Karpagam Academy of Higher Education

(Deemed to be University)
(Established Under Section 3 of UGC Act 1956)

FACULTY OF ENGINEERING

Department of Mechanical Engineering

(Aerospace Engineering)

Subject Name / Code : Aircraft Systems and Avionics (ASA) / 17BTAR403 (Credits - 3)

Name of the Faculty **:** R. Suresh Baalaji

Designation **:** Asst. Professor

Year/Semester/Section **:** II / IV / -

Branch **: Aerospace Engineering**

Karpagam Academy of Higher Education

(Deemed to be University)

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Coimbatore - 641021

Faculty of Engineering

Department of Mechanical Engineering

(Aerospace Engineering)

17BTAR403 AIRCRAFT SYSTEMS AND AVIONICS 3 0 0 3 100

INTENDED OUT COMES

To describe the principle and working of aircraft systems and instruments.

UNIT – I AIRCRAFT SYSTEMS

Hydraulic systems - Study of typical workable system - components - Hydraulic system controllers - Modes of operation - Pneumatic systems - Advantages - Working principles - Typical Air pressure system – Brake system - Typical Pneumatic power system - Components, Landing Gear systems - Classification – Shock absorbers - Retractive mechanism.

UNIT – II AIRPLANE CONTROL SYSTEMS

Conventional Systems – Power assisted and fully powered flight controls – Power actuated systems – Push pull rod system – operating principles – Modern control systems – Digital fly by wire systems – Auto pilot system, Active Control Technology, Engine control systems.

UNIT - III ENGINESYSTEMS AND AUXILLIARY SYSTEMS

Fuel systems – Components - Multi-engine fuel systems, lubricating systems - Starting and Ignition systems –Basic Air cycle systems -Oxygen systems - Fire protection systems, Deicing and anti-icing systems.

UNIT – IV INTRODUCTION TO AVIONICS

Need for avionics in civil and military aircraft and space systems – integrated avionics and weapon systems – typical avionics subsystems, design, technologies – Introduction to digital computer and memories. Avionics system architecture–8085 Architecture– data buses – MIL-STD-1553B – ARINC – 420 – ARINC – 629.

UNIT – V AVIONICS SYSTEMS

Control and display technologies -CRT, LED, LCD, EL and plasma panel- Civil cockpit and military cockpit: MFDS, HUD, MFK, HOTAS- Communication Systems - Navigation systemsADF, DME, VOR, LORAN, OMEGA, ILS, MLS - Air Data Systems.

TEXT BOOKS:

S.No.	AUTHOR(S)	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1.	Ian Moir, Allan Seabridge	Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration	John Wiley and Sons, New York.	2012
2.	David Lombardo	Aircraft Systems	McGraw Hill Professional New York.	2009
3.	R. P. G. Collinson	Introduction to Avionics Systems	Springer-Verlag, New York.	2013

REFERENCES BOOKS:

S.NO.	AUTHOR(S)	TITLE OF THE BOOK	PUBLISHER	YEAR OF PUBLICATION
1.	S. Nagabhushana	Aircraft Instrumentation and Systems	I. K. International Pvt Ltd, New Delhi	2010
2	Thomas Wild, Michael Kroes	Aircraft Power Plants	McGraw-Hill, New York.	2013
3	Treager, S.	Gas Turbine Technology	McGraw-Hill New York.	2002
4	Middleton, D.H., Ed.	Avionics Systems	Longman Group UK Ltd., England.	1989
5	Cary R. Spitzer and Cary Spitzer	Digital Avionic Systems	Prentice Hall, Englewood Cliffs, New Jersey, USA.	2000

WEB REFERENCE:

- www.aircraftinstruments.com/
- dcb.larc.nasa.gov/Introduction/Controls
- www.mtu-online.com/mtuonsiteenergy/products/gas-engine-systems
- academicearth.org/courses/aircraft-systems-engineering
- www.efunda.com

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FACULTY OF ENGINEERING

Department of Mechanical Engineering

(Aerospace Engineering)

LESSON PLAN

Subject Name/ Code : **Aircraft Systems and Avionics (ASA) / 17BTAR403 (Credits - 3)**
Name of the Faculty : R. Suresh Baalaji
Designation : Asst. Professor
Year/Semester/Section : II / IV / -
Branch : **Aerospace Engineering**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
1.	1	Introduction to Aircraft Systems and Avionics	
UNIT – I : AIRCRAFT SYSTEMS			
1.	1	Fundamentals of Aircraft Systems and Avionics	
2.	1	Hydraulic systems, Study of typical workable system, Components	
3.	1	Hydraulic system controllers, Modes of operation	
4.	1	Pneumatic systems, Advantages, Working principles	Aircraft Systems
5.	1	Typical Air pressure system	
6.	1	Brake system, Typical Pneumatic power system	David Lombardo
7.	1	Components of Landing Gear systems	
8.	1	Classification of Landing Gear systems	Lecture Notes - KAHE
9.	1	Shock absorbers, Retractive mechanism	
10.	1	**Tutorial 1:** Summary of Unit I and Part A questions	
Total No. of Hours Planned for Unit - I			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – II : AIRPLANE CONTROL SYSTEMS			
11.	1	Conventional Systems	
12.	1	Power assisted and fully powered flight controls, Power actuated systems	
13.	1	Push pulls rod system – operating principles	
14.	1	Modern control systems in aircraft	Aircraft Systems
15.	1	Digital fly by wire systems in aircraft	
16.	1	Auto pilot system in aircraft,	David Lombardo
17.	1	Active Control Technology in aircraft	
18.	1	Engine control systems - Boeing	Lecture Notes - KAHE
19.	1	Engine control systems - Airbus	

20.	1	**Tutorial 2:** Summary of Unit II and Part A questions	
Total No. of Hours Planned for Unit - II			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – III : ENGINE SYSTEMS AND AUXILLIARY SYSTEMS			
21.	1	Basics of engine systems and auxiliary systems	
22.	1	Fuel systems – Components	
23.	1	Multi-engine fuel systems in aircraft	
24.	1	Lubricating systems in aircraft	Aircraft Systems
25.	1	Starting and Ignition systems in aircraft	
26.	1	Basic Air cycle systems in aircraft	David Lombardo
27.	1	Oxygen systems in aircraft	
28.	1	Fire protection systems in aircraft	Lecture Notes - KAHE
29.	1	De-icing systems and Anti-icing systems in aircraft	
30.	1	**Tutorial 3:** Summary of Unit III and Part A questions	
Total No. of Hours Planned for Unit - III			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – IV : INTRODUCTION TO AVIONICS			
31.	1	Need for avionics in civil and military aircraft and space systems	
32.	1	Integrated avionics and weapon systems	
33.	1	Typical avionics subsystems, design, technologies	Introduction to Avionics Systems
34.	1	Introduction to digital computer and memories	
35.	1	Avionics system architecture	R. P. G. Collinson
36.	1	8085 Architecture– data buses	
37.	1	Aeronautical Radio, Incorporated (ARINC – 420)	Lecture Notes - KAHE
38.	1	Aeronautical Radio, Incorporated (ARINC – 629)	
39.	1	Military Standard (MIL-STD-1553B)	
40.	1	**Tutorial 4:** Summary of Unit IV and Part A questions	
Total No. of Hours Planned for Unit - IV			**(9L + 1T) 10 Hours**

Sl. No.	No. of Periods	Topics to be Covered	Support Materials
UNIT – V : AVIONICS SYSTEMS			
41.	1	Control and display technologies	
42.	1	Cathode Ray Tube CRT, Light Emitting Diode LED, Liquid Crystal Display LCD	
43.	1	Electroluminescent Display_EL and plasma panel	
44.	1	Civil cockpit and military cockpit:	
45.	1	Multi-Function Display MFDS, Head-Up Display HUD, Multi Function Keyboard MFK, Hands On Throttle-And-Stick HOTAS	Introduction to Avionics Systems
46.	1	Communication Systems in aircraft	
47.	1	Navigation systems - Automatic Direction Finder ADF, Distance Measuring Equipment DME, Very high frequency Omni directional Radio Range VOR.	R. P. G. Collinson
48.	1	Long Range Navigation LORAN, Optimized Method for Estimated Guidance Accuracy OMEGA, Instrument Landing System ILS, Microwave Landing System MLS	
49.	1	Air Data Systems	Lecture Notes - KAHE
50.	1	**Tutorial 5:** Summary of Unit V and Part A questions	
Total No. of Hours Planned for Unit - V			**(9L + 1T) 10 Hours**
1.	1	End Semester Possible Questions Discussion Discussion and Overview of All Five Units	

TOTAL PERIODS : 45 L + 5T = 50 Hours

TEXT BOOKS:

S.No.	Author(s)	Title of the Book	Publisher	Year of Publication
1.	David Lombardo	Aircraft Systems	McGraw Hill Professional	2012
2.	Ian Moir	Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration	John Wiley and Sons	2012
3.	R. P. G. Collinson	Introduction to Avionics Systems	Springer-Verlag,	2013

REFERENCES BOOKS:

S.No.	Author(s)	Title of the Book	Publisher	Year of Publication
1.	Mekinley, J.L. and Bent, R.D.	Aircraft Power Plants	McGraw-Hill	2012
2.	Spitzer, C.R.	Digital Avionic Systems	Prentice Hall	2013

WEBSITES

W [1] - dcb.larc.nasa.gov/Introduction/Controls
W [2] - Avionics - YouTube
W [3] – academicearth.org/courses/aircraft-systems-engineering

JOURNALS

J [1] - Aerospace Science and Technology - Journal – Elsevier
J [2] –Journal of Aerospace Engineering - ASCE Library
J [3] – Journal of Aircraft - AIAA

UNIT	Total No. of Periods Planned	Lecture Periods	Tutorial Periods
I	10	9	1
II	10	9	1
III	10	9	1
IV	10	9	1
V	10	9	1
TOTAL	50	45	05 + 02

I. CONTINUOUS INTERNAL ASSESSMENT : 40 Marks

(Internal Assessment Tests: 30(CIA – I -08 + CIA – II – 08 + Model Exam 14), Attendance: 5, Assignment/Seminar: 5)

II. END SEMESTER EXAMINATION : 60 Marks

TOTAL : 100 Marks

FACULTY **HOD / MECH** **DEAN / FOE**

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FACULTY OF ENGINEERING

Department of Mechanical Engineering

(Aerospace Engineering)

Subject Name: Aircraft Systems and Avionics **Year / Semester**: II / IV

Subject Code: 17BTAR403 **Programme:** UG / B. Tech. Aerospace Engineering

COURSE OBJECTIVE

This introductory course provides you with a practical and qualitative appreciation of aircraft systems. These systems are essential as they enable them to function safely and effectively.

This course is introduced to understand the principles of operation of microprocessors and various digital systems used in aircraft.

LEARNING OUTCOMES

1. Ability to understand the application Airframe systems; including hydraulic, pneumatic, and environmental control systems etc.

2. Ability to understand the application of avionics in civil, military and space aircraft.

3. Ability to understand the different types of microprocessor architecture.

4. Ability to understand, discuss and apply concepts of Communication Systems, Navigation systems and Flight control systems.

FACULTY

Aircraft Systems and Avionics

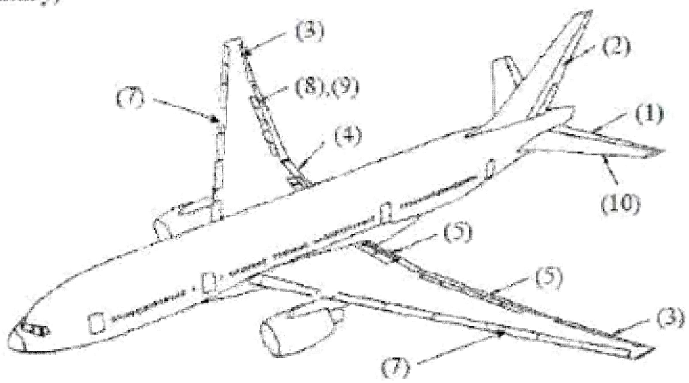
AIRCARFT SYSTEMS

AIRCRAFT HYDRAULIC SYSTEM

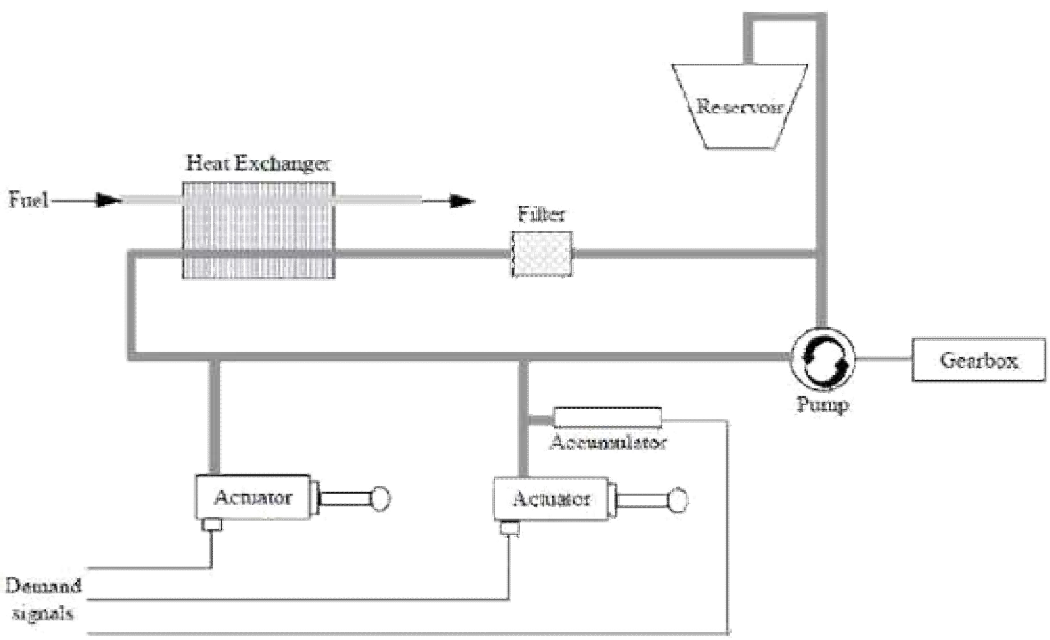
INTRODUCTION:

- The word hydraulics is based on the Greek word for water, and originally meant the study of the physical behaviour of water at rest and in motion.
- Today the meaning has been expanded to include the physical behaviour of all liquids, including hydraulic fluid.
- Hydraulic systems are not new to aviation.
- Early aircraft had hydraulic brake systems.
- As aircraft became more sophisticated newer systems with hydraulic power were developed.
- Although some aircraft manufacturers make greater use of hydraulic systems than others, the hydraulic system of the average modern aircraft performs many functions.
- Among the units commonly operated by hydraulic systems are landing gear, wing flaps, speed & wheel brakes, and flight control surfaces.
- Hydraulic systems have many advantages as a power source for operating various aircraft units.
- Hydraulic systems combine the advantages of lightweight, ease of installation, simplification of inspection, and minimum maintenance requirements.
- Hydraulic operations are also almost 100% efficient, with only a negligible loss due to fluid friction.
- All hydraulic systems are essentially the same, regardless of their function.
- Regardless of application, each hydraulic system has a minimum number of components, and some type of hydraulic fluid.

- **Primary Flight Controls:**
  - -Elevators – (1)
  - -All-moving tail surfaces (military)
  - -Rudders – (2)
  - -Ailerons – (3)
  - -Flaperons – (4)
  - -Canards
- **Secondary Flight Controls**
  - -Flaps – (5)
  - -Slats – (7)
  - -Spoilers – (8)
  - -Airbrakes – (9)
  - -Stabilizer trim – (10)
- **Utilities**
  - -Landing gear
  - -Brakes
  - -Gear steering
  - -Aerial refueling probes (military)
  - -Cargo doors
  - -Loading ramp (military)
  - -Passenger stairs

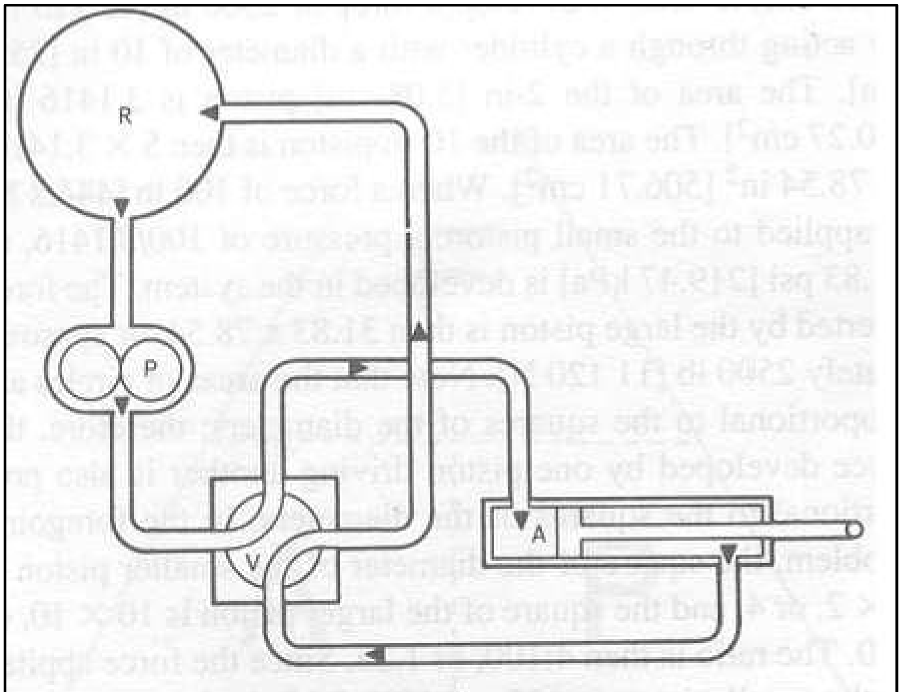


Hydraulic system loads



Hydraulic system

A SIMPLE HYDRAULIC SYSTEM:



A simple hydraulic system.

- Basically, a hydraulic system requires a source of hydraulic power [the pump]; pipes or hoses to carry the hydraulic fluid from one point to another; a valve mechanism to control the flow and direction of the hydraulic fluid.

- A device of converting the fluid power to movement [actuating cylinder or hydraulic motor]; and a reservoir to store the hydraulic fluid.
- A simple hydraulic system is shown in the diagram. The pump draws hydraulic fluid from the reservoir and directs it under pressure to the four-way selector valve.

- When the selector valve is in the position shown, the fluid will flow into the left end of the actuating cylinder and force the position to the right.
- This moves the piston rod and any device to which it is connected.
- As the piston moves to the right, the fluid to the right of the piston is displaced and flows out the port at the right end of the cylinder, through the tubing to the valve, and from the valve to the reservoir.
- When the valve is rotated one-quarter turn, the reverse action will take place.

PURPOSE OF HYDRAULIC FLUID

- Hydraulic fluids make possible the transmission of pressure and energy.
- They also act as a lubricating medium, thereby reducing the friction between moving parts and carrying away some of the heat.

TYPES OF HYDRAULIC FLUID

There are three principal types of hydraulic fluids;

1. Vegetable-base fluids.
2. Mineral-base fluids.
3. Phosphate ester-base fluids.

VEGETABLE BASE O I L :

- These fluids are usually mixtures containing castor oil and alcohol and are colored blue-green or are almost clear. They are considered obsolete and are not generally found in any hydraulic power systems but may still be found in some older brake systems.

MINERAL BASE FLUIDS:

- It consists of high-quality petroleum oil and is usually colored red. They are used in many systems, especially where the fire hazard is comparatively low. Small aircraft that have hydraulic power systems for operating wheel brakes, flaps, and landing gear usually use mineral-base fluids confirming to MIL-0-5606. Mineral-base fluids are less corrosive and less damaging to certain parts than other types of fluid.

PHOSPHATE ESTER-BASE FLUIDS:

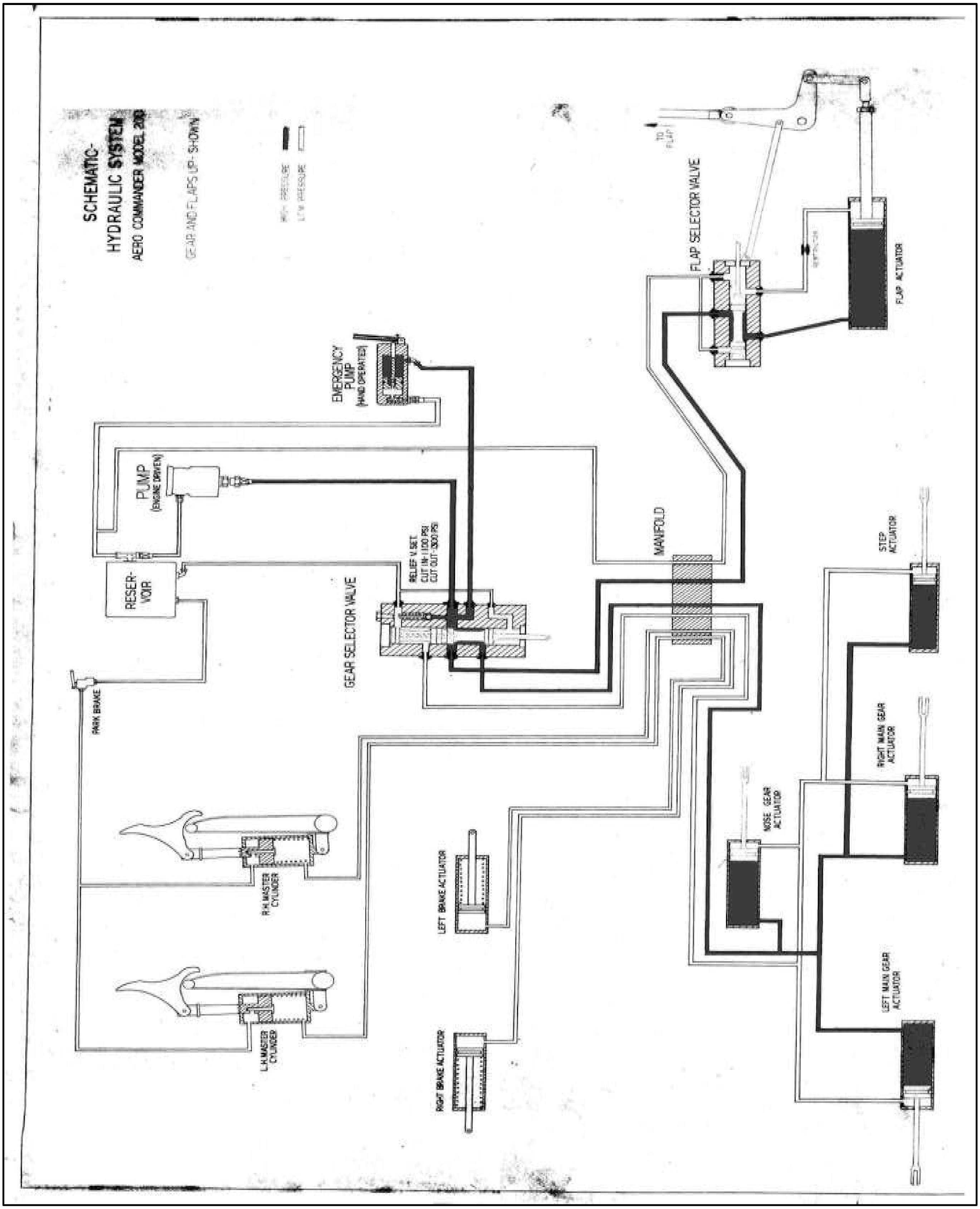
- It is utilized in most transport category aircraft are very fire resistant.
- Although phosphate ester fluids are extremely fire resistant, they are not fireproof.
- Under certain conditions phosphate ester fluids will burn.
- The continual development of more advanced aircraft has resulted in modification to the formulation of phosphate ester- base fluids.

COMPONENTS OF HYDRAULIC SYSTEM

The basic components of a hydraulic system are;

1. Reservoir.
2. Hydraulic filter.
3. Heat exchanger.
4. Hydraulic pumps.
5. Pressure control devices.
6. Accumulators.
7. Selector valves.
8. Operating valves.
9. Flow equalizers.
10. ydraulic actuators.

HYDRAULIC SYSTEMS FOR AIRCRAFT



- Every aircraft hydraulic system has two major parts or sections, the power section and the actuating section [or sections].
- The power section provides for fluid flow, regulates and limits pressure, and carries fluid to the various selector valves in the system.
- The actuating section or subsystems are the sections containing the various operating units, such as the wing flaps, landing
gear, brakes, boost systems, and steering mechanisms.
- The power section may either be an open or closed system using an engine-driven pump or a pump driven by an electric motor.
- Pressure developed by the pump in an open system is controlled by one of the following three valves; an open-center valve,
power-control valve, or a pump-control valve.
- The two types of aircraft hydraulic systems are;

1. Open system.
2. Closed system.

OPEN SYSTEM:

- An open system is one having fluid but no appreciable pressure in the system whenever the actuating mechanisms are idle.
- Fluid circulates from the reservoir, through the pump, through the open valves, and check valves, and back to the reservoir, as illustrated in the drawing.
- This system is also called an open-center system.
- Selector valves in an open system are always connected in series with each other, an arrangement whereby the pressure line goes through each selector valve.
- Fluid is allowed free passage through each selector valve and back to the reservoir unit until one of the selector valve is positioned to operate a mechanism, as illustrated in the diagram.
- Fluid is then directed to the actuator, and pressure is allowed to build up in the systems.
- A pump-control valve is placed in a line that goes directly from the pump to the reservoir.
- When closed, these valves block the flow to the reservoir and force the flow to a two-position valve and then to one of the actuating units.

CLOSED SYSTEM:

A closed system is one that directs fluid flow to the main system manifold and builds up pressure in that portion of the system that leads to all the selector valves.

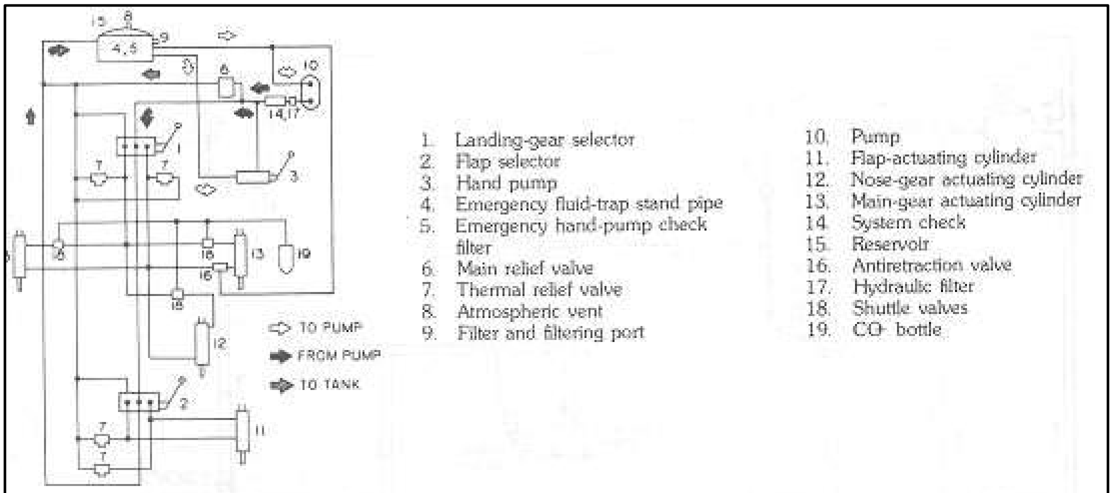
There are two basic types of closed systems:

1. One has a constant volume pump and a pressure regulator to control the pressure at the working range and to “unload” the pump when there is

no flow requirement and pressure builds up in the system manifold.

2. The second closed system utilizes a variable volume pump and directs the flow to the system manifold, similar to the constant volume system. The output of the variable volume pump is controlled by an integral control valve. This valve reduces the pump flow to zero when no units are operating in the system and pressure is built up in the storage chambers, called accumulators.

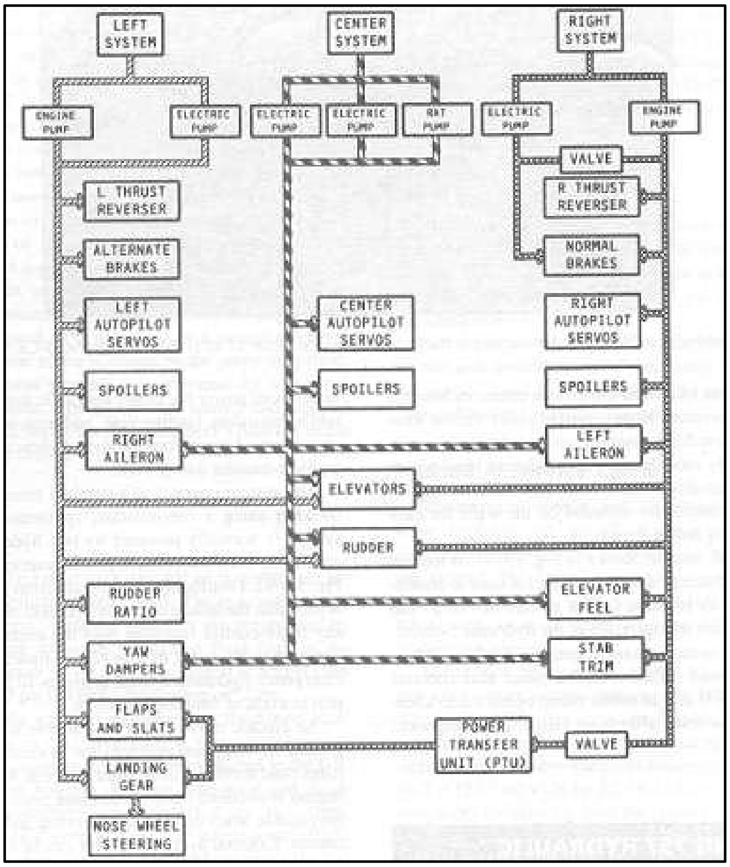
LIGHT AIRCRAFT HYDRAULIC SYSTEM



Schematic diagram of the hydraulic system for a light twin-engined airplane. *(Piper Aircraft Co.)*

- A schematic diagram of a hydraulic system for a light, twin- engine aircraft is shown in the figure.
- The diagram shows that the engine-driven hydraulic pump (10) draws hydraulic fluid from the reservoir (15) and pumps it through the pressure port of the 'power pack' assembly into the landing gear selector pressure chamber.
- When the two selector valves are in the neutral position, the fluid travels from the landing gear selector valve (1) through the flap selector valve (2) and back to the reservoir.
- The power pack assembly is a modular unit that includes the reservoir, relief valve, hand pump, landing gear selector valve, wing flap selector valve, filters, and numerous other small parts essential to the operation.
- When both selector valves are in the neutral position, the system acts as an open-center system, in that the fluid flows first through one selector valve and then through the other before returning to the reservoir.
- During this time the fluid flows freely at a reduced pressure.
- Since the fluid supply line runs first through the landing gear subsystem is in operation.
- Each selector valve has a separate return line to allow fluid from the actuating cylinder or cylinders to flow back to the reservoir.

THE BOEING 757 HYDRAULIC SYSTEM



- The Boeing 757 hydraulic system is presented as a representation of a modern transport aircraft with multiple redundant systems for the supply of hydraulic power and the operation of controls.
- Many modern transports and the corporate aircraft have systems that are similar, with the same philosophy of multiple redundancies.
- The primary emphasis in the following description is on system design and operation and not on specific components, which have been previously described.

- The 757 are equipped with three separate and independent hydraulic systems, titled LEFT, CENTER, and RIGHT, as illustrated in the figure.
- The hydraulic systems provide power to the thrust reversers, brakes, autopilot servos, flight controls, flaps/slats, landing gear, and nose wheel steering.

- The left & right systems are each powered by one engine pump and one electric pump.

- Two electric pumps power the center hydraulic system.
- If required, a ram air turbine can power the center hydraulic system.
- The center hydraulic system's flaps/slats, landing gear, and nose wheel steering can also receive power from the right hydraulic system through a power-transfer unit. PTU.

- The system operates at a nominal pressure 20,685 KPa using a fire-resistant, synthetic-type fluid.
- Each system is normally powered by two hydraulic pumps that are driven from independent power sources, as illustrated in the figure.
- Distribution of pressure from the 3 systems is such that the failure of one system will not result in loss of any flight-control malfunctions, and the airplane can be safely operated in the event of loss of two hydraulic systems.

- An emergency hydraulic system provides flight-control operation in event of dual engine failure.
- An electric motor pump is available in each system for ground servicing and maintenance.

- A central fill point facilitates fluid servicing of all 3 systems.
- Reservoir pressurization is obtained from the airplane pneumatic system and is available when engines are operating and during APU operation.
- External hydraulic power can be connected to each system.

COMPONENTS DESCRIPTION:

HYDRAULIC RESERVOIRS:

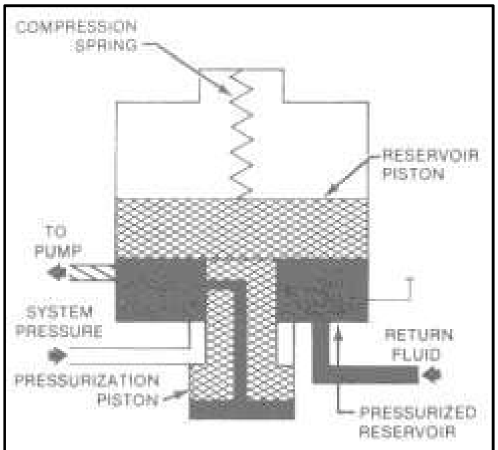
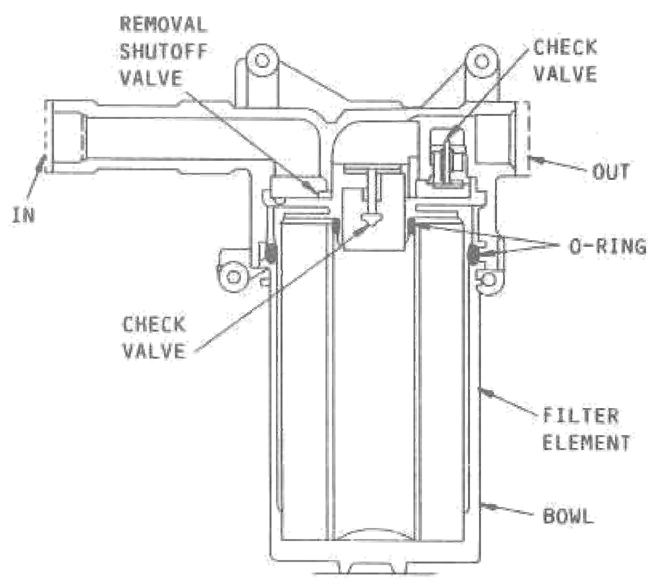


FIGURE 13-9 A reservoir pressurized by spring and hydraulic pressure. (Bell Helicopter Textron.)

- A hydraulic reservoir is a tank or container designed to store sufficient hydraulic fluid for all conditions of operation.
- Usually the hydraulic reservoir must have the capability of containing extra fluid not being circulated in the system during certain modes of operation.
- When accumulators, actuating cylinders, and other units do not contain their maximum quantities of fluid, the unused fluid must be stored in the reservoir.
- On other hand, when a maximum amount of fluid is being used in the system, the reservoir must still have a reserve adequate to meet all requirements.

HYDRAULIC FILTERS:

- Hydraulic filters are required to filter out any particles that may enter the hydraulic fluid.
- These particles may enter the system when it is being serviced or during wear of operating components.
- If these contaminants were allowed to remain in the circulating fluid, they could damage the seals and cylinder walls, causing internal leakage and prevent components such as check valves from seating properly.
- The number and location of filters in the hydraulic system depend on the specific model aircraft, but they are normally found at the inlet and outlet of the reservoir and the pump outlet.
- Commonly used filters are of the Micronics type and porous metal type.



Hydraulic filter assembly.

HYDRAULIC PUMPS:

Hydraulic pumps are designed to provide fluid flow and are made in many different designs, from simple hand pumps to very complex, multiple-piston, variable displacement pumps.

Some of the types of the hydraulic pumps are;

1. Hand pump
2. Gear type pump.
3. Vane type pump.
4. Gerotor pump.
5. Multiple piston pump.
6. Cam-type, variable-delivery pumps.

PRESSURE-CONTROL DEVICES:

Numerous devices have been designed to control pressure in the hydraulic systems; among these are pressure switches, pressure regulators, relief valves, and pressure-reducing valves.

PRESSURE-REDUCING VALVES:

Requirements of some parts of the system may demand that the designer utilize a lower pressure than the normal system operating pressure.

It may be desirable to have a reduced operating pressure to prevent overloading some structures.

A pressure-reducing valve will fill this need.

The proper valve will reduce system pressure to the desired level; it will also relieve thermal expansion in the section of the system that it isolates.

The figure illustrates how a pressure-reducing valve is positioned to bring about a lower pressure for operation of the actuating cylinder.

ACCUMULATORS:

- An accumulator is basically a chamber for storing hydraulic fluid under pressure.

- It can serve one or more purposes.
- It dampens pressure surges caused by the operation of an actuator.
- It can aid or supplement the system pump when several units are operating at the same time and the demand is beyond pump's capacity.
- An accumulator can also store power for limited operation of a component if the pump is not operating.
- Finally it can supply fluid under pressure to make up for small system leaks that would cause the system to cycle continuously between high and low pressure.

- Accumulators are divided into three types according to means used to separate the air and fluid chambers.
  Three types of accumulators are,

1. Diaphragm type accumulator
2. Bladder type accumulator.
3. Piston type accumulator.

SELECTOR VALVES:

Selector valves are used to direct the flow of hydraulic fluid to or from a component and achieve the desired operation.

These valves fall into one of four general types;

1. Rotary valve.
2. Poppet valve.
3. Spool or piston valve.
4. Open-centre-system selector valve.

AUTOMATIC-OPERATING CONTROL VALVES

An automatic-operating control valve is one that is designed to operate without being positioned or activated by any force outside of the hydraulic fluid pressure or flow.

These valves are located in line with the system flow and function to perform operations such as prevent or restrict flow in a line, allow flow at the proper time, and change control of components between independent pressure systems.

Types of operating control valves are,

1. Orifice or restrictor valves.
2. Check valves.
3. Orifice check valve.
4. Metering check valve.
5. Hydraulic fuse.
6. Sequence valve.
7. Shuttle valve.
8. Priority valve.
9. Flow equ a liz er s .

HYDRAULIC ACTUATORS:

Hydraulic actuators are devices for converting hydraulic pressure to mechanical motion.

The most commonly utilized actuator is the actuating cylinder: however, servo actuators and hydraulic motors are also employed for special applications where modified motion is required.

Actuating cylinders are used for direct and positive movement such as retracting and extending landing gear and the extension and
retraction of wing flaps, spoilers, and slats.

Servo actuators are employed in situations where accurately controlled intermediate positions of units are required.

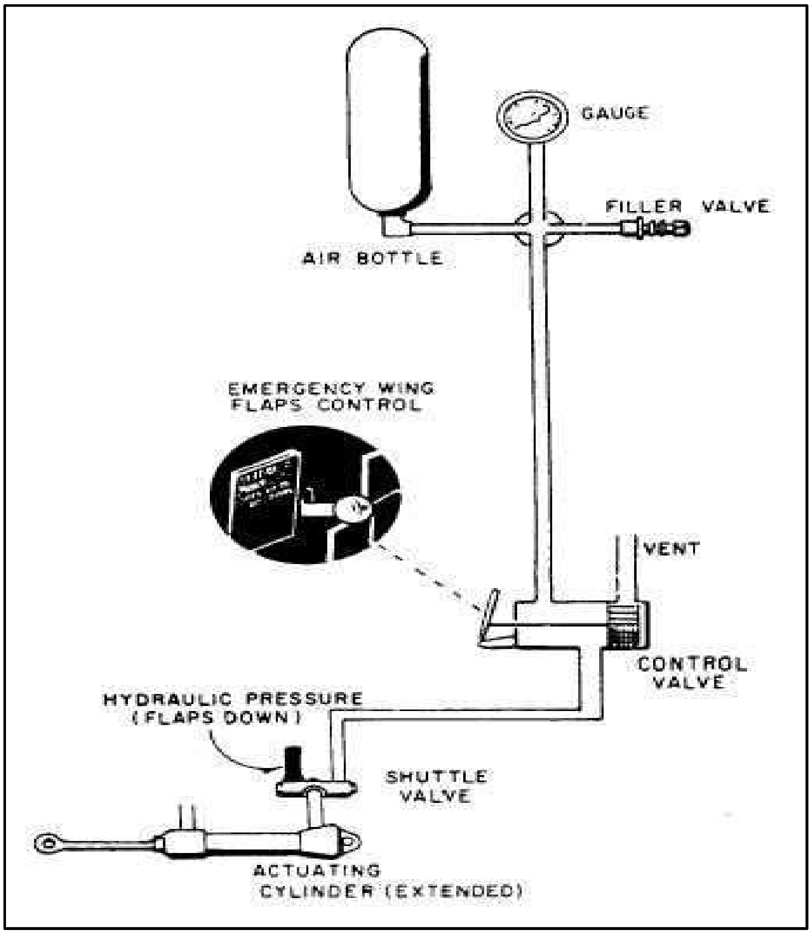
The servo unit feeds back position information to the pilot’s control, thus making it possible for the pilot to select any control position required.

Some types of hydraulic actuators are,

1. Actuating cylinders.
2. Inter-lock-type actuator.
3. Servo actuators.
4. Hydraulic motors.

PNEUMATIC SYSTEMS FOR AIRCRAFT
INTRODUCTION:

- Aircraft pneumatic systems are used primarily as emergency sources of pressure for many of the hydraulically actuated subsystems.
- The principle of operation for a pneumatic power system is the same, with one important exception, as that of a hydraulic power system.
- The air in a pneumatic system is compressible; therefore, the pressure in the system can reduce gradually from the maximum system pressure to zero pressure.
- In the hydraulic system, as soon as the accumulator fluid has been used and the pump is not operating, the fluid pressure drops immediately from accumulator pressure to zero pressure.
- The entire pneumatic system, including the air-storage bottles, can act to store air pressure.



PNEUMATIC SYSTEMS

- In the hydraulic system, the only pressure fluid storage is the accumulators, and the pressure is supplied by compressed air or gas in the air chamber of the accumulators.
- The air in a pneumatic system must be kept clean by means of filters and also be kept free from moisture and oil droplets or vapour.
- For this reason, liquid separators and chemical air driers are incorporated in the systems.
- Moisture in a pneumatic system may freeze in a low temperatures encountered at high altitudes, resulting in serious system malfunctions.
- Another important feature of a pneumatic system is that there is no need for return lines.
- After the compressed air has served its purpose, it can be dumped overboard, which saves tubing, fittings, and valves.

TYPES OF PNEUMATIC SYSTEMS

Depending upon the work to be done, pneumatic systems fall into two broad categories: high-pressure and low-pressure.

High-pressure systems are used as primary power sources for heavy-duty applications instead of hydraulics. Also, a pneumatic system used as a backup for a hydraulic system would also be high pressure. Low pressure systems drive the flight instruments and perform miscellaneous tasks. High pressure systems. Emergency and backup pneumatic systems normally use metal bottles to store air compressed to the range of 1000-3000 pounds per square inch. The air bottle will have two valves, one for charging the bottle and the other, a shutoff valve, to activate and deactivate the system. The bottle may be charged, through the charging valve, by a ground-based compressor. The major drawback to this system is the limited amount of air available in the bottle. Such a system could only function as a backup. Some aircraft use a similar system as a primary source of fluid power by adding permanently installed air compressors. When leaks result in decreasing system air pressure, the compressor automatically activates and brings the system pressure back up to full charge.

