to people in the air, how planes find their way in the vast skies and how we know their location in the air.

Avionics

Avionics refers to systems on aerospace vehicles, which rely on electronics for their operation. This includes navigation systems, communication systems, surveillance systems and instrumentation.

Activity 3.5

Make a list of traditional communication systems

Example

1. Talking drums
2.
3.
4.
5.

Which of these have you used before?

How does it work?

COMMUNICATION

Communication refers to the exchange of information between two or more parties. Traditional communication systems include sign language, talking drums, musical instruments, smoke signals, etc. In aircraft technology, communication involves a network of devices used in transmitting and receiving radio signals at various wavelengths either as speech or data. Let us now explore the various systems at play.

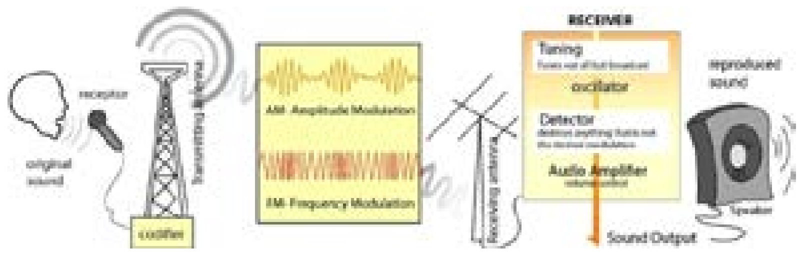
Radio Communication Basics

Radio waves

Radio waves are energy waves that occur in nature and are part of the electromagnetic spectrum. The earth's atmosphere has a lot of these waves. The number of oscillations per second gives the frequency of the wave. A high-frequency wave has a short wavelength whilst a low-frequency wave has a long wavelength.

How do radio waves carry information?

The basic principle is simple. At the first end, a transmitter gives codes to or modulates messages by varying the amplitude or frequency of the wave. At the other end, a receiver tuned to the same wavelength picks up the signal and breaks down the codes back to the original form as sound, image or data. Some communication devices can act as both transmitters and receivers. These are known as transceivers.



https://9w2bba.wordpress.com/2010/06/22/how-radio-waves-carry-information/

Fig. 3.31. Radio waves used for voice communication

Avionics Communication Systems

In aviation, communication may occur between the aircraft and air traffic controllers, between two or more aircraft, within the aircraft or between the aircraft and airline operations control. Different technologies are used to accomplish this. They include High-frequency (HF) communication, Very High Frequency (VHF) communication, and Satellite communications (SATCOM).

Very High Frequency (VHF) communications

VHF radio signals range from 30 – 300 MHz, but the range used in aviation is 118 – 137 MHz. It is used for air traffic control, approach and departure information, meteorological information, ground handling of aircraft, communications to airline operations control and the Aircraft Communications Addressing and Reporting System (ACARS). It is used for communication over distances reaching up to about 160 km. It supports both voice and data communications.

High Frequency (HF) communications

This occurs over the frequency range of 3 MHz to 30 MHz It is used for long-distance communication (500 to 2500 km) between aircraft and the ground. Different frequencies are used depending on the time of the day. A typical daytime frequency is 8 MHz, falling to about 3 MHz at night. HF communication effectively fills in the gap in VHF coverage. It supports both data and voice communications.

Satellite Communications (SATCOM)

SATCOM voice and data services facilitate aircraft-to-ground communication in locations and in situations where conventional HF and VHF radio communication is not possible. It is being used for airline operation control and air traffic control. SATCOM is also being increasingly used as a means of connecting to ground-based networks, allowing crew and passengers to make calls to conventional telephone equipment on the ground or provide internet access.

Aircraft Communications Addressing and Reporting System (ACARS)

The aircraft communications addressing and reporting system (ACARS) is a datalink system used to transmit messages and reports between an aircraft and a ground station of an airline. A message from the aircraft to the airline ground station is called a downlink. A message from the airline ground station to the aircraft is called an uplink.

Flight-deck audio systems

These allow for communication between the flight deck, crew and passengers.