TYPICAL AIR PRESSURE SYSTEM

The type of unit used to provide pressurized air for pneumatic systems is determined as pressure system.

These are of three types,

1. High-pressure system.
2. Medium pressure system.
3. Low-pressure system.

HIGH PRESSURE SYSTEM:

- For high-pressure systems, air is usually stored in metal bottles at pressure ranging from 1000 to 3000 p.s.i, depending on the particular system.
- This type of air bottle has two valves, one of which is a charging valve. A ground-operated compressor can be connected to this valve to add air to the bottle.
- Although the high-pressure storage tank is light in weight, it has a definite disadvantage.
- Since the system cannot be re-charged during flight, operation is limited by the small supply of bottled air.
- Such an arrangement cannot be used for the continuous operation of a system.
- On some aircraft, permanently installed air compressors have been added to re-charge air bottles whenever pressure is used for operating a unit.

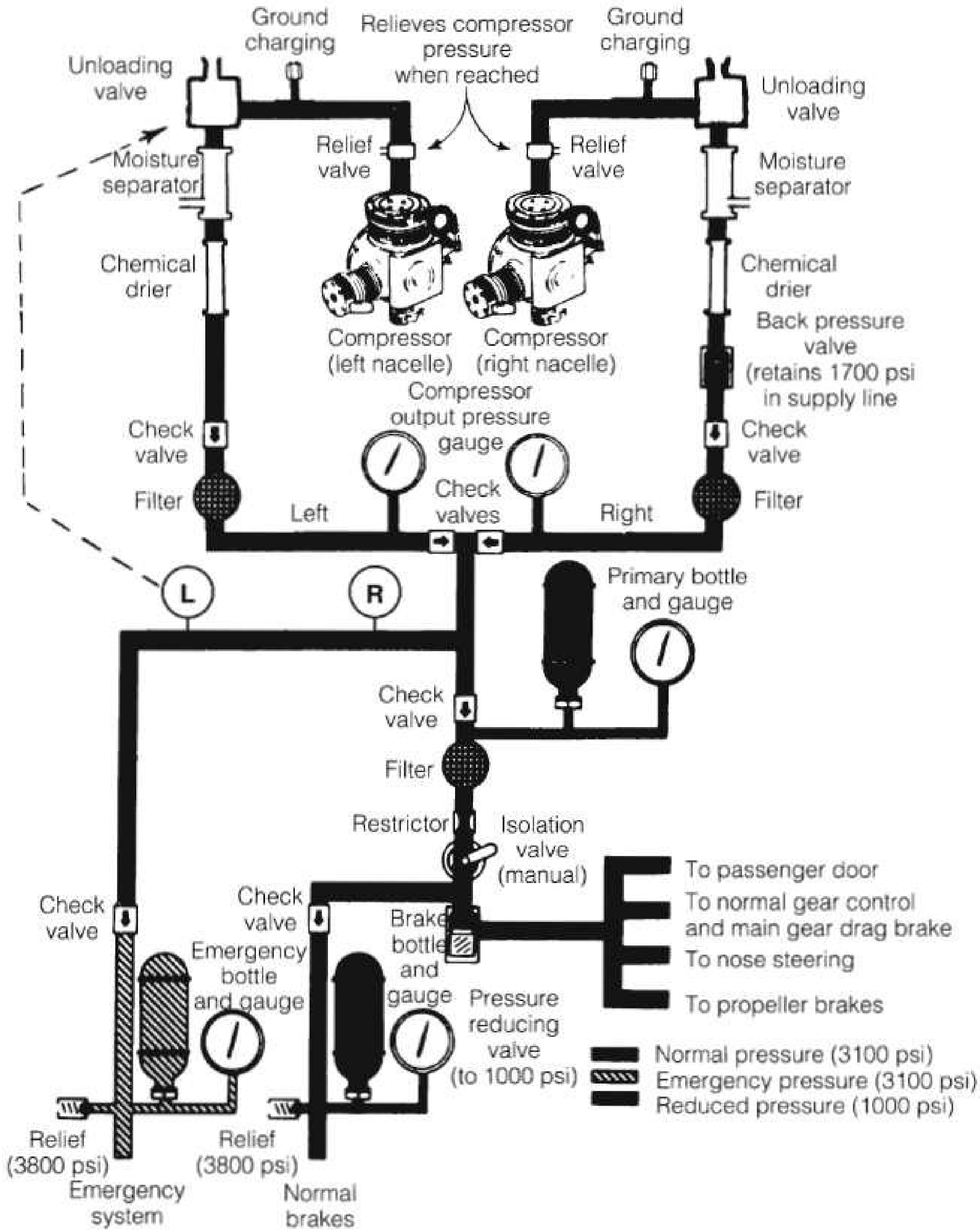
MEDIUM PRESSURE SYSTEM:

- A medium pressure pneumatic system ranging from 100 to 150 p.s.i usually does not include an air bottle.
- Instead, it generally draws air from jet engine compressor section. In this case, air leaves the engine through a takeoff and flows into tubing, carrying air first to the pressure-controlling units and then to the operating units.

LOW-PRESSURE SYSTEM:

- Many aircraft equipped with reciprocating engine obtain a supply of low-pressure air from vane-type pumps.
- These pumps are driven by electric motors or by the aircraft engine. When it begins to operate, the drive shaft rotates and changes position of the vanes and sizes of the chambers.

TYPICAL PNEUMATIC POWER SYSTEM



FH-227B Pneumatic power system schematic.

- The pneumatic system described in this section is utilized in the Fairchild F-27 aircraft.
- It provides power for operation of the landing gear retraction and extension, nose wheel centring, propeller brakes, main-wheel brakes, and passenger entrance-door retraction.
- This system described includes only the development and delivery of compressed air to each component or sub system, not the actual operation of the component or sub system.
- The pneumatic power in the aircraft is delivered by one of two systems; the primary system or the emergency system.
- The power section of the primary pneumatic system is that portion located in each engine nacelle.
- It consists of a gear box-driven compressor; bleed valve, unloading valve, moisture separator, chemical drier, backpressure valve, and a filter.
- In addition, each nacelle contains a shuttle valve, disk-type relief valve, and a ground charging connection to aid in ground maintenance or initial filling.
- Each power section independently supplies compressed air to the primary system is stored in two storage bottles, and the system delivers the air for normal operation components, as required by directional valves.

AIR PRESSURE SOURCES:

- One compressor is located in each engine nacelle.
- The compressors are of four-stage type, radial design, providing a delivery pressure of 22,753 KPa and 5.66 cubic meter/minute at sea level intake pressure on a standard day.
- The cylinders are caused to reciprocate in the proper sequence by a cam-assembly mechanism, which rotates with the crankshaft.
- Air-storage bottles are used for emergency operations when hydraulic or pneumatic pressure sources have been lost.
- The bottles are normally pressurizes with nitrogen, but some aircraft require the use of carbon dioxide.
- These bottles will power a system, normally a landing gear extension system or a brake system, for only a brief period of time.
- The bottles must be recharged on the ground.

MOISTURE CONTROL:

- In a pneumatic system it is of the utmost importance that the air in the system be completely dry.
- Moisture in the system can cause freezing of operating units, interfere

with the normal operation of valves, pumps, etc., and cause corrosion.

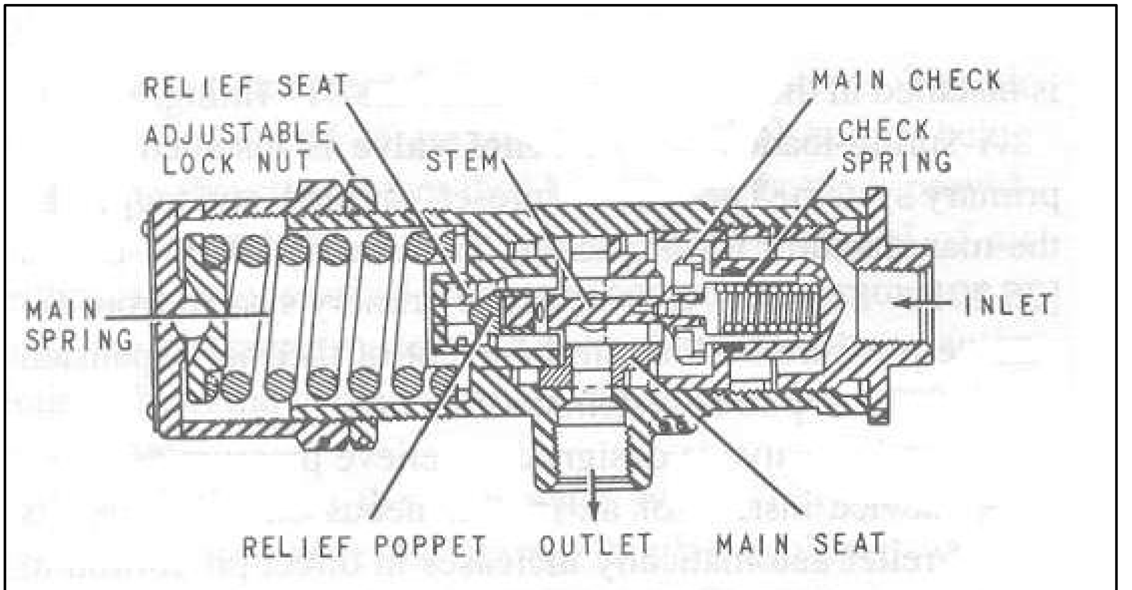
- It is for this reason that moisture separators and chemical driers are used in pneumatic systems.

FILTERS:

- Three sintered pneumatic filters are used, one in each compressor circuit and one in the primary circuit.
- The filter is a vertically mounted unit, containing a replaceable filter element of stainless steel that removes foreign matter of 10 microns or larger from the compressor output air.

- Other type of filters commonly found in pneumatic systems include o Micronics and wire-screen filters.
- The Micronics filter has a replaceable cartridge, whereas the wire-screen filter can be cleaned and reused.
- The basic construction of these filters is the same as the Micronics filter used in hydraulic systems.

PRESSURE CONTROL VALVES:



Pressure-reducing valve.

- The BLEED VALVE, controlled by compressor lubricating oil pressure, directs the compressed air to the compressor circuit relief valve and unloading valve.

- In the event the compressor oil pressure drop below 275.8 KPa , the bleed valve will direct compressed air from the fourth stage overboard.
- Pressure output from the bleed valve is routed to RELIEF VALVE in the unloading valve.

- The relief valve protects all components of the compressor circuit from excessive pressure buildup in the event any component downstream
- of the compressor malfunctions.
- The relief valve is set to open at 26,201 KPa.
- The UNLOADING VALVE contains a sensing valve and a directional control valve, and it directs compressor output through dehydration equipment to the system or vents the output overboard.
- The directional control valve, controlled by the sensing valve, opens and vents overboard when system pressure reaches 22,735.5 KPa and closes when the pressure is less than 19,95505 kPa.
- A BACK-PRESSURE VALVE is installed in the pressure tube of the right nacelle only, to ensure that the engine-driven air-compressor output is kept at a predetermined value of 11,721.5 +1034 kPa.
- This is to provide and maintain a fixed backpressure of approximately 1700 p.s.i, upstream of the air-drying equipment.
- The backpressure valve is similar in operation and construction to a check valve.

FLOW-CONTROL VALVES:

- Installed in both the right and left nacelle is a two-position, three-port shuttle valve.
- The valve functions to direct air to the primary system from the compressor or the ground-charging valve while preventing air flow from escaping through the lines not being used for supplying air.

AIRCRAFT BRAKE SYSTEM INTRODUCTION:

- Brake-actuating systems for aircraft can be classified as mechanically operated, hydraulically operated, or pneumatically operated.
- All brake-actuating systems provide for applying brakes either on one side of the aircraft or all the aircraft brakes by operating foot pedals or hand levers.
- Mechanical brakes are found on only a few of the older, small airplanes.
- A mechanical brake-actuating system includes pulleys, cables, and bell

cranks for connecting the foot pedals to the brake-shoe operating mechanism.

- In some aircrafts, the hydraulic brake system is a sub-system of the main hydraulic system.
- In other aircrafts, there is an entirely independent brake system. Many of the large aircrafts have a power brake system that is a sub-system of the main hydraulic system
- The smaller aircrafts usually have an independent, master brake-cylinder system.
- Pneumatic brake systems utilize air pressure instead of fluid pressure to operate the brakes.
- Some hydraulic brake systems are arranged with pneumatic backup systems for operation in case of hydraulic-fluid loss or failure of hydraulic pressure.

INDEPENDENT BRAKE SYSTEM

- An independent brake system, such as is shown in figure, is usually found on small aircraft.
- This system is self-contained and independent of the aircraft's main hydraulic system.
- The basic components of this type of system are a reservoir, a master cylinder operated by the brake-control pedal or handle, a brake assembly on the wheel, and necessary lines, hoses and fittings.
- Expander-tube, shoe, or disk-brake assemblies may be used with this type of system.
- The reservoir is a storage tank that supplies the fluid to compensate for small leaks in the connecting lines or cylinders.
- The reservoir may be a part of the master cylinder. The master cylinder is the energizing unit.
- There is one for each main landing-gear wheel.
- The master cylinder is actually a foot-operated, single action-reciprocating pump, the purpose of which is to build up hydraulic fluid pressure in the brake system.
- Mechanical linkages are required to transmit the energy of the foot to the master cylinder.
- Most aircrafts have the master cylinders mounted on the rudder pedals, although a few aircraft have the master cylinders mounted at a distance from the pedals.

- Other control arrangements make use of heel brakes, operated by the pilot pressing his heel on the brake pedal, and a central hand brake lever, which operates all brakes at the same time.
- The fluid lines may consist of flexible or rigid tubing or a combination of both.
- Usually flexible tubing is employed with retractable gear systems and between the movable parts of the shock strut.
- The brake actuating mechanism of the brake assembly causes braking action to occur when pressure from the master cylinders is transmitted to them.
- The parking brake mechanism is a sub assembly of the usual hydraulic brake system.
- The control for the mechanism is in the pilot's compartment and usually consists of a pull handle or lever.
- With respect to parking brakes, the setting of these brakes when the main brakes are hot may cause serious damage.
- Hot brakes should be allowed to cool b ef or e the parking brakes are applied.

POWER BOOST SYSTEM

- These are used on aircraft that have high landing speeds or too heavy for an independent brake system to operate efficiently but that do not require the power of a power brake system.
- This system, shown in the figure uses hydraulic system pressure to operate the brakes.
- When the pilot depresses the brake pedal, the power boost master cylinder opens a metered line to allow hydraulic system pressure to flow to the brakes.
- The metering mechanism is either a tapered pin or variable size orifice.
- The further the pedal is pressed, more the fluid flows through the metering device, with a resulting increase in braking action.
- When the pedal is released, the pressure inlet line is blocked and the master cylinder ports the pressure in the brake line to the hydraulic system return line.

POWER BRAKE SYSTEM

- A power brake system is used to operate the brakes of the large aircraft, where the independent and power boost systems are not adequate.

- The pilot operates the system by depressing the brake pedal.
- This causes a power brake control valve to direct hydraulic system pressure to the brakes and operate the brake assembly.
- The brake pedal is connected to the power brake control valve through an arrangement of cables, pulleys, bell cranks, and linkages.
- The power brake control valve for a transport aircraft or brake-metering valves are fitted in this system.
- One metering valve assembly is used for each main landing-gear brake.
- In a typical system, four hydraulic lines are attached to each valve. These lines are for pressure, return, brakes, and automatic braking.
- Valve ports are opened or closed by operating a circular grooved, sliding valve rod [spool].
- The linkage end of the valve rod projects beyond the valve body, whereas the opposite end is supported in a sealed compensating chamber.

WORKING:

- When the brake pedals are depressed, an inward movement is imparted to the metering valve rod through the mechanical linkage and cables.
- As the rod moves in, the return port is closed, and the pressure port is opened to direct hydraulic fluid pressure to the brakes.
- A passage through the valve rod permits the hydraulic fluid under pressure to a compensating chamber enclosing the inner end of the creates a return force tending to close the valve.
- This return force varies with the intensity of braking force and provides “feel” at the pedals.
- The desired braking effort is obtained by depressing the pedals a greater or lesser distance.
- Cable stretch and adjustment of pedal position permits the valve rod to move back until both pressure and return ports are closed.
- Releasing the brake pedals allows the pressure in the compensating chamber to move the valve out and open the brake line to return line.
- As pressure in the brake lines falls, the brakes are released, and return force on the valve rod is relieved.
- Automatic braking to stop the rotation of the wheels during retraction is provided by small-diameter piston actuating cylinder attached to the metering valve.
- The cylinder is connected to the landing gear retract hydraulic line.

MULTIPLE POWER BRAKES ACTUATING SYSTEM

- The brake actuating for a transport turbine aircraft involves many components and a number of subsystems and is described briefly here to provide the technician with a general understanding of how such a system operates.

- This information also emphasizes the need for careful work on the
- part of the technician while servicing, maintaining, and repairing such a system.

- The brakes are operated by two completely independent hydraulic power systems.

- The number 1 hydraulic system supplies pressure to the number 1 brake system, number 3 to number 2-brake system.
- Each wheel brake is actuated by power from both systems through independent pressure-metering valves.
- Each brake system consists of a dual brake control valve, pressure accumulator, brake-pressure transmitter and indicator, brake system manifold, eight skid-control valves, eight fluid quantity-limiter valves,

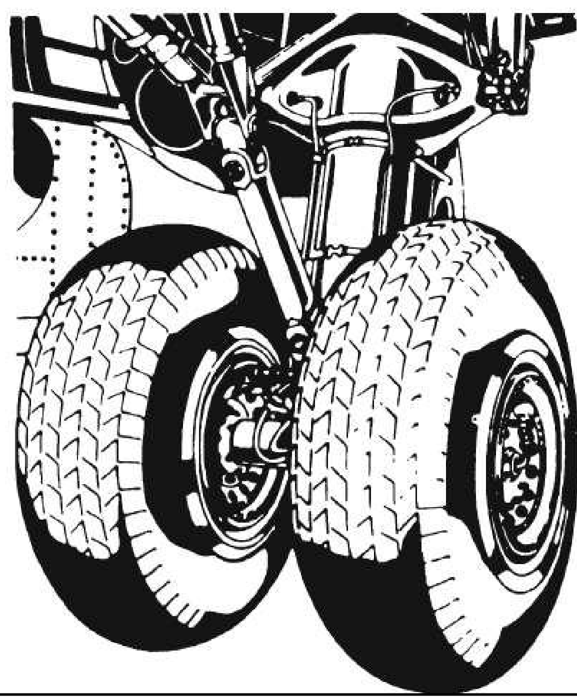
- a skid-control manifold for each gear, and a parking-brake valve, all of which contribute to the actuation of the independent cylinders in the eight main wheel brakes.
- Although both brake-pressure systems are normally used at all times, either system is capable of stopping the aircraft on a maximum-gross- weight landing.

LANDING GEAR SYSTEMS

INTRODUCTION:

- The main landing gear provides the principal support for the aircraft on the ground while the auxiliary (nose) gear provides supplemental support and steering capability.
- The earliest airplanes had tail skids and eventually tailwheels, but cabin-class aircraft are fitted with a nose gear. Three primary reasons for the change to nose gear were:
    - More forceful application of the brakes for higher landing speeds without nosing over.
    - Better forward visibility for the crew during landing and taxiing.
    - Prevent aircraft ground-looping (a quick 180° pivot that might occur after landing) by moving the aircraft center of gravity (c.g.) ahead of the main wheels. (Forces acting on the c.g. tend to keep the aircraft moving forward on a straight line rather than ground-looping.)

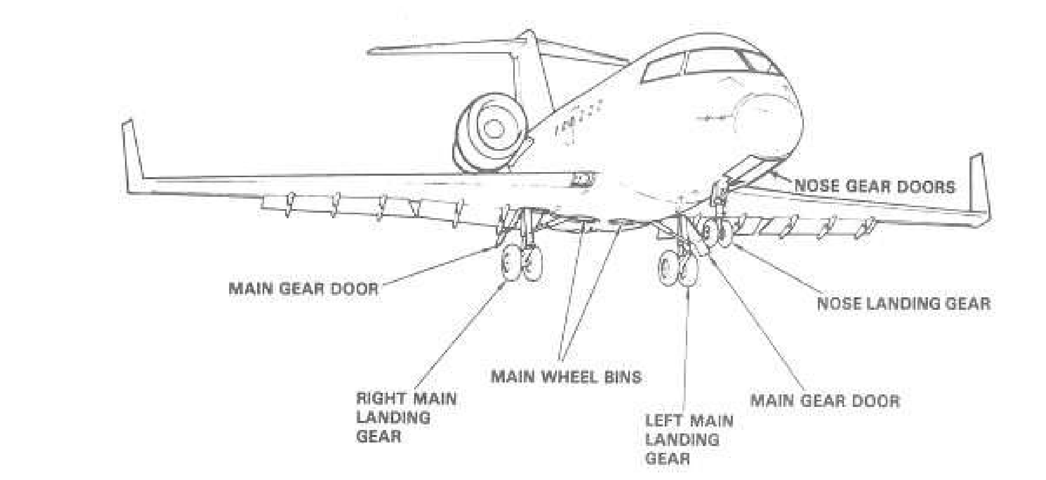
- Landing gear have many variables. The number and location of wheels on the main gear might vary. Some aircraft have a single wheel per strut; other aircraft have multiple wheels per strut More wheels per strut create a wider safety margin.
- The aircraft's weight is spread over a larger area, and the degradation in control associated with tire failure will be reduced.



Dual main landing gear wheel arrangement.

LANDING GEAR CONFIGURATIONS:

The majority of the aircraft are equipped with landing gear that can be classified as either tricycle or conventional.



A tricycle landing-gear arrangement. (Canadair, Inc.)

TRICYCLE TYPE landing gear is characterized by having a nose wheel assembly and two main gear assemblies, one on each side of the aircraft as shown in the figure. This keeps the aircraft fuselage in a level attitude when the aircraft is on the ground.

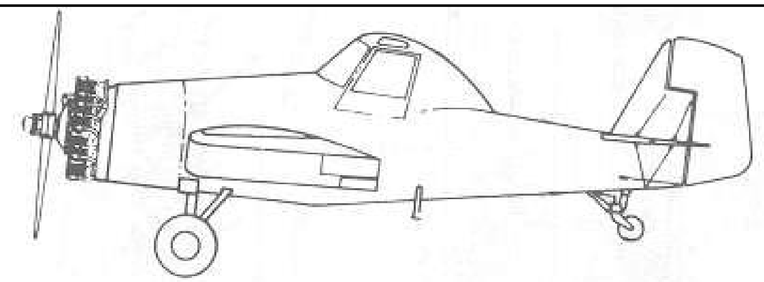


FIGURE 14–2 An aircraft with a conventional landing-gear configuration. (Ayres Corp.)

CONVENTIONAL TYPE landing geared aircraft illustrated in the figure has two main wheel assemblies, one on each side of the aircraft and a tail wheel.

This arrangement is normally associated with older aircraft and those designed for rough field operations.

CLASSIFICATION OF LANDING GEARS:

The landing gear of an aircraft serves a number of very important functions and is classified by a number of different characteristics.

- It supports the aircraft during ground operations, dampens vibrations when the aircraft is being taxied or towed, and cushions the landing impact.

- The landing of an aircraft often involves stresses far in excess of what may be considered normal; therefore the landing gear must be constructed and maintained in a manner that provides the strength and reliability needed to meet all probable landing conditions.
- The landing gear of an airplane consists of main and auxiliary units, either of which may be fixed or retractable.
- The main landing gear provides the main support of the aircraft on land or water.

- It may include a combination of wheels, floats, skis, shock-absorbing equipment, cowling, fairing and structural members needed for attachment to the primary structure of the aircraft.
- The auxiliary landing gear consists of tail or nose landing-wheel installations, skids, outboard pontoons, etc., with the necessary cowling and reinforcements.

The landing gear is classified into;

1. Non absorbing landing gear.
2. Shock-absorbing landing gear.
3. Fixed gear.
4. Retractable gear.
5. Hulls and Floats.

NONABSORBING LANDING GEAR:

- This includes those of landing gear that do not dissipate the energy of the aircraft contacting the ground during landing.
- They only temporarily store the energy and quickly return it to the aircraft.

- These types of gear include rigid landing gear, shock-cord landing gear, and spring-type gear.
- A RIGID la n d i n g gear is commonly found on helicopters and sail planes.

- This gear is rigidly mounted to the aircraft with no specific component to cushion the ground contact other than through the flexing of the landing gear or airframe structure.

- When rubber SHOCK CORD is used, the landing- gears struts are usually made of steel tubing mounted in such a manner that a stretching action is applied to tightly wound rubber cord.
- When the landing shock occurs, the cord is stretched, thus storing the impact energy of landing.

- The stored energy is gradually returned to the aircraft during the landing roll.

SHOCK-ABSORBING LANDING GEAR

- This dissipates the impact energy of landing through some means. Most of these types of landing gear do this forcing a fluid through a restriction.
- The movement of this fluid generates heat, and the heat is radiated into the surrounding atmosphere, thus dissipating the landing energy.
- The two types of shock-absorbing landing gear commonly used are the Spring-oleo and the air-oleo types.

FIXED GEAR:

- Non retractable landing gear is generally called as fixed gear, it is attached to the structural members of the aircraft with bolts, but it is not actually "fixed", because it must absorb stresses; therefore, the wheels must move up and down while landing or taxiing in order to absorb shocks.
- The landing gear is often equipped with a fairing where it joins the fuselage or wing to reduce the drag.

RETRACTABLE GEAR:

- It was developed to eliminate, as much as possible, the drag caused by the exposure of the landing gear to the airflow during flight.
- Usually the landing gear is completely retractable [that is, it can be fully drawn into the wing or fuselage]; however, there are aircraft in which a portion of the gear wheels is still exposed after the gear is retracted.
- The direction of retraction varies.
- On some aircrafts, the retraction is toward the rear; on others the landing gear folds inward toward the fuselage; and on still others it folds outward toward the wing tips.
- The method of retraction also varies, although modern aircraft usually have a gear that is power operated.
- The retraction is normally accomplished with hydraulic or electric power.
- In addition to the normal operating system, emergency systems are usually provided to ensure that the landing gear can be lowered in case of main-system failure.

LANDING GEAR COMPONENTS:

- Landing-gear assemblies are made up of various components designed to support and stabilize the assembly.
- The following terms identify many of these components.
- The terms are presented here as they relate to retractable landing-gear

systems they are;

1. Trunnion.
2. Struts.
3. Torque links.
4. Truck.
5. Drag link.
6. Side brace link.
7. Over center link.
8. Swivel gland.
9. Shimmy dampers.

TRUNNION:

- The trunnion is the portion of the landing gear assembly attached to the airframe.
- The trunnion is supported at its ends by bearing assemblies, which allow the gear to pivot during retraction and extension.
- The landing gear strut extends down from the approximate center of the trunnion.

STRUTS:

- The strut is the vertical member of the landing gear assembly that contains the shock-absorbing mechanism.
- The top of the strut is attached to or is an integral part of, the trunnion.
- The strut forms the cylinder for the air-oleo shock absorber. The strut is also called the outer cylinder.
- The strut assembly consists of the ring-seal nut, the compressing-ring seal, and the ring seal from the group that seals the air pressure in the upper part of the strut.
- The upper bearing keeps the inner cylinder aligned with the outer cylinder.
- The snubber valve releases when the weight is off the landing gear strut to allow the strut to extend.
- The outer torque collar is the lower bearing that helps to keep the inner cylinder aligned inside the outer cylinder.
- The filler plug is used to plug the hole through which the cylinder is filled with hydraulic fluid.

TORQUE LINKS:

- It is often referred to as a scissors assembly, are two A-frame type members, used to connect the strut cylinder to the piston and the axle.

- The torque links restrict the extension of the piston during gear retraction and hold the wheels and axle in a correctly aligned position in relation to the strut.

TRUCK:

- The truck is located on the bottom of the strut piston and has the axles attached to it.
- A truck is used when wheels are to be placed in tandem or in a dual piston connection to allow for changes in aircraft attitude during take off and landing and during taxiing.

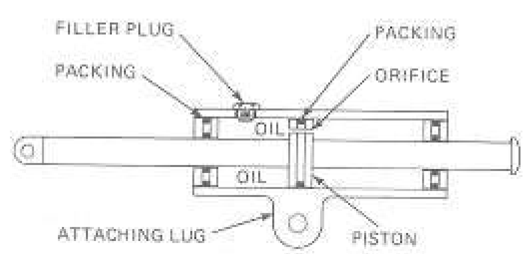
DRAG LINK:

- A drag link is designed to stabilize the landing-gear assembly longitudinally.
- If the gear retracts forward or aft, the drag link will be hinged in the middle to allow the gear to retract.
- This is also called a drag strut.

SIDE BRACE LINK:

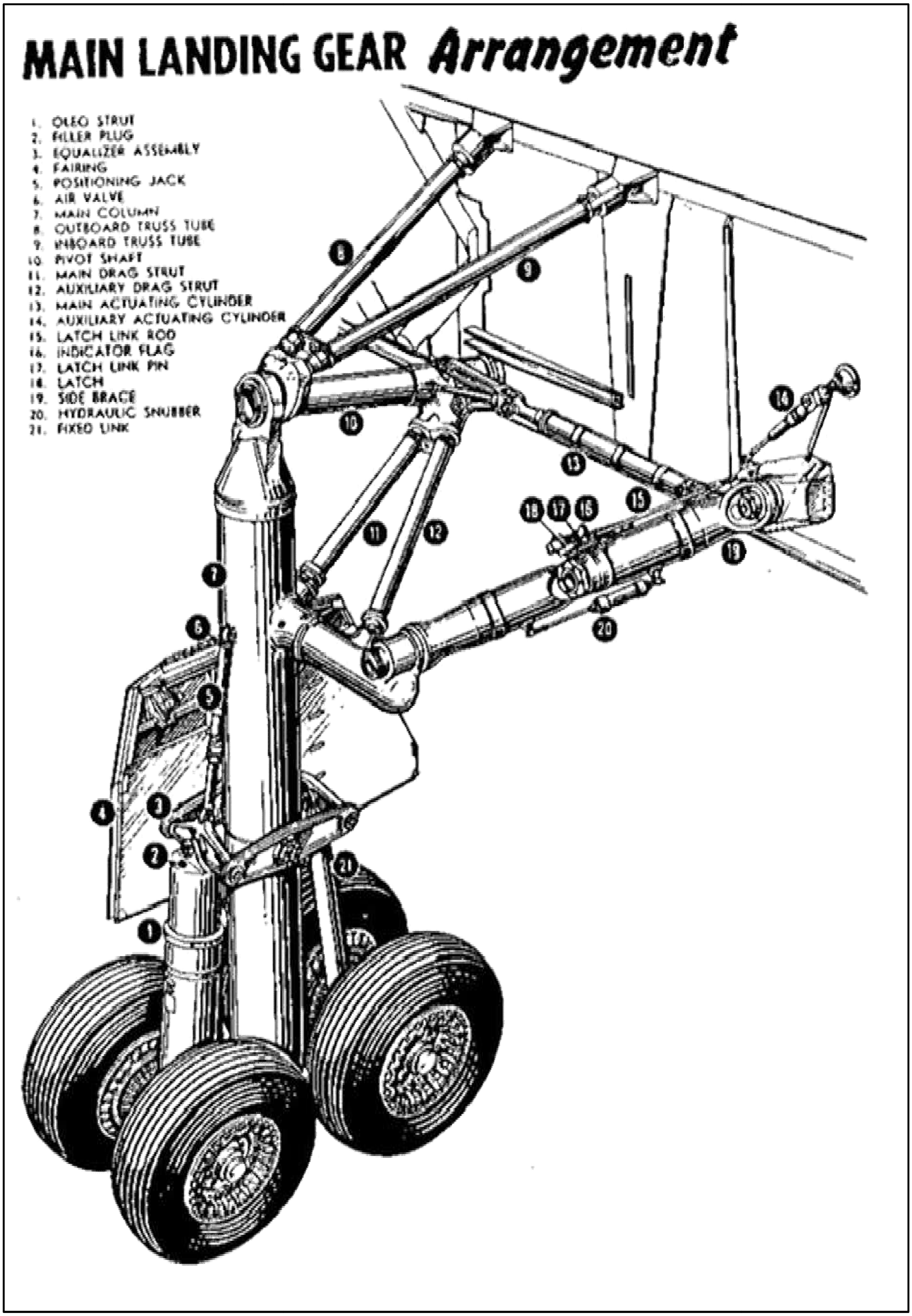
- A side brace link is designed to stabilize the landing gear assembly laterally.
- If the gear retracts sideways, the side brace link is hinged I the middle to allow the gear to retract.
- This is also called a side strut.

SHIMMY DAMPERS:



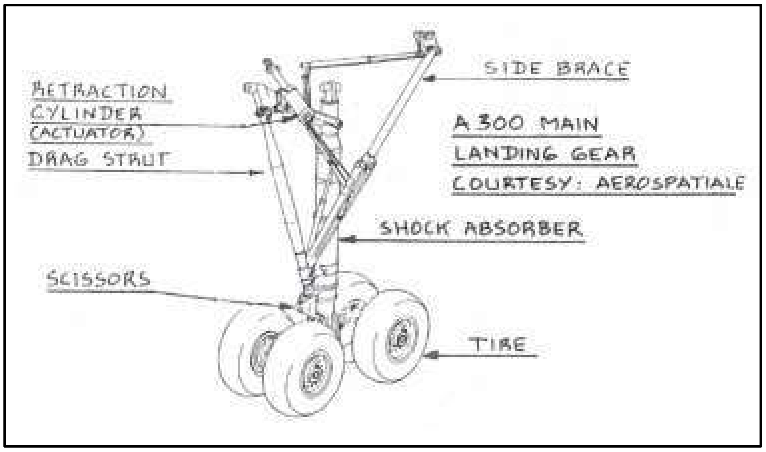
Drawing of a piston-type shimmy damper.

- The shimmy damper is a hydraulic snubbing unit that reduces the tendency of the nose wheel to oscillate from side to side.
- Shimmy dampers are usually constructed in one of two general designs, piston type and vane type, both of which might be modified to provide power steering as well as shimmy damper action.


MAIN LANDING GEAR Arrangement
1. OLEO STRUT
2. FILLER PLUG
3. EQUALIZER ASSEMBLY
4. FAIRING
5. POSITIONING JACK
6. AIR VALVE
7. MAIN COLUMN
8. OUTBOARD TRUSS TUBE
9. INBOARD TRUSS TUBE
10. PIVOT SHAFT
11. MAIN DRAG STRUT
12. AUXILIARY DRAG STRUT
13. MAIN ACTUATING CYLINDER
14. AUXILIARY ACTUATING CYLINDER
15. LATCH LINK ROD
16. INDICATOR FLAG
17. LATCH LINK PIN
18. LATCH
19. SIDE BRACE
20. HYDRAULIC SNUBBER
21. FIXED LINK

SHOCK ABSORBERS

A shock absorber is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. It is a type of dashpot. The landing gear shock absorber is an integral component of an aircraft's landing gear. The role of the shock absorber is to absorb and dissipate energy upon impact, such that the forces imposed on the aircraft's frame are tolerable. These accelerations must be acceptable not only to structural components, but also to everything contained within the aircraft (passengers, cargo, weapons, avionics etc). The shock absorber may be an independent element, or integrated with the landing gear strut.



Working

when the relative motion between the frame and the landing gear occurs due to vibration, the piston in the shock absorber moves up and down, the oil in the cavities of the shock absorber repeatedly flows from one cavity to another cavity via different holes, at this time, the friction between the hole walls and the oil and between oil molecules form the damping force, and the vibration energy of the automobile is converted into heat energy of the oil and then absorbed by the shock absorber and emitted to the atmosphere. Under the condition of the same total sectional area of oil channels, the damping force of the shock absorber increases or decreases along with the increase or decrease of the relative motion and is related to viscosity of the oil. The shock absorber and the elastic elements take the task of buffering impact and reducing vibration.

Shock Absorber Types

One of the most critical parts of an aircraft is the landing gear arrangement, as this system is responsible for ensuring the safety of those onboard during take-off and landing. These sections of flight only account for a short period of time, and yet are the most susceptible to accidents. For this reason significant time and effort is spent to ensure the reliability and functionality of these systems, with much of this time spent on an important component of the landing gear arrangement: the shock absorber system. Shock absorbers are not only of significant importance to aircraft performance, but are also of significant cost. There are many different types of shock absorbers, with the most effective discussed in this report along with other less conventional methods of shock absorption.

The main types of shock absorption used in aircraft are:

- Rigid axle
- Solid spring
- Levered bungee
- Oleo-pneumatic shock strut
- Telescopic strut
- Articulating strut
- Semi-Articulating strut
- Tyres
- Reserve energy dissipation devices
- Controlled crashes

AIRPLANE CONTROL SYSTEMS

AIRCRAFT FLIGHT CONTROL SYSTEMS

INTRODUCTION:

- Flight controls have advanced considerably throughout the years.
- In the earliest biplanes flown by the pioneers flight control was achieved by warping wings & control surfaces by means of wires attached to the flying controls in the cockpit.
- When top speeds advanced into the transonic region the need for more complex & sophisticated methods became obvious.
- They were needed first for high-speed fighter aircraft & then with larger aircraft when the jet propulsion became more wide spread.
- The higher speeds resulted in the higher loads on the flight control surfaces, which made the aircraft very difficult to fly physically.
- To overcome the higher loads powered surfaces began to be used with hydraulically powered actuators boosting the efforts of the pilot.

PRINCIPLESOF FLIGHT CONTROL

- All aircrafts are governed by the same basic principles of flight control, whether the vehicle is the most sophisticated high performance fighter or the simplest model aircraft.
- The following figure shows the direction of the aircraft velocity in relation to the pitch, roll & yaw axes.
- For most of the flight the aircraft will be flying straight & level and the velocity vector will be parallel with the surface of the earth & proceeding upon a heading that the pilot has chosen.

TYPES OF FLIGHTCONTROLSYSTEMS

1. Conventional system.
2. Power assisted flight controls.
3. Fully powered flight controls.
4. Power actuated systems.

ENGINE CONTROL SYSTEM

INTRODUCTION:

- In early jet aircraft, pneumatic & hydro mechanical flow control devices performed the control of fuel to the combustors.
- Thrust was demanded & maintained at an approximately fixed condition by the pilot adjusting the throttle lever & continuously monitoring his temperature & speed gauges.
- This was proved to be totally unsatisfactory, since the wide range of ambient conditions encountered in flight meant that continual throttle adjustments were needed.
- Further the engine had to be handled carefully to avoid flameout or surge during accelerations & decelerations.

- The task of handling the engines was eased by the introduction of electronic control in the form of magnetic amplifiers in the early civil & military aircrafts.

- The mag-amp allowed engines to be stabilized at any speed in the throttle range by introducing a servo-loop with engine exhaust temperature as a measure of engine speed & an analogue fuel valve to control fuel flow.
- This allowed the pilot to accelerate & decelerate the engine while the control system limited fuel supply to prevent over speeds or excessive temperatures.
- Control systems become more sophisticated with additional engine condition sensors with multiple servo-loops.
- On modern aircraft the engine is supervised by a computer to allow the pilot to operate at maximum performance in a combat aircraft or at optimum fuel economy in a passenger carrying aircraft.

THE CONTROLPROBLEMS:

- The basic control action is to control a flow of air & fuel to the engine to allow it to operate at its optimum efficiency over a wide range of forward speeds, altitudes & temperatures whilst allowing the pilot to handle the engine without fear of malfunction.

- The degree of control required to a large extent upon the type of engine & the type of aircraft in which it is installed.
- The civil operator requires reliable, economical & long-term operation under clearly defined predictable conditions with minimum risk to passengers and schedules to obtain these objectives, control can be exercised over the following aspects of engine control;

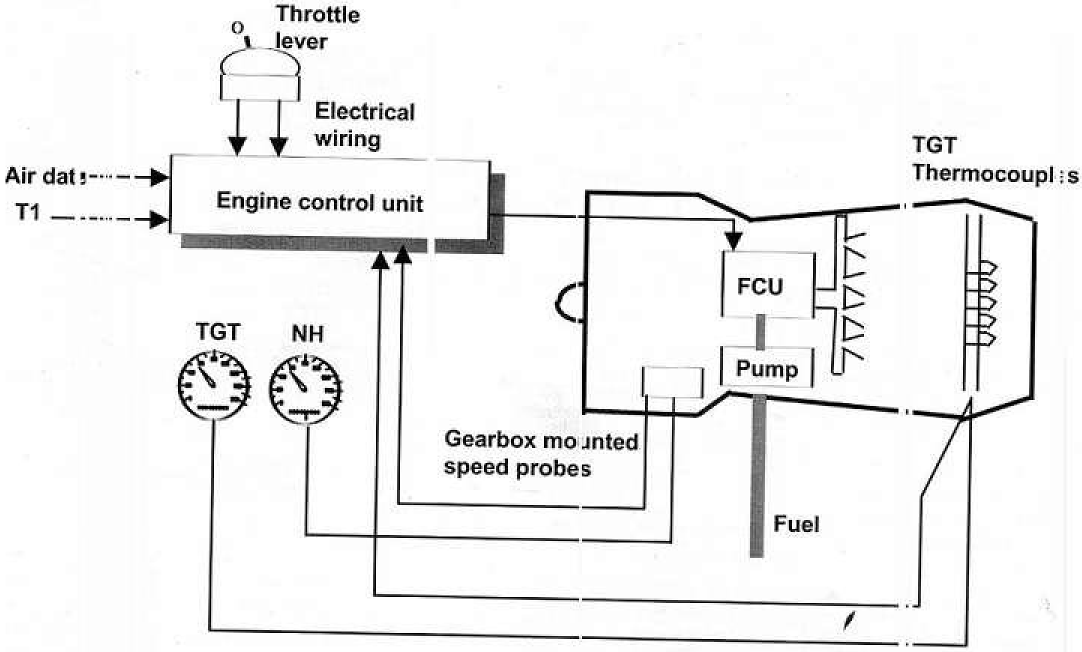
1. Fuel flow: - to allow varying engine speeds to be demanded and to allow the engine to be handled without damage by limiting rotating assembly speeds, rates of acceleration & temperatures.
2. Air flow: - to allow the engine to be operated efficiently throughout the aircraft flight envelope and with adequate safety margins.
3. Exhaust gas flow: - by burning the exhaust gases and varying the nozzle area to provide additional thrust.

TYPES:

Electronic control has been applied in all these cases with varying degrees of complexity and control authority. Such control can take the form of simple limiter functions through to sophisticated,

1. Multivariable control system.
2. Electronic engine control systems.
3. Full authority control systems.

ELECTONIC ENGINE CONTROL SYSTEMS: [EEC]



The need to control precisely the many factors involved in operation of modern high speed & by pass turbo fan engines & airliners.

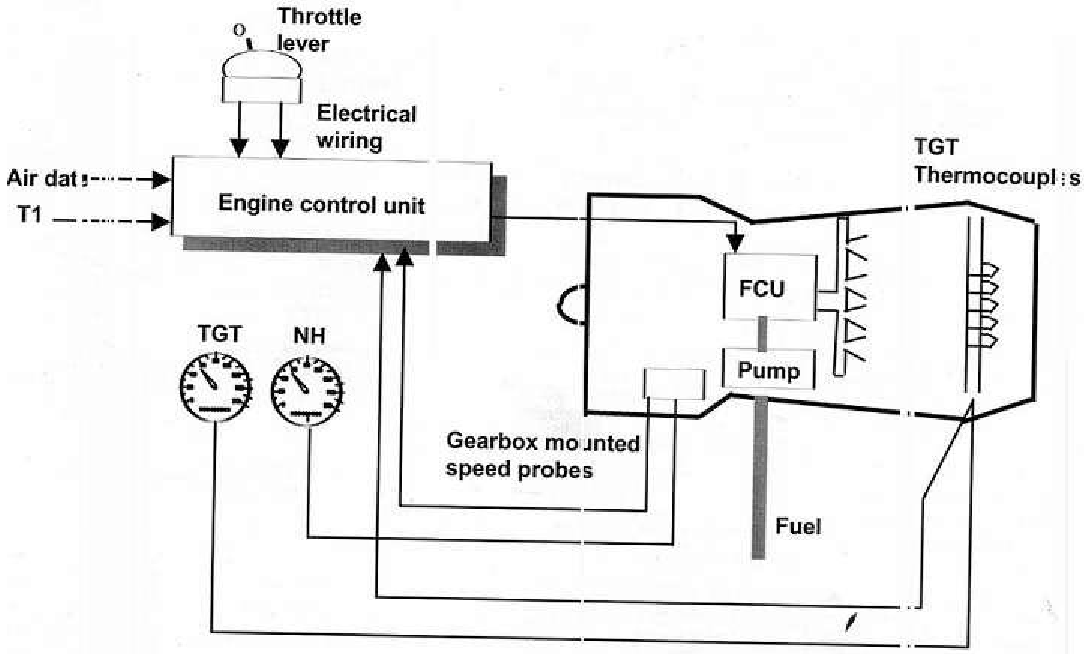
The manufacturers worked together to develop EEC system that prolong engine life, save fuel, improve reliability, and reduce flight crew workload & the maintenance cost.

<u>The two types of EECare</u>

1. Supervisory EEC.
2. Full authority EEC.

- The HFCU performs the functions necessary for engine operation & protection.
- By measuring exhaust gas pressure, thrust level angle, altitude data Mach number, inlet airflow, inlet air temperature & total air temperature it computes the requirement for flawless flight.
- The EEC is able to maintain constant thrust from the engine regardless of changes in air pressure & temperature and flight environment.

FULL AUTH O RI T Y DIGITAL ENGINE CONTROL SYSTEM: [FADEC]



- This control replaces previous hydro mechanical units, producing significant savings by precise and uniform control of power settings & other critical engine operating functions.

- This control does not employ any hydro mechanical computational elements. It performs the following functions
  1. Basic engine operation such as starting, acceleration, deceleration, speed governing, compressor vane and bleed scheduling.
  2. Engine operating & rating data.
  3. Fault detection.
  4. Indication of fault status for display & maintenance.

- It uses thrust lever position to determine the commanded 'T' setting parameter & modulates fuel flow to make the actual and commanded values equal.

- This system reduces flight crew workload, controls system components, and extends engine life.
- In addition provides increased engine fuel efficiency & allows improved integration & coordination of engine control and aircraft system.
- It assists in engine maintenance through its internal diagnostic capability, which is able to detect faults & generate maintenance messages that identify which control system components need to be repaired or replaced.
- This system will allow the same basic engine configuration to produce from 222400 N to 311360 N of thrust simply by changing the data entry plug for the control & the data plate for the engine.

FLIGHT CONTROL LINKAGE SYSTEM

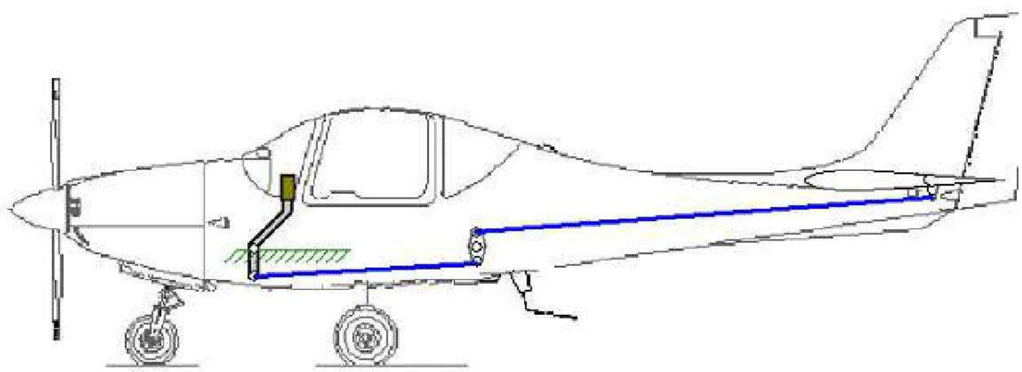
The pilot's manual inputs to the flight controls are made by moving the cockpit control column or rudder pedals in accordance with the universal convention:

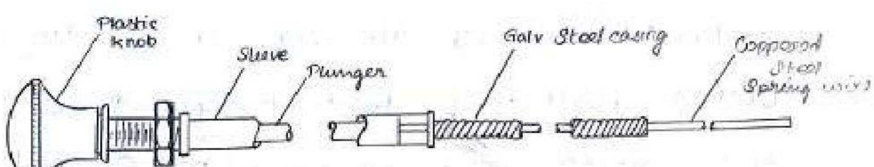
- Pitch control is exercised by moving the control column fore & aft.
- Moving the control column from side to side or rotating the control yoke achieves roll control.
- The rudder pedals control yaw.

There are presently two main methods of connecting the pilot's controls to the rest of the flight control system. These are;

1. Push-pull rod control system.
2. Flexible push-pull rod system.

PUSH-PULL ROD C O N T R O L SYSTEM





Push Pull control

- The following figure shows the simplified 3-d schematic of the Hawk 200 flight control, which is typical of the technique widely used for fighter aircraft.
- A push rod & lever system is a common form of remote control.
  Though actual mode of application may vary between aircraft constructions, but the same basic principles apply.
- The "push rods" are normally of tubular construction with either bell or fork end couplings to link them to the levers.
- One end of each rod is screwed so that its length can be adjusted accurately.
- The levers are usually light alloy stampings or forgings mounted on plain

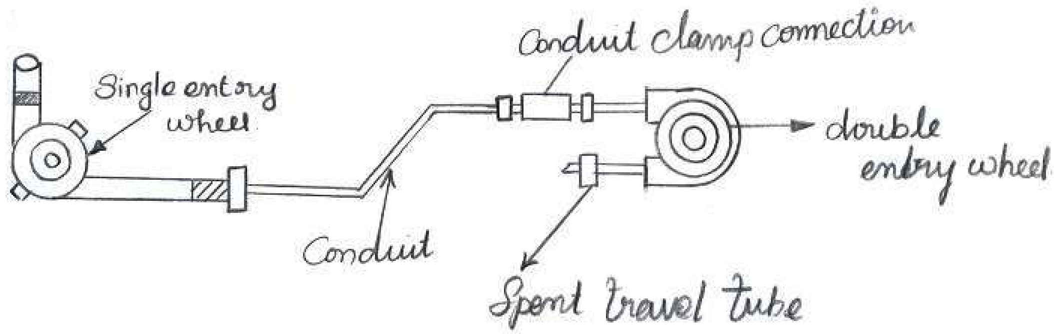
ball bearings.

- The lever and fittings are either ball or forked to suit the ends of the rods.
- One of the arms of each lever assembly may have its ends screwed to allow the length of the arm to be adjusted slightly.
- Some types of pushrod controls have springs loaded & fittings to eliminate play in the system.

- Push rods, levers & tubes can transmit both pull & push movements effectively without any loss.
- The direction of motion can be altered or changed by employing bell cranks mounted on by shafts.

FLEXIBLE PUSH PULL ROD S Y S T E M

TELE FLEX CONTROLS:

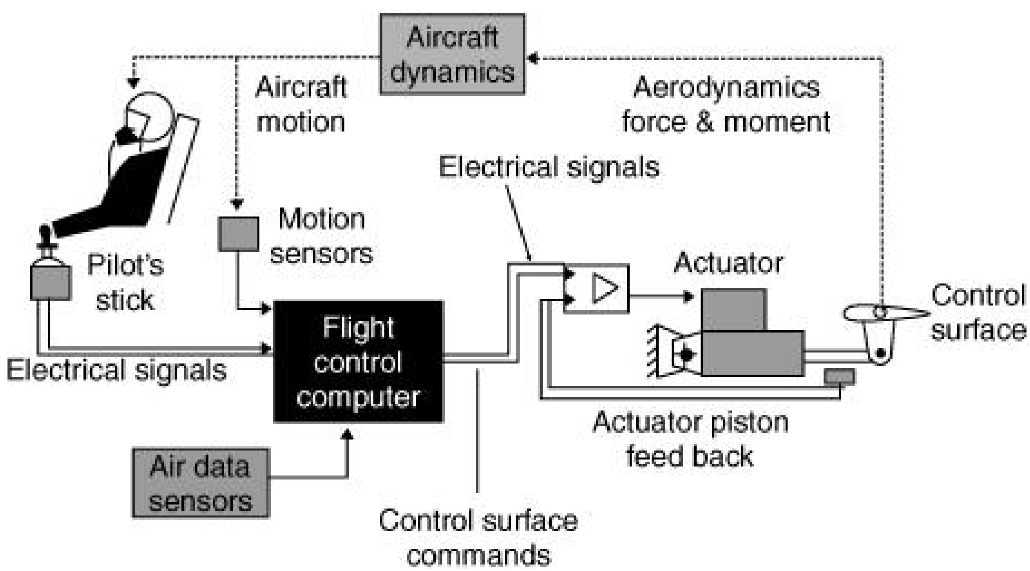


- The Teleflex control system of remote control is installed in aircraft to operate from the pilot cockpit, component such as engine and propeller controls, trimming controls and fuel valves and can be adapted for the indication of under carriage movement and

  position of flaps.
- These control system are not always Teleflex throughout, it may be instance cable, and chain or linkage is used for part of the control

  run in conjunction with Teleflex components for initial & final part.
- It is capable of relaying both pull & push motion, is basically a flexible cable transmitting cable working in a rigid conduit.

FLY – BY WIRE CONTROL SYSTEM

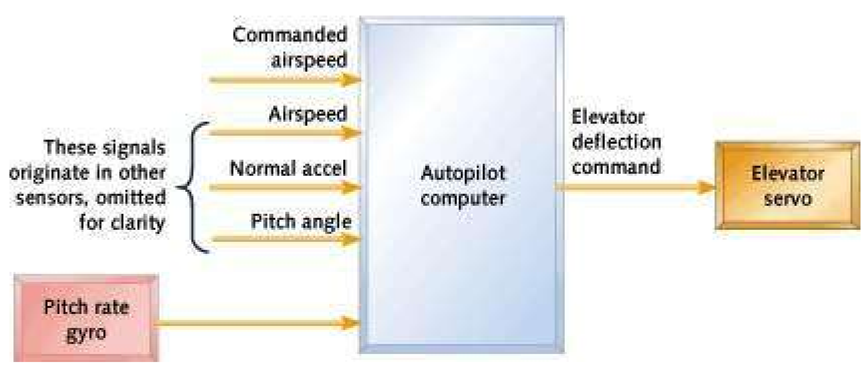


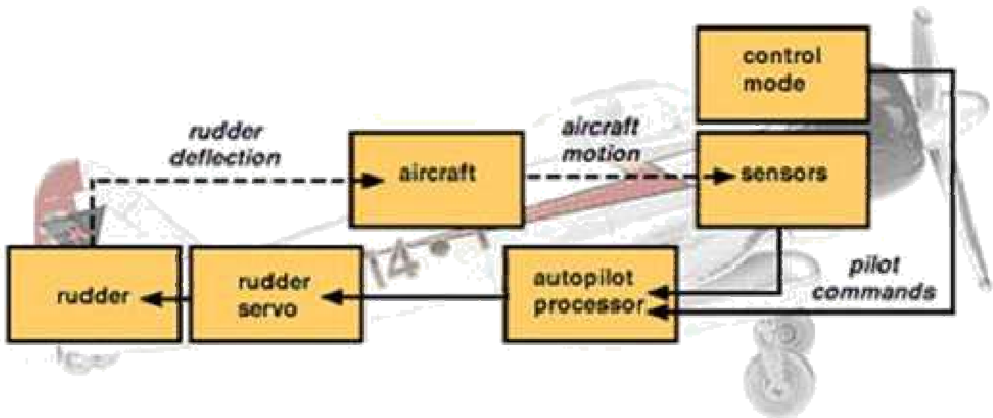
Fly-by-wire (FBW) is a system that replaces the conventional manual flight controls of an aircraft with an electronic interface. The movements of flight controls are converted to electronic signals transmitted by wires (hence the fly-by-wire term), and flight control computers determine how to move the actuators at each control surface to provide the ordered response. The fly-by-wire system also allows automatic signals sent by the aircraft's computers to perform functions without the pilot's input, as in systems that automatically help stabilize the aircraft.

Working:

- The Position Sensors produce electrical signals according to the information fed into them connecting the position of the cockpit controls. [Control Colu mn].
- These signals are also applied to a computer, which is already receiving the data concerning the Altitude & Airspeed of the Aircraft.
- The computer computes all the information applied to it & produces an Output signal, which is related not only to the control column movement but also the conditions under which the Aircraft is operating.
- The computed signals are Amplified & fed to a Quadruple Actuator.
- The Actuator is electrically controlled & hydraulically operated to reposition the Servo Valve controlling the PFCU.
- The PFCU then moves the control surface through its mechanical linkages.
- Under fault condition, the computer disengages; the system then reverts to direct electrical signalling from the sensors through the Amplifier to the Quadruple Actuator.
- With complete signalling failure, the electrical clutch disengages allowing the mechanical signalling of the servo valve through the Mechanical clutch.

AUTO PILOT SYSTEM





DEFINITION

The Autopilot or Automatic pilot is a system of automatic controls that holds the Aircraft on any selected magnetic heading & returns the Aircraft to that heading when it is displaced from it. The Automatic pilot also keeps the Aircraft stabilized around its horizontal & lateral axes.

PURPOSE:

The purpose of an Autopilot system is primarily to reduce the work strain & fatigue of controlling the Aircraft during long flights. It allows the pilot to manoeuvre the Aircraft with a minimum of manual operations. It provides for one, two or three axes control of the Aircraft.

PRINCIPLE: **Rate of disturbance = Rate of correction**

The autopilot system flies the Aircraft by using electrical signals developed in Gyro sensing units. These units are connected to flight instruments that indicate direction, rate of turn, bank or pitch. If the flight attitude or magnetic heading is changed, the electrical signals are developed in the Gyros. These signals are used to control the operation of the servo units, which convert the electrical energy into mechanical motion.

The servo is connected to the control surface & converts the electrical signals into mechanical force, which moves the control surface in response to corrective signals or pilot commands.

BASIC COMPONENTS:

All Autopilot system contain the same basic components,

1. The sensing elements. [Gyros]
2. The command elements.

3. The computing elements. [Amplifier]
4. The output elements. [Servos]

SENSING ELEMENTS: GYRO

The directional Gyro, turn & bank Gyro, Attitude Gyro & Altitude control Gyro are the sensing elements. These units sense the movements of the Aircraft & automatically generate signals to keep the movements in control.

COMMANDELEMENTS:

The command unit [flight controller] is manually operated to generate signals that cause the Aircraft to climb, dive or perform coordinated turns. Additional command signals can be sent to the Autopilot system by the Aircraft's navigational equipments. The Autopilot system is engaged or disengaged electrically or mechanically, depending on design.

COMPUTING ELEMENTS: COMPUTER OR AMPLIFIER

The computing element consists of an amplifier or computer. The amplifier receives signals, determines what action to the signals is calling for and amplifies the signals received from the sensing elements. It passes these signals to the Ailerons, Rudder & Elevators servo to drive the control surfaces to the position called for.

OUTPUT ELEMENTS: SERVO MOTORS

These are the servomotors, which actuate the control surfaces. The majority of the servos in use are either electric motors or electro pneumatic motors.

ENGINE SYSTEMS AND AUXILLIARY SYSTEMS

FUEL SYSTEM

INTRODUCTION:

- The aircraft fuel system is used to deliver fuel to the engines safely under a wide range of operational conditions.
- The system must have a means of safely holding the fuel, allow filling and draining of the tanks, prevent unwanted pressure build ups in the system, protect the system from contamination, and assure a steady supply of fuel to the engine.
- The system must also provide a means of monitoring the quantity of fuel on the aircraft during flight and, in some aircraft, a means of checking fuel pressures, temperatures, and flow rates.
- All these capabilities must be carried out without compromising the safety of the aircraft or its occupants.

REQUIREMENT FOR FUEL SYSTEMS:

- The purpose of a fuel system is to deliver a uniform flow of clean fuel under constant pressure to the carburetor or other fuel-control unit.
- This supply must be adequate to meet all engine demands at various altitudes and attitudes of flight.
- Recommended installations employ gravity-feed or mechanical pumping systems.
- The location of the various units in the fuel system must be such that the entire fuel supply, except that designated as unusable fuel, is available for use when the aircraft is in steepest climb, in the best angle of glide, or in any reasonable maneuver.
- Each fuel system must be constructed and arranged to ensure a flow of fuel at a rate and pressure established for proper engine and auxiliary power-unit functioning under each likely operating condition.
- Auxiliary power units are usually installed only in large transport-type aircraft.
- In case the certification of the aircraft involves unusual maneuver approval, the fuel system must perform satisfactorily during these maneuvers.
- Each fuel system must be arranged so that any air that may be introduced into the system as a result of fuel depletion in a tank will not result in power interruption for more than 20 s for a reciprocating engine and will not

cause the flameout of a turbine engine.

- To assure that fuel systems and components meet the requirements of applicable Federal Aviation Regulations, systems are tested under actual or simulated operating conditions.
- These tests involve the individual components as well as the complete system.
- Fuel system can be sub-divided into two sections,

1) Aircraft fuel system,
2) Engine fuel system.

AIRCRAFT FUEL SYSTEM

BASIC COMPONENTS OF AIRCRAFT FUEL SYSTEM

1) Fuel tank in which the fuel is stored for flight,
2) Fuel pump to supply the engine or engines when it is required.
3) Filters to ensure the fuel is clean for use.
4) On/Off cocks to isolate the fuel system or sections of it, when it is not in use.

COMPONENT DESCRIPTION:

FUELTANKS:

Fuel tanks are used to store the fuel for the aircraft until the engines use it. The following section discusses the requirements and components associated with fuel tanks to assure a proper supply of fuel for the engines.

FUELTANK REQUIREMENTS:

- Fuel tanks for aircraft may be constructed of aluminium alloy, fuel resistant synthetic rubber, composite rubber or stainless steel.
- The material selected for the construction of a particular fuel tank depends upon the type of aircraft.
- Fuel tanks and the fuel system, in general, must be made of materials that will not react chemically with any fuels stored in it.

TYPES OF FUELTANKS:

There are various basic types of fuel tanks designed for use in aircraft. The specific type chosen when designing the aircraft is a result of the available technology at the time the aircraft was designed, the size and the shape of the tank area, and the types of operations for which the aircraft is designed. The fuel tank construction can be divided into three basic types;

1. Integral type.
2. Rigid removal type.
3. Bladder type.

FUELPUMPS:

- Fuel pumps are used to move fuel through the fuel system when gravity flow is insufficient.
- These pumps are used to move fuel from the tanks to the engines, from tanks to other tanks, and from the engine back to the tanks.

FUELPUMP REQUIREMENTS:

- Fuel systems for reciprocating engines and turbine-engines require main pumps and emergency pumps. Reciprocating engine systems that are not gravity-fed require at least one main pump for each engine, and the pump must be driven by the engine.
- The pump capacity must be such that it supplies the required fuel flow for all operations.

TYPES OF FUELPUMP:

The types of fuel pump are;

1. Vane-type fuel pump.
2. Variable-volume pumps.
3. Centrifugal pump.
4. Ejector pump.

FUEL STRAINERS AND FILTERS:

- Because of the ever-present possibility of fuel contamination by various types of foreign matter, aircraft fuel systems are required to include fuel strainers and filters. The fuel is usually strained at three points in the system, first through a finger strainer; second through a master strainer, which is usually located at the lowest point in the fuel system; and third, through a strainer in the carburettor or near the fuel control unit.
- A fuel strainer or filter is required between the fuel-tank outlet and the inlet of either the fuel-metering device or an engine-driven positive displacement, whichever is nearer the fuel-tank outlet.

TYPES OF FUEL SYSTEMS:

All fuel systems can be classified in one of two broad categories;

1. Gravity-fees fuel system.
2. Pressure feed fuel system.

GRAVITY-FEED FUEL SYSTEM

- A gravity-feed fuel system uses the force of gravity to cause fuel to the engine fuel-control mechanism.

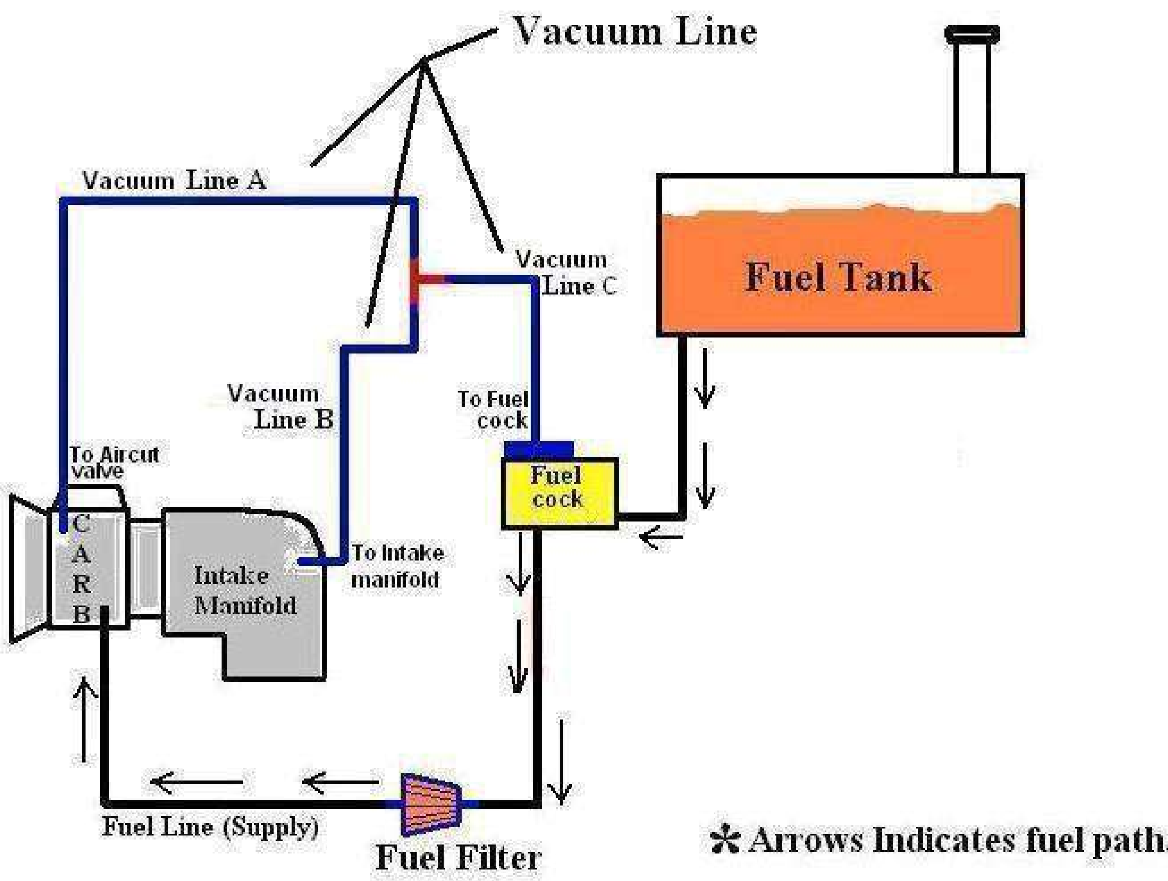
- For this to occur, the bottom of the fuel tank must be high enough to assure a proper fuel-pressure head at the inlet to the fuel-control component [carburettor] on the engine.
- In high-wing aircraft this is accomplished by placing the fuel tanks in the wings.

- In this example fuel flows by gravity from the wing tanks through the feed lines to the fuel-selector valve.

- After passing through the selector valve, the fuel flows through the fuel strainer and then continues on to the carburettor.

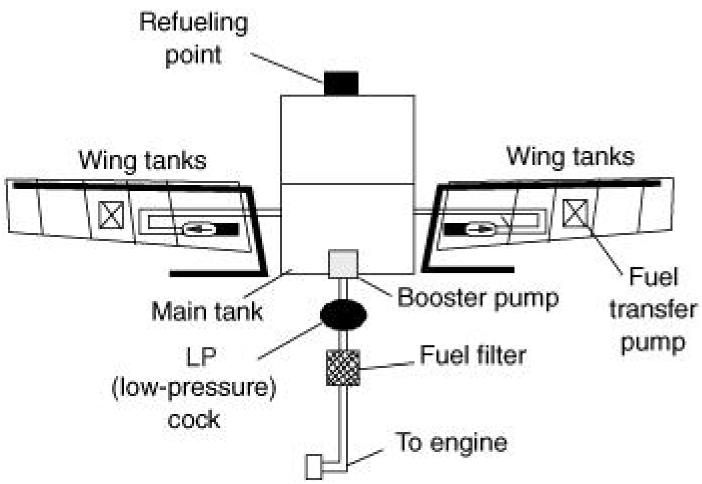
- Fuel for the primer is taken from the main fuel strainer.

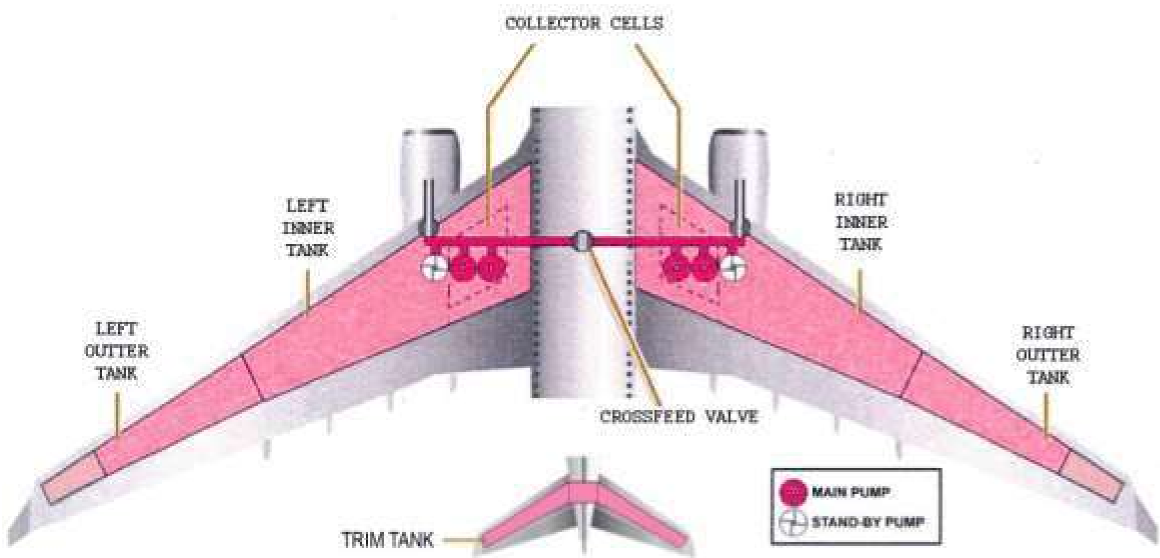
- Since both tanks may feed fuel to the engine simultaneously, the
- space above the fuel must be interconnected and vented outside of the wing, where the possibility of fuel siphoning is minimized.



Gravity Fed Fuel

PRESSURE FEED FUEL SYSTEM:





- A pressure-feed fuel system, a simple version of which is shown in figure. It uses a pump to move fuel from the tank to the engine- fuel-control component.

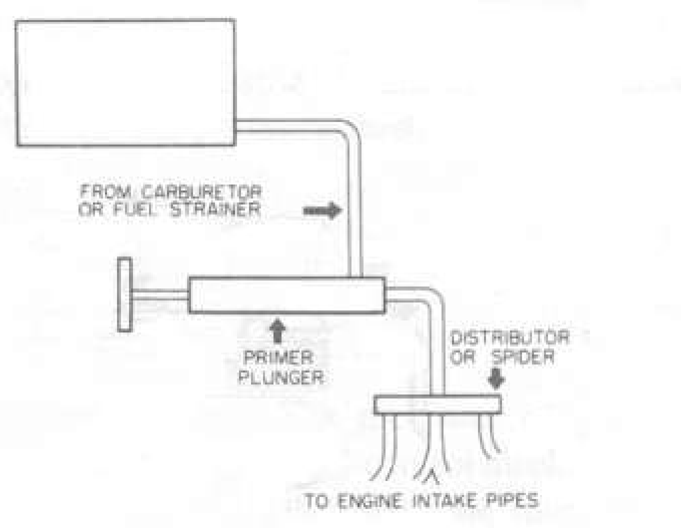
- This arrangement is required because the fuel tanks are located too low for sufficient head pressure to be generated or because the tanks are some distance from the engine.

- The system in figure is for a low wing aircraft, where the wing tanks are on the same approximate level as the carburettor.
- The fuel flows from the tanks through separate fuel lines to the fuel- selector valve.

- After leaving the selector valve, the fuel flows through the fuel strainer and into the electric fuel pump.
- Note that the engine-driven pump supplies the fuel pressure necessary for normal operation.

- During high-altitude operation, take-off, and landing, the boost pump is operated to ensure adequate fuel pressure.
- Most large aircraft and aircraft with medium-to-high powered engines require a pressure-feed system, regardless of fuel-tank location, because of the large volume of fuel that must be delivered to the engines at a high pressure.
- When reference is made to high pressure in the fuel-feed system, the value is on the order of 137.9, 206.9, 275.8 Kpa.

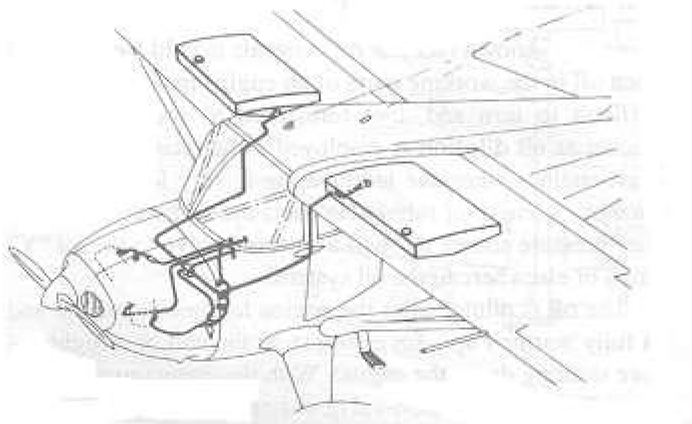
PRIMERS AND PRIMING SYSTEMS:



Priming system for a light aircraft engine.

Reciprocating aircraft engines must often be primed before starting because the carburetor does not function properly until the engine is running. For this reason it is necessary to have a separate system to charge, or prime, the cylinders with raw fuel for starting. This is accomplished by the priming system. The usual arrangement is to have the primer draw fuel from the carburetor inlet bowl or fuel strainer and direct it to a distributor valve, which, in turn, distributes the fuel to various cylinders.

LIGHT AIRCRAFT GRAVITY-FEED SYSTEM



Fuel system for a light single-engine airplane.

LIGHT AIRCRAFT PRESSURE-FEED SYSTEM

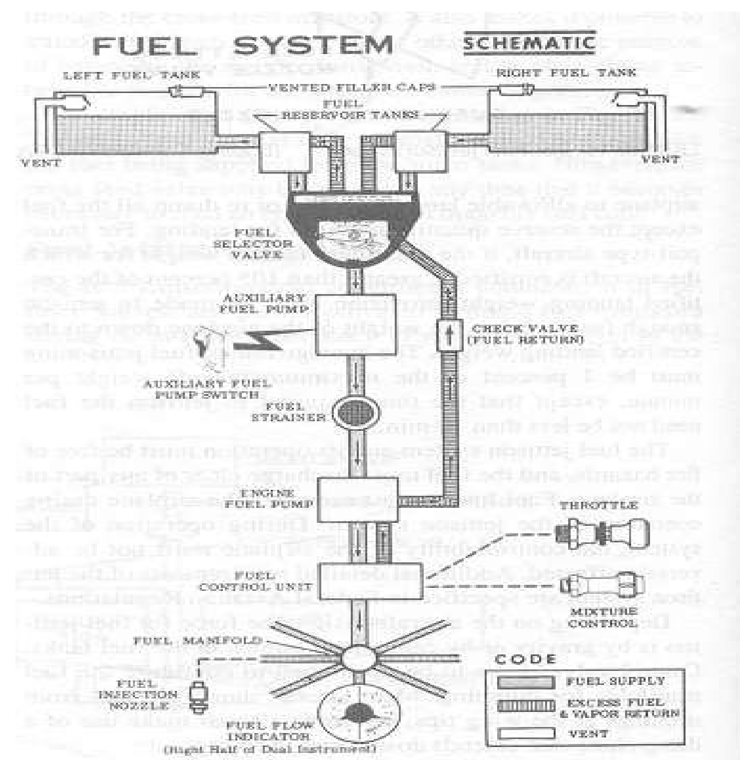


FIGURE 15–39 Fuel system for a high-performance single-engine aircraft. *(Cessna Aircraft Co.)*

FUEL SYSTEM FOR A GAS TURBINE ENGINE:

- The fuel system is utilized in a small turboprop aircraft consists of a center tank is an integral fuel tank divided into three compartments.
- Fuel in the two outboard main tanks flows by gravity through flapper valves into the center main tank.
- Fuel in the outer tanks must be transferred to the main tank before it can be used by the engines.
- This transfer is achieved by a submerged centrifugal pump in each outer tank.
- Fuel in the tip tanks is transferred to the main tank by pressurizing the tip tank with engine bleed air.
- All tanks are vented through the valves to vent exists on the underside of each wing.
- Two submerged centrifugal boost pumps are located in the main Center fuel tank.
- Fuel from these pumps is fed to a fuel manifold, through a shutoff valve for each engine, through fuel filters, and then to the engine pumps and the engine fuel-control units.
- Three fuel-quantity indicators are provided, one for the main tank, one dual-needle gauge for the outer tanks, and one dual-needle gauge for the tip tanks.
- A fuel-flow indicator is provided for each engine.
- A valve in each tip tank prevents over-or under pressurization and is used to depressurize the tank before fuelling.

NECESSARY DESCRIPTIONS:

- Aircraft fuel tanks in civil aircraft are normally located in the wings or fuselage.
- Fuel tanks may of rigid, flexible, integrated construction.
- Engine driven fuel pumps in the fuel system of piston engine aircraft are usually either:
    - Gear type,
    - Rotary vane type,
    - Diaphragm type.
- Aviation gasoline, which is used for piston engines, low lea content, and octane rating of 100, relative density, is 0.72.
- Aviation kerosene which is used for gas turbine engines and high flash point, relative density is -0.8

FUEL SYSTEM OF MULTI-ENGINE AIRCRAFT:

COMPONENTS:

Fuel Pump(engine driven)

It delivers a continues supply of fuel at the proper pressure an tat all times during the operation of aero engine it is capable of delivering maximum needed flow at high pressure to regulation. Fuel pump is divided to distinct two categories,

1) Contact displacement
2) Variable displacement.

Fuel Heater:

Gas turbine engine fuel systems are very susceptible to the formation of ice in the fuel filters when the fuel in the tank cools to 32° F (or) below residua water.

The fuel tends to freeze when it contacts filter screen.

The function of fuel heater is to protect the engine fuel system from ice formation.

Fuel filter:

Low-pressure filter which is between the fuel tank and the engine fuel system protects the engine driven fuel pump and various control devices.

High pressure filter between fuel pump and various control devices is to protect the fuel from contaminations

The three most common types of filters are

1) Micron,
2) Wafer,
3) Plain screen mesh filter.

The most common type used in units where filtering action is not so critical i.e., before the high pressure pump filters, the use of these three filters are dictated by the filtering treatment required at location.

Fuel Spray Nozzle:

- It injects fuel into the combustion area in a highly atomized precisely patterned spray so that burning is completed evenly and in the shortest possible time and in smallest possible space.
- This prevents the formation of any hot spot on the combustion chamber.

Two types of fuel spray nozzles are

1) Simplex,
2) Duplex.

Simplex which was the first type nozzle used in turbojet engine was replaced in most installations by Duplex. Duplex is most widely used in present Day Gas Turbine engine.

Flow divider:

- It is fitted inside the Duplex nozzle i.e., It is an integral part of duplex nozzle.

- It created the primary and secondary fuel supplies which are discharged through separate concentric spray tips thus providing proper spray angle at all fuel flows.

Fuel pressure and dump valves:

Pressure valve perform essentially the same function as a flow divider. The two major functions of this valve are,

1) During engine operation it divides metered fuel flow into two portions, primary and secondary, as required for atomization at the fuel nozzles.

2) At engine shut down it provides a dump system which connects the fuel manifolds to an overboard drain.

- They are units used for draining fuel from the various components of the engine where accumulated fuel is most likely to present operating problems.

- In some instances the fuel manifold are drained by an individual unit known as a drip/dump valve, operated by a pressure differential/solenoid.

Fuel Transmitter, Fuel quantity Indicator (resistance & capacitance), Fuel pressure Gauge, Fuel Temperature gauge, Fuel flow meter, Fuel selector valve /controlvalve/shut off valve.

AIRCRAFT ENGINE LUBRICATION SYSTEM

NEED FOR LUBRICATION

- There are many moving parts in an aircraft engine.
- Some reciprocate and others rotate, but regardless of the motion, each moving part must be guided in its motion or held in a given position during motion.

- The contacts between surfaces moving in relation to each other produce friction, which consumes energy.
- This energy is transformed to heat at comparatively low temperatures and therefore reduces the power output of the engine.
- Furthermore, the friction between moving metallic parts causes wear. If lubricants are used, a film of lubricant is applied between the moving surfaces to reduce wear and to lower the power loss.

LUBRICATION OIL REQUIREMENTS

The proper lubrication of aircraft engines requires the use of a lubricating oil which has the following characteristics;

- It should have the proper viscosity at the engine operating temperatures.

- It should have high anti-friction characteristics.
- It should have maximum fluidity at low temperatures.
- It should have minimum changes in viscosity with changes in temperatures.
- It should have high antiwear properties.
- It should have maximum cooling ability.
- It should offer the maximum resistance to oxidation.

ENGINE OIL FUNCTIONS

The engine oil performs these functions;

- It lubricates, thus reducing the friction between moving parts.
- It cools various parts of the engine.
- It tends to seal the combustion chamber by filling the spaces between the cylinder walls and piston rings, thus preventing the flow of combustion gases past the rings.
- It cleans the engine by carrying the sludge and other residues away from the moving engine parts and depositing them in the engine oil filter.
- It aids in preventing corrosion by protecting the metal from oxygen, water, and other corrosive agents.
- It serves as a cushion between parts where impact loads are involved.

PISTON ENGINE LUBRICATION SYSTEM:

The piston engine lubrication is classified into two broad categories;

- Wet sump lubrication engine.
- Dry sump lubrication system.

OIL SYSTEM FOR WET-SUMP ENGINE:

- The lubrication system for the continental IO-470-D engine is shown
- Lubricating oil for the engine is stored in the sump, which is attached to the lower side of the engine.
- Oil is drawn from the sump through the suction oil screen, which is positioned in the bottom of the sump.
- After passing through the gear type pump, the oil is directed through the oil filter screen and along an internal gallery to the forward part of the engine where the oil cooler is located.
- A bypass check valve is placed in the bypass line around the filter screen to provide for oil flow in case the screen becomes clogged.
- A non-adjustable pressure relief valve permits excess pressure to return to the inlet side of the pump.
- Oil temperature is controlled by a thermally operated valve which
- either causes the oil to bypass the externally mounted cooler or routes it through the cooler passages.

OIL SYSTEM FOR WET-SUMP ENGINE

- Drilled and cored passages carry oil from the oil cooler to all parts of the engine requiring lubrication.
- Oil from the system is also routed through the propeller for control of pitch and engine rpm.
- The oil temperature bulb is located at a point in the system where it senses oil temperature after the oil has passed through the cooler.
- Thus, the temperature gauge indicates the temperature of the oil before it passes through the hot sections of the engine.
- The lubrication system may be equipped with provision for oil dilution.
- A fuel line is connected from the main fuel strainer case to an oil dilution solenoid valve mounted on the engine fire-wall.
- From the solenoid valve a fuel line is routed to a fitting on the engine oil pump.
- When the oil dilution switch is closed, fuel flows from the fuel strainer to the inlet side of the oil pump.

OIL SYSTEM FOR DRY-SUMP ENGINE:

- The system is called a dry-sump system because oil is pumped out of the engine into an external oil tank.
- In this system oil flows from the oil tank to the engine-driven pressure pump.
- The oil temperature is sensed before the oil enters the engine; that is, the temperature of the oil in the oil-in line is sensed, and the information is displayed by the engine oil temperature gauge.
- The pressure pump has greater capacity than is required by the engine; therefore, a pressure relief valve is incorporated to bypass excess oil back to the inlet side of the pump.
- A pressure gauge connection, or sensor, is located on the pressure side of the pressure pump to actuate the oil pressure gauge.
- The oil screen is usually located between the pressure pump and the
- engine system.
- Oil screens are provided with bypass features to permit unfiltered oil to flow to the engine in case the screen becomes clogged, since unfiltered oil is better than no oil.
- After the oil has flowed through the engine system, it is picked up by the scavenge pump and returned through the oil cooler to the oil tank. The scavenge pump has a capacity much greater than that of the pressure pump, because the oil volume it must handle is increased as a result of the air bubbles and foam entrained during engine operation.
- The oil cooler usually incorporates a thermostatic control valve to bypass the oil around the cooler until the oil temperature reaches a proper value.
- To prevent pressure build up in the oil tank, a vent line is connected from the tank to the engine crankcase.
- This permits the oil tank to vent through the engine venting system. Check valves are employed in some systems to prevent oil from flowing by gravity to the engine when the engine is inoperative.

LUBRICATION SYSTEM OF GAS TURBINE ENGINES:

- Gas turbine engines have been designed and manufactured in many different configurations; thus, there are correspondingly different designs for the lubrication systems of such engines.

- There are three basic oil-lubricating systems, known as a pressure relief valve system, a full-flow system and a total loss system.
- The major difference lies in the control of oil flow to the bearings.

IGNITION SYSTEM

The function of the ignition system is to supply a spark to ignite the fuel/air mixture in the cylinders.

BATTERY IGNITION SYSTEM:

- Few aircraft and most automobiles use a battery ignition system which has a battery or generator rather than a magneto as its source of energy.
- In the battery ignition system, a cam which is driven by the engine opens a set of points to interrupt the flow of current in a primary circuit.
- The resulting collapsing magnetic field induces a high voltage in the secondary of the ignition coil, which is directed by a distributor to the proper cylinder.

MAGNETO IGNITION SYSTEM:

- It is superior to battery ignition because it produces a hotter spark at high engine speeds and it is self contained unit, not dependent on any external source of electrical energy.
- The magneto, a special type of engine driven a.c. generator uses a permanent magnet as a source of energy.
- It develops a high voltage that forces a spark to jump across the spark plug gap in each cylinder.
- Magneto operation is timed to engine so that spark occurs only when the piston is on the proper stroke at specified no. of crank shaft degrees before the TDC piston position.

It is classified into two,

1) Low tension magneto system,
2) High-tension magneto system.

- Low-tension magneto system generates low voltage and high-tension magneto system generates high voltage.
- High-tension magneto system is older of the two systems. Low- tension magneto system eliminates some problems inherent in the high-tension

magneto system during high altitudes, all weather condition operation and more no. of cylinders per engine, flashover and radio radar communication interference.