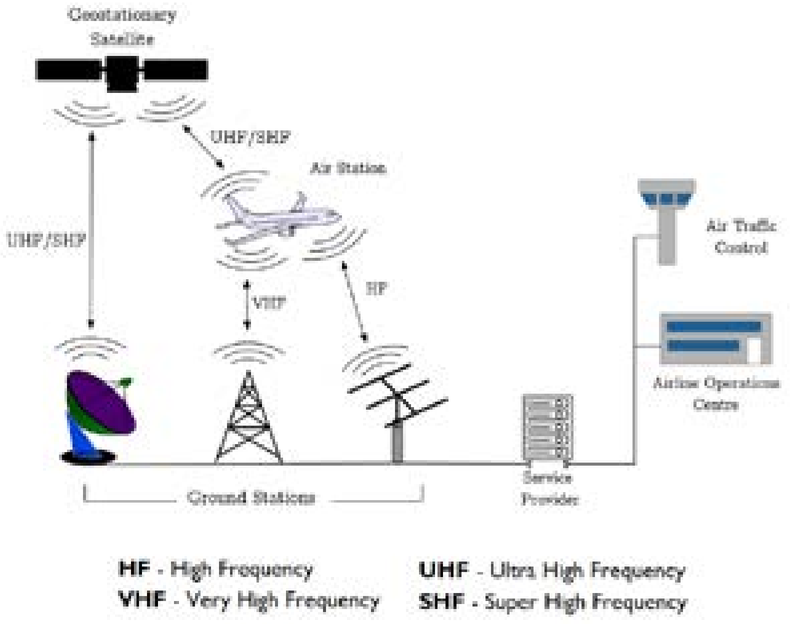


Fig. 3.32: Aircraft communication technologies

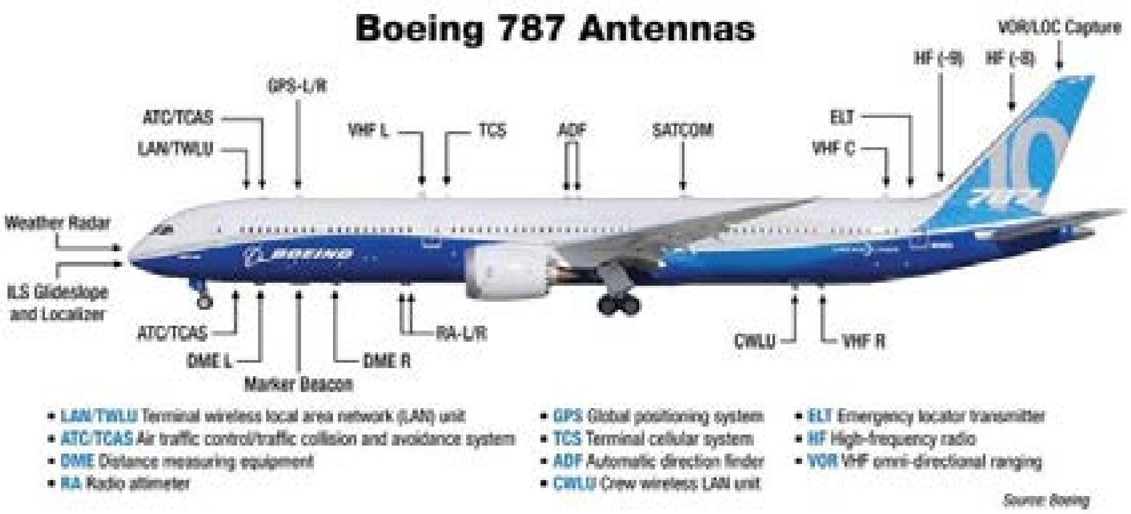
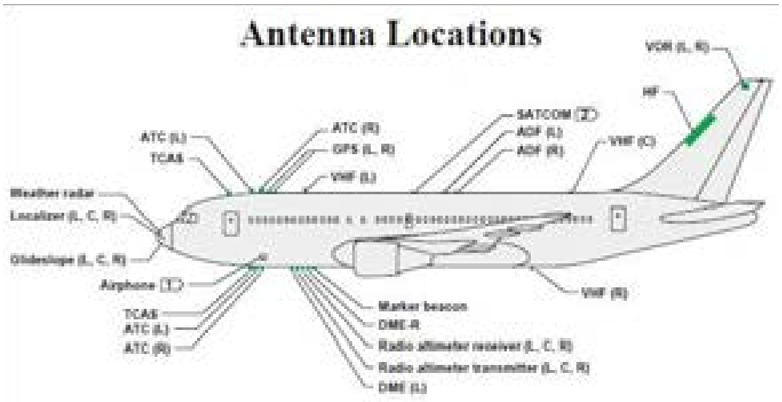


Fig 3.33. Communication antennas of a Boeing 787 airliner.

https://aerocorner.com/blog/types-of-aircraft-antennas/

Fig 3.34. Satellite communication antenna on a modern airliner.



https://www.aviationnepal.com/high-frequency-hf-very-high-frequency-vhf-and-transponder-usage-in-aircraft/

Fig 3.35. Radio communication antennas on an aircraft.

Activity 3.5

Watch the following video.

https://www.youtube.com/watch?v=iTJUHGGErp4

In the video, take note of the following;

What are the parts of an aircraft's communication system?

What are some of the information displayed by the ACARS system?

Name some antennas installed on aircrafts for communication

AVIONICS NAVIGATION SYSTEMS

Navigation

Navigation refers to the determination of the position, velocity and orientation of a moving vehicle with respect to a known reference. A unique position is identified by specifying its longitude, latitude and altitude. There are two kinds of navigation: position fixing and dead reckoning.