LOW TENSION MAGNETO SYSTEM:

- The figure represents a simplified schematic of a typical low-tension system.
- Electronically, Low-tension system is different from high-tension system.
- In low-tension system, low voltage is generated in the magneto and flows to the primary winding of transformer coil through the distributor.
- In transformer, the voltage is increased to a high voltage by transformer action and conducted to the spark plug by very short high-tension leads.
- Low tension system normally eliminates flashover in both the distributor and ignition harness because the "Air caps" within the distributor have been eliminated by use of brushed type distributor and high voltage is present only in short leads between the transformer and spark plug.
- Electrical leakage is considerably reduced because the current throughout the most of the low-tension system is transmitted at a low voltage potential.

The various componentsof the ignition systems are

1) Ignition switch,
2) Magneto
3) Distributor
4) Transformer
5) Spark plug.

AUXILARY IGNITION UNITS:

During engine starting output of magneto is low because of the cranking speed of the engine is low; here lesser the amount of induced voltage produced by the magneto.

AIO is employed in order to provide a high ignition voltage there by facilitate engine starting.

The variousauxiliary ignition limits are

1) Booster coil,
2) Induction vibrator,
3) Impulse coupling.

SPARK PLUG:

The purpose is to conduct a short impulse of high voltage current through the wall of the combustion chamber.

The main components are

1) Outer shell,
2) Insulator,
3) Electrode.

JET ENGINE IGNITION SYSTEM:

- It is required only for starting the engine.
- Once combustion has begun, the flame is continuous; it is more trouble free than piston engine ignition system.
- Most turbojet engines are equipped with a high-energy capacitor type o (or) electronic type ignition system.

ELECTRONIC IGNITON SYSTEM:

- This system consists of a dynamotor (or) regulator filter assembly, an exciter unit; two high-tension transformer units tow high-tension beds, tow igniter plugs and necessary control switches and equipment for operation in an aircraft.
- The dynamotor is used to step up the direct current f aircraft battery (or) the external owner supply to the operation voltage of the exciter unit.
- The voltage is used to charge two storage capacitor (located inside the excite unit) which store the energy to be used for ignition purposes.
- The voltage across these capacitors is stepped up by the transformer unit.
- At the instant of ignition plug firing. To resistance of gap is lowered sufficiently to permit the larger capacitor to across the gap.
- The discharge of second capacitor is used of low voltage but of very high energy.
- The result is a spark of great heat intensity; capable not only of igniting abnormal mixtures but also of burning away any foreign deposits on the plug electrodes.
- The exciter is dual unit and it produces spark at each of the two-igniter plugs. A continuous series of spark is produced until the engine stars.
- The battery current is then cut-off, and the plug does not fire while the engine is operating.

STARTING SYSTEM FOR PISTON ENGINE:

Before starting an engine,

1) Position the aircraft to lead in to the prevailing wind to endure adequate airflow over the engine.
2) Make sure that no damage or personal injury will occur from the

propeller.

DIRECT CRANKING ELECTRIC STARTER:

- This type of starter provides instant and continual cranking when energized.
- The direct cranking electric starter consists of an electric motor, reduction gears and automatic engaging-disengaging mechanism, which is operated through an adjustable torque overload release clutch.
- The engine is cranked directly when the starter solenoid is closed.
- The main cables leading from the starter to the battery are heavy high current flow, which may be as high as 350 amperes.
- The typical starter motor is a 12V or 24V series wound motor, which develops high starting torque.
- The torque of the motor is transmitted through reduction gears to the overload release clutch.
- This action actuates a helically splinted shaft moving he starter jaw outward engage the engine cranking jaw before the starter jaw begins to rotate.
- After the engine reaches a predetermined speed, the starter automatically disengages.

TO START THE ENGINE:

1) Turn the auxiliary "fuel pump" ON.
2) Place the mixture control to the position recommended for the engine.
3) Open the throttle to a position that will provide 1000 to 1200rpm.
4) Energize the starter after the propeller has made at least two complete revolutions and turn the ignitions switch on.

STARTING TORQUES OF ENGINE:

- The turning moment necessary to turn the crankshaft of an aircraft engine depends upon no. of factors:
  - Power rating of the engine, i.e., 150 to 200Hp.
  - The cranking speed,
  - The temperature of the engine.
  - The throttle opening.
- In general, the starting torque increased with Hp of the engine, the cranking speed and throttle opening.
- The torque required to rotate the crank shaft from rest with the throttle nearly closed varies from about
  - 40 lbs.ft for engine of 200 to 300 Hp.
  - 120 lbs.ft for engine of 600 to 700 Hp.
- The starting torque increases as the engine temperature falls from normal air value 15°c to 20°c down to freezing point viscosity. The electric motor is designed to crank the engine for which it is selected through a reduction gear ratio of 90:1, continually from12 or 24 volt battery.
- It has also a hand turning gear shaft coupling with a gear reduction ratio 18:1

GAS TURBINE STARTING SYSTEM

Two separate systems are required to ensure that a G.T.E. will start satisfactorily.

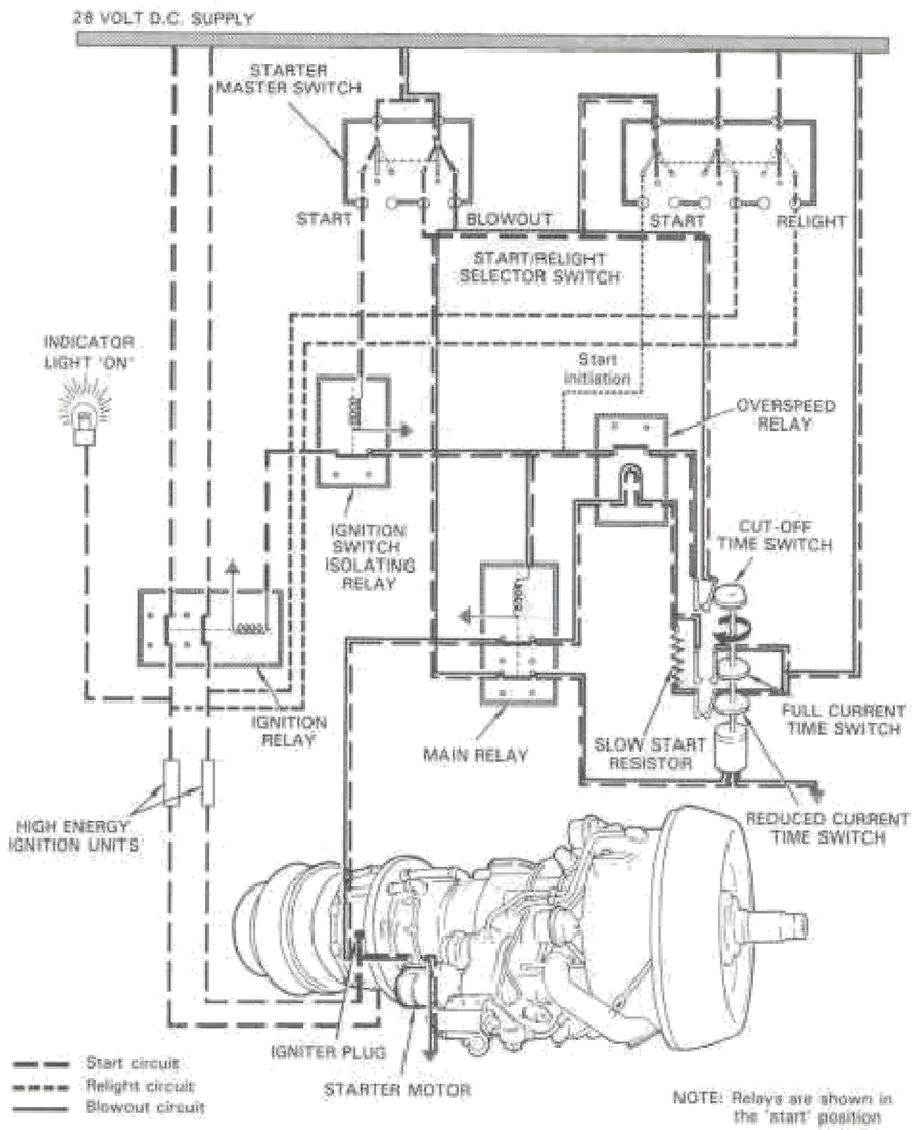
- Provision must be made for the compressor and Gas Turbine to rotate up to a speed at which adequate air passes into o the combustion system to mix w it h fuels.
- Provision must be made for ignition of the air/fuel mixture in the combustion system.
- During engine starting the two systems must operate simultaneously. Sequence of events during the start of a turbo jet engine:
- The starting procedure for all jet engines is basically the same, but can be achieved by various methods.
- The type and power source for the starter varies in accordance engine and aircraft requirements.
- Commercial aircraft requires the engine to be started with the minimum disturbance to the passengers by the economical means.
- Whichever system is used reliability is prime importance. The starter motor produces a high torque and transmits to the engine

TYPES OF STARTERS:

- Electrical starter,
- Cartridge starter,
- Isopropyl Nitrate starter,
- Air starter,
- Gas Turbine starter.

ELECTRICAL STARTER:

- The electric starter is usually a D.C. electric motor coupled to the engine through a reduction gear and clutch, which automatically disengages after the engine has reached a self-sustaining speed.
- The electric supply may be of low or high voltage and is passed through a system of relays and resistance to allow the full voltage to be progressively built up as the starter gains seed.
- The electrical supply is automatically cancelled when the started load is reduced after the engine has satisfactorily started.



Low-voltage electric starting system. (Rolls-Royce)

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CARTRIDGE STARTER:

- Sometimes used on military engine and provide a quick methods of staring.
- The starter motor is basically a small impulse type turbine that is driven by high velocity gases from a burning cartridge.
- The power output of the turbine is passed through a reduction gear and automatic disconnect mechanism to rotate the engine.

ISOPROPYL NITRATE:

- It has a turbine that transmits power through a reduction gear to the engine.

- The turbine is rotated by high-pressure gases resulting from the combustion of isopropyl nitrate.

AIR STARTERS:

- Air starting is used on most commercial aircraft, advantages are light weight and simple and most economical to operate.

- Air starter motor transmits power through a reduction gear and clutch to the starter output shaft, which is connected to the engine.
- The starter turbine is rotated by air taken from an external ground supply auxiliary power unit (or) cross feed from a running engine.

GAS TURBINE STARTER:

- G.T.Starter is used for some jet engines and is completely self-contained. It has its own fuel, ignition, and starting and oil system.
- This type of starter is economical to operate and provides a high power output for a low weight.

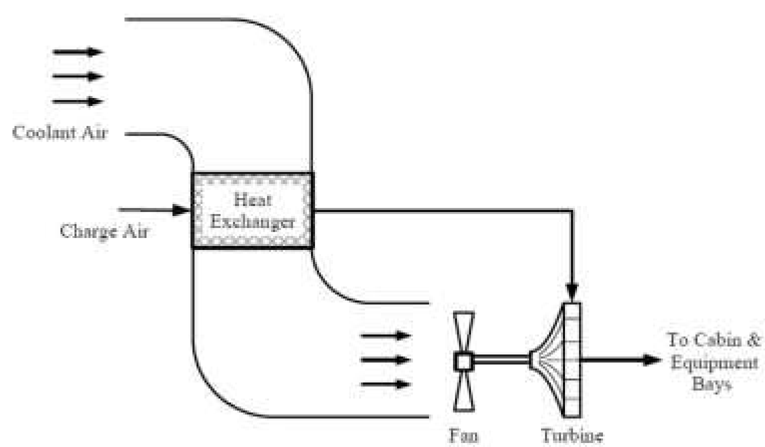
AUXILLIARY SYSTEMS

BASIC AIR CYCLE SYSTEM

The basic principle is that energy (heat) is removed by a heat exchanger from compressed air which then performs work by passing through a turbine which drives the compressor, and hence energy is transferred resulting in a reduction in temperature and pressure. The resultant air is then at a temperature (and to a small extent pressure) below that at which it entered the compressor. Air cycle refrigeration systems are used to cool engine bleed air down to temperatures required for cabin and equipment conditioning. Since engine bleed air is generally available, air cycle refrigeration is used because it is the simplest solution to the cooling problem, fulfilling both cooling and cabin pressurization requirements in an integrated system. However, although lighter and more compact than vapor cycle, air cycle systems have their limitations. Very large air flows are required in high heat load applications which require large diameter ducts with the corresponding problems of installation in the limited space on board an aircraft. Large engine bleed flows are detrimental to engine performance and large aircraft drag penalties are incurred due to the need for ram air cooling.

Turbofan System

This will typically be used in a low-speed civil aircraft where ram temperatures will never be very high. A typical turbofan system is illustrated



Turbofan cooling system

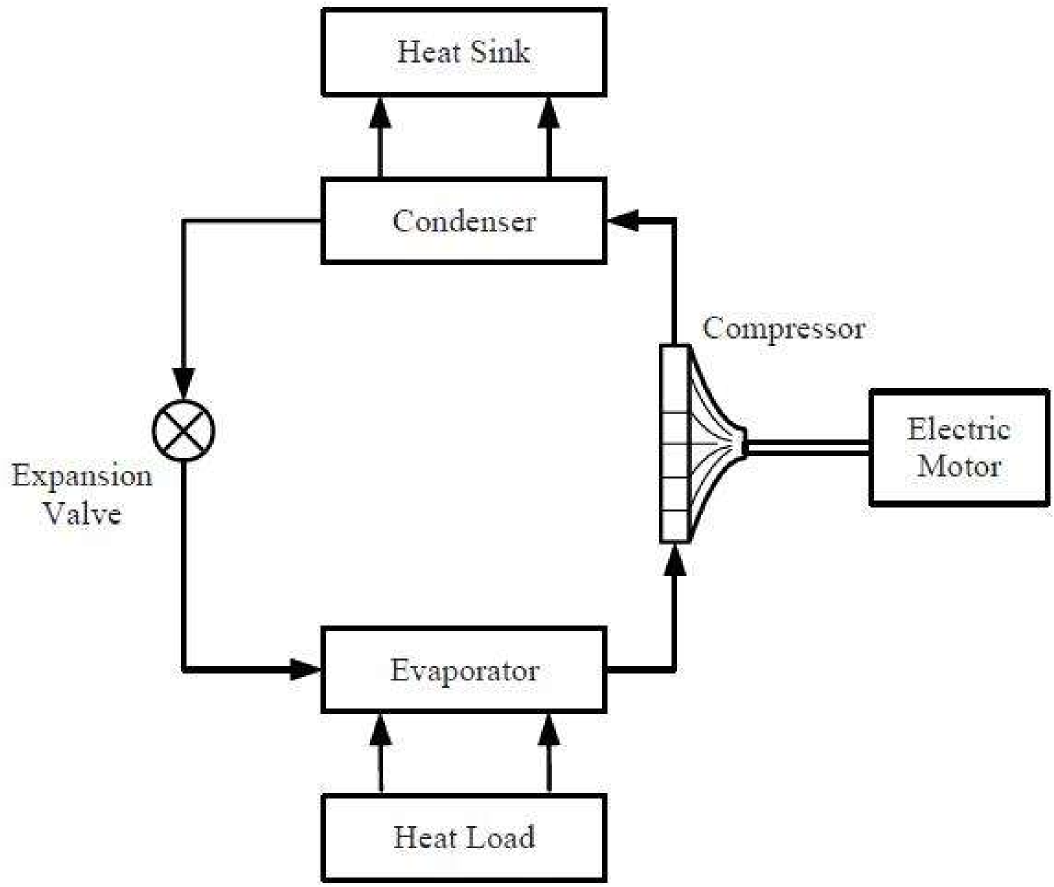
AIR-CYCLE COOLING:

- Modern large turbine-powered a/c makes use of air-cycle machines to adjust the temperature of the air directed into the passenger and crew compartments of this large a/c
- Although this topic of discussion of air-cycle system is directed to the ability to provide cabin-cooling air, it should be noted that the cabin could also be heated and pressurized by the use of an air-cycle system.
- This large a/c utilizes air-cycle cooling because of its simplicity, freedom from troubles, and economy.
- In these systems the refrigerant is air.
- Air-cycle cooling systems utilize the same of gases involved in vapor-cycle systems.
- One principal difference is that the air is not reduced to a liquid, as is the refrigerant in a vapor-cycle system.

PRINCIPLE OF COOLING :

- The principle of cooling by means of a gas is rather simple. When the gas (air) is compressed, it becomes cooled.
- If a pressure cylinder is connected to an air compressor and compressed air is forced into the cylinder, one can observe that the cylinder becomes warm or even hot, depending upon the level of compression and the rate at which the air is compressed.
- If the cylinder filled with highly compressed air is then allowed to cool to ambient temperature, the pressure in the cylinder will be reduced to a certain degree as the air is allowed to escaping will be much lower than the ambient temperature, due to the air expanding as its pressure returns to the ambient value.
- This cold air can then be used as a cooling agent.
- In air cycle system, the air is continuously compressed and then cooled by means of heat exchangers through which ram air is passed then the pressure is reduced by passing the air through the expansion turbine.
- The air is leaving expansion turbine is at low pressure and temperature.
- The cooled air is directed through ducting with control valves to regulate the amount of cooling air needed to produce the desired temperature.

VAPOUR CYCLE COOLING SYSTEM:



Vapour cycle cooling system

- The vapor-cycle air conditioning system is used in reciprocating engine powered aircraft and in smaller turboprop aircraft that does not make use of air-cycle machine to reduce the cabin interior temperature.

- The operation of vapor-cycle machine is controlled by the pilot and may incorporate automatic cutout or interrupt systems, which are used to damage the refrigerant compressor during demand for high engine power output, such as during take-off operation allows all available power to be used to maintain controllable flight.

- In aircraft basic science, where the nature of gases is discussed, it is shown that the temperature of a gas is directly proportional to its pressure and/or volume.

- In addition, as heat is added to a solid, it becomes liquid and then a gas, conversely, as heat is extracted from a gas, it becomes a liquid and then solid.

PRICIPLES USED:

1. As liquids change to a gas, they absorb heat, called the latent heat of vaporization.
2. As a given quantity of gas is condensed to a liquid, it emits heat in the same amount that it absorbs when being changed from liquid to a gas.
3. When a gas is compressed, its temperature increases and when the pressure on the gas on decreased its temperature decreases.
4. Another law of science used in the vapor-cycle cooling system is that when two materials have difference temperature and heat is free to flow between them, they will attempt to equalize.
5. Heat transfers only from a material having a given temperature, to a material having a lower temperature.

MECHANISM:

- A vapor cycle cooling system takes the advantage if the above said laws of nature using two heat exchangers to control the temperature of the cockpit and cabin.
- One heat exchanger takes the heat from the closed system called evaporator. The other draws heat from the air and adds it to the closed system called a condenser.
- The refrigerant is a special fluid called Freon, which takes two forms liquid and gas.
- The cooling process starts at the compressor, which pushes the refrigerant under pressure through the entire system.
- As the gas enters the condenser, heat is drawn from the refrigerant and passed to the atmosphere. The cooling of the refrigerant causes it to condense into a liquid. Because of compressor, this liquid is under pressure.
- The pressurized liquid is then metered into tiny droplets by an expansion valve. Because of the change in the form, the pressure past the expansion valve is lowered.
- The droplets then enter the evaporator, where they draw heat from the air and then change into a gas.
- As a result of heat being drawn from the air, its temperature is decreased; it is this cooler air that is introduced into the cabin for cooling.
- A more detailed description of vapour-cycle system components follows.
- An actual system includes controlling devices to provide for changes in cooling demand and changes in operating conditions

OXYGEN SYSTEMS:

- Oxygen systems are required on aircrafts that fly for extended periods at altitudes substantially above 10,000 ft.
- Although the normal human body can survive without a special supply of oxygen at altitudes of over 15000 ft, the mental and physical capacities of a human being are reduced when the usual supply of oxygen is not available in the air.
- It is particularly important that the pilot and crew of an aircraft have an adequate supply of oxygen when operating an unpressurized aircraft at altitudes in excess of 10000 ft.
- A lack of oxygen causes a person to experience a condition called hypoxia.
- This condition results in light-headedness, headaches, dizziness, nausea, unconsciousness, death depending upon its duration and degree.
- When permanent physical damage results from lack of oxygen, the condition is defined as anoxia.
- The importance of oxygen, especially when flying at higher altitudes, is not appreciated by many persons who fly, including pilots.
- It is generally known that the human body requires oxygen to sustain life, but the effects of a lack of sufficient oxygen on various functions of the body are not understood by many persons.

TYPES OF OXYGEN SYSTEMS:

Oxygen systems classified according to source of oxygen supply may be described as

1. Chemical or solid state.
2. Stored gas.
3. Liquid oxygen (LOX) systems.

- For private and commercial aircraft or of stored gas or chemical type.
- LOX systems are limited to military aircrafts.
- Oxygen systems may also be portable and fixed.
- The fixed system is permanently installed in airplane where a need of oxygen exists at any time during flight at high altitudes.
- Commercial airplanes are always equipped with fixed systems, augmented by a few portable units for crewmembers, who must be mobile and for emergency situations
- Oxygen systems are also classified according to the type of regulator that controls the flow of oxygen.

CONTINUOUSFLOW TYPE:

Majority of oxygen systems are of this type the regulator on the oxygen supply provides the continuous flow of oxygen to the mask. the mask valving provides for mixing of ambient air with the oxygen during breathing process.

DEMAND&DILUTEREGULATORS:

These regulators are used with demand mask and supply oxygen- using inhalation when the individual inhales; it causes a pressure reduction in a chamber with regulator. This reduction in pressure activates oxygen valve and supplies oxygen to the mask. The demand mask covers most of users face and creates an airtight seal. This why a low pressure is created when the user inhales.

PRESSUREDEMANDREGULATOR:

Such regulator contains an aneroid mechanism, which automatically increases the flow of oxygen into mask under positive pressure. This type of equipment is normally used at altitudes

above 40,000ft. A pressure demand mask must be worn with a pressure-demand regulator .by action of special pressure- compensating valves, the mask provides for a buildup of oxygen pressure from the regulator and creates the required input of oxygen into the lungs.

PARTS OF AN OXYGEN SYSTEM:

1. Oxygen bottles.
2. Regulators.
3. Oxygen masks.

OXYGEN BOTTLES:

Oxygen cylinders, also called as oxygen bottles, are the containers used to hold the a/c gaseous oxygen supply. The cylinders may be designed to carry Oxygen at a high or low pressure.

High-pressure cylinders are designed to contain oxygen at a pressure of approximate 1800psi. They are usually green in color. Low-pressure cylinders are painted yellowish and are designed to store oxygen at a maximum of 450psi.

There are several type of cylinder valves

1. The hand wheel type as a wheel on the top if the valve and operates like a water faucet

2. Another type of valve is of the self-opening design when the valve is attached to the oxygen system; a check valve is moved off of its seat allowing the cylinder to charge the system

3. A third type of valve is uses a cabin operated push-pull control to operate the control lever on the top of the valve. This eliminates the necessity of always of oxygen system charged but allows the pilot to activate the system whenever needed.

Oxygen cylinders are often fitted with safely disks, which rupture if the pressure in the cylinder becomes too great (which is due to
high ambient air temperature heating the cylinder).

REGULATORS:

Regulators for the pressure and flow of oxygen are incorporated in stored-gas systems because the oxygen is stored in high-pressure cylinders under pressures of 1800psi or more. The high pressure must be reduced to a value suitable for application directly to a mask or to a breathing regulator. This lower pressure is usually in the range of 279 and 517 kpa, depending upon the system.

OXYGEN MASKS:

Oxygen masks vary considerably in size, shape and design; however each is designed for either a demand system or a continuous flow system. A mask for a demand system must fit the face closely, enclosing both the mouth and nose and must form an airtight seal with the face. A mask for a constant-flow system is designed so that some ambient air is mixed with the oxygen. The complete mask usually includes an oronasal face piece; a reservoir bag, valves, a supply hose and a coupling fitting some models include a flow indicator in the supply hose.

COOLING PACKS.

- The cooling of air for this model of the Boeing 727 aircraft is provided by means of two cooling packs.
- These packs also remove excess moisture from the air.
- With the exception of the water separator, which is located in the distribution bay, all cooling-pack equipment is contained inside the center fuselage fairing.
- The cooling devices used in the cooling packs consists of a primary heat exchanger, a secondary heat exchanger, and an air-cycle system. ACS.
- The heat exchangers are of the air-to-air type, with heat being

transferred from the air going through the packs to air going through the ram air system.

- The ACS consists of a turbine and a compressor.
- Air expanding through the turbine drops in temperature as the energy is extracted for the major cooling pack, as explained previously.
- An air-cooling pack is shown in the figure 16-28.
- In the drawing it can be seen that engine bleed air passes through the preliminary heat exchanger for initial cooling, then through the air-cycle system compressor, through the secondary heat exchanger, and then through the expansion turbine of the air-cycle system.
- At this point the air is at its lowest temperature, since the heat energy has been extracted by means of the heat exchangers and the expansion turbine.
- Protection from overheat and the over speed of the air-cycle system is provided by two thermal switches.
- One thermal switch senses compressor discharge temperature to close the pack valves when an overheat condition exists.
- The other thermal switch, located in the turbine inlet duct, closes the pack valves to prevent over speed.
- As the air-cools, its moisture content condenses.
- The moisture is atomized so finely, however, that it will stay in suspension unless a special moisture-removing device is employed.
- This is the function of the water separator.
- Moisture entering the water separator is prevented from freezing by anti-icing system.
- An anti-icing thermostat in the water separator actuates a 35‘F control valve in a duct between the primary heat-exchanger exit and the water-separator inlet.
- The valve opens to add warm air if the turbine discharge temperature approaches the freezing temperature of water.
- The primary heat exchanger is the first unit of the cooling packs through which engine bleed air passes to be cooled.
- The unit is rectangular and is located between two sections of the ram air duct.
- Two plenum chambers in the heat exchanger are connected by a bank of tubes to allow maximum surface exposure of each tube to ram air passing across the outside of the tubes.
- Hot air enters one plenum chamber from the pneumatic duct at the aft inboard side of the exchanger.
- The ACS is a cooling unit consisting of an expansion turbine on a

common shaft with a compressor.

- The ACS cools compressed air by expansion.
- When the air is originally compressed by the engine compressor, its temperature rises in approximate proportion to the rise in air pressure.
- The heated compressed air is passed through the primary heat exchanger, where some of the heat energy is removed.
- In the compressor section the air is further compressed and heated.
- This additional heat is reduced in the secondary heat exchanger, which is located between the compressor and turbine of the air-cycle system.
- Air from ACS compressor outlet enters the forward inboard connection to the secondary heat exchanger, passes through the cooling tubes, and then returns to the turbine section of the ACS.
- As the air expands across the turbine, heat energy is expended in driving the turbine and through the expansion process.
- Thus the air leaving the turbine is at its lowest temperature.

FIRE PROTECTION SYSTEM:

INTRODUCTION:

- The majority of the modern aircraft, primarily the large transport type, are equipped with certain systems that are not necessary for the actual operation and flight of the aircraft but are needed for the comfort and convenience of the crew and passengers and may be required by Federal Aviation Regulations [FARs]. Some of these systems are important for the safe operation of the aircraft under a variety of conditions, and some are designed to provide for emergencies.
- Systems not essential to the actual operation of the aircraft are commonly called as Auxiliary systems.
- Among such systems are ice & rain protection systems, fire warning and fire extinguishing systems, water and waste systems, position and warning systems, and auxiliary power units.
- Fire protection system on a/c usually consists of two separate operating systems with associated controls and indicators. One system is for fire or over heat detection and the other is for fire suppression or extinguishing. In some cases the systems can be interconnected so extinguishing takes place automatically when a fire is detected.

Requirements for Overheat and Fire Protection systems:

Certain general features and operational capabilities for fire warning and protection systems must be met or exceeded if they are to be used in certified a/c.
They are:

- The fire warning system must provide an immediate warning of fire or over heat by means of a red light and an audible signal in the cockpit or flight compartment.
- The system must accurately indicate that a fire has been extinguished and indicate if a fire reignites.
- The system must be durable and resistant to damage from all the environmental factors that may exist.
- The system must include an accurate and effective method for testing to assure the integrity of the system.
- The system must be easily inspected, removed and installed.
- The system and its components must be designed so the possibility of false indications is unlikely.
- The system must require a minimum of electrical power and must operate from the a/c electrical system without inverters or special equipment.

Types of Fire or over heat detectors:

High temperature caused by fires or other conditions can be detected by a variety of devices. Among these are

1. Thermal switches
2. Thermo-couple
3. Tubular detectors

Thermal-switch system

- This is simply a circuit in which one or more thermal switches are connected in an aural alarm unit to warn the pilot or flight crew that an over heat condition exists in a particular area. If more than one thermal switch is in the circuit, they are connected in parallel, so the closing of any one switch will provide a warning.

- A thermal switch, called a spot detector, works by the expansion of the outer case of the unit. When the detector is exposed to heat,
  the case becomes longer and causes the two contacts inside the case to be drawn together. When the contacts meet the electrical circuit is completed and the alarm activates.

Thermo couple detection system

Also called a ‘rate-of-rise’ detection system, this utilizes one or more thermo couples connected in series to activate an alarm system when there is a sufficiently high rate of temperature increases at the sensor. The thermo couple is made two dissimilar metals such as chromel and constantan, which are twisted together and located inside an open frame, as shown. The frame protects the sensing wires from damage while allowing a free flow of air over the wires. The exposed wires make up the hot junction. A cold junction is located behind insulating material in the sensor unit. When there is a difference in temperature between the hot and cold junctions, a current is created. When a sufficient current is being generated, a sensitive relay in a relay box closes, activating a slave relay and causing the alarm to activate.

Tubular sensing system:

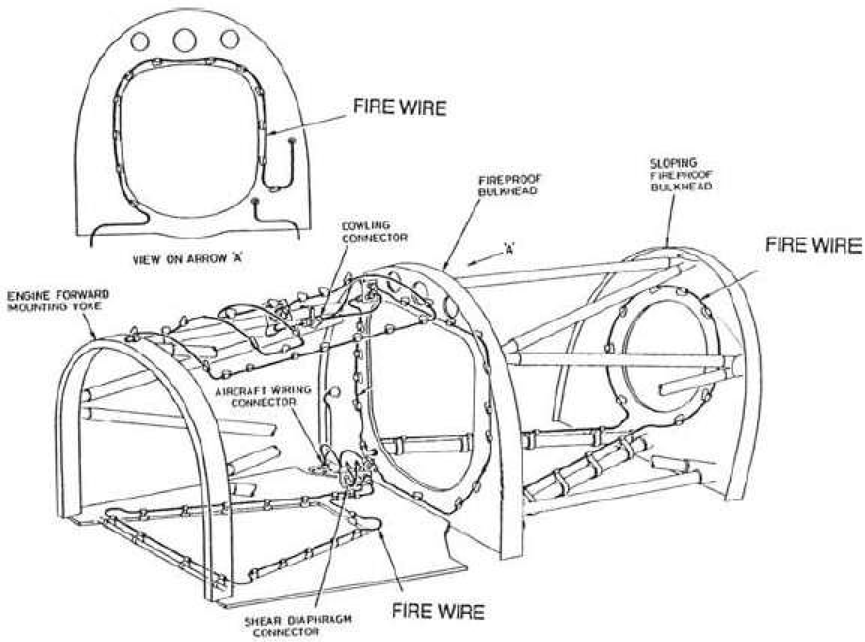
There are three types of tubular sensing devices, called “continuous-loop” systems, commonly employed in modern a/c for detecting over heat or fire. These tubular sensors are manufactured in lengths from 18 inch to more than 15ft. The diameter of these sensing elements may be from les than .060 inch to more than .090inch.

Fire-extinguishing agents:

- Fire-extinguishing agents are those chemicals that are injected into a compartment or area to extinguish a fire. These agents work by either displacing the oxygen or chemically combining with the oxygen to prevent combustion. Some additional extinguishing effect can occur, by the low temperature at which the agents are discharged.

- The commonly used agents are carbon dioxide, Freon and halon1301.

- Freon and halon are in a liquid state when under sufficient pressure but become gaseous when released to atmosphere pressure.



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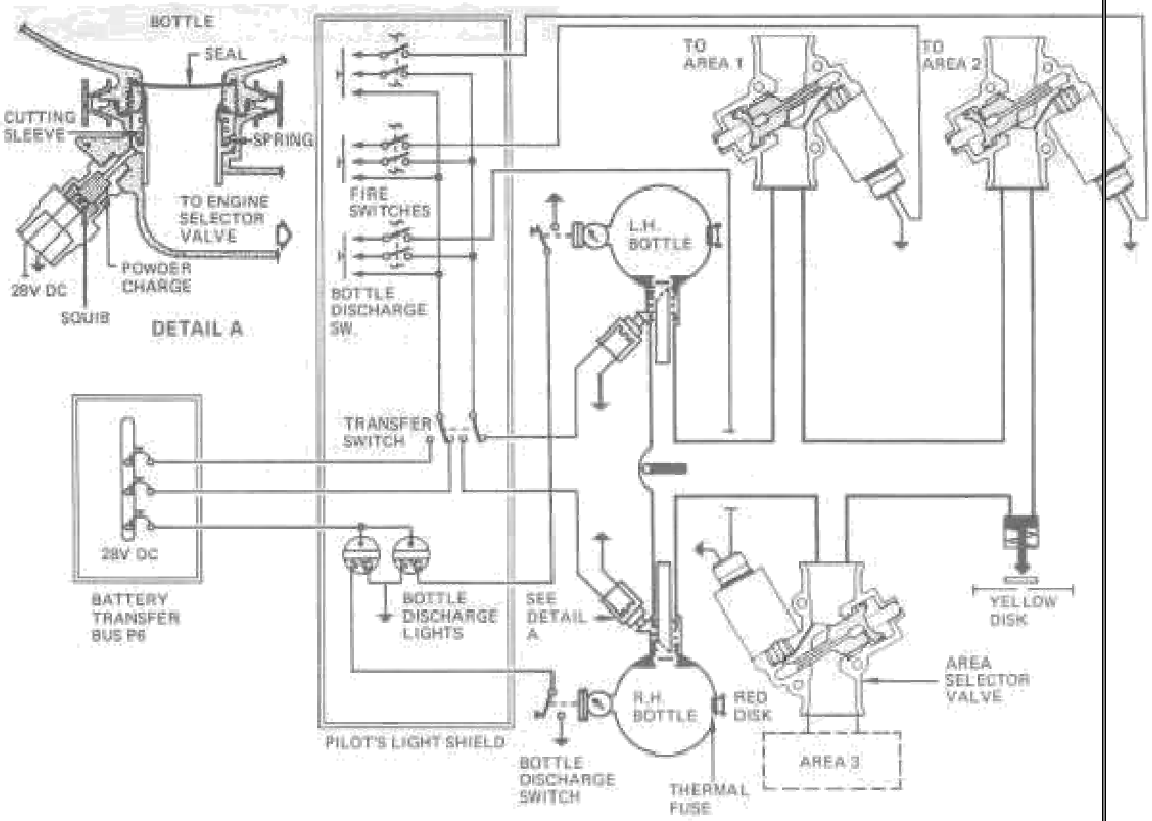
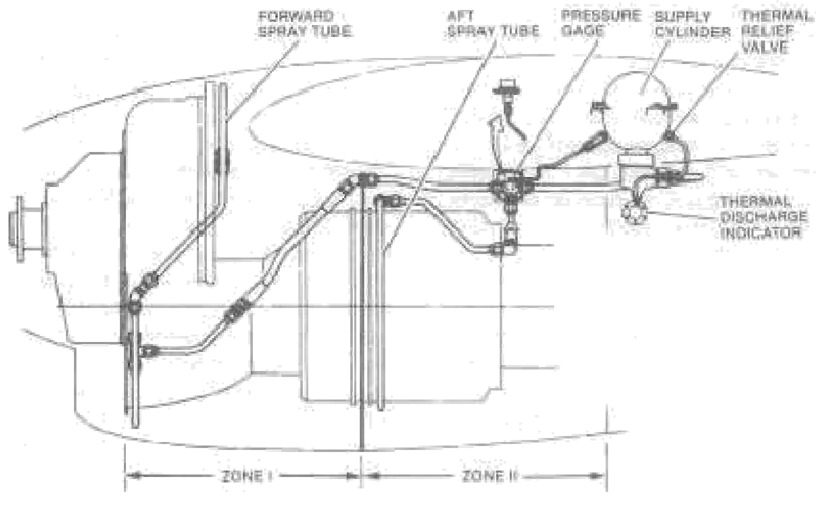


Schematic diagram of a fire-suppression system (Boeing Co.)



Fire-extinguishing system configuration for a twin-engine turboprop airplane.

Fire suppression system:

Fire suppression system or fire extinguishing system usually consists of fire extinguishing agent stored in pressurized containers, tubing to carry the agent to areas that require protection, control valves
indicators control circuitry and associated components.

ICE P R O TE C T IO N SYSTEM:

An a/c that operates in weather conditions where ice likely to form must be provided with ice protection. This may be anti-icing or de- icing. An anti-icing system prevents the formation of ice on the

a/p and a de-icing system remover ice that has already formed.

De-icing systems – pneumatic and mechanical:

Mechanical de-icing system consists of inflatable rubber ‘boots’ formed to the leading edge of wings, struts and stabilizers, by means of cement and fasteners. The inflatable boots are usually constructed with several separate air passages, so that some are inflated while alternate chambers are deflated. The inflation is accomplished by using the output pressure from a vacuum pump.

This results in alternate raising and lowering of sections of the boots, and this action cracks off any ice formed on the boots.

Anti-icing systems:

- **Thermal anti-icing**
- **Probe anti-icing**

Thermal anti-icing:

- Thermal anti-icing uses heated air flowing through passages in leading edge of wings, stabilizers and cowlings to prevent the formation of ice.
- The heat source is normally the combustion heaters or engine bleed air.
- From the source, the hot air distributed along the leading edge of the item being anti-iced by the use of a perforated air duct called a piccolo or spray tube. The skin is heated and ice is prevented from forming.

- Thermal systems used for the purpose of preventing the for formation of ice or for deicing airfoil leading edges, usually use heated air ducted span wise along the inside of the leading edge of the airfoil and distributed around its inner surface.

- There are several methods used to provide heated air. These include bleeding hot air from the turbine compressor, engine exhaust heat exchangers, and ram air heated by a combustion heater.

- The heated air carried through the ducting is passed into the gap. This provides sufficient heat to the outer skin to melt the layer of ice next to the skin or to prevent its formation.

- The air is then exhausted to the atmosphere at the wing tip or at points where ice formation could be critical; for example, at the leading edge of control surfaces.

- When the air is heated by combustion heaters, usually one or more heaters are provided for the wings. Another heater is located in the tail area to provide hot air for the leading edges of the vertical and horizontal stabilizers.

- When the engine is the source of heat, the air is routed to the empennage through ducting which is usually located under the floor.

Anti-icing using combustion heaters:

- Anti-icing systems using combustion heaters usually have a separate system for each wing and the empennage.

- A system if ducting and valves controls the airflow.
- The anti-icing system is automatically controlled by over heat switches, thermal cycling switches, a balance control, and a duct pressure safety switch.
- The over heat and cycling switches allow the heaters to operate at periodic intervals, and they also stop heater operation completely if combustion occurs.

- The duct pressure safety switch interrupts the heater ignition circuits if ram air pressure falls below a specified amount. This protects the heaters from overheating when not enough ram air is passing through.

PNEUMATIC DEICING SYSTEM:

- Pneumatic de-icing systems use rubber de-icers, called boots or shoes, attached to the leading edge of the wing and stabilizers.

- The de-icers are composed of a series of inflatable tubes.

- During operation, the tubes are inflated with pressurized air, and deflated in an alternating cycle as shown in fig.

- This inflation and deflation causes the ice to crack and break off. The ice is then carried away by the air stream.

- De-icers tubes are inflated by an engine driven air pump.

- The inflation sequence is controlled by either a centrally located distributor valve or by solenoid capsule located adjacent to the deicer air inlets.
- Deicers are installed in sections along the wing with the different sections operating alternately and symmetrically about the fuselage.
- This is done so that any disturbance to air flow caused by an inflated tube will be kept to a

minimum by inflating only short sections on each wing at a time.

- In some aircrafts cement is used for attaching the deicer boots to leading edge surface.
- The inflatable boots are usually constructed with several separate air passages or chambers, so that some can be inflated while alternate chambers are deflated.

- The control of the pressure and suction is accomplished by means of a distributor valve, which rotates periodically changes the flow of air to or from the different section of the boots, or by floe-control valves.

- This results in alternate raising and lowering of sections of the boots, and this action cracks off any ice that has formed on the boots.
- The pneumatic deicing system installed on one model of a twin-engine aircraft provides a good example of the application of such a system.

  De-icer boots, also referred as de-icers, consists of fabric-reinforced rubber sheet containing built-in inflation tubes.

- The de-icers are attached by cement to the leading edges of the surfaces being protected.
- Either aluminium or flexible rubber air connections called air-connection stems are provided on the backside of each de-icer.
- Each stem projects from the underside of the boot into the leading edge through a round hole provided in the metal skin.

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INTRODUCTION TO AVIONICS

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AVIONICS

Avionics are the advanced electronics used in aircraft, spacecraft and satellites. The term Avionics derived from the combination of Aviation and electronics. It is the science and technology of electronic systems and devices for aeronautics and astronautics. Avionics covers the diverse topics of computing, electronics, control and communications. In essence it comprises all electronic systems designed for use on an aircraft. At a basic level this comprises communications, navigation and the display and management of multiple systems. It also comprises the literally hundreds of systems that are fitted to aircraft to meet individual roles.

AVIONICS SYSTEMS

Avionics systems perform various functions include communication, navigation, flight control, display systems, flight management etc. There is a great need for advanced avionics in civil, military and space systems. All electronic and electromechanical systems and subsystems (hardware and software) installed in an aircraft that are dependent on electronics for its operation. Avionics Systems are essential to enable the flight crew to carry out the aircraft mission safely and to meet the mission requirements with minimum flight crew.

1.1 NEED FOR AVIONICS IN CIVIL AND MILITORY AIRCRAFT AND SPACE SYSTEM

Reliable and timely transfer of data between avionics systems is a necessity in military and civil aircraft design.

Modernization initiatives put forth a road map for avionics in areas mainly

- Published Routes and Procedures – Improved navigation and routing
- Negotiated Trajectories – Adding data communications to create preferred routes dynamically
- Delegated Separation – Enhanced situational awareness in the air and on the ground
- Low Visibility/Ceiling Approach/Departure – Allowing operations with weather constraints with less ground infrastructure
- Surface Operations – To increase safety in approach and departure
- ATM Efficiencies – Improving the ATM process

To meet the mission requirements with the minimum flight crew in any flight operations

- Have to consider economic benefits such as crew salaries, expenses and training costs.
- Reduction in weight, which results more passenger carrying capability or longer range on less fuel.

System safety

All parts of the aircraft are subject to regular system safety analyses. In avionics, methods for analyzing the safety impacts of a system are dictated by airworthiness authorities of the individual nation. Invariably methods like one managed by the FAA or EASA (JAA) will be used for civilian aircraft. In the military world, whilst there are some worldwide standards, lots of military purchasing authorities will dictate local standards (like Def Stan 00-56). The safety methodologies will significantly impact the design in terms of reliability and usage. Any system using software will be subject to even more scrutiny with respect to its safety impact.

Physical environment

The environment for any aircraft is different. Systems have many uses. Some need to be more robust than others. Today all avionics systems go through some level of environmental testing. This allows design authorities the ability to be assured of the robustness of the design. The testing comes in many forms, and has for many aircraft been pre-ordained by airframe manufacturers. As avionics became more ubiquitous on all sorts of aircraft, the Airworthiness Authorities (e.g. UK CAA or US FAA) set performance standards which equipment should meet. The manufacturers grew this to standards that define the environmental standards that the equipment should meet.

These standards place upon the avionics manufacturers predefined methods and agreed levels of testing for aircraft parts. Things such as salt spray, waterproofness, mould growth, and effects of external contamination and so on are all tested for. Standards such as BS 3G 100, MIL-STD-810, DEF STAN 00-35 have all been written to provide manufacturers with these methods. Each individual test is assessed as to its usefulness on the item (e.g. salt spray tests may not need to be done on equipment housed inside sealed bays). Manufacturers maintain standards by cross referencing these standards and level of testing required; often generating top level general requirements. These do not dictate performance, but are an expression of the environment which the equipment must operate within.

Vibration

For even the most benign of aircraft (like an airliner), vibration is a serious issue as it has major impacts on reliability. On more aggressive aircraft like helicopters, vibration can be the major driver in the design. There are aircraft standards available for vibration, but many airframes do not recognize them. Vibration resonances will be different for almost every aircraft built, but they are certainly different for every type.

Quality

The procurement of avionics equipment is all part of a worldwide assortment of manufacturers. Whilst highly recognizable manufacturers will provide the parts for the 'insides' of a box or LRU (Line-replaceable unit), the specialist element of packaging, testing and managing the configuration of avionics falls into the domain of a few big players. Quality control of parts is a significant part of any major industry, but in avionics and aviation as a whole, supplier quality can break entire programs (see the Boeing Chinook problems). Quality procedures dictated by ISO 9001 are now the starting blocks for any major business. However, all the main air framers have their own highly stringent quality procedures for delivery of documentation and hardware. It is often said that aircraft fly not on fuel, but on paperwork, since a single LRU (a radio or instrument) can produce excessive documentation.

Electromagnetic compatibility (EMC)

EMC is the interaction of electrical and electronic equipment with its electromagnetic environment, and with other equipment. All electronic devices have the potential to emit electromagnetic fields.EMC is an engineering activity that assesses the effect of one electrical electronic system on another. In the world of aircraft, EMC can cause all sort of problems, and equipment's and aircraft are extensively tested using specific standards (Def Stan 59-41, MIL-STD-464 etc.).

Design constraints

Any equipment fitted to aircraft has to meet a series of rigorous design constraints. The aircraft presents electronics with a unique and sometimes highly complex environment. Airworthiness and certification is one of the most costly, time consuming, troublesome and difficult aspects of building any aircraft. As aircraft and aircrew reliance on avionics has increased, it has placed a heavy duty of responsibility on the robustness of these systems. One necessary factor of constructing avionics systems is that a flight control system must be designed so that it never fails. However, degrees of this level of robustness can be found in every system fitted to aircraft.

Other considerable needs are

- Minimal power consumption
- Air traffic control requirements
- All weather operations
- Reduction in fuel consumption
- Improved in aircraft performance and control
- Reduction in maintenance cost.

ADVANTAGES OF USING AVIONICS IN CIVIL & MILITARY AIRCRAFT AND SPACE SYSTEMS:

The major advantages of using avionics in civil aircraft are

- To enable the flight crew to carry out the aircraft mission safely and efficiently.
- The reduction in weight can be translated to increased passengers or long range.
- All weather operation and reduction in maintenance costs.
- For better flight control, performing computations and increased control over flight control surfaces.
- For navigation, provide information using sensors like Altitude and Head Reference System (AHRS).
- Provide air data like altitude, atmospheric pressure, temperature, etc.
- Reduce crew workload.
- Increased safety for crew and passengers.
- Reduction in aircraft weight which can be translated into increased number of passengers or long range.
- All weather operation and reduction in aircraft maintenance cost.

The major advantages of using avionics in military aircraft are

- A single seat fighter or strike aircraft is lighter and Costs less than an equivalent two seat version.
- Avionics in fighter aircraft eliminates the need for a second crew member like navigator, observer etc., which helps in reducing the training costs.
- Improved aircraft performance and control and handling and reduction in maintenance costs
- Secure communication.
- Reduction in maintenance cost.

The general advantage of Avionics over the conventional aircraft system is

- Increased safety
- Air traffic control requirements
- All weather operation
- Reduction in fuel consumption
- Improved aircraft performance and control and handling and reduction in maintenance costs

The usage of avionics in space systems are

- Fly-by-wire control systems were used for vehicle attitude and translation control.
- Sensors used around the aircraft for data acquisition.
- Redundancy system and autopilot.
- On board computers used in satellites for processing.

INTEGRATED AVIONICS&WEAPON SYSTEM

Integration of systems into aircraft is one of the largest problems for engineers today. The early avionics systems were integrated by the air crew who had to look at various dials and displays connected to disjoint sensors, correlate the data provided by them, apply errors corrections, orchestrate the functions of the sensors and perform mode and failure management in addition to flying the aircraft. However small the aircraft, there is always some level of integration (whether or not it operates with the aircraft power supply, for example). As the digital technology evolved, a contract computer was added to integrate the information from the sensors and subsystems. The large aircraft projects (military and civilian alike) employ hundreds of engineers to integrate these complex systems.

The Avionics and Weapon System (AWS) in any modern day fighter aircraft enable the pilot to perform various mission functions and thereby meet the stipulated operational role of the aircraft.

The AWS must meet the following functional requirements in order to complete a Mission:

a) Receive inputs from

   - Sensors
   - Communication Systems
   - Radio Navigation System
   - Identification System

- Missiles
- Electronic Counter Measures System
- Pilot Controls

b) Compute required parameters for navigation and fire control

- Navigation algorithms
- Fire Control algorithms

c) Output computed results to

- Displays:
- Audio System: AWS status and warnings
- Weapons

d) Control weapon launch/firing

- Weapon selection and preparation
- Launch/fire sequencing

e) Control/co-ordinate/manage sensors optimally

- Mode commands
- Slaving commands

Integration

The means of connecting the vast array of systems together such that the information can be used in a cohesive and useful fashion have vexed the avionics industry from the start. The simplicity of a discrete wire telling a device that something is either on or off has grown all the way to the incorporation of fibre optic data buses moving flight control data around the aircraft. Ever more complex software has been written to ever more rigorous standards.

In modern avionics systems, the mission requirements are met by the cooperative functioning of various subsystems each containing segments of the operational flight program (OFP).Integration of avionics system is essential for the success of any aircraft program. The major advantages obtained by integrating the avionics system using multiplex bus are;

- Reduction of total hardware, by sharing sensors, controls and displays
- Weight reduction and flexibility
- Effective redundancy without massive hardware duplication made possible by the integration of identical, similar or dissimilar sensors to make multiple sources of similar data available
- Reduction of the effect of systematic error sources by the effective use of dissimilar or similar subsystems to reduce the effect of systematic error sources.
- Built in redundancy with consequent fault tolerance
- Battle damage tolerance
- Growth potential in a cost effective manner

INTEGRATED MODULAR AVIONICS SYSTEMS

The Integrated Modular Avionic (IMA) provides computation, memory and Input/output data processing resources, shared between several avionics applications. Airplanes require avionics systems that offer excellent maintainability and high dispatch reliability. By eliminating the need for separate Line Replaceable Units, Integrated Modular Avionics (IMA) concept reduces weight, space and power consumption while improving overall system reliability and maintainability.Avionics systems are conventionally designed using a federated architecture. The system is partitioned into a number of physically separated black boxes, each of which is then treated as a separate subsystem. Integrity requirements are often defined at this level of resolution, with each black box being given an integrity requirement based on its most critical function.

Integrated functions include: Flight Management, Displays, Navigation, Central Maintenance, Airplane Condition Monitoring, Flight Deck Communications, Thrust Management, Digital Flight Data, Engine Data Interface and Data Conversion Gateway. Future plans include integration of more airplane utility control functions, such as Environmental & Electrical Control, Fire & Smoke Detection, and Fuel System Control & Indicating

• Conventional Federated Architecture:

- Each unit has individual control in the cockpit
- Connected by a dedicated wire;
- Continuous signals
- Tons of wires onboard

• Integrated Modular Avionics:

- Units are connected to a common bus (AFDX);
- Discrete signals;
- Control protocols
- Readings are processed and displayed by onboard computing nodes

Integrated Modular Avionics Architecture

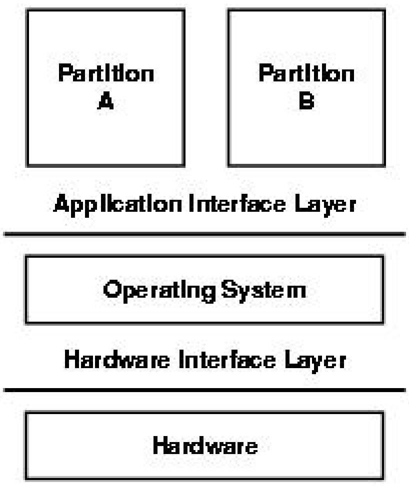


Figure: basic IMA computing module.

INTEGRATED AVIONICS PROCESSOR SYSTEM

The latest technology used to simplify the variety of avionics systems found on corporate aircraft is called the integrated avionics processor system (IAPS). The system is designed to function as a central distribution network for virtually all the avionics of an aircraft. The IAPS coordinators the weather radar (WXR); the instrument display unit (IDU); the flight management system (FMS); the flight control system (FCS); the radio sensor system (RSS), which may include all navigation and communication radios, the aircraft data acquisition system (ADAS), the air data system (ADS); and the altitude heading system (AHS).

The IAPS uses a digital data bus system to link all the avionics sub systems to the IAPS. The processor controls the outputs to the various flight deck displays and monitors the system for defects. A central diagnostic system is used to record and troubleshoot faults within the avionics sub systems. This type of built in test equipment greatly enhances troubleshooting of these relatively complex sub systems. The centralized design of the IAPS also reduces the number and size of sub system components.

INTEGRATED NAVIGATION AND FLIGHT SYSTEMS

When all or most of the conditions affecting the flight of an airplane are brought together and sensed by a system that is able to present information regarding the conditions to the pilot, the total system may be termed an integrated navigation and flight system or simply 'Integrated flight

systems'. A completely integrated navigation and flight system includes flight instrumentation, navigation systems, communication systems and the automatic flight systems.

Aircraft Networks

The avionics systems in military, commercial and advanced models of civilian aircraft are interconnected using an avionics data bus. These network protocols are similar in functionality as an in-home network connecting computers together, however, the communication and electrical protocols can be very different. Here is a short list of some of the more common avionics data bus protocols with their primary application:

- Aircraft Data Network (ADN): Ethernet derivative for Commercial Aircraft
- AFDX: Specific implementation of ARINC 664(AND) for Commercial Aircraft
- ARINC 429: Commercial Aircraft
- ARINC 629: Commercial Aircraft (Boeing 777)
- ARINC 708: Weather Radar for Commercial Aircraft
- ARINC 717: Flight Data Recorder for Commercial Aircraft
- MIL-STD-1553: Military Aircraft

Few examples of integrated avionics system used in civil airlines are

• INS & GPS (Navigation)
• MFKs and MFDU (Display I/O)
• HUD
• Glass Cockpit

Few examples of integrated avionics system used in weapon system are

- Hemet Mounted Display (HMT)
- Head Level Display (HLD)
- Night Vision Goggles (NGV)
- Forward Looking Infra-Red Displays (FLIR)

TYPICAL AVIONICS SUBSYSTEMS:

The cockpit of any aircraft is the most obvious location for avionics. It is also the most contentious and difficult. Systems that allow the aircraft to fly safely or have direct control over the aircraft are all directly controlled by the pilot. These safety critical systems and the items that support them are all referred to as aircraft avionics.

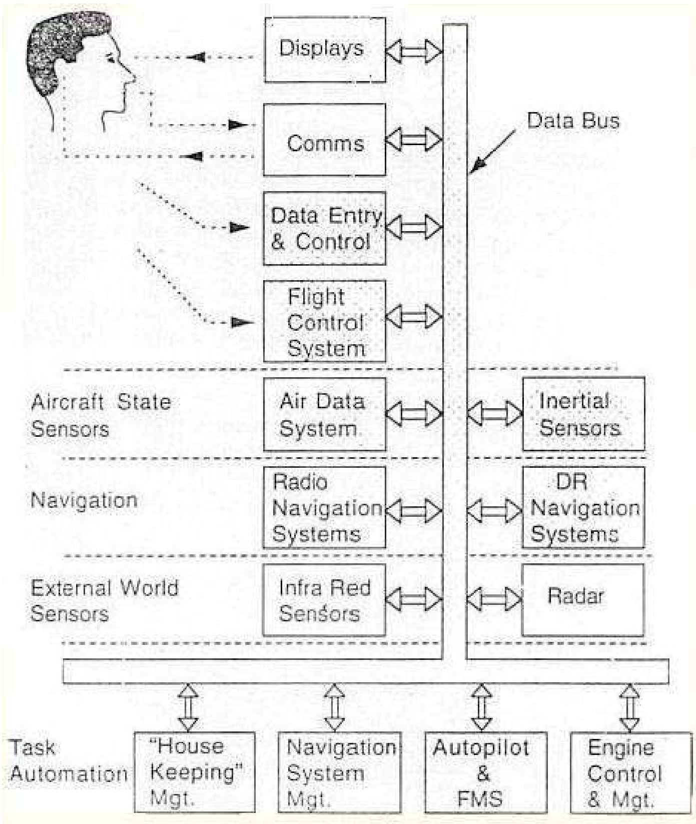


Fig: Avionics sub systems

Main categories:

The main avionic sub systems have been grouped into five layers according to their role and function.

- Systems, which interface directly with the pilot
- Aircraft state sensor systems
- Navigation systems
- External world sensor systems

- Task automation systems

1. SYSTEMS INTERFACING DIRECTLY WITH THE PILOT

- **Displays :**The display system provide the visual interface between the pilot and the aircraft systems and comprise head up displays (HUD), Helmet mounted displays (HMD) and Head down displays (HDD). Display systems carry out checks of key

  sensor data that allows the aircraft to fly safely in very aggressive environments. Display software is often written in the same way as that for flight control software, as essentially the pilot will follow it. The display systems can take multiple different methods of determining attitude, heading and altitude that the aircraft use, and provide them in a safe and easy to use manner to aircrew.

The latest multi function color displays provide the

- Primary flight displays (PFD) information such as height, air speed, mach number, vertical speed, artificial horizon, pitch angle, bank angle and heading, and velocity vector.
- Navigation displays such as aircraft position and track relative to the destination or way points together with the navigational information and distance and time to go
- Weather radar display information
- Engine data are presented so that the health of the engine can easily be monitored and any deviations from the normal can be highlighted.
- The aircraft systems such as electrical power supply systems, cabin pressurization system and fuel management system can be shown in easy to understand line diagram format on the multi function displays.

- **Communications**

Communication radio systems provide reliable two way communication between the ground bases and the aircraft or between aircrafts. Probably the first piece of avionics to exist, the ability to communicate from the aircraft to the ground has been crucial to aircraft design since its inception. The boom in telecommunications has meant aircraft (civilian and military) fly with a vast array of communication devices. A small number of these provide the critical air to ground communications systems for safe passage. On board communications are provided by public address systems and aircraft intercoms

Military communications:

While aircraft communications provide the backbone for safe flight, the tactical systems are designed to withstand the rigours of the battle field. UHF, VHF Tactical (30-88 MHz) and SatCom systems combined with ECCM methods, and cryptography secure the communications. Data links like Link 11, 16, 22 and BOWMAN, JTRS and even TETRA provide the means of transmitting data (such as images, targeting information etc.).

- **Data entry and control**

Data entry and control systems are essential for the crew to interact with the avionics systems

- Keyboard
- Touch panels
- Direct voice input(DVI) controls

- **Flight control**

Airplanes and helicopters have had different means of automatically controlling flight for many years. They reduce pilot workload at useful times (like on landing, or in the hover), and they make these actions safer by 'removing' pilot error. The first simple auto-pilots were used to control heading and altitude and had limited authority on things like thrust and flight control surfaces. In helicopters, auto stabilisation was used in a similar way. The old systems were all electromechanical in nature until very recently. The software driven systems fitted to almost all new major aircraft today have made a significant leap forward. The advent of fly by wire and electro actuated flight surfaces (rather than the traditional hydraulic) has massively increased safety. As with displays and instruments, critical devices which were electro-mechanical had a finite life which was very restrictive. Electronic systems are not limited by the mechanical constraints. With safety critical systems, the software is written in very strict conditions, where the ideal scenario is that it will never fail.

Two areas of flight control are

- Auto stabilization systems
- FBW flight control systems

2. AIRCRAFT STATE SENSOR SYSTEMS:

These comprise the air data systems and inertial sensor systems.

- **Air data system**

Information on the air data quantities such as altitude, calibrated air speed, vertical speed, true air speed, Mach number and air stream incidence angle is essential for the control and navigation of the aircraft. Air data computing systems calculates these quantities from various sensors that measure the static pressure, total pressure, air stream incidence and the outside air temperature.

- **Inertial sensor systems:**

The altitude and the heading information is provided by the inertial sensor systems. These consist of set of gyros and accelerometers, which measures the aircraft angular and linier motion about the aircraft axis together with a computing system, which derives aircrafts altitude and heading from the gyro and accelerometer. These data are utilized in INS (Inertial navigation system) to provide aircraft velocity vector information. The INS is thus a very important aircraft state sensor system – it is also completely self-contained and does not required any access to the outside world.

3. NAVIGATION SYSTEMS:

Navigation information such as aircraft position, ground speed and track angle (direction of motion of the aircraft relative to true north) is clearly essential for the aircraft mission, weather civil or military. Navigation systems can be divided into two major categories:

- Dead reckoning navigation systems (DR)
- Radio Navigation systems

- **Dead reckoning navigation systems**

DR navigation systems derive the vehicle's present position by estimating the distance traveled from a known position from knowledge of the speed and direction of motion of the vehicle. They have the major advantages of being completely self-contained and independent of external systems. The main types of DR navigation systems used in the aircraft are

- Inertial navigation systems
  - They are the most accurate and widely used systems
- Doppler / Heading reference systems
  - These are widely used in helicopters.
- Air data / Heading reference systems
  - These systems have lesser accuracy than the above systems

- **Radio Navigation systems**

Various important navigation systems used in the aircraft are

- Position fixing systems
- Hyperbolic navigation systems
- Satellite navigation

Various examples of radio navigation systems commonly used are ADF, VOR, DME, OMEGA, GPS, ILS, TACAN

4. EXTERNAL WORLD SENSOR SYSTEMS:

These systems, which comprise

- RADAR systems
- Infrared sensor systems

This gives all weather and night time operation and transform the operational capability of the aircraft.

5. AIRCRAFT MANAGEMENT SYSTEMS

The main purpose of these systems is to reduce the crew work load by automating and manage as many tasks as appropriate, so that the crew role is a supervisory management one.

As integration became the buzzword of the day in avionics, and as PCs came onto the market, there was a natural progression towards centralized control of the multiple complex systems fitted to aircraft. Combined with displays and flight control systems, these three core systems allow all the aircraft systems (not just avionics) to have their data compiled and manipulated to make it easier to maintain, easier to fly and safer.

Engine monitoring and management was an early progression into aircraft management for ground maintenance. Now the ultimate extension of this is total management of all the components on the aircraft, giving them longer lives (and reducing cost). Health and Usage Monitoring Systems (HUMS) are integrated with aircraft management computers to allow maintainers early warnings of parts that will need replacement.

The aircraft management computer or flight management systems are used by aircrew in place of reams of maps and complex equations. Combined with the digital flight bag they can manage every aspect of the aircraft chock to chock.

Although avionic manufacturers provide flight management systems, aircraft management and HUMS tend to be specific to the airframe as the design of the software is dependent on the aircraft it is fitted to.

- **Navigation Management systems:**

It collects the data of all navigation systems such as from GPS and INS systems, to provide the best possible estimate of aircraft position, ground speed and track. Then derives the steering commands for the auto pilot, so that the aircraft automatically follows the planned navigation route. This function is carried out by the flight management system, if installed.

- **Autopilot and flight management systems:**

The modern autopilot systems in addition to height hold and heading hold can also provide a very precise control of the aircraft flight path, for example automatic landing in poor or even zero visibility conditions. The tasks carried out by a FMS are;

- Flight planning
- Navigation management
- Engine control to maintain the planned speed
- Control of the aircraft flight path to follow the optimized planned route
- Control of the vertical flight profile
- Minimizing the fuel consumption

- **Engine control and management:**

Modern jet engines have a 'Fully authority digital engine control system' (FADEC). This automatically controls the flow of fuel to the engine combustion chambers by the fuel control unit, so as to provide a closed loop control of engine thrust in response to the throttle command. FADEC also ensure the engine limits in terms of temperatures, engine speeds and accelerations. It has a high integrity failure survival control system, so that in case of failure, avoids the damage of the engine.

Other important engine avionics systems include engine health monitoring systems, which measure process and record every wide range of parameters associated with the performance and health of the engines. These give early warning of engine performance deterioration, excessive wear, fatigue damage, high vibration levels, excessive temperature levels.

- **House keeping management:**

It covers the automation of background tasks, which are essential for the aircrafts safety and efficient operation. Such task includes;

- Fuel management
- Electrical power supply system management
- Hydraulic power supply system management
- Cabin / cockpit pressurization systems
- Warning systems
- Environmental control system
- Maintenance and monitoring systems:
    - This provides the information to enable speedy diagnosis and rectification of equipment and system failures by pin – pointing faulty units and providing all the information such as part number etc., for replacement units down to module level in some cases.

6. COLLISION-AVOIDANCE SYSTEMS

A collision avoidance system is an aircraft system that operates independently of ground-based equipment and air traffic control in warning pilots of the presence of other aircraft that may present a threat of collision. If the risk of collision is imminent, the system indicates a manoeuvre that will reduce the risk of collision.

To supplement air traffic control, most large transport aircraft and many smaller ones use a TCAS (Traffic Alert and Collision Avoidance System), which can detect the location of other, nearby aircraft, and provide instructions for avoiding a midair collision. Smaller aircraft may use simpler traffic alerting systems such as TPAS, which are passive (they do not actively interrogate the transponders of other aircraft) and do not provide advisories for conflict resolution. To help avoid collision with terrain, aircraft use systems such as ground-proximity warning systems (GPWS), often combined with a radar altimeter. Newer systems use GPS combined with terrain and obstacle databases to provide similar alerting for light aircraft.

7. WEATHER SYSTEMS

Weather systems such as weather radar (typically Arinc 708 on commercial aircraft) and lightning detectors are especially important for aircraft flying at night or in Instrument meteorological conditions, where it is not possible for pilots to see the weather ahead. Heavy precipitation (as sensed by radar) or lightning activity are both indications of strong convective activity and severe turbulence, and weather systems allow pilots to deviate around these areas.

Recently, there have been three important changes in cockpit weather systems. First, the systems (especially lightning detectors like the Stormscope or Strikefinder) have become inexpensive enough that they are practical for light aircraft. Second, in addition to the traditional radar and lightning detection, observations and extended radar pictures (such as NEXRAD) are now available through satellite data connections, allowing pilots to see weather conditions far beyond the range of their own in-flight systems. Finally, modern displays allow weather information to be integrated with moving maps, terrain, traffic, etc. onto a single screen, greatly simplifying navigation.

8. RADAR

An acronym for Radio Detecting And Ranging: a method and the equipment used for the detection and determination of the velocity of a moving object by reflecting radio waves off it. Airborne radar was one of the first tactical sensors. As with its ground based counterpart it has grown in sophistication. The obvious massive benefit of altitude providing massive range has meant a significant focus of developing airborne radar technologies. The general ranges of radar of Airborne Early Warning (AEW), Anti Submarine Warfare (ASW), and even Weather radar (Arinc 708) and ground tracking/proximity radar.

The military has used radar in fast jets to help pilots fly at low levels. While the civil market has had weather radar for a while, there are strict rules about using it to navigate the aircraft.

9. SONAR

Sonar (originally an acronym for SOund Navigation And Ranging) is a technique that uses sound propagation (usually underwater, as in submarine navigation) to navigate, communicate with or detect objects on or under the surface of the water.Soon after radar came sonar. Dipping sonar fitted to a range of military helicopters allows the helicopter to protect shipping assets from submarines or surface threats. Maritime support aircraft can drop active and passive sonar devices (Sonobuoys) and these are also used to determine the location of hostile submarines.

10. ELECTRO-OPTICS

Electro-optic system covers a wide range of systems, including Forward Looking Infrared (FLIR), and Passive Infrared Devices (PIDS). These are all used to provide imagery to crews. This imagery is used for everything from Search and Rescue through to acquiring better resolution on a target.

11. ESM/DAS

Electronic support measures and defensive aids are used extensively to gather information about threats or possible threats. Ultimately they can be used to launch devices (in some cases automatically) to counter direct threats against the aircraft. They are also used to determine the state of a threat or even identify it.

12. MISSION OR TACTICAL AVIONICS

The major developments in avionics have tended to happen 'in the back' before the cockpit. Military aircraft have been designed either to deliver a weapon or to be the eyes and ears of other weapon systems. The vast array of sensors available to the military (as for the front) is then used for whatever tactical means required. As with aircraft management, the bigger sensor platforms (like the E-3D, JSTARS, ASTOR, Nimrod MRA4, Merlin HM Mk 1) have mission management computers.As the sophistication of military sensors increases and they become more ubiquitous, the pseudo-military market has started to dip into the product. Police and EMS aircraft can now carry some very sophisticated tactical sensors.

DESIGN AND TECHNOLOGIES

Modern avionics design with enhanced functionality makes it possible for airlines to operate safely and efficiently; designers to develop and manufacture electric and green aircraft; air traffic controllers to manage traffic efficiently; and for military pilots to perform their missions effectively.

Avionics is one of the most developing fields of aircraft design. Its importance and range has increased over recent years and as much as 40% of the cost of a new aircraft can be attributed to avionics. There is a bewildering range of avionics systems, each of which usually requires the use of many acronyms.The main steps in designing section are

- Design
- Coding
- Testing

The process of designing consists of a sequence of steps, as is illustrated in below

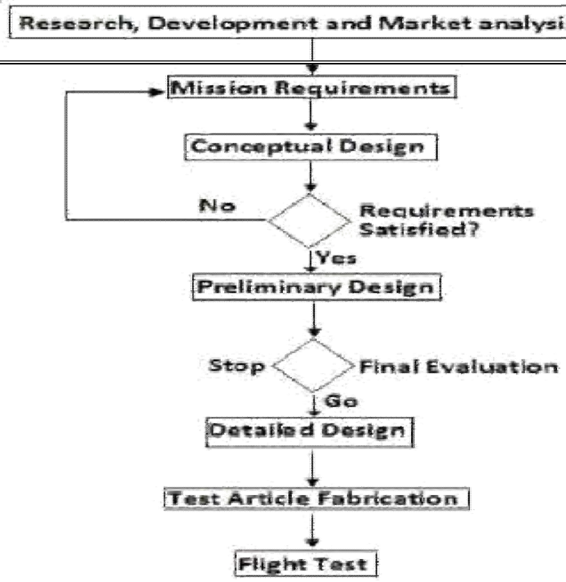


Fig: Design process flow chart

The three stages involved in design of avionics system are i.

Conceptual design

ii. Preliminary design

iii. Detailed design

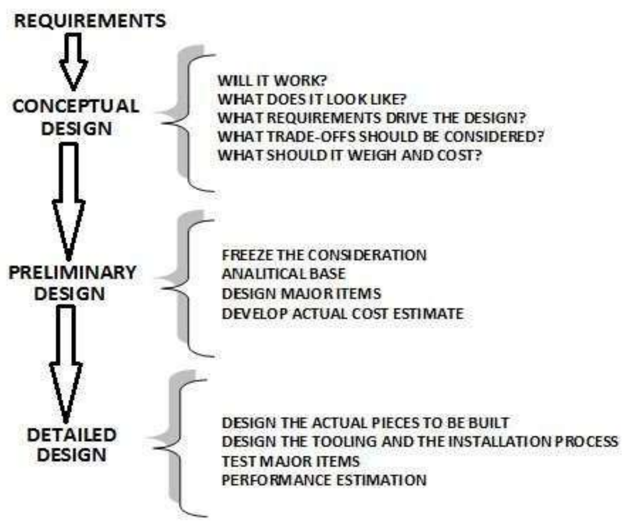


Fig: Three stages of design

Automatic test equipment is also known as automated test equipment.

These test fixtures can be considered as ‘filtering’ devices, often designed to prevent unwarranted flagging of unit as faculty. ATE is designed to perform number of roles;

1. Conform a fault that is believed to exist
2. Diagnosing the fault and its location
3. Testing the equipment function before reinstallation.

PRINCIPLES OF DIGITAL SYSTEMS

A computer that stores data in terms of digits (numbers) and proceeds in discrete steps from one state to the next. The states of a digital computer typically involve binary digits which may take the form of the presence or absence of magnetic markers in a storage medium, on-off switches or relays.

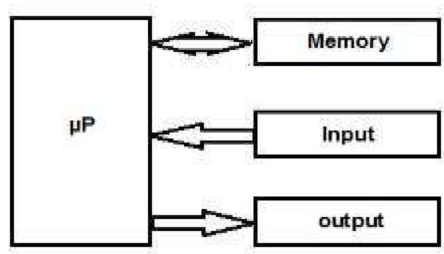


Fig: programmable machine

A program is a list of instructions written in a programming language that is used to control the behavior of a machine. For example, a computer is a programmable machine. This means it can execute a programmed list of instructions and respond to new instructions that it is given.

A typical programmable machine can be represented with four components:

- Microprocessor
- Memory
- Input
- Output

These four components work together or interact with each other to perform a given task; thus they comprise a system.

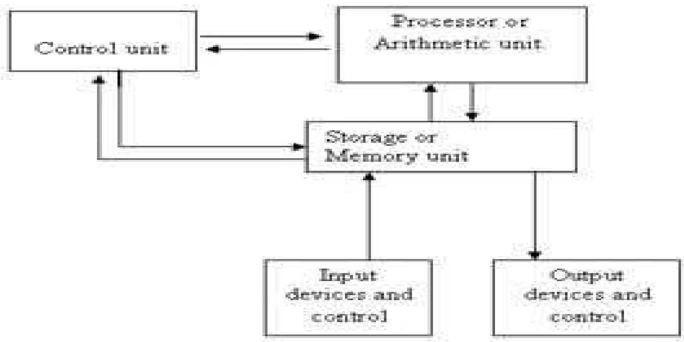
- The physical components of this system one called Hardware.
- A set of instructions written for the microprocessor to perform a task is called a program
- A group of programs is called software

DIGITAL COMPUTERS AND DIGITAL SYSTEMS

- A **computer** is a programmable device, usually electronic in nature that can store, retrieve, and process data.
- A computer that stores data in terms of digits (numbers) and proceeds in discrete steps from one state to the next is called as digital computer.
- The most striking property of a digital computer is a generality.
- It can follow a sequence of instructions.
- The user can specify and change programs and/or data according to the specific need.
- As a result of this flexibility, general purpose digital computers can perform a wide variety of information-processing tasks.

PRINCIPLE OF DIGITAL SYSTEMS:

In digital computers, even letters, words and whole texts are represented digitally. Unlike analog computers, digital computers can only approximate a continuum by assigning large numbers of digits to a state description and by proceeding in arbitrarily small steps.



DIGITAL AIRCRAFT SYSTEMS

Digital electronics provide for greater reliability, faster response, smaller components, lighter equipments and lower operating costs than can be provided by analog systems. It is no wonder that modern commercial, corporate and military aircraft contain countless digital circuits. Smaller civilian aircraft also contain a limited amount of digital equipment; however, this type of aircraft traditionally lags several years behind in utilizing state of art technologies.

Digital systems increase the mean time between failures and reduce the subsequent repair time for failed equipment. The built-in test equipment (BITE) found in most digital systems provides rapid fault isolation. The majority of the digital aircraft systems contain several line replaceable units (LRUs). Defective LRUs may be quickly identified by the BITE system and exchanged during ground maintenance. Use of the LRU and BITE concepts greatly reduces aircraft maintenance downtime.

Another concept of digital aircraft technologies is to remove as many moving parts from the electrical system as possible. Throughout the aircraft, switches are replaced with proximity indicators, relays are replaced with transistors, and instruments are replaced with digital displays. In the flight compartment, the CRT replaces conventional analog instruments, thus eliminating thousands of moving parts. Fewer moving parts mean greater system reliability.

The major advantages of Digital technology systems over analog systems:

- Better reliability
- Lower weight and size
- More relaxed power and cooling requirements
- Greater flexibility for change or modification
- Self – test ability
- Faster response

MICROPROCESSORS

A microprocessor is a programmable integrated logic device that has computing and decision making capability. It is a multi-purpose, clock driven, register based electronic device that reads binary instruction from a storage device called memory, accepts binary data as input and processes data according to those instructions, and provide results as output.Microprocessor based systems can be generally grouped into two categories ie., Reprogrammable systems and embedded systems.

- Reprogrammable systems include general purpose microprocessors that can be reprogrammed for a variety of tasks. The personal computer (PC) is a typical example of a reprogrammable system.
- An embedded system, on the other hand, is one where the microprocessor is programmed and then included or embedded in a final product that does not require any reprogramming of the microprocessor. A copy machine is a typical example of an embedded system, as is the fuel-injection controller in an automobile. In these instances, the user is not allowed to reprogram the microprocessor.

ARCHITECTURE

The microprocessor has a set of instructions, designed internally, to manipulate data and communicate with peripherals. The process of data manipulation and communication is determined by the logic design of the microprocessor, called the Architecture.

A typical microprocessor contains an arithmetic and logic unit (ALU), an accumulator, an instruction decoder, a control unit, registers and an internal bus. Figure shows the hardware architecture of a typical microprocessor.

The Intel 8085 Microprocessor:

Intel 8085A is a single chip 8-bit N-channel microprocessor which works at +5V DC power supply. It is a 40 pin IC available as a DIP (Dual Inline Package) chip. 8085A can operate with a 3MHZ singlephase clock and 8085A-2 version can operate at a maximum frequency of 5MHZ. This 8085 is an enhanced version of its predecessor the 8080A. Its instruction set is upward compatible with that of the 8080A. 8085A has an on-chip clock generator with external crystal, LC or RC network. This 8085 microprocessor is built with nearly 6200 transistors. The enhanced version of 8080 is the Intel

8085AH. It is an N channel depletion load, silicon gate (HMOS) 8-bit processor. Here 3MHZ, 5MHZ and 6MHZ selections are available. It has 20% lower power consumption than 8085A for 3MHZ and 5MHZ. Its instruction set is 100% software compatible with the 8085A. It is also 100% compatible with 8085A.

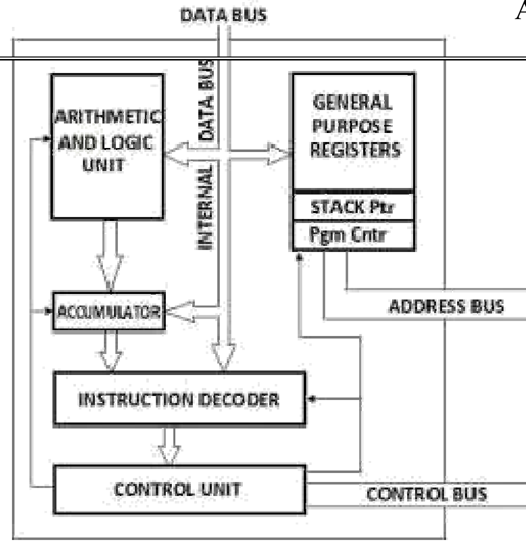


Fig: The microprocessor hardware architecture

The Arithmetic and Logic unit (ALU):

The Arithmetic and Logic unit (ALU) performs arithmetic operations such as add and subtract, and logic operations such as AND, OR, XOR, and so on. When data is sent externally from the microprocessor or received from an external source, the data comes into, or goes out from, the accumulator via the data bus

The instruction decoder

The instruction decoder decodes the instructions it receives over the internal data bus. The address of the next instruction to be executed is stored in the program counter, and when this address is sent out the microprocessor to an external memory over the address bus, the resulting instruction (stored at the address in the memory) is returned over the data bus and is sent internally to the instruction decoder. The instruction decoder decodes the instruction at a binary level and sends the appropriate signals to the control unit.

The control unit

The control unit receives the information from the information decoder after it decodes the instruction as to what operations need to be performed. It then sends the binary signals to the appropriate internal sections of the microprocessor and dispatches any needed control signals over the control bus to external devices such as memories and input or output devices.

Accumulator

In a computer's central processing unit (CPU), an accumulator is a register in which intermediate arithmetic and logic results are stored. Without a register like an accumulator, it would be necessary to write the result of each calculation (addition, multiplication, shift, etc.) to main memory, perhaps only to be read right back again for use in the next operation. Access to main memory is slower than access to a register like the accumulator because the technology used for the large main memory is slower (but cheaper) than that used for a register.

FUNCTIONS

The microprocessor can be programmed to perform functions on given data by selecting necessary instructions from its set. These instructions are given to the microprocessor by writing them into its memory. Writing (or entering) instructions and data is done through an input device such as a key board. The microprocessor reads or transfers one instruction at a time, matches it with its instruction set, and performs the data manipulation indicated by the instruction. The result can be stored in memory or sent to such output devices as LEDs or a CRT terminal.

When the microprocessor executes instructions, it does a continuous sequence of fetch, decode, and execute operations.

- **Fetching an instruction**

The microprocessor places a memory address on the address bus and reads binary information using the data bus. Therefore, it needs a register that can hold memory addresses and increment these addresses after the fetching is complete, a sort of memory pointer.

- **Decoding an instruction**

Once an instruction byte is fetched, it needs to be decoded to answer the following:

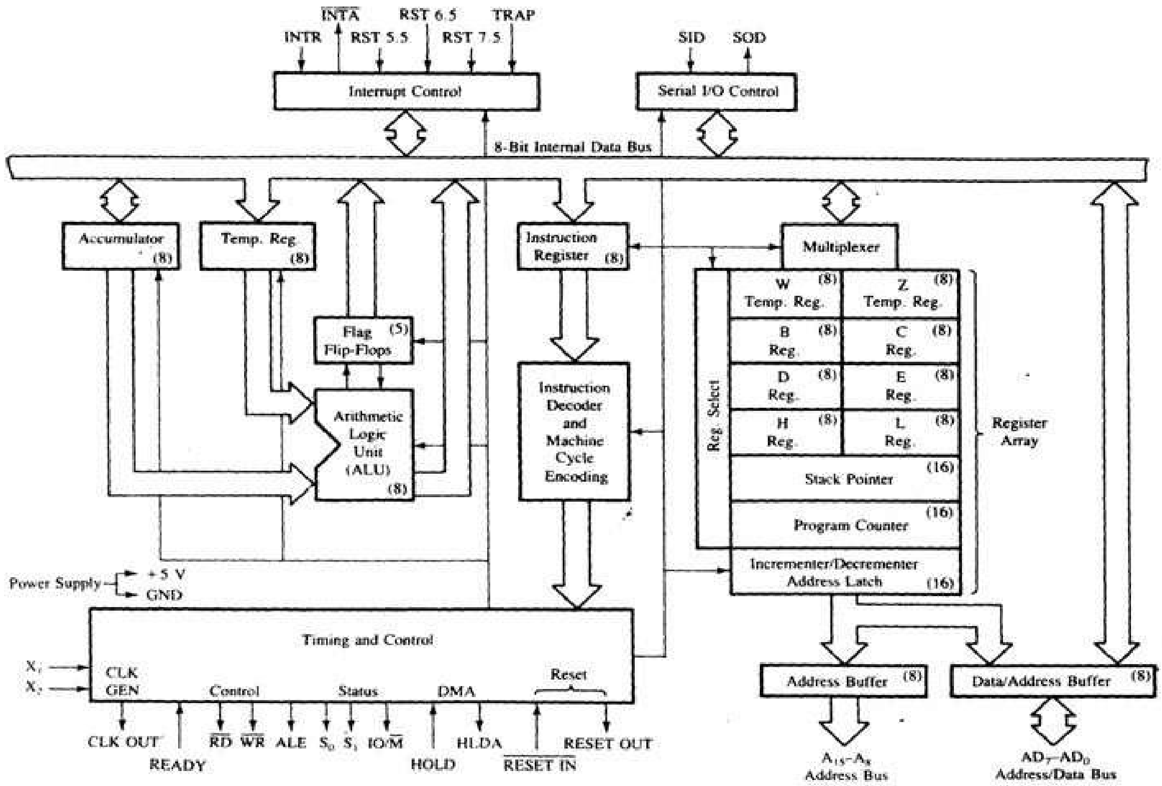
- Is it a complete instruction? If not, how many more bytes need to be fetched?
- What type of operation is required and on what data?

- **Executing an instruction**

The type of data manipulation the MPU can perform depends on its internal micro programs, that is, on its instruction set. These operations can be classified as data copy (transfer), arithmetic/logic operations, and decision making. For example, to subtract two numbers, both numbers must be loaded into registers. After the subtraction, it is necessary to indicate whether the result is positive, negative, or zero. This can be indicated by setting or resetting flip-flops called flags.

ARCHITECHTURE or FUNCTIONAL BLOCK DIAGRAM OF 8085

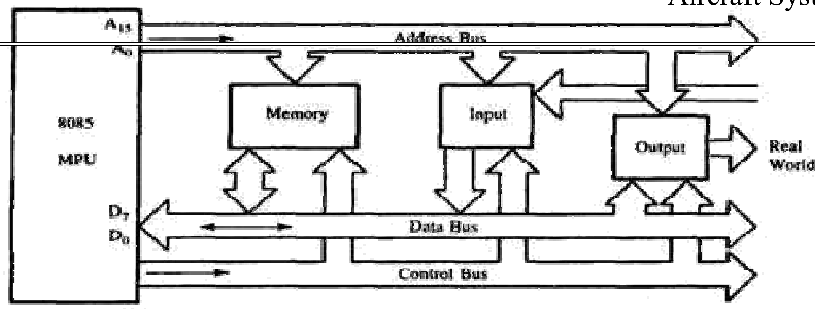
The functional block diagram or architechture of 8085 Microprocessor is very important as it gives the complete details about a Microprocessor. Fig. shows the Block diagram of a Microprocessor.



8085 BUS STRUCTURE:

Address Bus:

- The address bus is a group of 16 lines generally identified as A0 to A15.
- The address bus is unidirectional: bits flow in one direction-from the MPU to peripheral devices.
- The MPU uses the address bus to perform the first function: identifying a peripheral or a memory location.



Data Bus:

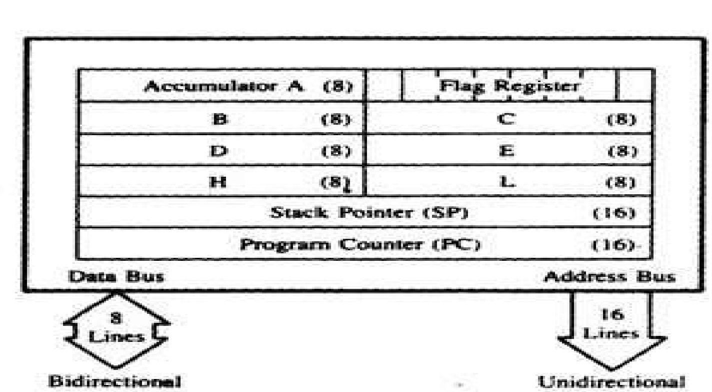
- The data bus is a group of eight lines used for data flow.
- These lines are bi-directional - data flow in both directions between the MPU and memory and peripheral devices.
- The MPU uses the data bus to perform the second function: transferring binary information.
- The eight data lines enable the MPU to manipulate 8-bit data ranging from 00 to FF (28 = 256 numbers).
- The largest number that can appear on the data bus is 11111111.

Control Bus:

- The control bus carries synchronization signals and providing timing signals.
- The MPU generates specific control signals for every operation it performs. These signals are used to identify a device type with which the MPU wants to communicate.

REGISTERS OF 8085:

- The 8085 have six general-purpose registers to store 8-bit data during program execution.
- These registers are identified as B, C, D, E, H, and L.
- They can be combined as register pairs-BC, DE, and HL-to perform some 16-bit operations.