A navigation system refers to the devices in the cockpit that help the pilot determine the position of the aircraft. An aircraft can know its location using both onboard systems and ground-based radio aids.

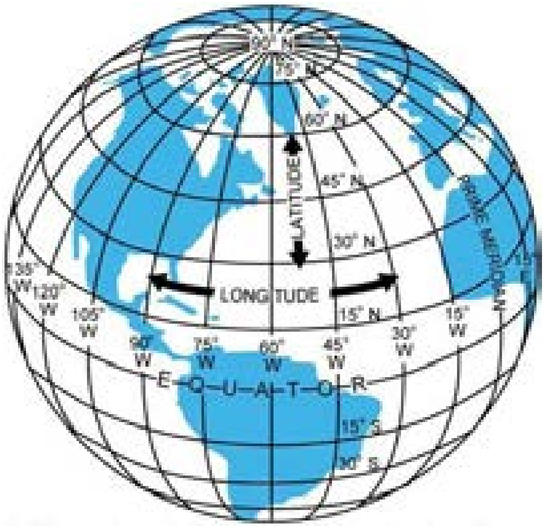


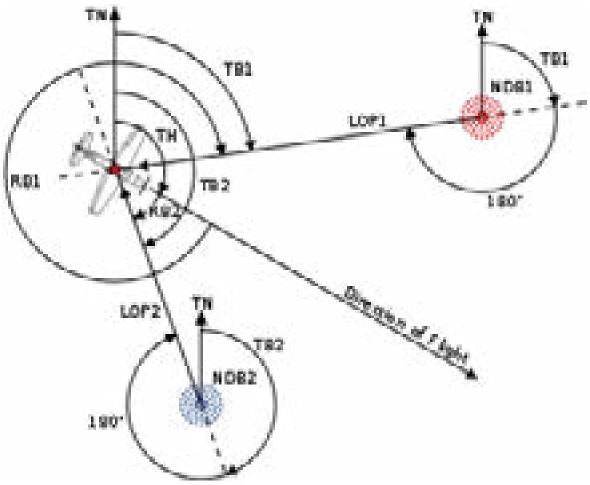
Fig 3.36: Latitudes and longitudes.

https://socratic.org/earth-science/earth-s-surface/location-longitude-and-latitude

Position Fixing

Position fixing involves determining the position of the vehicle using external references. When travelling short distances over land, natural terrestrial features such as rivers, valleys, hills, can be used as direct observation. Celestial navigation was used effectively in the early days of long-distance aircraft navigation. For navigation using radio signals, the intersection of signals from two or more navigation aids can be used to fix a position; the distance and bearing from a single navigation aid may also be used; as well as distance from any two navigation aids.

The radio navigation systems include: Distance measuring equipment (DME), VHF Omnidirectional Range (VOR), Automatic Direction Finder (ADF). Satellite navigation systems also include: the American Global Positioning System (GPS), Russian GLONASS, Chinese BeiDou and European Galileo.



https://en.wikipedia.org/wiki/Radio_fix

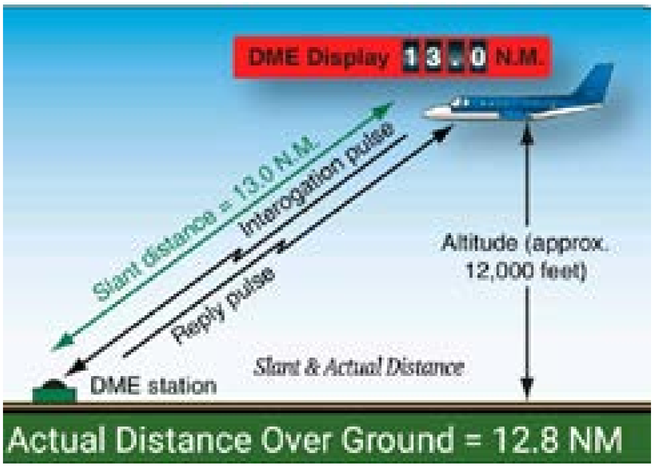
Fig 3.37. Obtaining a position fix using the bearing to two radio stations

VHF Omnidirectional Range (VOR)

VOR is a short/medium-range navigation system operating in the 108 – 117.95 MHz range of frequencies. It provides the bearing to-or-from a radio navigation aid on the ground. Each VOR navigation aid is identified by a unique three-letter code on navigation charts. To use this system, aircraft must be fitted with the appropriate antennas, receivers, control panels and displays.

Distance Measuring Equipment (DME)

DME is a short/medium range navigation system that enables the crew to determine the distance to a navigation aid. The aircraft transmits to the ground station and measures the time it takes to receive a response. Transmission occurs at frequencies ranging between 1025 and 1150 MHz; Receiving is in the range 962 to 1215 MHz. The aircraft must have the appropriate antenna, interrogator, and display installed to use the system.



https://www.linkedin.com/pulse/distance-measuring-equipment-dme-pramod-prabhakaran/

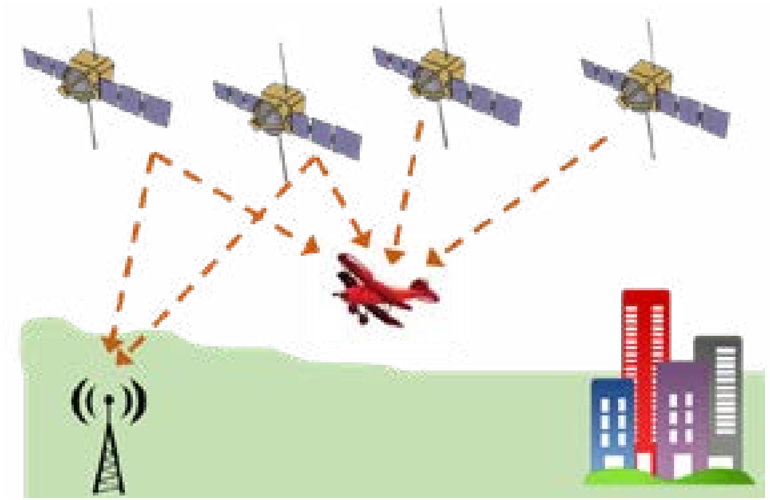
Fig 3.38: Distance measuring equipment operation. Source:

Automatic Direction Finder (ADF)

ADF is a short to medium range (200 nautical miles) navigation system providing directional information. It operates within the frequency range 190 – 1750 kHz. It provides the relative bearing from the aircraft to a suitable station.

Global Navigation Satellite Systems (GNSS)

It refers to a navigation system based on satellites. There are several operating systems: GPS, GLONASS, Galileo, Beidou, IRNSS. Knowing the position of the satellite, and measuring the time delay between when the signal was transmitted (from the satellite) and received (at the ground station) provides a means of calculating the range between the satellite and the aircraft. Range measurements from at least four satellites are required to determine a unique three-dimensional position.

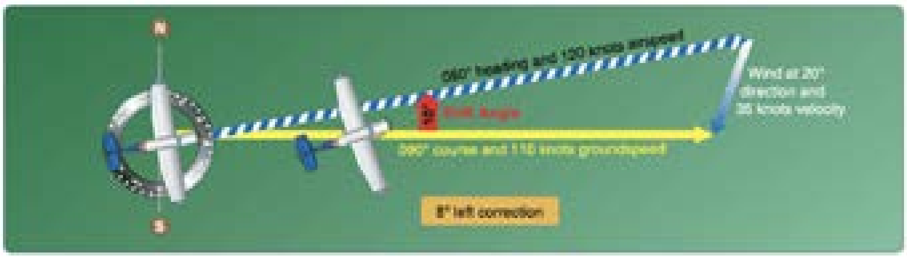


https://tc.canada.ca/en/aviation/publications/aviation-safety-letter/issue-4-2019/presence-satellites-general-aviation

Fig 3.39: GNSS navigation uses ranging signals from four or more satellites to determine the unique position of the aircraft.

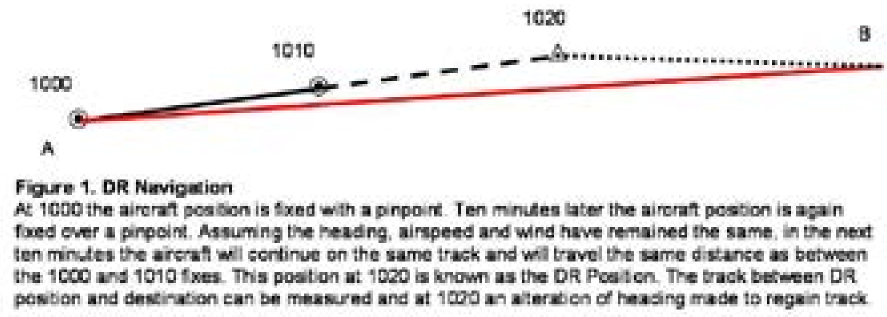
Dead Reckoning

Dead reckoning refers to estimating position by extrapolating from a known position and then keeping note of the direction, speed and elapsed time. Dead reckoning systems include: Doppler navigation systems and inertial navigation systems.