Accumulator (A):

- The accumulator is an 8-bit register that is part of the arithmetic/logic unit (ALU).
- This register is used to store 8-bit data and to perform arithmetic and logical operations.
- The result of an operation is stored in the accumulator.

Flags:

- The ALU includes five flip-flops that are set or reset according to the result of an operation.
- The microprocessor uses the flags for testing the data conditions.
- They are Zero (Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags. The most commonly used flags are Sign, Zero, and Carry.

The bit position for the flags in flag register is,

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

1.Sign Flag (S):

After execution of any arithmetic and logical operation, if D7 of the result is 1, the sign flag is set. Otherwise it is reset. D7 is reserved for indicating the sign; the remaining is the magnitude of number. If D7 is 1, the number will be viewed as negative number. If D7 is 0, the number will be viewed as positive number.

2.Zero Flag (z):

If the result of arithmetic and logical operation is zero, then zero flag is set otherwise it is reset.

3.Auxiliary Carry Flag (AC):

If D3 generates any carry when doing any arithmetic and logical operation, this flag is set. Otherwise it is reset.

4.Parity Flag (P):

If the result of arithmetic and logical operation contains even number of 1's then this flag will be set and if it is odd number of 1's it will be reset.

5.Carry Flag (CY):

If any arithmetic and logical operation result any carry then carry flag is set otherwise it is reset.

ARITHMETIC AND LOGIC UNIT (ALU):

- It is used to perform the arithmetic operations like addition, subtraction, multiplication, division, increment and decrement and logical operations like AND, OR and EX-OR.
- It receives the data from accumulator and registers.
- According to the result it set or reset the flags.

Program Counter (PC):

- This 16-bit register sequencing the execution of instructions.
- It is a memory pointer. Memory locations have 16-bit addresses, and that is why this is a 16-bit register.

- The function of the program counter is to point to the memory address of the next instruction to be executed.
- When an opcode is being fetched, the program counter is incremented by one to point to the next memory location.

Stack Pointer (Sp):

- The stack pointer is also a 16-bit register used as a memory pointer.
- It points to a memory location in R/W memory, called the stack.
- The beginning of the stack is defined by loading a 16-bit address in the stack pointer (register).

Temporary Register: It is used to hold the data during the arithmetic and logical operations.

Instruction Register: When an instruction is fetched from the memory, it is loaded in the instruction register.

Instruction Decoder: It gets the instruction from the instruction register and decodes the instruction. It identifies the instruction to be performed.

Serial I/O Control: It has two control signals named SID and SOD for serial data transmission.

TIMING AND CONTROL UNIT:

- It has three control signals ALE, RD (Active low) and WR (Active low) and three status signals IO/M(Active low), S0 and S1.

- ALE is used for provide control signal to synchronize the components of microprocessor and timing for instruction to perform the operation.

- RD (Active low) and WR (Active low) are used to indicate whether the operation is reading the data from memory or writing the data into memory respectively.

- IO/M(Active low) is used to indicate whether the operation is belongs to the memory or peripherals.

- If,

IO/M(Active Low)	S1	S2	Data Bus Status(Output)
0	0	0	Halt
0	0	1	Memory WRITE
0	1	0	Memory READ
1	0	1	IO WRITE
1	1	0	IO READ
0	1	1	Opcode fetch
1	1	1	Interrupt acknowledge

INTERRUPT CONTROL UNIT:

- It receives hardware interrupt signals and sends an acknowledgement for receiving the interrupt signal.

PIN DIAGRAM AND PIN DESCRIPTION OF 8085

- The microprocessor is a clock-driven semiconductor device consisting of electronic logic circuits manufactured by using either a large-scale integration (LSI) or very-large-scale integration (VLSI) technique.
- The microprocessor is capable of performing various computing functions and making decisions to change the sequence of program execution.
- In large computers, a CPU implemented on one or more circuit boards performs these computing functions.
- The microprocessor is in many ways similar to the CPU, but includes the logic circuitry, including the control unit, on one chip.
- The microprocessor can be divided into three segments for the sake clarity, arithmetic/logic unit (ALU), register array, and control unit.
- 8085 is a 40 pin IC, DIP package. The signals from the pins can be grouped as follows

1. Power supply and clock signals
2. Address bus
3. Data bus
4. Control and status signals
5. Interrupts and externally initiated signals
6. Serial I/O ports

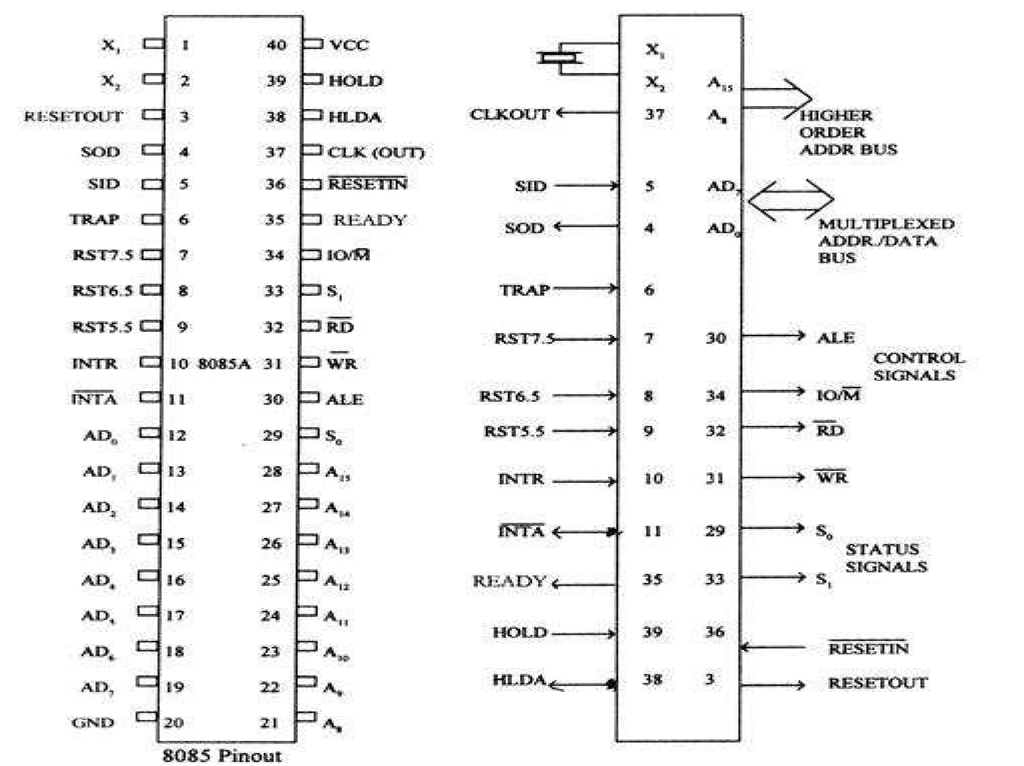


Fig (a) - Pin Diagram of 8085 & Fig(b) - logical schematic of Pin diagram.

1. **Power supply and Clock frequency signals**:

- Vcc + 5 volt power supply
- Vss Ground
- X1, X2 : Crystal or R/C network or LC network connections to set the frequency of internal clock generator.
- The frequency is internally divided by two. Since the basic operating timing frequency is 3 MHz, a 6 MHz crystal is connected externally.
- CLK (output)-Clock Output is used as the system clock for peripheral and devices interfaced with the microprocessor.

2. Address Bus:

- A8 - A15 (output; 3-state)
- It carries the most significant 8 bits of the memory address or the 8 bits of the I/O address;

3. Multiplexed Address / Data Bus:

- AD0 - AD7 (input/output; 3-state)
- These multiplexed set of lines used to carry the lower order 8 bit address as well as data bus.
- During the opcode fetch operation, in the first clock cycle, the lines deliver the lower order address A0 - A7.
- In the subsequent IO / memory, read / write clock cycle the lines are used as data bus.
- The CPU may read or write out data through these lines.

4. Control and Status signals:

- ALE (output) - Address Latch Enable.
- This signal helps to capture the lower order address presented on the multiplexed address / data bus.
- RD (output 3-state, active low) - Read memory or IO device.
- This indicates that the selected memory location or I/O device is to be read and that the data bus is ready for accepting data from the memory or I/O device.
- WR (output 3-state, active low) - Write memory or IO device.
- This indicates that the data on the data bus is to be written into the selected memory location or I/O device.
- IO/M (output) - Select memory or an IO device.
- This status signal indicates that the read / write operation relates to whether the memory or I/O device.
- It goes high to indicate an I/O operation.
- It goes low for memory operations.

5. Status Signals:

- It is used to know the type of current operation of the microprocessor.

MEMORIES

The user (programmer) selects instructions from the list and determines the sequence of execution for a given task. These instructions are entered or stored in storage, called memory, which can be read by the microprocessor.

Memory is like the pages of a note book with space for a fixed number of binary numbers on each line. However, these pages are generally made of semiconductor materials. Memory is an essential component of microcomputer system; it stores binary instructions and data for the microprocessor.

A memory unit is an integral part of any microprocessor system and its primary purpose is to store programs and data. A microprocessor memory system can be logically divided into three groups.

- Processor memory
- Primary (or) main memory
- Secondary memory

The 'Processor memory' refers to registers inside the microprocessor. These registers are used to hold the 'data and results' temporarily when a computation is in progress.

The 'Primary (or) Main memory' refers to the storage area which can be directly accessed by the microprocessor. Therefore, all programs and data must be stored only in primary memory prior to execution.

The 'secondary memory' refers to the storage medium comprising slow devices such as magnetic tapes and discs (hard disc, flappy disc and compact disc (CD)). They are called as auxillary or back up storage.

Semiconductor memory: The main or primary memory elements are semiconductor devices, because the semiconductor devices alone can work at high speeds and consume less power. More ever, they can be fabricated as ICs and so they occupy less space.

A typical semiconductor memory IC will have 'n' address pins (lines) and 'm' data pins (lines), then the 'capacity' of the memory will be 2^n x m bits.

CLASSIFICATIONS:

The different types of semiconductor memory are ROM, PROM, EPROM, static RAM, DRAM AND NDRAM.

(i) Volatile and non volatile memories:

Volatile memory, also known as volatile storage, is computer memory that requires power to maintain the stored information, unlike non-volatile memory which does not require a maintained power supply. It has been less popularly known as temporary memory. Most forms of modern random access memory (RAM) are volatile storage, including dynamic random access memory (DRAM) and static random access memory (SRAM).

Non-volatile memory, NVM or non-volatile storage, is computer memory that can retain the stored information even when not powered. Examples of non-volatile memory include read-only memory, flash memory, most types of magnetic computer storage devices (e.g. hard disks, floppy disks and magnetic tape), optical discs, and early computer storage methods such as paper tape and punch cards.

(ii) Read only memories and Read / write memories:

In 'Read only memories' the information are stored permanently either during manufacturing or after manufacturing and then interfaced to micro computer system. The processor can only read the stored information from these memories and cannot write into it. But in 'Read / write memory', the processor can store (write) the information as well as read from it. Example: ROM, PROM AND EPROM are read only memories and the NVRAM, static RAM and DRAM are read / write memories.

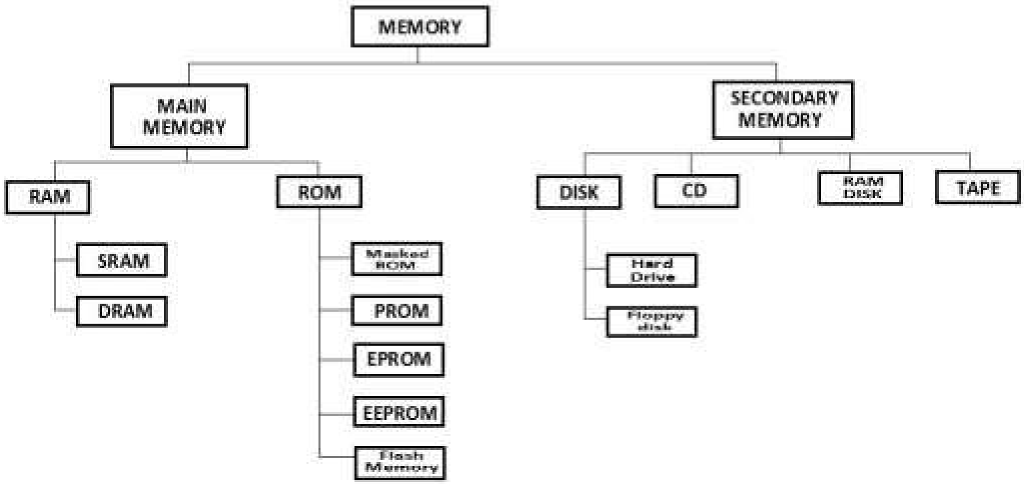


Fig: Memory classifications

ROM

The ROM is a semiconductor memory which permits only a read access. The ROM functions as a memory array whose contents, once programmed, are permanently fixed and cannot be altered by the microprocessor to which the memory is interfaced.

Programming:

The progress of storing information in ROM is called programming. The technique employed for storing information in the ROM provides a convenient method for classifying ROMs into one of the following three categories.

- Custom programmed (or) Mask programmed ROM (ROM)
- Programmable or field programmable ROM (PROM)
- Reprogrammable or Erasable programmable ROM (EPROM)

The 'custom programmed ROMs' are programmed by the manufacturer as specified by the user during fabrication and the contents cannot be changed after packing.

The 'Programmable ROMs' are one time programmable by the user.

The 'Reprogrammable ROMs' have facilities for programming as well as for erasing its content and reprogramming the memory. The reprogrammable ROMs are erased either by passing 'Electrical current' or 'Ultra-violet' light.

PROM

'Programmable Read only Memory' has nichrome or poly silicon wires arranged in a matrix; these wires can be functionally viewed as diodes or fuses. This memory can be programmed by the user with a special PROM programmer that selectively burns the fuses according to the bit pattern to be stored. The process is known as 'burning the PROM', and the information stored is permanent.

EPROM

The 'Read only memory (ROM) which has reprogrammable feature is called EPROM (Erasable Programmable Read Only Memory). In an EPROM, the binary information are entered using 'electrical impulses' and the stored information is erased using 'Ultra violet' rays. Typical erase time vary between 10 to 30 minutes. The EPROMs are manufactured by many semiconductor industry like INTEL, Hitachi, Toshiba, Cypress etc.,

EE-PROM

The Electrically Erasable PROM (EE-PROM) is functionally similar to EPROM, except that information can be altered by using electrical signals at the register level rather than erasing all the information. This has an advantage in field and remote control applications.

In microprocessor systems, software update is a common occurrence. If EE-PROMs are used in the systems, they can be updated from a central computer by using a remote link via telephone lines. Similarly, in a process control where timing information needs to be changed, it can be changed by the sending electrical signals from a central place. However this memory is expensive compared to EOROM or 'Flash memory'.

FLASH MEMORY (NVRAM)

This is a variation of EE-PROM that is becoming popular. The major difference between the flash memory and the EE-PROM is in the erasure procedure:

- The EE-PROM can be erased at a register level, but the flash memory must be erased either in its entirety or at the sector (block) level.

These memory chips can be erased and programmed at least a million times. The power supply requirement for programming these chips was around 12 V, but now chips are available that can be programmed using a power supply as low as 1.8 V. Therefore, this memory is ideally suited for low power systems.

RAM

It is used primarily for information that is likely to be altered, such as writing programs, or receiving data. The memory is volatile, meaning, that where the power is turned off, all the contents are destroyed. Two types of R/W memories are;

- Static memory (SRAM)
  - Its stores the bit as a voltage
  - The memory chip has low density but high speed
  - This memory is more expensive and consumes more power than the dynamic memory
- Dynamic memory (DRAM)
  - It stores the bit as a electric charge (bit informations).

    Advantages:
    - It has high density
    - Low power consumption

- Cheaper than static

memory Disadvantages:

- The charge (bit information) leaks; therefore, stored information needs to be read and written again every few milli seconds. This is called refreshing the memory.

DIGITAL AVIONICS ARCHITECTURE

"Architecture is the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time" –DoD Integrated Architecture Panel.

INTRODUCTION

Current avionics architectures utilize a number of different digital interconnects for a number of different avionics applications. Figure shows a typical design for a current system with the various interconnects conspicuously labelled. The speed and flexibility of these new interconnects opens the opportunity for reducing avionics costs by allowing a single network to replace most or all of the current interconnects.

DATA BUS SYSTEM

A system architecture enabling integration in both federated and integrated modular avionics. A conventional system comprises either 8 or 16 bidirectional lines capable of carrying information to and from a central processing unit memory or an interface device. There are two types of data-bus systems—electrical bus systems, in which the data are transmitted as electrical pulses by wires, and optical data-bus systems, in which the data are transmitted as light pulses by optical fibers. More famous electrical data buses are the MIL standard 1553B, which are widely used in most military aircraft, and the ARINC 429 and the ARNIC 629, which are used in civil aircraft.

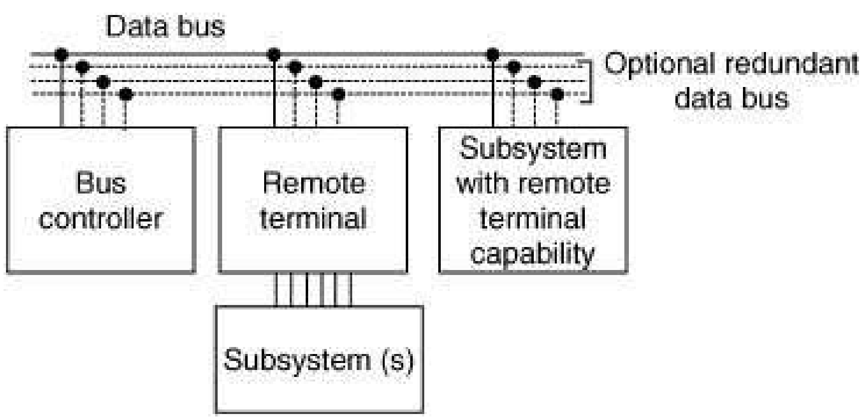


Fig: Typical multiplex data bus system.

Once the equipments are standardized, equipments are easily available, maintainable, reinstalled and reconfigured (Interchangeability). Also safety measure is different for military and civil aircrafts. So we need different standards for military and civil aircrafts. Standardization of equipments are based on the document Military Standard (MIL-STD) and Aeronautical Radio Inc. (ARINC) specifications and Reports.

DATA TRANSMISSION IN AIRCRAFT COMPUTER SYSTEMS

A control system is used to co operate the functions performed by each section of the computer. To do this, a communication link must be provided between the central control unit (CCU) and the various computer sections. A data transfer bus is typically used to provide this communication link. A data transfer bus is a digital connection, or link, between two or more digital devices. On some systems, this is a two way communication bus; on other systems the data bus is a one way link.

Fig: Data bus block diagram

Since the CCU performs the main co ordination of the functions of each peripheral device, it must be connected to each unit via a data transfer bus. The concept of a CCV and data bus is illustrated in figure. Here each section of the computer is linked to the data bus, which is linked to the CCU. Most digital communication data are transmitted in a serial form. That is, only binary digit at a time. Parallel data transmission is a continuous – type transmission requiring two wires (or one wire & ground) for each signal to be sent. Parallel transmission is so named because each circuit is wired in parallel with respect to the next circuit.

Serial data transmission requires less wire than a parallel system; however, an interpretation circuit is needed to convert all parallel data to serial type information prior to transmission. The device for sending serial data is called a multiplexer (MUX), and the device for receiving serial data is called a demultiplexer (DEMUX). As illustrated in the figure, Parralel data are sent to a multiplexer, where they are converted into serial data and sent to the data transfer bus. The data transfer bus is a two wire connection between the multiplexer and the demultiplexer.

COMMERCIAL / TRANSPORT AIRCRAFT DATA BUSES

For major industries like Aviation, Airports, Defence, Government and Transportation, Aeronautical Radio Incorporated (ARINC) is the leading provider of transport communications and systems engineering solutions. This corporation established by foreign and domestic Airlines, Aircraft manufacturers and transport companies. The purpose of ths organization is to aid in the standardization of systems.

Standards Categories

- 400 Series :guidelines for installation, wiring, data buses, databases, etc...
- 500 Series : analog avionics equipment (used for example on B-727, DC-9, DC-10, and early models of B-737, B-747, and A-300 aircraft)
- 600 Series :design foundation for equipment specified per the ARINC 700 Series
- 700 Series : digital systems and equipment installed on aircraft of digital avionics systems. Among the topics covered by Specifications are data link protocols
- 800 Series : enabling technologies supporting the networked aircraft environment. Among the topics covered in this series is fiber optics used in high-speed data buses
- 900 Series :avionics systems in an integrated modular and/or networked architecture

ARINC specifications have been established for digital flight data recorder (ARINC 573), inertial navigation systems (ARINC 561), digital information transfer system (ARINC 429 and 629) and various other aircraft communication and navigation systems.

MILITARY STANDARD

Military standard (MIL STD) is approved for use by all department and agencies of the department of defence. In recent years, the use of digital techniques in aircraft equipment has greatly increased, as have the number of avionics subsystems and the volume of data processed by them.

Because analog point-to-point wire bundles are inefficient and cumbersome means of interconnecting the sensors, computers, actuators, indicators, and other equipment onboard the modern military vehicle, a serial digital multiplex data bus was developed. MIL-STD-1553 defines all aspects of the bus, therefore, many groups working with the military tri-services have chosen to adopt it.

The Department of Defense chose multiplexing because of the following advantages:

- Weight reduction
- Simplicity
- Standardization
- Flexibility

Some 1553 applications utilize more than one data bus on a vehicle. This is often done, for example, to isolate a Stores bus from a Communications bus or to construct a bus system capable of interconnecting more terminals than a single bus could accommodate. When multiple buses are used, some terminals may connect to both buses, allowing for communication between them.

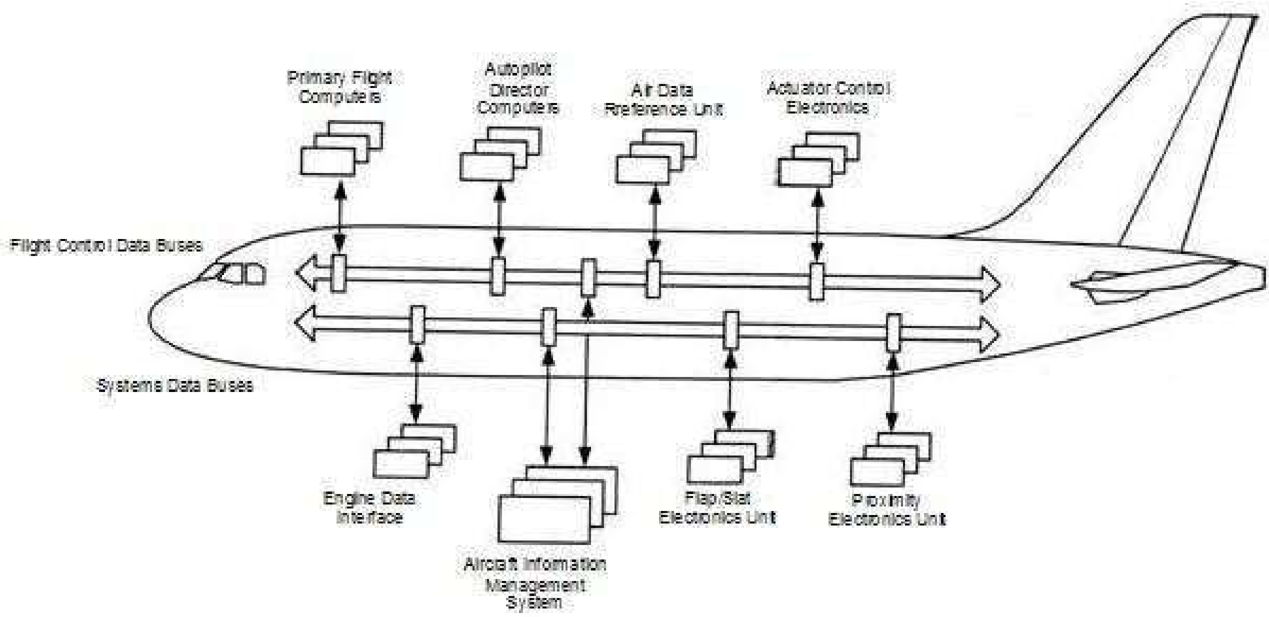


Fig: Multiple bus systems implemented on modern passenger aircraft

MIL-STD-1553

MIL-STD-1553, "Aircraft Internal Time-Division Command/Response Multiplex Data Bus," has been in use since 1973 and is widely applied. MIL-STD-1553 is referred to as "1553" with the appropriate revision letter (A or B) as a suffix. The basic difference between the 1553A and the 1553B is that in the 1553B, the options are defined rather than being left for the user to define as required. It was found that when the standard did not define an item, there was no coordination in its use. Hardware and software had to be redesigned for each new application. The primary goal of the 1553B was to provide flexibility without creating new designs for each new user. This was accomplished by specifying the electrical interfaces explicitly so that compatibility between designs by different manufacturers could be electrically interchangeable.

MULTIPLEXING

Multiplexing facilitates the transmission of information along the data flow. It permits the transmission of several signal sources through one communications system.

BUS

The bus is made up of twisted-shielded pairs of wires to maintain message integrity. MIL-STD-1553 specifies that all devices in the system will connect to a redundant pair of buses. This provides a second path for bus traffic should one of the buses be damaged. Signals are only allowed to appear on one of the two buses at a time. If a message cannot be completed on one bus, the bus controller may switch to the other bus. In some applications more than one 1553 bus may be implemented on a given vehicle. Some terminals on the bus may actually connect to both buses.

BUS COMPONENTS

There are only three functional modes of terminals allowed on the data bus: the bus controller, the bus monitor, and the remote terminal. Devices may be capable of more than one function. Figure 1 illustrates a typical bus configuration.

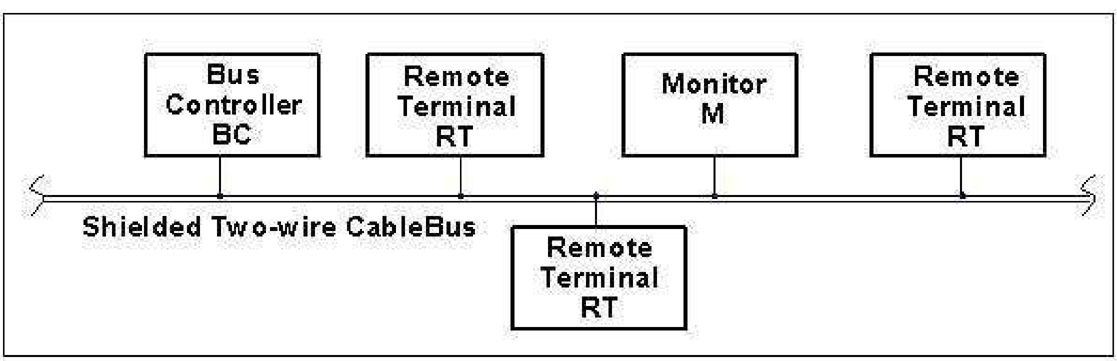


Fig: 1553 bus structure

- Bus Controller - The bus controller (BC) is the terminal that initiates information transfers on the data bus. It sends commands to the remote terminals which reply with a response. The bus will support multiple controllers, but only one may be active at a time. Other requirements, according to 1553, are: (1) it is "the key part of the data bus system," and (2) "the sole control of information transmission on the bus shall reside with the bus controller."

- Bus Monitor - 1553 defines the bus monitor as "the terminal assigned the task of receiving bus traffic and extracting selected information to be used at a later time." Bus monitors are frequently used for instrumentation.
- Remote Terminal - Any terminal not operating in either the bus controller or bus monitor mode is operating in the remote terminal (RT) mode. Remote terminals are the largest group of bus components.

MODULATION

The signal is transferred over the data bus using serial digital pulse code modulation.

DATA ENCODING

The type of data encoding used by 1553 is Manchester II biphase.

- A logic one (1) is transmitted as a bipolar coded signal 1/0 (in other words, a positive pulse followed by a negative pulse).
- A logic zero (0) is a bipolar coded signal 0/1 (i.e., a negative pulse followed by a positive pulse).

A transition through zero occurs at the midpoint of each bit, whether the rate is a logic one or a logic zero. Figure 2 compares a commonly used Non Return to Zero (NRZ) code with the Manchester II biphase level code, in conjunction with a 1 MHz clock.

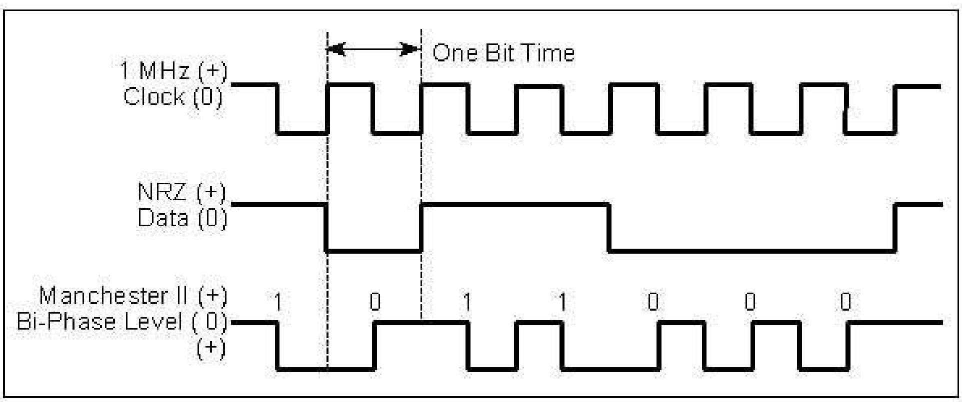


Fig: DATA Encoding

BIT TRANSMISSION RATE

The bit transmission rate on the bus is 1.0 megabit per second with a combined accuracy and long-term stability of +/- 0.1%. The short-term stability is less than 0.01%.

There are 20 1.0-microsecond bit times allocated for each word. All words include a 3 bit-time sync pattern, a 16-bit data field that is specified differently for each word type, and 1 parity check bit.

WORD FORMATS

Bus traffic or communications travels along the bus in words. A word in MIL-STD-1553 is a sequence of 20 bit times consisting of a 3 bit-time sync wave form, 16 bits of data, and 1 parity check bit. This is the word as it is transmitted on the bus; 1553 terminals add the sync and parity before transmission and remove them during reception. Therefore, the nominal word size is 16 bits, with the most significant bit (MSB) first.

There are three types of words: command, status, and data. A packet is defined to have no intermessage gaps. The time between the last word of a controller message and the return of the terminal status byte is 4-12 microseconds. The time between status byte and the next controller message is undefined. Figure (in 1553 chapter) illustrates these three formats.

COMMAND WORD

Command words are transmitted only by the bus controller and always consist of:

- 3 bit-time sync pattern
- 5 bit RT address field
- 1 Transmit/Receive (T/R) field
- 5 bit subaddress/mode field
- 5 bit word count/mode code field
- 1 parity check bit.

DATA WORD

Data words are transmitted either by the BC or by the RT in response to a BC request. The standard allows a maximum of 32 data words to be sent in a packet with a command word before a status response must be returned. Data words always consist of:

- 3 bit-time sync pattern (opposite in polarity from command and status words)• 16 bit data field
- 1 parity check bit.

STATUS WORD

Status words are transmitted by the RT in response to command messages from the BC and consist of:

- 3 bit-time sync pattern (same as for a command word)
- 5 bit address of the responding RT
- 11 bit status field
- 1 parity check bit.

The 11 bits in the status field are used to notify the BC of the operating condition of the RT and subsystem.

INFORMATION TRANSFER

Three basic types of information transfers are defined by 1553:

1. Bus Controller to Remote Terminal transfers
2. Remote Terminal to Bus Controller transfers
3. Remote Terminal to Remote Terminal transfers

These transfers are related to the data flow and are referred to as messages. The basic formats of these messages are shown in Figure 4.

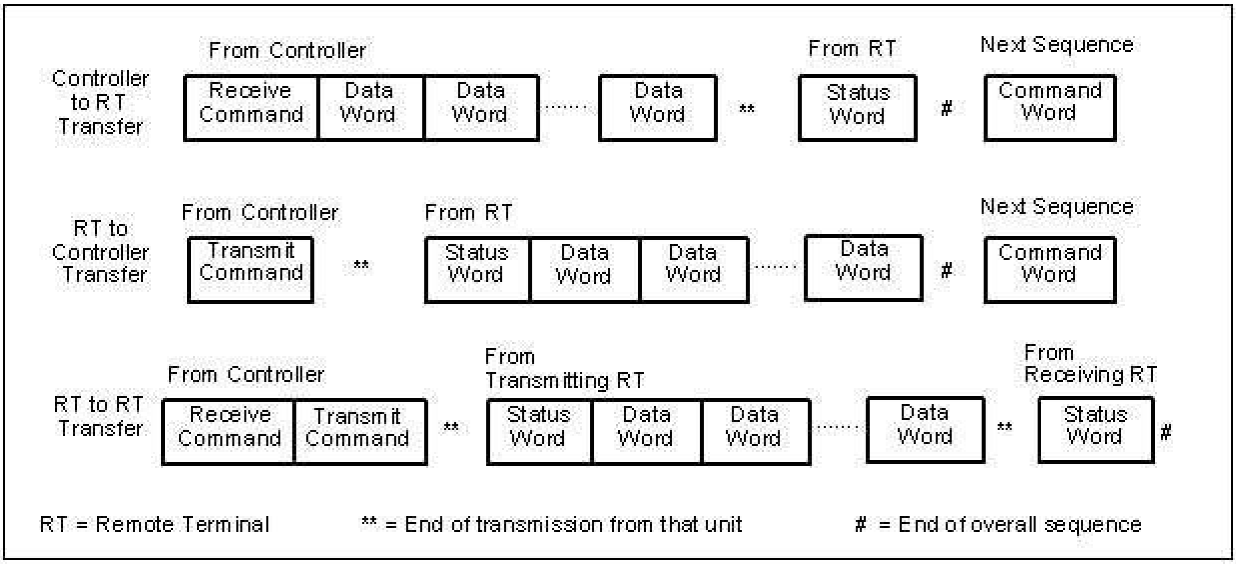


Fig: 1553 Data Message Format

The normal command/response operation involves the transmission of a command from the BC to a selected RT address. The RT either accepts or transmits data depending on the type (receive/transmit) of command issued by the BC. A status word is transmitted by the RT in response to the BC command if the transmission is received without error and is not illegal.Figure illustrates the 1553B Bus Architecture in a typical aircraft.

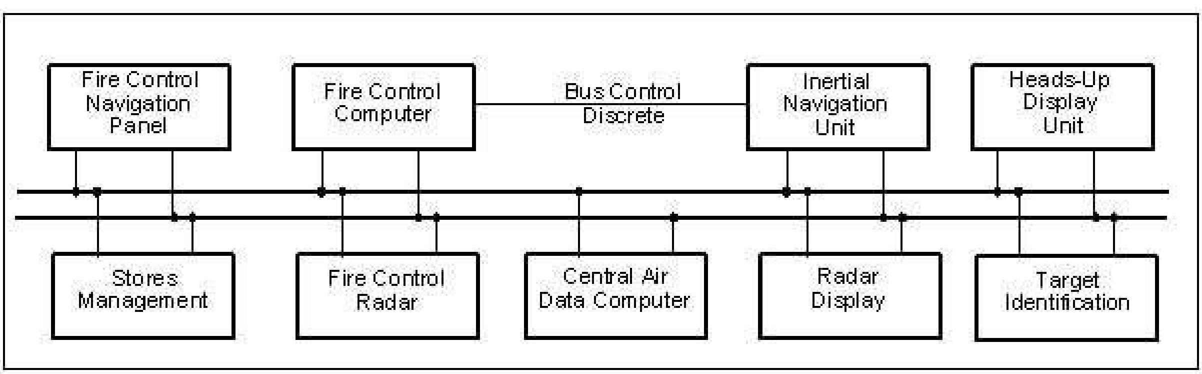


Fig: Typical Bus Architecture

1553
APPLICATIONS

The 1553 multiplex data bus provides integrated, centralized system control and a standard interface for all equipment connected to the bus. The bus concept provides a means by which all bus traffic is available to be accessed with a single connection for testing and interfacing with the system. The standard defines operation of a serial data bus that interconnects multiple devices via a twisted, shielded pair of wires. The system implements a command-response format.

The 1553 data bus is the most commonly used military data bus today. It is used in systems where data integrity and system reliability are critical. It is heavily used in aircraft avionics and stores and in ships, submarines and ground vehicles such as tanks. The data bus is also being used in space in numerous satellites and the Space Station and in some commercial applications such as reactors, subway cars and oil drilling.

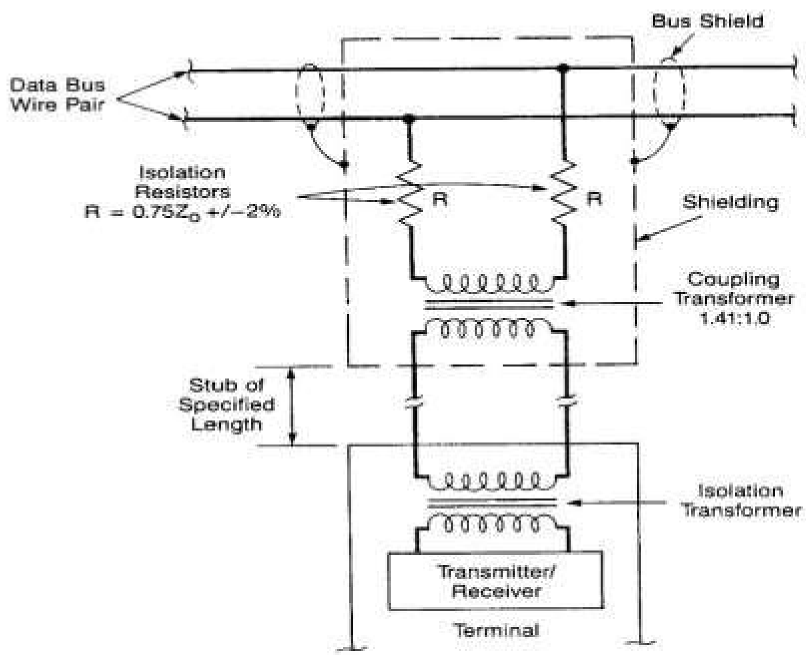


Fig: MIL-STD 1553 Standard Transformer coupled
Stub.

DATA INTEGRITY AND SYSTEM RELIABILITY

MIL-STD-1553 provides a high degree of data integrity by specifying word and message validation requirements. These include checks for parity, proper Manchester encoding, bit count, word count and proper timing. The Standard also specifies a tolerance to input signal zero crossings, requirements for noise rejection and wide margins between the transmitted signal and the received signal. To improve system reliability, most systems today use two buses operating standby redundant (dual standby redundant).

MIL STD 1553 B

MIL-STD-1553 is referred to as "1553" with the appropriate revision letter (A or B) as a suffix. The basic ifference between the 1553A and the 1553B is that in the 1553B, the options are defined rather than being left for the user to define as required. It was found that when the standard did not define an item, there was no coordination in its use. Hardware and software had to be redesigned for each new application. The primary goal of the 1553B was to provide flexibility without creating new designs for each new user. This was accomplished by specifying the electrical interfaces explicitly so that compatibility between designs by different manufacturers could be electrically interchangeable.

CONCEPTUAL DESCRIPTION

Figure shows a typical MIL STD 1553 B system

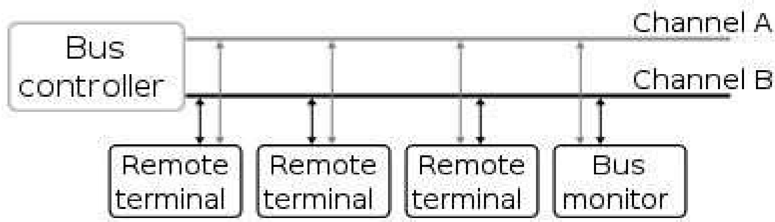


Fig: Dual-redundant MIL STD-1553B bus

1553B HARDWARE COMPONENTS

MIL-STD-1553B defines three types of terminal devices that are allowed on the bus:

a. Bus Controller (BC)
b. Remote Terminal (RT)
c. Bus Monitor (BM).

(a) Bus Controller

The main function of the bus controller (BC) is to provide data flow control for all transmissions on the bus. In addition to initiating all data transfers, the BC must transmit, receive and coordinate the transfer of information on the data bus. All information is communicated in command/response mode - the BC sends a command to the RTs, which reply with a response.

The bus controller, according to MIL-STD-1553B, is the “key part of the data bus system” and “the sole control of information transmission on the bus shall reside with the bus controller, which shall initiate all transmission”. The bus can support multiple BCs, but only one can be active at a time Normal BC data flow control includes transmitting commands to RTs at predetermined time intervals. The commands may include data or requests for data (including status) from RTs. The BC has control to modify the flow of bus data based on changes in the operating environment. These changes could be a result of an air-to-ground attack mode changing to air-to-air, or the failure mode of a hydraulic system. The BC is responsible for detecting these changes and initiating action to counter them. Error detection may require the BC to attempt communications to the RT on the redundant, backup bus.

(b) Remote Terminal

The remote terminal (RT) is a device designed to interface various subsystems with the 1553 data bus. The interface device may be embedded within the subsystem itself, or be an external interface to tie a non-1553 compatible device to the bus. As a function of the interface requirement, the RT receives and decodes commands from the BC, detects any errors and reacts to those errors. The RT must be able to properly handle both protocol errors (missing data, extra words, etc) and electrical errors (waveform distortion, rise time violations, etc). RTs are the largest segment of bus components. RT characteristics include:

a. Up to 31 remote terminals can be connected to the data
bus b. Each remote terminal can have 31 subadresses
c. No remote terminal shall speak unless spoken to first by the bus controller and specifically commanded to transmit

(c) Bus Monitor

The bus monitor (BM) listens to all messages on the bus and records selected activities. The BM is a passive device that collects data for real-time or post capture analysis. The BM can store all or portions of traffic on the bus, including electrical and protocol errors. BMs are primarily used for instrumentation and data bus testing.

WORD FORMAT

The multiplex data bus system in its most elemental configuration shall be as shown in above figure. The multiplex data bus system shall function a synchronously in a command / response mode, and transmission shall occur in a half duplex manner. Sole control of information transmission on the bus shall reside with the bus controller, which shall initiate all transmissions. The information flow on this data bus shall be comprised of messages which are, in turn, formed by three types of words (command, data and status).

(a) COMMAND WORD:

A command word shall be comprised of a sync wave form, remote terminal address field, transmit / receive (T/R) bit, sub address /mode field,word count / mode code field, and a parity (P) bit as shown in the figure.

i) Sync:

The command sync wave form shall be an invalid Manchester wave form as shown in below figure. The width shall be three bit times, with the sync wave form being positive for the first one and one half bit times, and then negative for the following one and one half bit times. If the next bit following the sync wave form is a logic zero, then the last half of the sync wave form will have an apparent width of two clock periods due to the Manchester encoding.