https://aerocorner.com/blog/dead-reckoning/

Fig 3.40. Dead reckoning diagram

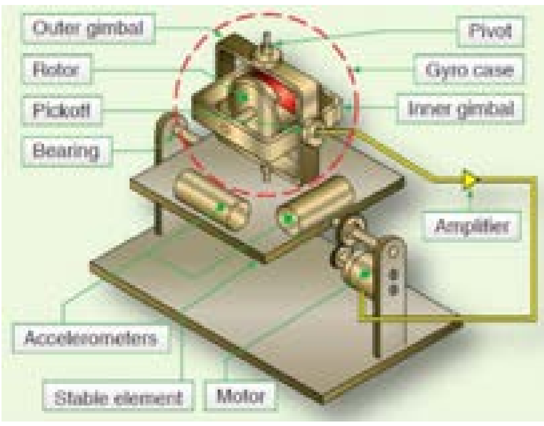


https://skybrary.aero/articles/dead-reckoning-dr

Fig. 3.41. Dead reckoning diagram

Inertial navigation systems

Inertial navigation systems require no external inputs or references from ground stations for their operation. The primary devices used are accelerometers and gyroscopes. Inertial navigation is ideally suited to long distance navigation over oceans and undeveloped areas.



https://wiki.ivao.aero/en/home/training/documentation/Inertial_Navigation_Systems

Fig 3.42. An aircraft's inertial reference system

Doppler navigation system

Doppler navigation uses the change in frequency of reflections from radio waves (Doppler effect) to determine aircraft speed and direction.

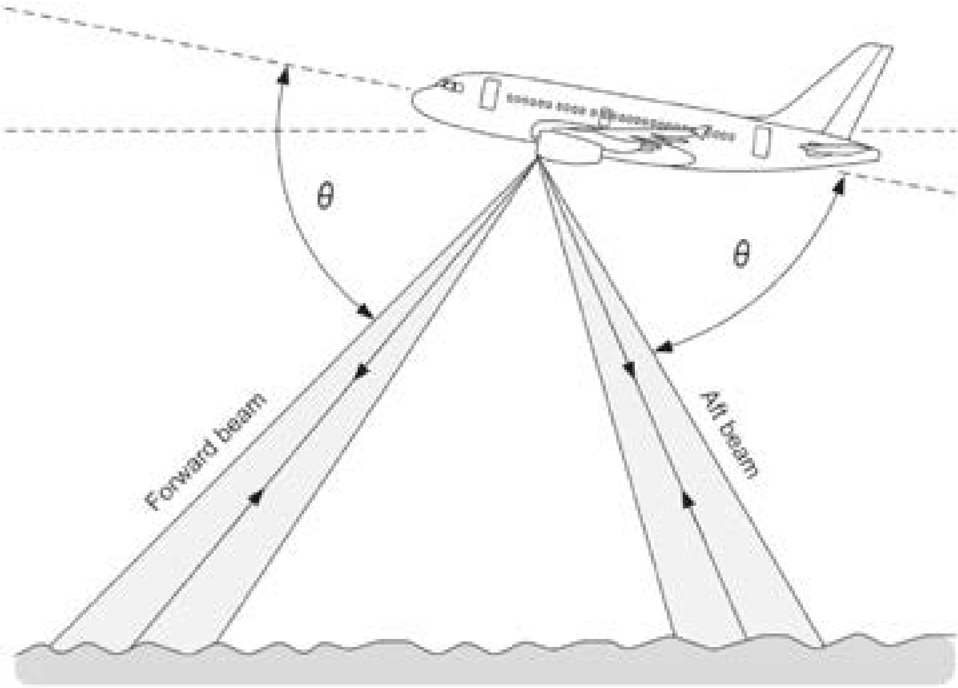


Fig 3.43. Aircraft Doppler navigation (Tooley and Wyatt, 2017)

Activity 3.6

Watch the following video.

https://www.youtube.com/watch?v=BxIi57Y4v74

In the video, take note of the following;

What is the difference between VFR and IFR?

How does the GNSS navigation system work?

How does aircraft Inertial Navigation System work?

AVIONICS SURVEILLANCE SYSTEMS

Surveillance Systems on Aircraft

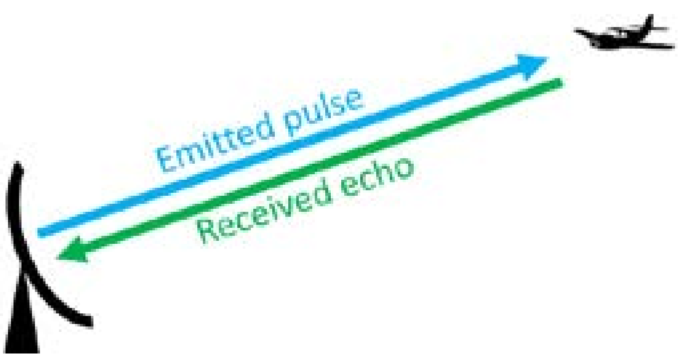
Surveillance systems refer to the equipment that makes it possible to determine the position of an aircraft in range and bearing. There are four main technologies that enable this.