Fig: command and status sync

ii) Remote terminal address:

The next five bits following the sync shall be the RT address. Each RT shall be assigned a unique address. Decimal address 31 (11111) shall not be assigned as a unique address. In addition to its unique address, a RT shall be assigned decimal address 31 (11111) as the common address, if the broad cast option is used.

iii) Transmit / receive:

The next bit following the remote terminal address shall be the T/R bit, which shall indicate the action required of the RT. A logic zero shall indicate the RT is to receive, and a logic one shall indicate the RT is to transmit.

iv) Sub address / mode:

The five bits following the R/T bit shall be utilized to indicate an RT sub address or use of mode control, as is dictated by the individual terminal requirements. The sub address / mode values of 00000 and 11111 are reserved for special purposes, and shall not be utilized for any other function.

v) Data word count / mode code:

The next five bits following the sub addresses / mode field shall be the quantity of data words to be either sent out or received by the RT. A maximum of 32 data words may be transmitted or received in any one message block. All 1's shall indicate a decimal count of 31, and all 0's shall indicate a decimal count of 32.

vi) Parity:

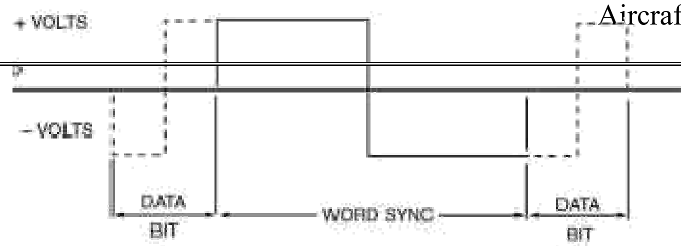
The last bit in the word shall be used for parity over the preceding 16 bits. Odd parity shall be utilized.

(b) DATA WORD

A data word shall be comprised of a sync wave form, data bits, and a parity bit.

i) Sync:

The data sync wave form shall be an invalid Manchester wave form as shown in below figure. The width shall be three bit times, with the wave form being negative for the first one and one half bit times, and then positive for the following one and one half bit times. Note that if the bits preceding and following the sync are logic ones, then the apparent width of the sync wavw form will be increased to four bit times.



ii) Data:

The sixteen bit following the sine shall be utilized for data transmission.

iii) Parity:

The last bit in the word shall be used for parity over the proceding 16 bits. Odd parity shall be utilized.

(c) STATUS WORD

A status word shall be comprised of a sync wave form, RT address, message error bit, instrumentation bit, service request bit, three reserved bits, broadcast command received bit, busy bit, sub system flag bit, dynamic bus control acceptance bit, terminal flag bit and a parity bit.

i) Sync:

(explained above)

ii) RT address:

The next five bits following the sync shall contain the address of the RT which is transmitting the status word. (also explained above)

iii) Message error bit:

The status word bit at bit time nine shall be utilized to indicate that one or more of the data words associated with the proceeding receive command word from the bus controller has failed to pass the RT's validity tests. A logic one shall indicate the presence of a message error, and a logic zero shall show its absence. All RT's shall implement the message error bit.

iv) Instrumentation bit:

The status word at bit time ten shall be reserved for the instrumentation bit and shall always be a logic zero. This bit is intended to be used in conjunction with a logic one in bit time ten of the command word to distinguish between a command word and a status word. The use of the instrumentation bit is optional.

v) Service request bit:

The status word bit at bit time eleven shall be reserved for the service request bit. The use of this bit is optional. This bit when used, shall indicate the need for the bus controller to take specific pre-defined actions relative to either the RT or associated subsystem. Multiple subsystems, interfaced to a single RT, which individually require a service request signal shall logically or their individual signals into the single status word bit.

vi) Reserved status bits:

The status word bits at bit times twelve through fourteen are reserved for future use and shall not be used. These bits shall be set to a logic zero.

vii) Broad cost command received bit:

The status word at bit time fifteen shall be set to a logic one to indicate that the preceding valid command word was a broad cast command and a logic zero shall show it was not a broad cast command. If the broad cast command option is not used, this bit shall be set to a logic zero.

viii) Busy bit:

The status word bit at time sixteen shall be reserved for the busy bit. The use of this bit is optional. This bit, when used, shall indicate that the RT or subsystem is unable to move data to or from the subsystem in compliance with the bus controller's command.

A logic one shall indicate the presence of a busy condition, and logic zeros its absence. In the event the busy bit is set in response to a transmit command, then the RT shall transmit its status word only. If this function is not implemented, the bit shall be set to logic zero.

ix) Sub system flag bit:

The status word bit at bit time seventeen shall be reserved for the subsystem flag bit. The use of this bit is optional. This bit when used, shall flag a subsystem fault condition, and alert the bus controller to potentially invalid data.

Multiple subsystems, interfaced to a single RT, which individually require a subsystem flag bit signal shall logically or their individual signals into the single status word bit. In the event this logical OR is performed, then the designer must make provisions in a separate data word to identify the specific reporting sub system. A logic one shall indicate the presence of the flag, and a logic zero its absence. If not used, this bit shall be set to logic zero.

x) Dynamic bus control acceptance bit:

The status word bit at bit time eighteen shall be reserved for the acceptance of dynamic bus control. This bit shall be used if the RT implements the optional dynamic bus control function.

This bit, when used, shall indicate acceptance or rejection of a dynamic bus control offer. A logic one shall indicate acceptance of control, and a logic zero shall indicate rejection of control. If then function is not used, this bit shall be set to logic zero.

xi) Terminal flag bit:

The status word bit at bit time nineteen shall be reserved for the terminal flag function. The use of this bus is optional. This bit, when used, shall flag a RT fault condition. A logic one shall indicate the presence of the flag, and a logic zero, its absence. If not used, this bit shall be set to logic zero.

xii) Parity:

The least significant bit in the status word shall be utilized for parity. (Already explained)

ARINC

Aeronautical Radio, Incorporated (ARINC), as it is known today, was incorporated in 1929 as Aeronautical Radio, Incorporated. ARINC is a major company that develops and operates systems and services to ensure the efficiency, operation, and performance of the aviation and travel industries. It was organized in 1929 by four major airlines to provide a single licensee and coordinator of radio communications outside the government. It is now a large international company with headquarters in Annapolis, Maryland and over 50 operating locations worldwide. ARINC has two regional headquarters: London to serve the Europe, middle East, and Africa region and Singapore for the Asia Pacific region.

The company has two major thrusts:

- Communications and information processing services for the aviation and travel industry.
- System engineering, development and integration for government and industry.

STANDARDS

- ARINC 404 and ARINC 600 define the **ATR** and MCU form factors for line-replaceable electronics units in aircraft. These standards date back to the 1930s.

- ARINC 424 is an international standard file format for aircraft navigation data.

- ARINC 429 is the most common standard, as all modern aircraft from Airbus and Boeing use this protocol. It provides the basic description of the functions and the supporting physical and electrical interfaces for the digital information transfer system. This protocol works either with 12.5 to 14.5 kHz or 100 kHz, and 32 bits of data length. Using the low speed mode of operation tolerances of 10% apply, whereas only 5% tolerances apply to the high-speed operation mode. ARINC 429, like the ARINC 561 standard, it is based on the ARINC 575 data format.

- ARINC 624 is a standard for aircraft onboard maintenance system (OMS). It uses ARINC 429 for data transmission between embedded equipements.

- ARINC 604 is a standard and guidance for the purpose of designing and implementing the Built-In Test Equipment (BITE). The description of the Centralized Fault Display System (CFDS) is included in this standard.

- ARINC 629 is a multi-transmitter protocol where many units share the same bus. It was a further development of ARINC 429 especially designed for the Boeing 777.

- ARINC 653 is a standard for partitioning of computer resources in the time and space domains. The standard also specifies APIs for abstraction of the application from the underlying hardware and software.

- ARINC 661 normalizes the definition of a cockpit display system (CDS), and the communication between the CDS and User Applications (UA). The GUI definition is completely defined in binary definition files (DF) – except the Look and feel, such as the CDS software is constituted of a kernel which is able to create the GUI hierarchy specified in the DF during initialisation, thus not needing to be recompiled if the GUI definition changes (apart from the "look and feel"). The concepts used by ARINC 661 are close to those used in user interface markup languages, except that the UI language is binary and not XML-based.

- ARINC 664 defines the use of a deterministic Ethernet network as an avionic databus in modern aircraft like the Airbus A380 and the Boeing 787.

- ARINC 708 is the standard for airborne weather radar. It defines the airborne weather radar characteristics for civil and military aircraft. This standard also defines the way to control and get information from the radar.

- ARINC 739 is the standard for communication between the MCDU and the systems attached to it.

ARINC 429

ARINC 429 is a data format for aircraft avionics. It provides the basic description of the functions and the supporting physical and electrical interfaces for the digital information system on an airplane. ARINC 429 is the predominant avionics data bus for most higher-end aircraft today.

ARINC 429 is the technical standard for the predominant avionics data bus used on most higher-end commercial and transport aircraft. It defines the physical and electrical interfaces of a two-wire data bus and a data protocol to support an aircraft's avionics local area network.

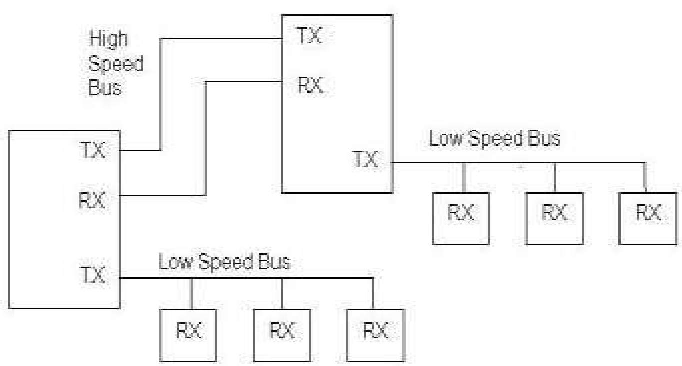


Fig: ARINC 429 architecture

ARINC 429 is a two-wire data bus that is application-specific for commercial and transport aircraft. The connection wires are twisted pairs. Words are 32 bits in length and most messages consist of a single data word. The specification defines the electrical and data characteristics and protocols.

ARINC 429 uses a unidirectional data bus standard (Tx and Rx are on separate ports) known as the Mark 33 Digital Information Transfer System (DITS). Messages are transmitted at either 12.5 or 100 kbit/s to other system elements that are monitoring the bus messages.

The transmitter is always transmitting either 32-bit data words or the NULL state. No more than 20 receivers can be connected to a single bus (wire pair) and no fewer than one receiver, though there will normally be more.

ARINC 429 WORD FORMAT

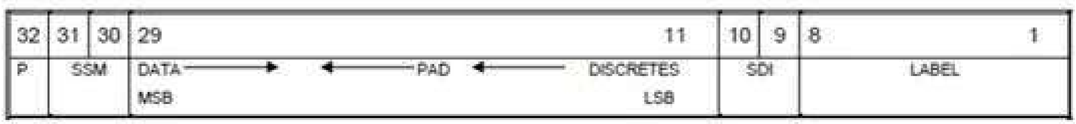


Fig: Generalized ARINC Word Format

Transmission and Reception Bit Pattern and Word Format

ARINC data messages are always 32 bit words and in general exploit the format shown in Figure, which includes five key fields, called Parity, SSM, Data, SDI, and Label. ARINC convention numbers the bits from 1 (LSB) to 32 (MSB).

ARINC Parity

Bit 32 is the parity bit, and is used to verify that the word was not damaged or garbled during transmission.

The Most significant bit MSB is always the parity bit in ARINC 429 protocol. Parity is usually set to odd except for particular tests. Odd parity in the sense, there must be an odd number of “1” bits in the 32-bit message word that is assured by either setting or re-setting the parity bit. Such as if number of bits 1-31 have an even number of “1” bits, then bit 32 (ie, parity bit) must be set to produce ODD parity in the message. Alternatively, if numbers of bits 1-31 have an odd number of “1” bits, then parity bit must be cleared to make ODD parity. Similar procedure will be followed for EVEN parity.

ARINC SSM (Sign Status Matrix)

Bits 30 to 31 is the Sign/Status Matrix, or SSM, and often indicates whether the data in the word is valid.

- OP (Operational) - Indicates the data in this word is considered to be correct data.
- TEST - Indicates that the data is being provided by a test source.
- FAIL - Indicates a hardware failure which causes the data to be missing.
- NCD (No Computed Data) - Indicates that the data is missing or inaccurate for some reason other than hardware failure. For example, autopilot commands will show as NCD when the autopilot is not turned on.

The SSM can also indicate the Sign (+/-) of the data or some information related to it like an orientation (North/South/East/West). This ARINC message bit field contains the hardware equipment state, operational mode or state, and validity of the data or message content.

ARINC Data (Information)

Bits 11 to 29 contain the data, ie information which needs to be communicated, and may be in different formats like Boolean, discrete words, discrete states, modes, 1's complement value, 2's complement values, binary coded decimal (BCD) values, and also lots of non standard formats that have been employed by a variety of manufacturers. In some scenarios, the data ie information field go beyond down to the SDI bits when SDI bit field is not used. Bit-field, Binary Coded Decimal (BCD), and two's complement binary encoding (BNR) are common ARINC 429 data formats. Data formats can also be mixed.

ARINC SDI (Source Destination Identifier)

Bits 9 and 10 are Source/Destination Identifiers (SDI) and indicate for which receiver the data is intended or more frequently which subsystem transmitted the data. These bits are used for numerous receivers to recognize the receiver for which the data or message is intended. It is used in multiple ARINC systems to recognize the source of the transmission. In a few special applications, these SDI bits are used along with data bits. ARINC 429 should have only one transmitter on a pair of transmission wires with up to 20 (Maximum) receivers.

ARINC Label (identifier)

Bits 1 to 8 contain a label (label words), expressed in octal, identifying the data type. The label is an essential element of the message. It is used to decide the data/message type of the rest of the word/information and, method of data transformation to use. ARINC 429 Labels are classically represented as in octal numbers.

ARINC Transmission Order

The least significant bit (LSB) of each byte apart from the label (which is transmitted MSB at the beginning) is transmitted first; the label is transmitted in front of the data in each case.

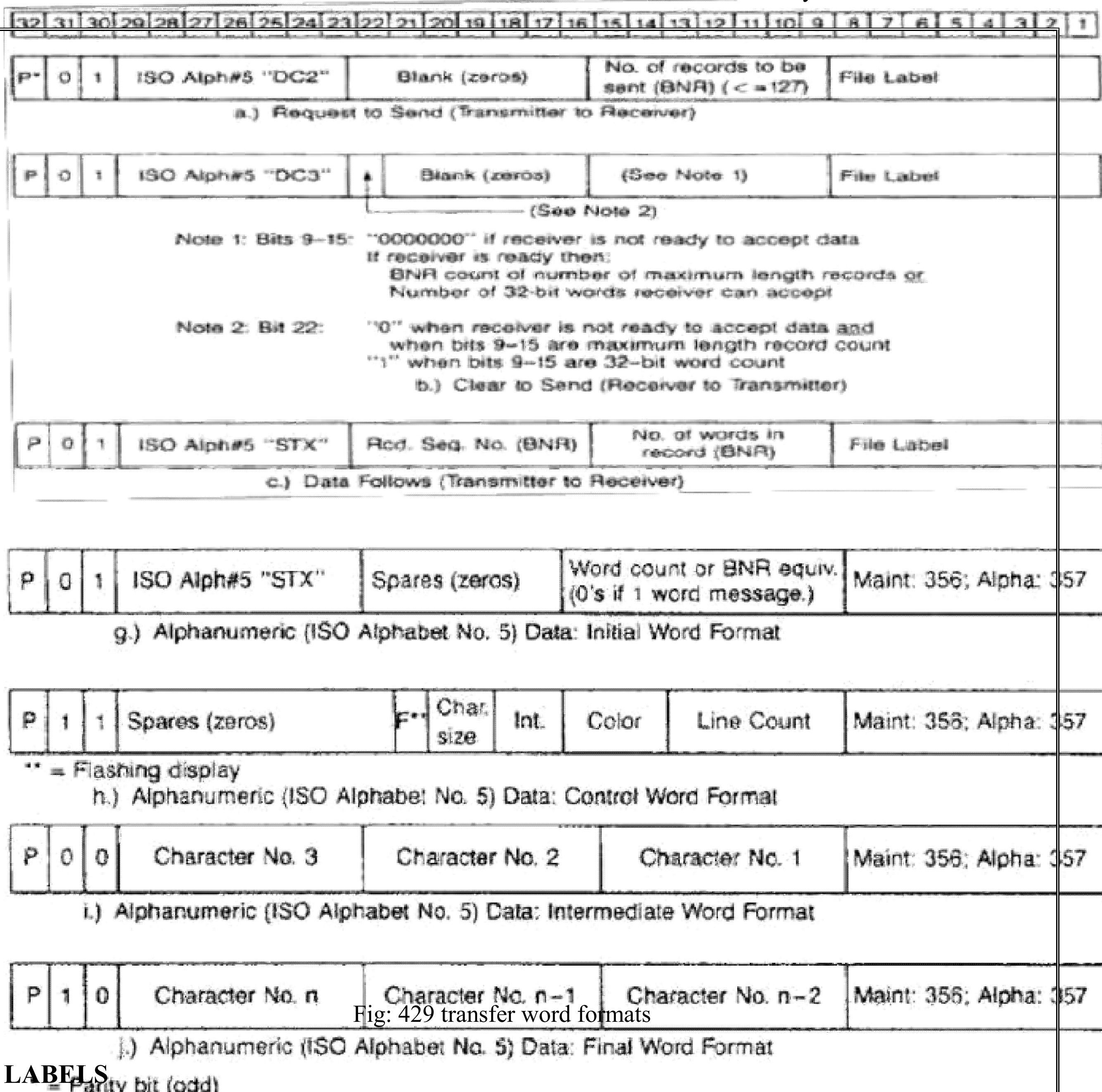


Fig: 429 transfer word formats

LABELS

Label guidelines are provided as part of the ARINC 429 specification, for various equipment types. Each aircraft will contain a number of different systems, such as Flight Management Computers, Inertial Reference Systems, Air Data Computers, Radio Altimeters, Radios, and GPS Sensors. For each type of equipment, a set of standard parameters is defined, which is common across all manufacturers and models.

For example, any Air Data Computer will provide the barometric altitude of the aircraft as label 204. This allows some degree of interchangeability of parts, as all Air Data Computers behave, for themost part, in the same way. There are only a limited number of labels, though, and so label 204 may have some completely different meaning if sent by a GPS sensor, for example.

Many very commonly needed aircraft parameters, however, use the same label regardless of source. Also, as with any specification, each manufacturer has slight differences from the formal specification, such as by providing extra data above and beyond the specification, leaving out some data recommended by the specification, or other various changes.

ARINC 629

ARINC 629 is a multi-transmitter protocol where many units share the same bus. It was a further development of ARINC 429 especially designed for the Boeing 777. It is a new digital data bus format that offers more flexibility and grater speed than the 429 system. ARINC 629 has two major improvement over the 429 system. First, there is a substantial weight saving. Second, the 629 bus operates at speeds up to 2 Mbits/s; the 429 is capable of only 100 Kbits/s.

ARINC 629 was introduced in May 1995 and is currently used on the Boeing 777, Airbus A330 and A340 aircraft. The ARINC 629 bus is a true data bus in that the bus operates as a multiple-source, multiple sink system as shown in below figure. That is, each terminal can transmit data to, and receive data from, every other terminal on the data bus. This allows much more freedom in the exchange of data between units in the avionics system. The true data bus topology is much more flexible in that additional units can be fairly readily accepted physically on the data bus.

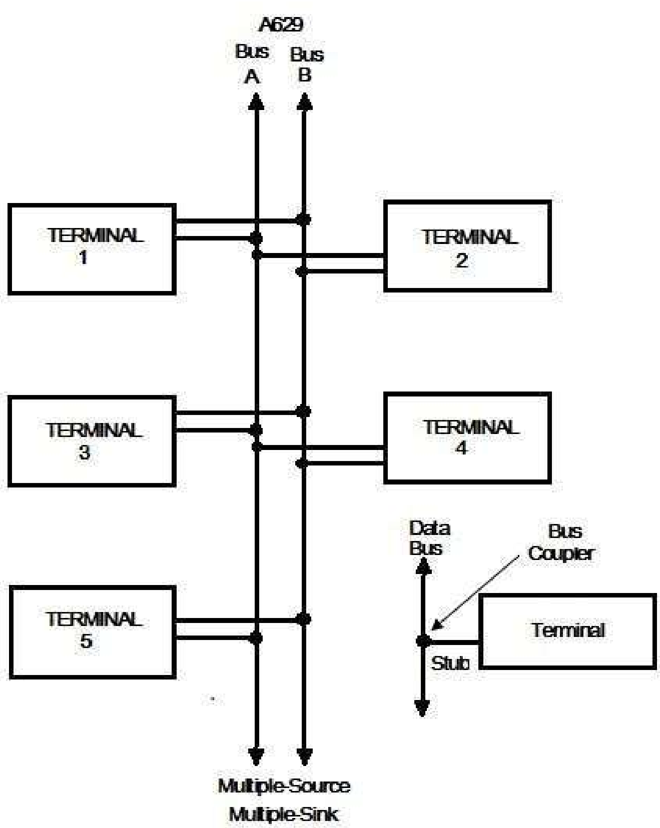


Fig: ARINC 629 Data bus topology

The protocol utilized by ARINC 629 is a time based, collision-avoidance concept in which each terminal is allocated a particular time slot to access the bus and transmit data on to the bus. Each terminal will autonomously decide when the appropriate time slot is available through the use of several control timers embedded in the bus interfaces and transmit the necessary data. Below figure shows the typical ARINC 629 20 bit data word format which is very similar to MILSTD- 1553B.

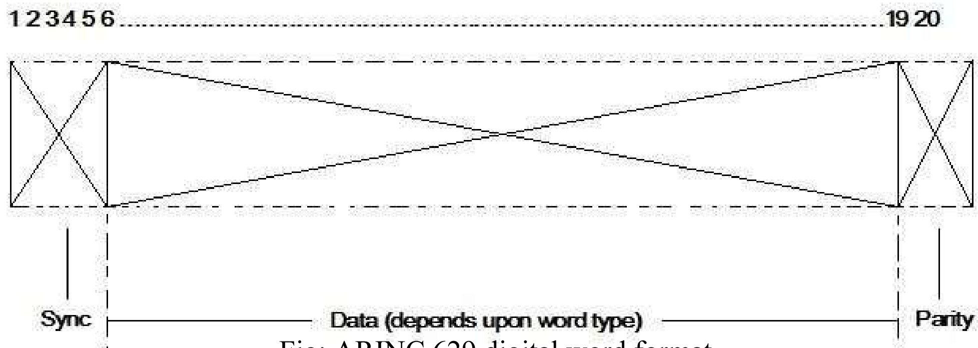


Fig: ARINC 629 digital word format

The first three bits are related to word time synchronization. The next 16 bits are the data contents, and the final bit is a parity bit. The data words may have a variety of formats depending on the word function; there is provision for general formats, systems status, function status, parameter validity, and binary and discrete data words.

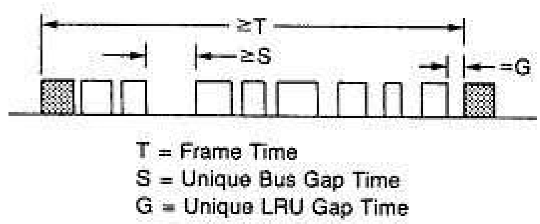


Fig: ARINC 629 Timing Parameters

The ARINC 629 data bus cable consists of an unshielded twisted pair of wires. The wires are #20 AWG and are bonded together continuously along their length. The cables can be up to 100 meters long and have no provisions for field splicing. ARINC 629 is defined for both voltage and current modes of operation.

The functions of Terminal controller in ARINC-629 is to provides Protocol Function and Data Validation. It acts as Subsystem/SIM Interface. It converts subsystem data to Manchester for SIM and decode Manchester data from SIM for subsystem. It also provides message and word sync pulses. It provides inter-word string gaps.

The functions of current mode coupler in ARINC-629 is to

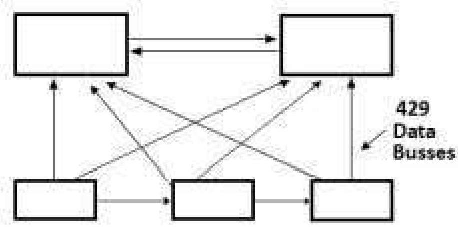
- Provides Non-intrusive connection to the Bus
- Transmits/Receives Doublets onto/from the Bus
- Provides Low Impedance to Bus under all conditions
- Decodes SIM Doublet Polarity for Channel selection
- Provides appropriate Receive Doublet Polarity for SIM
- Shuts Down Transmitters on Power Reversal

FEATURES OF ARINC 629 OVER ARINC 429:

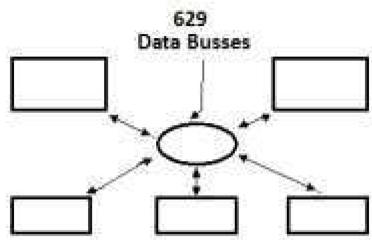
One attractive feature of ARINC 629 is that it will be defined for a fiber optic interface ARINC 629 data transmitted in groups called messages. Messages are comprised of word strings, up to 31 word strings can be in a message. Word strings begin with a label followed by up to 256 data words. Each label word and data word is 20 bits.

ARINC 629 is a new digital data bus format that offers more flexibility and greater speed than the 429 system. ARINC 629 permits up to 120 devices to share a bidirectional serial data bus, which can be up to 100 m long. The bus can be either a twisted wire pair or a fiber optic cable. The Boeing company, in developing the new B-777, is anticipating the use of ARINC 629 in a two format.

The 429 system requires a separate wire pair for each data transmitter. With the increased number of digital systems on modern aircraft, the 629 system will save hundreds of pounds by using one data bus for all transmitters. The fiure shows the simplified diagrams of the 429 and 629 bus structures. Here it can be seen that the 629 system requires must less data cables.



ONE WAY ARINC 429



TWO WAY ARINC 629

The ARINC 629 system can be thought of as a parity line for the various electronic systems on the aircraft. Any particular unit can transmit on the bus or "listen" for information. At any given time, only one user can transmit, and one or more units can receive data. This "open bus" scenario poses some interesting problems for the 629 system".

1. How to ensure that no single transmitter dominates the use of the bus
2. How to ensure that the higher – priority systems have a chance to talk first, and
3. How to make the bus compatible with a variety of systems

The answer is found in a system called the periodic – aperiodic multi transmitter bus. To understand this system, study the examples using four receivers / transmitters in the below figure.

Here the unique feature of ARINC 629 is that access to the bus to transmit by a given terminal is based on meeting three timing conditions. They are Transmit Interval (TI), Terminal Gap (TG) and Synchronization Gap (SG).

Transmit Interval (TI) is a global Bus Parameter. For a particular terminal, TI begins the moment the terminal starts transmitting. Once it has transmitted, it must wait the length of time specified by the TI before it can transmit again (0.5 to 64 ms).

Terminal Gap (TG) is an unique timer assigned to each terminal on the Bus. TG begins only after the SG has elapsed and only if no carrier is present. TG and SG cannot overlap in time, they must run consecutively(4 to 128 μs).

Synchronization Gap (SG) is a global access parameter. SG is the second longest timer and is set to the same value in all terminals. SG starts the moment the bus is quiet, it is reset if a carrier appears on the bus before it has elapsed.

A further attractive feature of ARINC 629 is the ability to accommodate up to a total of 128 terminals on a data bus shown in figure, though in a realistic implementation the high amount of data bus traffic would probably preclude the use of this large number of terminals. It supports a data rate of 2 Mbps.

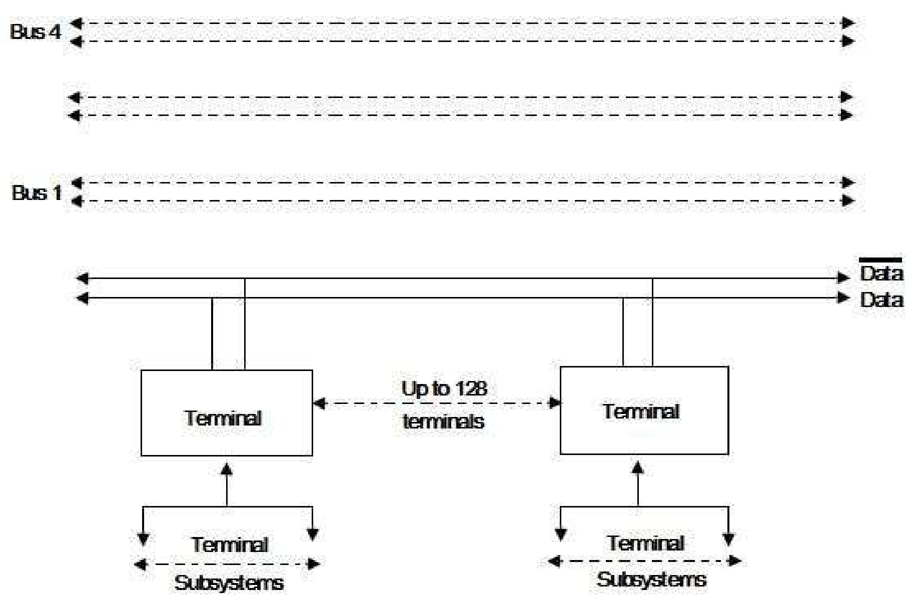


Fig: ARINC 629 data bus

Another unique feature of the ARINC 629 bus is the inductive coupling technique used to connect the bus to receiver / transmitters. As shown in above figure, the bus wires are fed through an inductive pick-up, which uses electromagnetic induction to transfer current from the bus to the user, or from the user to the bus. This system improves reliability, since no break in the bus wiring is needed to form connections.

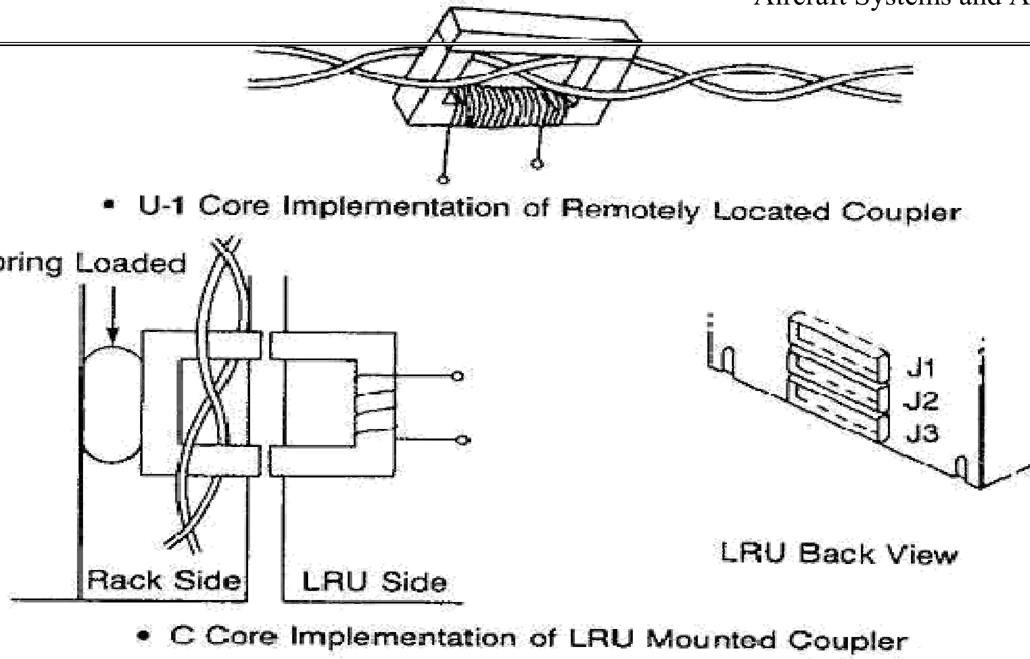
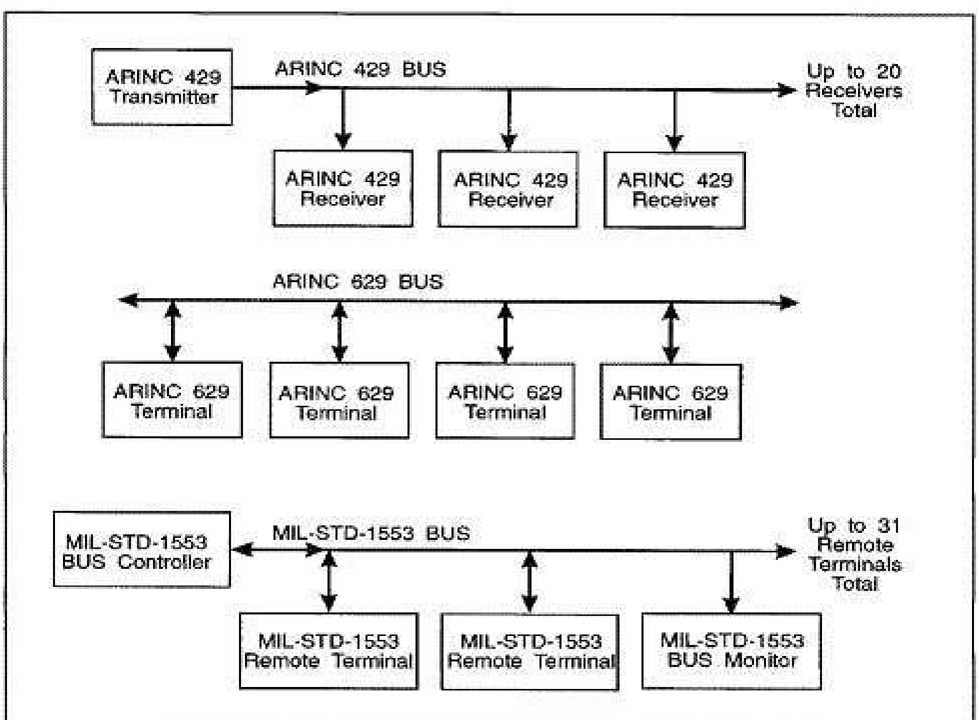


Fig: ARINC 629 Inductive Coupler

MAJOR DIFFERENCE BETWEEN ARINC-629 AND MIL-STD 1553:

ARINC-629 uses word formats that are very similar to those in MIL-STD-1553, but it does not have a bus controller. Instead, ARINC-629 gives each terminal autonomous access to the bus based upon meeting three timing conditions stored in a Transmit Personality programmable read-only memory, or PROM (XPP) in the host terminal. One of these timing conditions is unique to the terminal. Another difference from MIL-STD-1553 is the use of a Receive Personality PROM (RPP) to identify the labels of messages to be recorded from the bus.

Fig: Various Avionics Data bus architectures



COMPARISON OF DATABUSES

	Mil-Std-1553	ARINC 429	ARINC 629
Bus architecture	time division Multiplex	simplex point-to-point	time division multiplex
Encoding	bipolar Manchester II	bipolar, return to zero	bipolar, doublets Manchester
Transmission mode & coupling	voltage, direct or transformer	voltage direct connection	current coupling
Media	shielded twisted wire pair	shielded twisted wire pair	shielded twisted wire pair
Data bit rate	1 Mbps	12-14,5 kbps HS 100 kbps	2 Mbps
Effective data rate	800 kbps	HS 53 kbps	1,6 Mbps
# of terminals	1BC+31RT+xM	1TX+20RC	120

FLIGHT DECK AND COCKPITS

FLIGHT DECK AND COCKPIT

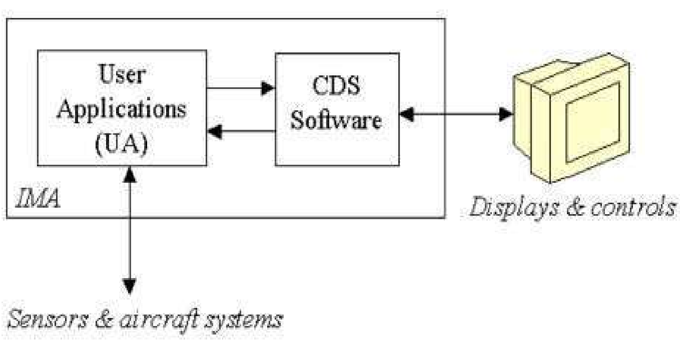
A cockpit or flight deck is the area, usually near the front of an aircraft, from which a pilot controls the aircraft. Most modern cockpits are enclosed, except on some small aircraft, and cockpits on large airliners are also physically separated from the cabin. From the cockpit an aircraft is controlled on the ground and in the air. The cockpit of an aircraft contains flight instruments on an instrument panel, and the controls which enable the pilot to fly the aircraft. In most airliners, a door separates the cockpit from the passenger compartment.

COCKPIT DISPLAY SYSTEMS

The Cockpit display systems (or CDS) provides the visible (and audible) portion of the Human Machine Interface (HMI) by which aircrew manage the modern Glass cockpit and thus interface with the aircraft avionics.

Architecture

Glass cockpits routinely include high-resolution multi-color displays (often LCD displays) that present information relating to the various aircraft systems (such as flight management) in an integrated way. Integrated Modular Avionics (IMA) architecture allows for the integration of the cockpit instruments and displays at the hardware and software level to be maximized.



CDS software typically uses API code to integrate with the platform (such as OpenGL to access the graphics drivers for example). This software may be written manually or with the help of COTS tools such as VAPS or SCADE Display.

Standards such as ARINC 661 specify the integration of the CDS at the software level with the aircraft system applications (called User Applications or UA).

ELECTRONIC FLIGHT INSTRUMENT SYSTEMS (EFIS)

EFISs employ CRTs to display alpha numeric data and representations of aircraft instruments. It replays several conventional instruments and caution and warning annuciators. A digital data bus system is used to transfer a majority of information between the various components of an EFIS. It is used to display flight data like horizontal situation indicators (HSIs) and altitude director indicators (ADIs).

An EFIS is composed by three sub systems;

- Pilot display system (PDS)
- Co pilot display system (CDS)
- Weather Radar system (WX)

Another version of EFIS found on many corporate aircraft having two EADIs and two EHSIs. Each one for the pilot and copilot. These four tubes are referred to as the primary displays.

The right side electronic displays receive data inputs from the right side Disply processor unit. The left side display inputs directly from the aircraft systems and from the Multi function processor unit (MPU). The multi function display (MFD), typically located in the center console of the flight deck, is used as the fifth display of the system. An EFIS with an MFD is often referred to as a 5 tube EFIS.

The EFIS uses input data from several sources including:

1. VOR/localizer/glideslope/TACAN/microwave landing system (MLS) receiver;
2. pitch, roll, and heading rate, and acceleration data from an Attitude Heading System (AHS) or conventional vertical gyro, compass system, and longitudinal accelerometer;
3. radar altimeter;
4. air data system;
5. DME;
6. area navigation system (RNAV) (i.e., ONS, INS, VLF, LORAN, GPS, etc.);
7. vertical navigation system;
8. weather radar system; and
9. ADF

Two variations of the basic electronic flight instrument system are;

- Engine indicating and crew alerting system (EICAS)
- Electronic centralized aircraft monitoring (ECAM) system

Like the EFIS, the above systems employ digitally controlled CRT displays. It is used to display various system parameters, such as engine pressure ratio, RPM and exhaust gas temperature. It is also used to monitor the various aircraft systems and display caution and warning information in the event of a system failure. Most transport and some corporate aircraft using these systems

Example: EICAS used in modern Boeing aircraft and ECAM system is used on modern Airbus aircraft.

CATHODE RAY TUBE (CRT)

The cathode ray tube (CRT) is a vacuum tube containing one or more electron guns (a source of electrons or electron emitter) and a fluorescent screen used to view images. It has a means to accelerate and deflect the electron beam(s) onto the screen to create the images. The images may represent electrical waveforms (oscilloscope), pictures (television, computer monitor), radar targets and others.

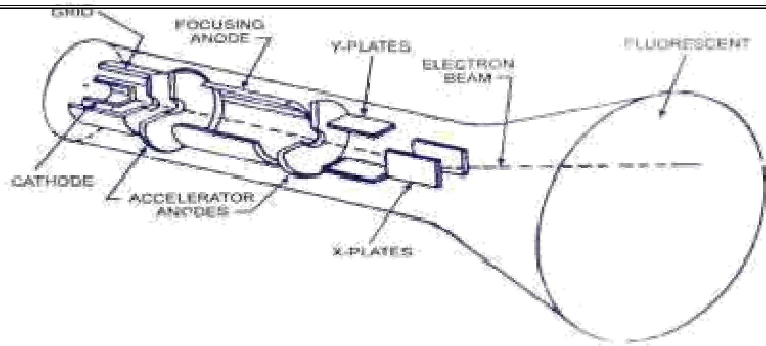


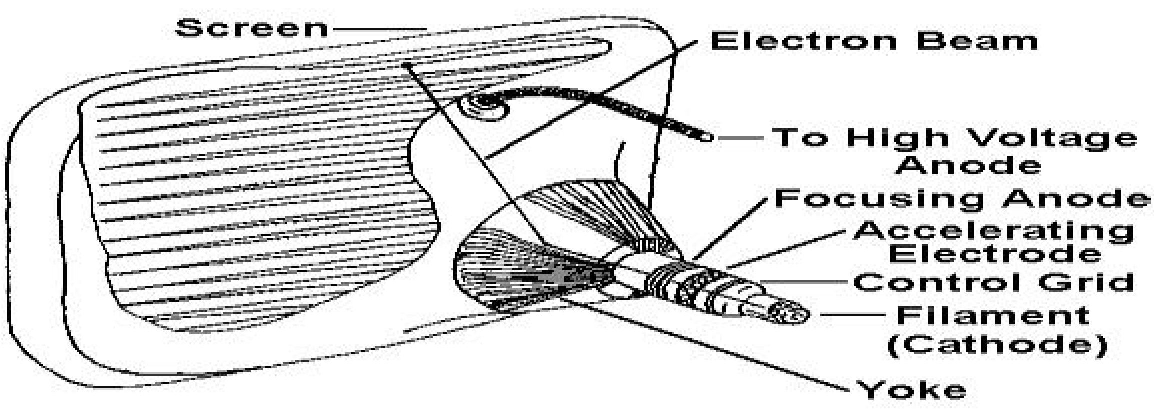
Fig: Cathode Ray Tube

Basic principle:

It works on the following principles: (i) thermionic emission (ii) deflection of the electron beam by the electric and magnetic field (iii) fluorescence produced by the electron beam on a fluorescent screen.

The screen itself is one end of a sealed glass tube, coated on the inside with substances (phosphors) which glow when electrons strike them. The other end of the tube has a substance such as barium oxide, with electrical connections from the control circuits. When a current flows from the control circuits, the oxide is heated. The heated oxide releases electrons from this negatively charged 'cathode' or 'electron gun'; they flow to the screen at the other end which has a positive electrical charge. When the electrons strike the fluorescent screen, the phosphors emit light (glow), and continue to glow for a finite time depending on the particular phosphor.

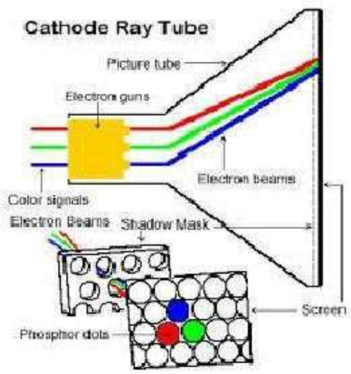
The image may represent electrical waveforms (oscilloscope), radar targets and others. CRTs have also been used as memory devices, in which case the visible light emitted from the fluoresecent material (if any) is not intended to have significant meaning to a visual observer (though the visible pattern on the tube face may cryptically represent the stored data).