They include:

1. Primary surveillance radar (PSR)
2. Secondary surveillance radar (SSR)
3. Traffic Alert and Collision Avoidance System (TCAS)
4. Automatic Dependent Surveillance Broadcast (ADS-B)

Primary Surveillance Radar

PSR is a surveillance radar system, which uses reflected radio signals. An antenna rotating at speeds of 5–12 rpm emits a pulse of radio wave. Upon reaching an aircraft the wave is reflected and some of the energy is returned to the antenna. Primary Surveillance Radar provides range and bearing of the targets found with respect to the antenna position. Range is determined by the time difference of the emitted and received pulse, while the bearing is obtained from the antenna's angular position. PSR does not require any equipment on board the aircraft to function. It requires that the antenna transmits at a high power so that a reflection is received.

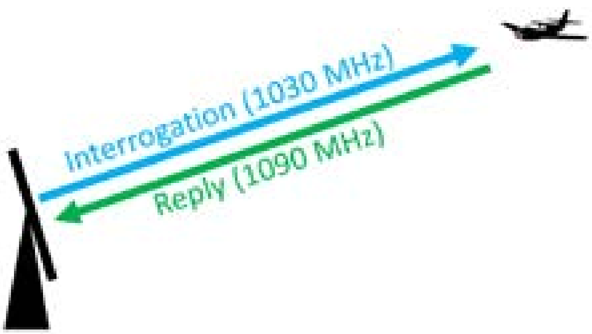


https://skybrary.aero/articles/primary-surveillance-radar-psr

Fig. 3.44: Primary surveillance radar operation.

Secondary Surveillance Radar

SSR is a surveillance radar system that requires a transponder on board the aircraft to determine its position. A radar antenna on the ground rotates (usually at 5-12 rpm) and transmits a pulse (at 1030 MHz), which is received by the onboard equipment (transponder). The transponder sends back a reply containing information such as the aircraft identification and altitude (the reply is at 1090 MHz). When the reply is received, aircraft position (range and bearing) is determined: range is calculated by knowing the time difference between the interrogation and the reply, while azimuth is taken from the antenna position.



https://skybrary.aero/articles/secondary-surveillance-radar-ssr

Fig 3.45: Secondary surveillance radar operation.

https://www.radartutorial.eu/19.kartei/03.atc/karte017.en.html

Fig. 3.46: PSR/SSR antenna

Activity 3.7

Watch the following videos.

https://www.youtube.com/watch?v=mt43UeqVaZU

https://www.youtube.com/watch?v=XCXxQNCEQZ4

What is the main difference between Primary Surveillance Radar and Secondary Surveillance Radar?

Traffic Alert and Collision Avoidance System

TCAS is an aircraft collision avoidance system designed to reduce the incidence of mid-air collisions. It monitors the airspace of an aircraft for other aircraft equipped with TCAS and warns about the presence of traffic, which may present a threat of mid-air collision.

Each TCAS aircraft interrogates all other aircraft in a determined range about their position via the 1030 MHz radio frequency. All other aircraft reply to interrogations via the 1090 MHz channel. The interrogation-and-response cycle occurs several times per second. The TCAS system builds a 3D map of aircraft in the airspace, incorporating their range, altitude and bearing.

Current range and altitude are extrapolated to determine their future values, and whether a risk of collision exists. After identifying potential collisions, TCAS automatically negotiates a mutual avoidance manoeuvre; this involves modification of altitude and rate of climb or descent. The avoidance manoeuvres are communicated to the flight crew by synthesised voiced instructions.

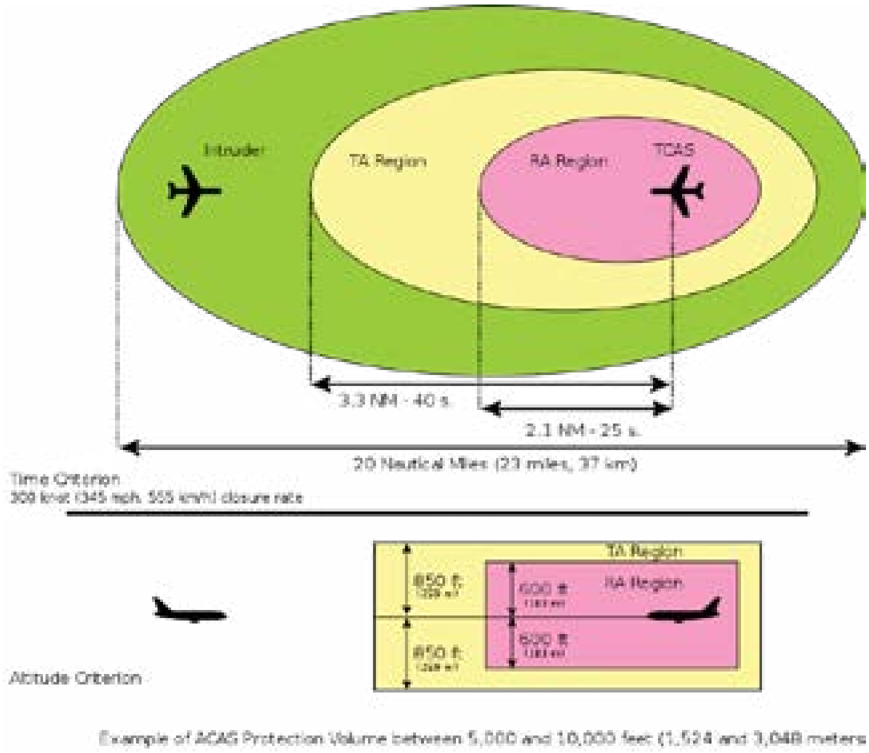


Fig. 3.47. TCAS Protection volume

https://en.wikipedia.org/wiki/Traffic_collision_avoidance_system

Automatic Dependent Surveillance-Broadcast

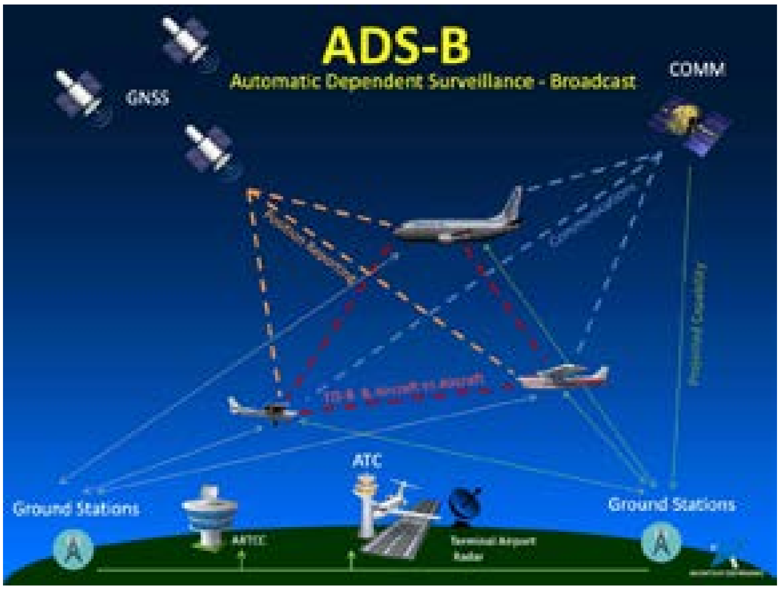
ADS-B is a means by which aircraft, aerodrome vehicles and other objects can automatically receive data such as identification and position as appropriate, in a broadcast, which is made via a data link. It is a surveillance technique that relies on aircraft or airport vehicles broadcasting their identity, position and other information desired from onboard systems such as GPS.

ADS-B is automatic because no external stimulus is required and dependent because it relies on data from onboard systems. ADS-B signals can be captured for surveillance purposes on the ground or on-board other aircraft to facilitate airborne traffic situation awareness, spacing and separation.

Aircraft equipment includes:

1. A transponder with “ADS-B out” capability
2. A receiver which has “ADS-B in” capability
3. A processing system (traffic computer)
4. Cockpit display of traffic information

Data transmitted by aircraft or airport vehicles are received by the ADS-B ground stations. In most cases, output of ADS-B ground stations is sent to Surveillance Data processing and distribution systems, where they are fused with inputs from other surveillance sensors, e.g., Radar, to create an accurate traffic situation picture.



https://www.sportys.com/blog/ads-b-101-what-you-need-know/

Fig. 3.48. Automatic dependent surveillance broadcast system

Activity 3.8

1. Watch the following videos

https://www.youtube.com/watch?v=znsowAz8WP0

https://www.youtube.com/watch?v=F-v54MlxMIo

In the video, take note of the following;

How does the TCAS system work?

How does aircraft ADS-B system work?

2. Case Study – Aircrash Investigation: **Malaysia Airlines Flight 134**
Note: Watch this video in your leisure time.

https://www.youtube.com/watch?v=f80WwpNuaxg

Reflection:

a. What caused this aircraft incident?

b. Which navigation equipment were involved?

How could this have been prevented?

d. What alternatives could be used or developed in place of these equipment?

Review Questions

1. Scenario

   You are an electronics enthusiast interested in learning more about the components inside everyday household appliances. You decide to disassemble an old, non-functional DVD player to practice identifying and understanding the functions of its electronic components. Your goal is to recognise at least five basic components and explain their roles in the device.

   a. As you begin to disassemble the DVD player, what steps would you take to ensure safety and prevent damage to the components?
   b. How would you identify a resistor inside the DVD player? Describe its appearance and markings.
   c. Once you identify a resistor, explain its function in an electronic circuit.
   d. Describe the process of identifying a capacitor and the types you might find. What is the function of a capacitor in the circuit?
   e. You come across a diode. How would you recognize it, and what function does it serve in the DVD player?
   f. Explain how to identify an integrated circuit (IC). What roles do ICs play in electronic devices?
   g. As you continue examining the circuit board, you find an inductor. Describe its appearance and state its function in the DVD player.
2. You have a 60-watt light bulb connected to a 120-volt power supply. What is the current flowing through the light bulb?
3. You are using an electric heater with a resistance of 24 ohms in your home, which is supplied with a voltage of 240 volts. How much current does the heater draw?
4. A circuit has a voltage supply of 12 volts and the resistance in the circuit is 4 ohms. What is the current flowing through the circuit?
5. Mention three systems used for aircraft surveillance
6. Explain how the following systems work in aircraft navigation
   a. Inertial Navigation System
   b. Position Fixing
   c. Dead Reckoning

Answers To Review Questions

1.
   a. Make sure the DVD player is disconnected from any power source to avoid electric shock.
   b. Resistors are small cylindrical components with colored bands. The colored bands represent the resistance value, tolerance, and sometimes reliability.
   c. Resistors limit the current flow and divide voltage in a circuit. They protect other components by ensuring the current stays within safe levels.
   d. Capacitors can be cylindrical (electrolytic) or small and disc-shaped (ceramic). Capacitors store and release electrical energy. They smooth out voltage fluctuations, filter signals, and in power supplies, they stabilize the voltage.
   e. Small cylindrical component with a stripe on one end indicating the cathode. The stripe shows the cathode (negative end). Diodes allow current to flow in one direction only. They are used for rectification (converting AC to DC)
   f. Integrated circuits are rectangular packages with multiple small pieces of resistors, transistors and capacitors mounted on it. It receives and sends signals to communicate with other components in an electronic circuit
   g. Inductors are coils of wire, often wrapped around a core, and can be toroidal or cylindrical. Inductors store energy in a magnetic field when electrical current flows through them.
2. The current flowing through the light bulb is 0.5 amperes.
3. The heater draws 10 amperes of current.
4. The current flowing through the circuit is 3 amperes.
5.
   - Primary Surveillance Radar
   - Secondary Surveillance Radar
   - Traffic Alert and Collision Avoidance System
6. a. Inertial Navigation System: This system uses measurements done by accelerometers and gyroscopes to determine and track the orientation and position of an aircraft, using a reference point, orientation and velocity.
   b. Position Fixing: This is a system of determining the position of an aircraft using various electronic methods to determine the bearing and range or geographical coordinates from a reference point.
   c. Dead Reckoning: This is a way of estimating an aircraft's position based on groundspeed and current track from a previous point.

REFERENCES

1. Philip D, Electronics for Absolute beginners (2018) 1st Edition (Chapters 1 and 2)
2. Collinson, R.P., (2012) Introduction to avionics (Vol. 11). Springer Science & Business Media
3. Tooley, M. and Wyatt, D., (2017) Aircraft communications and navigation systems. Routledge
4. I. Moir, A. Seabridge, M. Jukes, Civil Avionics Systems, 2nd Edition. West Sussex: Wiley
5. Spitzer C. R., Ferrel U, Ferrel T. (Eds), Digital Avionics Handbook, 3rd Edition. Boca Raton: Taylor and Francis

EXTENDED READING

How to Build a Simple LED Circuit

Soldering for Beginners in Electronics (startingelectronics.org)

Tutorial 1: Building a Circuit on Breadboard for Beginners in Electronics (startingelectronics.org)

GLOSSARY

WORD	MEANING
Antenna	A device used to transmit or receive radio waves.
Azimuth	A horizontal angle measured clockwise from a north baseline or meridian.
Datalink system	A communication system that facilitates the exchange of data between two or more devices or systems
Electromagnetic spectrum	Electromagnetic waves arranged according to their frequency and wavelength
Fibreglass	A material made from extremely fine fibres of glass.
Gyroscopes	A device that detects rotational motion and helps in determining the orientation or angular velocity of an object.
Interrogator	An electronic device that transmits a signal to another device to obtain information about identity, condition, etc.
Oscillation	regular variation in magnitude or position about a central point.
Resistivity	A fundamental property of a material that quantifies how strongly a material opposes the flow of electric current
Transponder	An electronic device that gives out a radio signal when it receives a similar signal telling it to.
Wafer	A thin slice of semiconductor used for the fabrication of integrated circuits.
Wavelength	The distance between identical points in the adjacent cycles of a wave

ACKNOWLEDGEMENTS

Ghana Education Service (GES)

(GAST)

List of Contributors

Name	Institution
Bismark Owusu	Afua Kobi Ampem Girls SHS
Baiden Alexander Kwesi	STEM SHS, Abomosu
Joel Opoku Mintah	Altair Unmanned Technologies
Ferdinand Sam	Afua Kobi Ampem Girls SHS