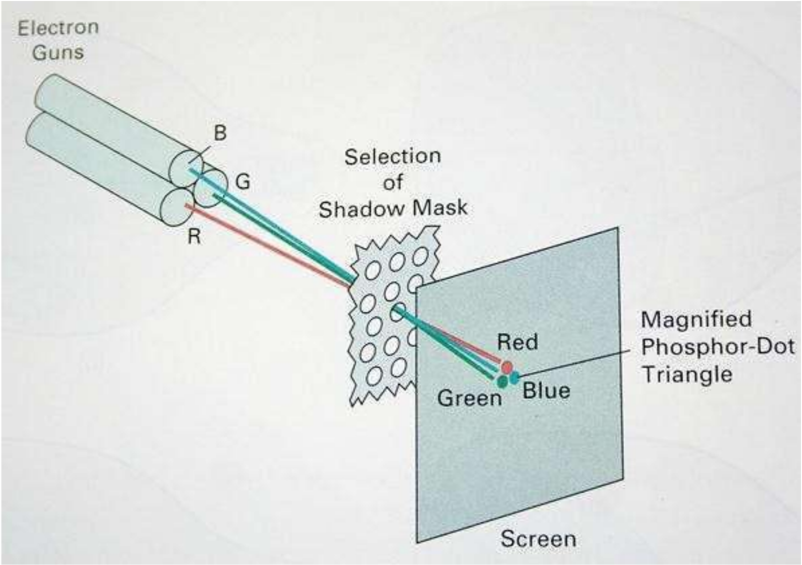


COLOR CRTS

Color tubes use three different phosphors which emit red, green, and blue light respectively. They are packed together in stripes (as in aperture grille designs) or clusters called "triads" (as in shadow mask CRTs). Color CRTs have three electron guns, one for each primary color, arranged either in a straight line or in an equilateral triangular configuration (the guns are usually constructed as a single unit).

The triangular configuration is often called "delta-gun", based on its relation to the shape of the Greek letter delta.) A grille or mask absorbs the electrons that would otherwise hit the wrong phosphor. A shadow mask tube uses a metal plate with tiny holes, placed so that the electron beam only illuminates the correct phosphors on the face of the tube. Another type of color CRT uses an aperture grille to achieve the same result.





There are two popular techniques for producing color displays with a CRT are:

1. **Beam-penetration method**
2. **Shadow-mask method**

1. Beam Penetration method

This CRT is similar to the simple CRT, but it makes use of multi coloured phosphorus of number of layers. Each phosphorus layer is responsible for one colour. All other arrangements are

similar to simple CRT. It can produce a maximum of 4 to 5 colours.

The organization is something like this - The red, green and blue phosphorus are coated in layers - one behind the other. If a low speed beam strikes the CRT, only the red colored phosphorus is activated, a slightly accelerated beam would activate both red and green (because it can penetrate deeper) and a much more activated one would add the blue component also.

But the basic problem is a reliable technology to accelerate the electronic beam to precise levels to get the exact colors - it is easier said than done. However, a limited range of colors can be conveniently produced using the concept.

2. The Shadow - Mask method.

This works, again, on the principle of combining the basic colors - Red, green and Blue - in suitable proportions to get a combination of colors, but it's principle is much more sophisticated and stable.The shadow mask CRT, instead of using one electron gun, uses 3 different guns placed one by the side of the other to form a triangle or a "Delta" as shown. Each pixel point on the screen is also made up of 3 types of phosphors to produce red, blue and green colors. Just before the phosphor screen is a metal screen, called a "shadow mask".

This plate has holes placed strategically, so that when the beams from the three electron guns are focused on a particular pixel, they get focused on particular color producing pixel only i.e. If for convenience sake we can call the electronic beams as red, blue and green beams (though in practice the colors are produced by the phosphors, and until the beams hit the phosphor dots, they produce no colors), the metal holes focus the red beam onto the red color producing phosphor, blue beam on the blue producing one etc. When focused on to a different pixel, the red beam again focuses on to the red phosphor and so on.

Now, unlike the beam penetration CRTs where the acceleration of the electron beam was being monitored, we now manipulate the intensity of the 3 beams simultaneously. If the red beam is made more intense, we get more of red color in the final combination etc. Since fine-tuning of the beam intensities is comparatively simple, we can get much more combination of colors than the beam penetration case. In fact, one can have a matrix of combinations to produce a wide variety of colors.

The shadow mask CRT, though better than the beam penetration CRT in performance, is not without it's disadvantages. Since three beams are to be focused, the role of the "Shadow mask" becomes critical. If the focusing is not achieved properly, the results tend to be poor. Also, since instead of one pixel point in a monochrome CRT now each pixel is made up of 3 points (for 3 colors), the resolution of the CRT (no. of pixels) for a given screen size reduces.

Another problem is that since the shadow mask blocks a portion of the beams (while focusing them through the holes) their intensities get reduced, thus reducing the overall brightness of the picture. To overcome this effect, the beams will have to be produced at very high intensities to begin with. Also, since the 3 color points, though close to each other, are still not at the same point, the pictures tend to look like 3 colored pictures placed close by, rather than a single picture. Of course, this effect can be reduced by placing the dots as close to one another as possible.

COCKPIT DISPLAY CRTs

Cockpit display CRTs are similar to television screens. In those, the time base is swept across the screen in lines. At the end of the line, the beam is switched off while it is brought back to the start of the next line. The picture is drawn from top to bottom. The control signal alters the brightness of each part of the line to produce the total picture.

LIGHT EMITTING DIODE (LED)

An LED is a solid- state display device comprising a forward –biased p-n junction transistor formed from a slice or chip of gallium arsenide phosphate (GaAsP) mounted into a transparent covering. When the current flows through the chip it emits light which is in direct proportion to the current flow.

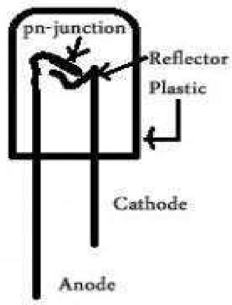


Fig: LED

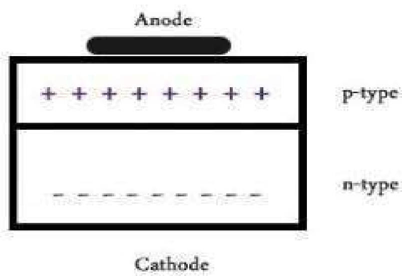


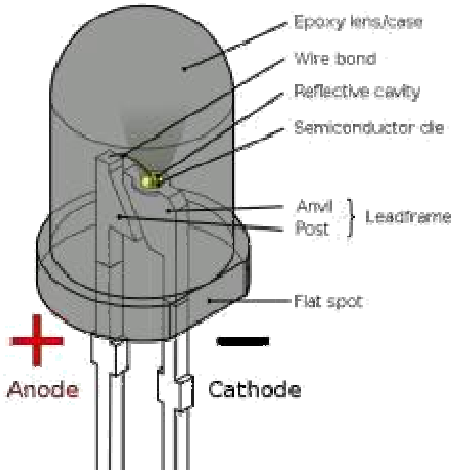
Fig: Sectional view

Light emission in different colors of spectrum can be obtained by varying the proportions of the elements comprising the chip, and can also be obtained by using the technique called doping with other elements, e.g. Nitrogen.

Design

Designs using LEDs have arrays of standard-sized push button switches with legends built into the surface of the switches. These legends are generated by small arrays of matrix addressable LEDs in the switch cover. Color can be used if desired. The legends are changed by the user or automatically by the aircraft as the mission phase changes.

The above figure shows the parts of an LED. Although not directly labeled, the flat bottom surfaces of the anvil and post embedded inside the epoxy act as anchors, to prevent the conductors from being forcefully pulled out from mechanical strain or vibration.



Working principle

When a light-emitting diode is forward-biased (switched on), electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence and the color of the light (corresponding to the energy of the photon) is determined by the energy gap of the semiconductor. LEDs are often small in area (less than 1 mm^2), and integrated optical components may be used to shape its radiation pattern.

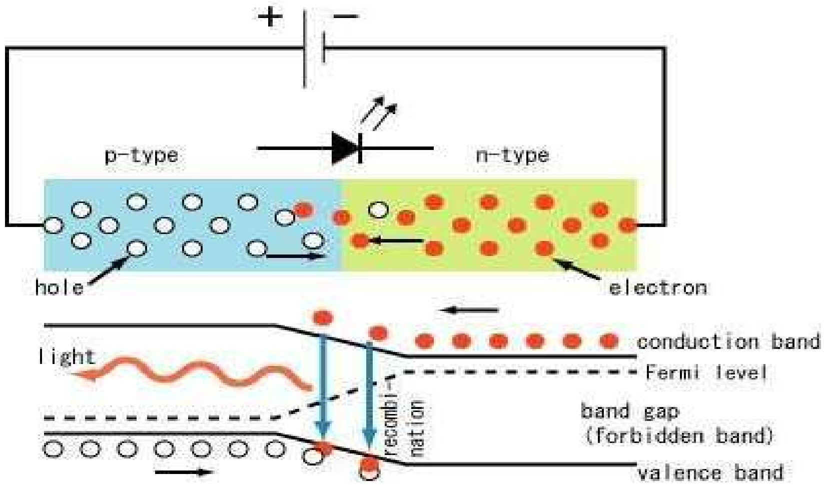


Fig: The inner workings of an LED

The heart of the display is a slice or chip of gallium arsenide phosphide (GaAsP) mounted into a transparent plastic covering which not only serves to protect the chip, but also as a diffuser lens. The diode leads are soldered to a printed circuit board to form the numerical display required.

When current flows through the chip it produces light, which is directly transmitted in proportion to the current flow. To provide different colors, the proportion of GaP and GaAs is varied during manufacture of the chip, and also the technique of 'doping' with other elements eg, Oxigen or Nitrogen is applied.

Advantages:

LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, and faster switching. LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

Applications

Light-emitting diodes are used in applications as diverse as aviation lighting, automotive lighting, advertising, general lighting, and traffic signals. LEDs have allowed new text, video displays, and sensors to be developed, while their high switching rates are also useful in advanced communications technology. Infrared LEDs are also used in the remote control units of many commercial products including televisions, DVD players, and other domestic appliances.

LIQUID CRISTAL DISPLAY (LCD)

A liquid crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals (LCs). LCs do not emit light directly.

Basic structure of an LCD

A liquid crystal cell consists of a thin layer (about 10 u m) of a liquid crystal sandwiched between two glass sheets with transparent electrodes deposited on their inside faces. With both glass sheets transparent, the cell is known as *transmittive type cell.* When one glass is transparent and the other has a reflective coating, the cell is called *reflective type.* The LCD does not produce any illumination of its own. It, in fact, depends entirely on illumination falling on it from an external source for its visual effect

Working principle

LCDs are made from liquid crystals, an intermediary substance between a liquid and a solid. When liquid crystals are inserted between alignment layers, they line up with the grooves of the layers. Light then follows the direction in witch the liquid crystal molecules are arranged. When an electrical charge is applies, the molecules re-arrange themselves in a vertical pattern and light passes through without being twisted.

A combination of polarizing filters along with alignment layers and liquid crystal molecules form a liquid crystal display. Two types of drive panels are used to control an LCD, active and passive. An active matrix display contains a transistor while a passive one does not. A transistor allows for superior picture quality and faster response times. All Vision Touch LCDs contain a transistor.

TYPES OF LCD/LIQUID CRYSTAL DISPLAYS

Two types of display available are dynamic scattering display and field effect display.

When dynamic scattering display is energized, the molecules of energized area of the display become turbulent and scatter light in all directions. Consequently, the activated areas take on a frosted glass appearance resulting in a silver display. Of course, the unenergized areas remain translucent.

Field effect LCD contains front and back polarizers at right angles to each other. Without electrical excitation, the light coming through the front polarizer is rotated 90° in the fluid.

COLOUR LIQUID CRYSTAL DISPLAY

Colour LCDs are those that can display pictures in colours. For this to be possible there must be three sub-pixels with red, green and blue colour filters to create each colour pixel. For combining these sub-pixels these LCDs should be connected to a large number of transistors. If any problem occurs to these transistors, it will cause a bad pixel.

One of the main disadvantages of these types of LCDs is the size. Most manufacturers try to reduce the height than gain it. This is because more transistors and greater pixels will be needed to increase the length. This will increase the probability of bad pixels. It is very difficult or also impossible to repair a LCD with bad pixels. This will highly affect the sale of LCDs.

Applications

LCDs are used in a wide range of applications, including computer monitors, television, instrument panels, aircraft cockpit displays, signage, etc. They are common in consumer devices such as video players, gaming devices, clocks, watches, calculators, and telephones. LCDs have replaced cathode ray tube (CRT) displays in most applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they cannot suffer image burn-in. LCDs are, however, susceptible to image persistence.

Advantages

The LCD is more energy efficient and offers safer disposal than a CRT. Its low electrical power consumption enables it to be used in battery-powered electronic equipment. It is an electronically modulated optical device made up of any number of segments filled with liquid crystals and arrayed in front of a light source (backlight) or reflector to produce images in color or monochrome. The most flexible ones use an array of small pixels.

Disadvantages

The main drawbacks of LCDs are additional requirement of light source, a limited temperature range of operation (between 0 and 60° C), low reliability, short operating life, poor visibility in low ambient lighting, slow speed and the need for an ac drive.

MAJOR DIFFERENCE BETWEEN LED & LCD

LEDs are based on the semiconductor diode. When the diode is forward biased (switched on), electrons are able to recombine with holes and energy is released in the form of light. This effect is called electroluminescence and the color of the light is determined by the energy gap of the semiconductor. LEDs present many advantages over traditional light sources including lower energy consumption, longer lifetime, improved robustness, smaller size and faster switching. However, they are relatively expensive and require more precise current and heat management than traditional light sources.

A liquid crystal display (LCD) is a thin, flat panel used for electronically displaying information such as text, images, and moving pictures Among its major features are its lightweight construction, its portability, and its ability to be produced in much larger screen sizes than are practical for the construction of cathode ray tube (CRT) display technology. Its low electrical power consumption enables it to be used in battery-powered electronic equipment. It is an electronically-modulated optical device made up of any number of pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector to
Produce images in color or monochrome.

ELECTROLUMINISCENT DISPLAY (EL)

Electroluminescent Displays (ELDs) are a type of Flat panel display created by sandwiching a layer of electroluminescent material such as GaAs between two layers of conductors. When current flows, the layer of material emits radiation in the form of visible light. Electroluminescence (EL) is an optical and electrical phenomenon where a material emits light in response to an electric current passed through it, or to a strong electric field.

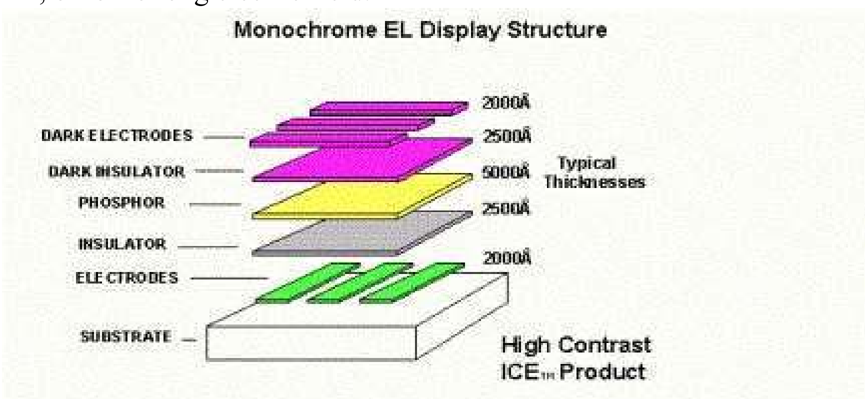
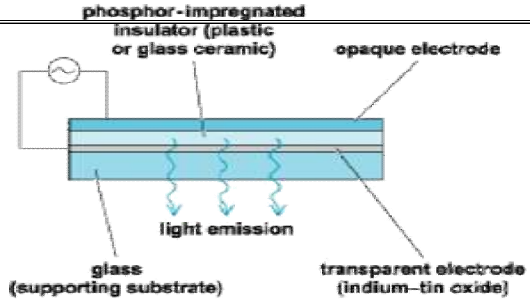


Figure 4

EL works by exciting atoms by passing an electric current through them, causing them to emit photons. By varying the material being excited, the colour of the light emitted can be changed. The actual ELD is constructed using flat, opaque electrode strips running parallel to each other, covered by a layer of electroluminescent material, followed by another layer of electrodes, running perpendicular to the bottom layer. This top layer must be transparent in order to let light escape. At each intersection, the material lights, creating a pixel.



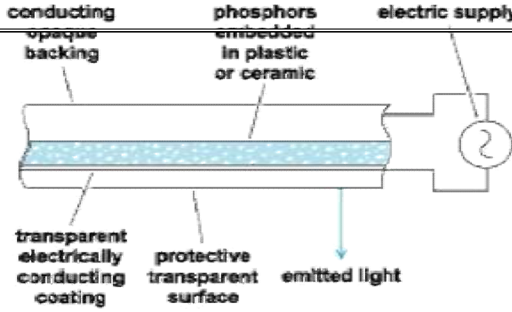


Fig: A structure of Electroluminescence Fig: simplified diagram of EL cell

There are four steps necessary to produce electroluminescence in ELDs:

1. Electrons tunnel from electronic states at the insulator/phosphor interface;
2. Electrons are accelerated to ballistic energies by high fields in the phosphor;
3. The energetic electrons impact-ionize the luminescent center or create electron-hole pairs that lead to the activation of the luminescent center; and
4. The luminescent center relaxes toward the ground state and emits a photon.

All ELDs have the same basic structure. There are at least six layers to the device. The first layer is a baseplate (usually a rigid insulator like glass), the second is a conductor, the third is an insulator, the fourth is a layer of phosphors, and the fifth is an insulator, and the sixth is another conductor.

Advantages

An electroluminescent (EL) device is similar to a laser in that photons are produced by the return of an excited substance to its ground state, but unlike lasers EL devices require much less energy to operate and do not produce coherent light. EL devices include *light emitting diodes*, which are discrete devices that produce light when a current is applied to a doped p-n junction of a semiconductor, as well as EL displays (ELDs) which are matrix-addressed devices that can be used to display text, graphics, and other computer images.

Applications

ELDs are particularly useful in applications where full color is not required but where ruggedness, speed, brightness, high contrast, and a wide angle of vision is needed. EL is also used in lamps and backlights.

PLASMA PANEL

A plasma display is an element displaying letter or graphic using light from plasma, generated during gas discharge. A plasma display panel (PDP) is a type of flat panel display. Many tiny cells between two panels of glass hold a mixture of noble gases (Neon and Xenon). The gas in the cells is electrically turned into a plasma which then excites phosphors to emit light.

Working principle

A plasma display panel (PDP) is essentially a matrix of tiny fluorescent tubes which are controlled in a sophisticated fashion. There are two main types, DC and AC of which the latter has become mainstream because of simpler structure and linger lifetime. This section treats the AC type.

A plasma discharge is first induced by the positive period of an AC field and a layer of carriers is shortly thereafter formed on top of the dielectric medium. This causes the discharge to stop but is induced again when the voltage changes polarity. In this way, a sustained discharge is achieved. The AC voltage is tuned just below the discharge threshold so the process can be switched on/off by adding a relatively low voltage at the address electrode.

The discharge creates a plasma of ions and electrons which gain kinetic energy by the electric field. These particles collide at high speed with neon and xenon atoms, which thereby are brought to higher-energy states. After a while, the excited atoms return to their original state and energy is dissipated in the form of ultraviolet radiation. This radiation, in turn, excite the phosphors which glow in red, green and blue (RGB) colors, respectively. Since each discharge cell can be individually addressed, it is possible to switch on and off picture elements (pixels).

TYPES

Plasma Display is divided into Direct Current type and Alternating Current type.

Electrode used to supply voltage from the outside and make plasma is exposed to the plasma directly and conduction current flows directly through electrode, which is Direct Current type. On the other hand, the electrode is covered by a dielectric and it is not directly exposed. So, displacement current flows, which is Alternating Current type.

And also it is divided into Partners Facing Discharge type, Surface Discharge type, Barrier Rib Discharge type, etc in accordance with the electrode structure of discharge cell. In case of using visible rays directly from discharge gas, it is mostly used for single color displaying PDP element.

For a typical example, there is a PDP using orange color from Ne gas. If full color display is required, ultraviolet rays from discharge gas such as Kr or Xe excite red, green, and blue phosphors and generate visible light, which is available.

Advantages

- Slim profile
- Can be wall mounted
- Less bulky than rear-projection televisions
- Produces deep blacks allowing for superior contrast ratio
- Wider viewing angles than those of LCD; images do not suffer from degradation at high angles unlike LCDs

Dis a d v a n t a g e s

- Susceptible to screen burn-in and image retention, although most recent models have pixelorbiter, that moves the entire picture faster than it's noticeable to the human eye, which reducesthe affect of burn-in but doesn't prevent burn-in. However turning off individual pixels doescounteract screen burn-in on modern plasma displays.
- Phosphors lose luminosity over time, resulting in gradual decline of absolute image brightness(newer models are less susceptible to this, having lifespans exceeding 100,000 hours, far longer than older CRT technology)
- Susceptible to "large area flicker"
- Generally do not come in smaller sizes than 37 inches
- Susceptible to reflection glare in bright rooms
- Heavier than LCD due to the requirement of a glass screen to hold the gases
- Use more electricity.

ADVANTAGE OF EL OVER PLASMA DISPLAY

- Less flickering
- Sustainable luminosity even during aging
- Light weight than plasma displays
- Simple light weight component
- Available in smaller size (unlike plasma displays, which are available only at 32")

COMPARISON OF CRT, LCD, PLASMA

CRT

Pros:

- High contrast ratio (over 15,000:1), excellent color and wide gamut, excellent black level
- No native resolution; the only current display technology capable of true multisyncing (displaying many different resolutions and refresh rates without the need for scaling).
- No input lag
- No ghosting and smearing artifacts during fast motion due to sub-millisecond response time, and impulse-based operation.
- Near zero color, saturation, contrast or brightness distortion
- Allows the use of light guns/pens.
- Excellent viewing angle

Cons:

- Large size and weight, especially for bigger screens (a 20-inch (51 cm) unit weighs about 50 lb (23 kg)).
- Relatively high power consumption at high brightness and contrast levels and fast scan rates.
- Generates a considerable amount of heat when running.
- Geometric distortion caused by variable beam travel distances but almost no distortion in most high-end displays.
- Can suffer screen burn-in
- Produces noticeable flicker at low refresh rates.

- Apart from televisions, CRT displays are normally only produced in 4:3 aspect ratio (though some widescreen CRT monitors, notably Sony's GDM-FW900, do exist).
- Hazardous to repair/service
- Color displays cannot be made in sizes smaller than 7 inches. Maximum size for direct-view displays is limited to about 40 inches due to practical and manufacturing restrictions (a CRT display of this size can weigh about 300 pounds).
- The glass envelopes contain large amounts (often kilograms) of toxic lead and barium as X-ray radiation shielding. The phosphors can also contain toxic elements such as cadmium.

CIVIL AND MILITARY COCKPIT

As aircraft displays have modernized, the sensors that feed them have modernized as well. Traditional gyroscopic flight instruments have been replaced by electronic Attitude and Heading Reference Systems (AHRS) and Air Data Computers (ADCs), improving reliability and reducing cost and maintenance. GPS receivers are usually integrated into glass cockpits.

Glass cockpit

A glass cockpit is an aircraft cockpit that features electronic (digital) instrument displays, typically large LCD screens, rather than the traditional style of analog dials and gauges. While a traditional cockpit relies on numerous mechanical gauges to display information, a glass cockpit uses several displays driven by flight management systems, which can be adjusted to display flight information as needed. This simplifies aircraft operation and navigation and allows pilots to focus only on the most pertinent information. They are also popular with airline companies as they usually eliminate the need for a flight engineer. In recent years the technology has become widely available in small aircraft.

Head Level displays

An HLD avoids the physiological limitation on eye refocusing time by placing directly below the HUD or top edge of the instrument panel a display in which an image and supplemental alphanumeric information are focused at a long distance. Thus, the need for the pilot to refocus his or her eyes to scan at least some information inside the cockpit is eliminated. Typically the HLD will contain a radar or infrared image of the outside scene. An HLD uses a high-intensity lamp coupled with dichroic filters to sort the white light into red, green and blue and with optics to collimate and fold the light. The red and green bands are each modulated by liquid crystal shutters in which each pixel is either opaque or transparent as required to generate a color image.

Multi Function Displays (MFDS)

A Multi-function display (MFD) (part of Multi Function structures) is a small screen (CRT or LCD) in an aircraft surrounded by multiple buttons that can be used to display information to the pilot in numerous configurable ways. Often an MFD will be used in concert with a Primary Flight Display.

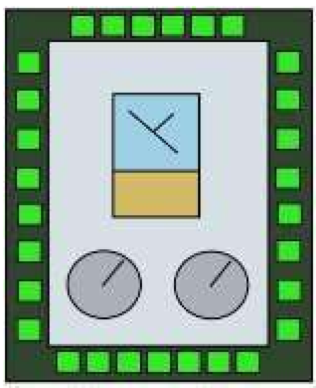


Fig: A schematic example of a multi-function display

Significance in Aircraft

MFDs are part of the digital era of modern planes or helicopter. The first MFD were introduced by air forces. The advantage of an MFD over analog display is that an MFD does not consume much space in the cockpit. All information is displayed on the MFD pages. The possible MFD pages could differ for every plane, complementing their abilities (in combat).

Many MFDs allow the pilot to display their navigation route, moving map, weather radar, NEXRAD, GPWS, TCAS and airport information all on the same screen. MFDs are added to the Space Shuttle (as the glass cockpit) starting in 1998 replacing the analog instruments and CRTs. The information being displayed is similar, and the glass cockpit was first flown on the STS-101 mission. In modern automotive technology, MFDs are used in cars to display navigation, entertainment and vehicle status information.

Installation and Location

In multifunction displays, CRT displays serve as MFKs. The most common way is for the CRT face to contain function labels correlated with adjacent switches mounted in the bezel surrounding the CRT. It is easy through software to change the switch function and the associated label on the CRT. The second method of implementing MFKs on CRTs is to overlay the CRT face with a touch-sensitive screen. The CRT face contains various switch function legends and the corresponding function is selected by touching that portion of the screen over the switch label.

Multi function display is normally located in the centre console of the flight deck. An EFIS (electronic flight instrument system) with MFD is often referred to a tube EFIS. The MFD unit is normally installed in the location reserved for the radar display and is therefore accessible to both members of the flight crew.

The MFDs different from the other two displays in that it contains its own power unit, check list data file and display controls. During a normal flight, the MFD will display navigation and will weather radar information. In the event of a system mal function, the MFD can be used as a back up for the primary displays and also it is used for displaying diagnostic information retrieved from (MPU) multi function processor unit.

HEAD UP DISPLAY (HUD)

A head-up display or heads-up display—also known as a HUD—is any transparent display that presents data without requiring users to look away from their usual viewpoints. It allows the pilot to see representations of the flight instruments while looking out of the wind screen. The origin of the name stems from a pilot being able to view information with the head positioned "up" and looking forward, instead of angled down looking at lower instruments.

Principle and Working of HUD

The principle adopted in a HUD system is to display the required data on the face of a CRT and to project them through a collimating lens as a symbolic image on to a transparent reflector plate, such that the image is superimposed on a pilot’s normal view, through the window screen, of the terrain ahead. The display is a combined alphanumeric and symbolic one, and since it is focused at infinity it permits simultaneous scanning of the ‘outside world’ and display without refocusing the eyes.

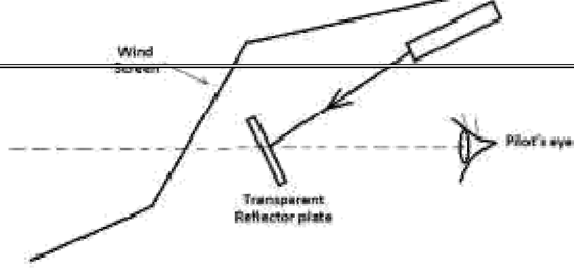


Fig: HUD basic principle

The HUD is basically a transparent glass plate placed in the pilot's line of vision on which the symbology of the required instrument is projected from behind and above the pilot's head. The projection is focused at infinity, so that the pilot's eyes do not have to refocus from the view out side to the display.

To use the HUD properly, the pilot's eyes must be aligned carefully with the screen. This makes the seating position of paramount importance. The screen itself needs to be coated with a substance to allow the projected image to show clearly, while still giving the pilot clear vision through it. The above figure shows a typical system, consisting of screen and projector, mounted in the cockpit structure.

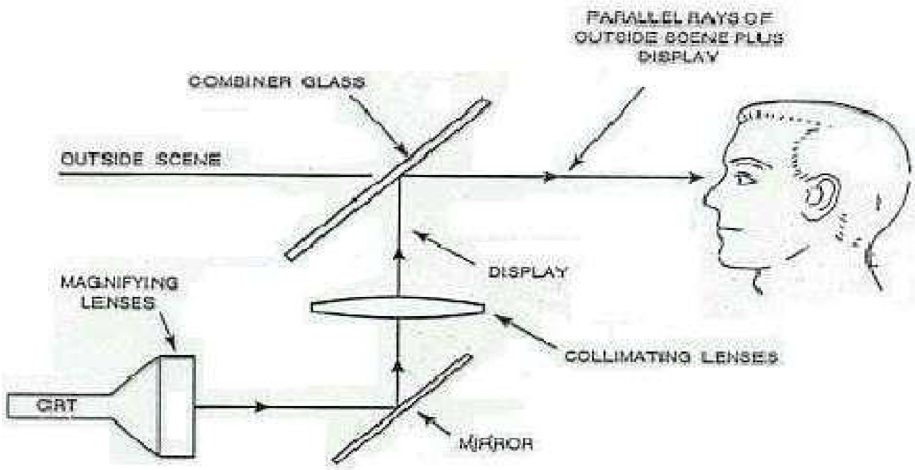


Fig: HUD Schematic

HUDs are initially developed for military aviation, HUDs are now used in commercial aircraft, automobiles, and other applications.

DESIGN FACTORS

- **Field of View** – also "FOV", indicates the angle(s), vertically as well as horizontally, subtended at the pilot's eye, that the combiner displays symbology in relation to the outside view.
- **Collimation** – The projected image is collimated which makes the light rays parallel. Because the light rays are parallel the lens of the human eye focusses on infinity to get a clear image.
- **Eyebox** – The optical collimator produces a cylinder of parallel light so the display can only be viewed while the viewer's eyes are somewhere within that cylinder, a three-dimensional area called the *head motion box* or *eyebox*. Modern HUD eyeboxes are usually about 5 lateral

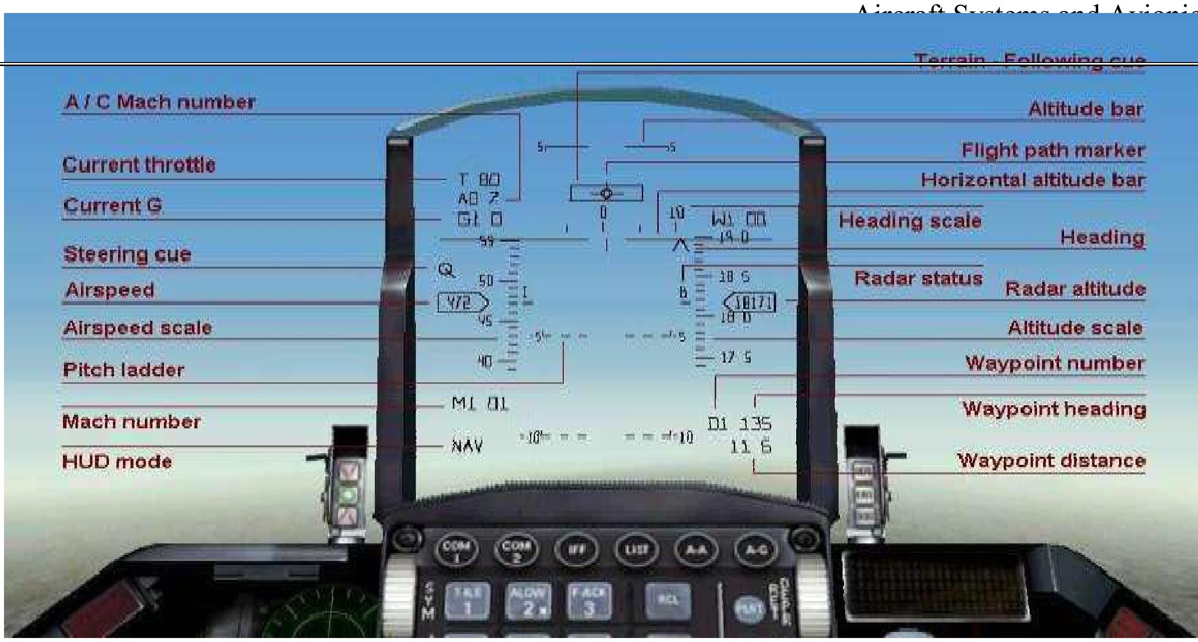
by 3 vertical by 6 longitudinal inches.

- **Luminance/contrast** – Displays have adjustments in luminance and contrast to account for ambient lighting, which can vary widely.
- **Boresight** – Aircraft HUD components are very accurately aligned with the aircraft's three axes – a process called *boresighting* – so that displayed data conforms to reality typically with an accuracy of ±7.0 milliradians.
- **Scaling** – The displayed image (flight path, pitch and yaw scaling, etc.), are scaled to present to the pilot a picture that overlays the outside world in an exact 1:1 relationship.
- **Compatibility** – HUD components are designed to be compatible with other avionics, displays, etc.

DISPLAYED DATA

Typical aircraft HUDs display

- airspeed- to display the craft's airspeed, typically in knots, to the pilot
- altitude-altitude is a distance measurement, usually in the vertical or "up" direction, between a reference datum and a point or object.
- a horizon line-to inform the pilot of the orientation of the aircraft relative to Earth's horizon
- heading- to inform the pilot of the aircraft's heading
- turn/bank and slip/skid indicators
- boresight or waterline symbol—is fixed on the display and shows where the nose of the aircraft is actually pointing.
- flight path vector (FPV) or velocity vector symbol—shows where the aircraft is actually going, acceleration indicator or energy cue—typically to the left of the FPV symbol, it is above it if the aircraft is accelerating, and below the FPV symbol if decelerating.
- angle of attack indicator—shows the wing's angle relative to the airflow, often displayed as "α".
- navigation data and symbols—for approaches and landings, the flight guidance systems can provide visual cues based on navigation aids such as an Instrument Landing System or augmentedGlobal Positioning System such as the Wide Area Augmentation System.



TYPES

Other than fixed mounted HUDs there are also head-mounted displays, including helmet mounted displays (both abbreviated HMD), forms of HUD that features a display element that moves with the orientation of the users' heads.

Many modern fighters (such as F/A-18, F-22, Eurofighter) use both a HUD and HMD concurrently. The F-35 Lightning II was designed without a HUD, relying solely on the HMD, making it the first modern military fighter not to have a fixed HUD.

Designing an HMD requires careful consideration of two factors they are Weight and Helmet aerodynamics. During high vertical acceleration maneuvers such as tight turns and ejection from the aircraft, the helmet can become a very heavy object, which leads to the mandate to design absolutely minimum-weight helmet mounted optics. Immediately following ejection, the helmet is exposed to a high-speed airflow which can generate substantial lift when flowing over a properly shaped object. Thus, the designer must ensure that the helmet is poorly designed from an aerodynamics perspective to ensure that it does not generate any lift and thereby suddenly pull on the pilot’s neck immediately following ejection.

APPLICATIONS:

Military applications include:

- Navigation and situation awareness
- Targeting
- Night vision systems
- Visual enhancement
- Security monitoring
- Simulation and training
- Maintenance and inspection
- Remotely-piloted vehicle interface

Commercial applications include:

- Computer-aided design/ Computer-aided engineering (CAD/CAE)
- Surgical aid - microsurgery, endoscopic surgery
- Emergency medical telepresence
- Security monitoring
- Maintenance, Repair and Overhaul (MRO)

ADVANTAGES OF HMD OVER HUD

- In HMD the gimballed sensors enables the pilot to watch critical data in the helmet in the directions through which he/she moves/looks, thus facilitating him/her to watch the primary data always.

- HMD display formats are very similar to those of HUDs except for the addition of helmet-pointing azimuth and elevation information and vectors showing where the last target of interest was prior to looking down into the cockpit or searching for another target.

MULTI FUNCTION KEYS

As the cockpits of modern aircraft have more controls jammed into them, the point reached where there is no more space. Multifunction keyboards (MFKs) offer a very attractive solution to this space problem wherein a single panel of switches performs a variety of functions depending on the phase of the mission or the keyboard menu selected. The Multi Function Keyboard (MFK) is an avionics sub-system through which the pilot interacts to configure mission related parameters like flight plan, airfield database, communication equipment during initialization and operation flight phase of mission.

Multifunction keyboards can be implemented in several ways. The first two ways use LEDs or LCDs in panels in a central location. Designs using LEDs have arrays (typically ranging from five rows of three switches to seven rows of five switches) of standard sized push button switches with legends built into the surface of the switches. The MFK consists of a MOTOROLA 68000 series processor with ROM, RAM and EEPROM memory. It is connected to one of the 1553B buses used for data communication. It is also connected to the Multi Function Rotary switch (MFR) through a RS422 interface. The MFK has a built-in display unit and a keyboard. The display unit is a pair of LCD based Colour Graphical Display, as well as a Monochrome Heads-Up Display.

FIG.GLV2000 MFD with multifunction keys

1. Power Switch
2. Nav Frequencies
3. Last/Next Wpt
4. Magnetic HDG
5. ADF Frequency
6. WPT Info Window
7. COM Frequencies
8. Range Selector
9. LNAV/VNAV Ind
10. COM Ctrl Knob
11. COM Freq Swap
12. Direct To Menu
13. Main Menu
14. Flight Plan Menu
15. Procedure Menu
16. Enter Key
17. Clear Key
18. Selector Knob
19. XPDR Menu
20. Auto/Susp Ind
21. Softkeys
22. Time Display
23. ADF Swap Key
24. ADF Knob
25. Escape Key
26. NAV Swap Key
27. NAV Ctrl Knob

Using multi-function keys, the system is very powerful and provides the pilot with everything needed for both vertical (VNav) and lateral (LNav) navigation.

HANDS ON THROTTLE AND STICK (HOTAS)

A design of a fighter cockpit so that every control switch, button, or trigger the pilot needs to operate radar, weapons, and aircraft controls in combat is located either on the throttle or the control column. Also called HOTAS—hand on throttle and stick.

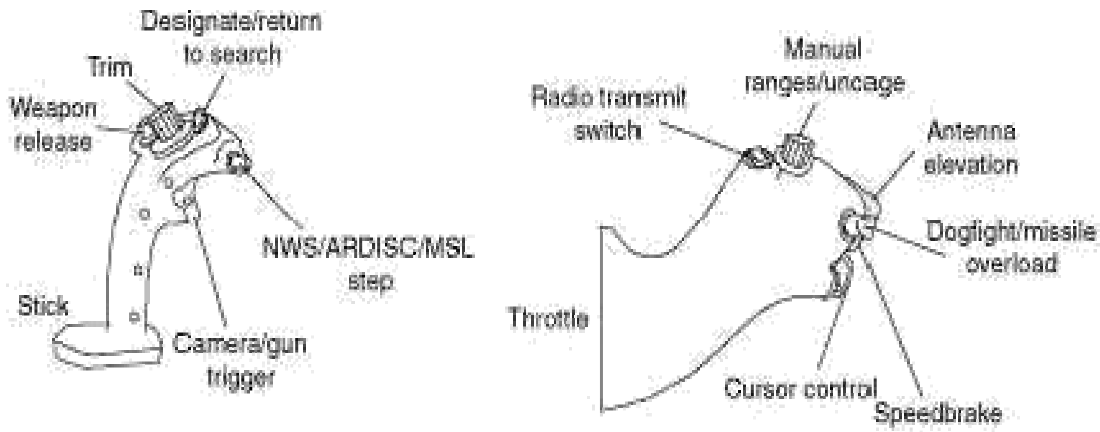


Fig: A typical HOTAS arrangement.

Hands On Throttle-And-Stick, is the name given to the concept of placing buttons and switches on the throttle stick and flight control stick in an aircraft's cockpit, allowing the pilot to access vital cockpit functions and fly the aircraft without having to remove his hands from the throttle and flight controls.

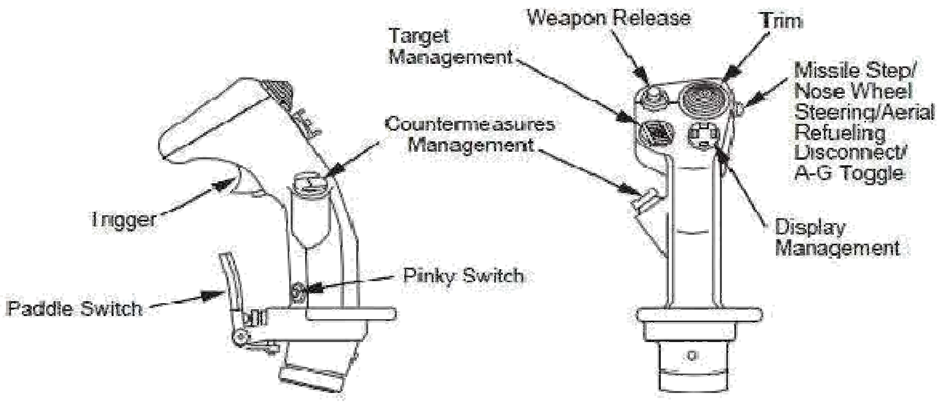
HOTAS allowing the modern fighter aircraft pilots to remain focused on more important duties than looking for controls in the cockpit. The goal is to improve the pilot's situational awareness, his ability to manipulate switch and button controls in turbulence, under stress, or during high G-force maneuvers, to improve his reaction time, to minimize instances when he must remove his hands from one or the other of the aircraft's controls to use another aircraft system, and total time spent doing so.

TYPICAL SYSTEM (F 16: HANDS – ON)

The Hands-On Throttle And Stick (HOTAS) are the primary flight controls for the F-16. They are referred to as "hands-on" since many of the common tasks the pilot needs to perform can be done using buttons and switches on the throttle and stick, which precludes the pilot from having to take his hands off the controls in combat or in other high-workload situations.

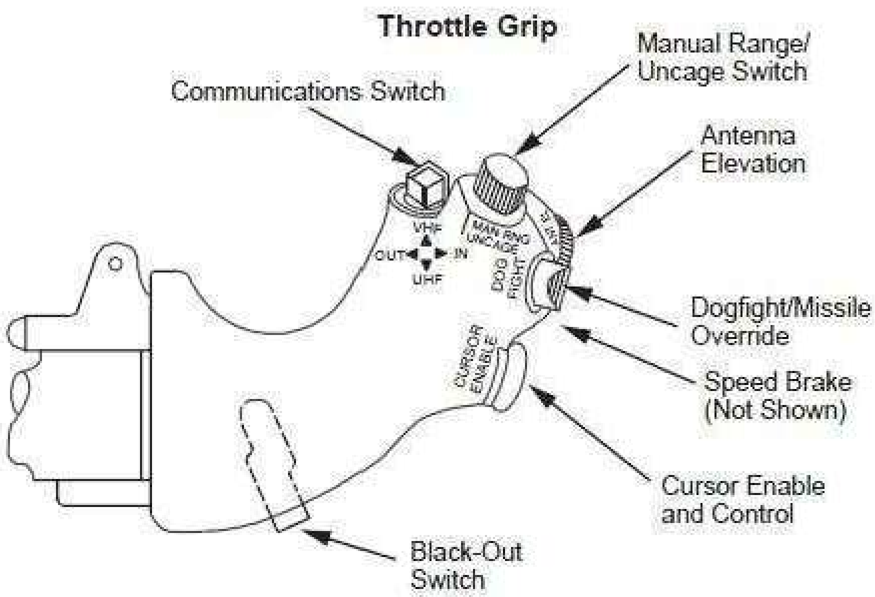
SIDE-STICK CONTROLLER (SSC)

This diagram and the table beneath it show the layout and functionality of the F-16 control stick.



THROTTLE

The HOTAS throttle is summarized below.



SWITCH	FUNCTION
Communications Switch	This switch is used to talk on various radio frequencies. This is not generally simulated in Falcon 4, although it is often used to toggle Teamspeak/Ventrilo communications.
Uncage Switch	This switch is used to "uncage" the seeker head for infrared missiles such as the AIM-9. When the seeker head is uncaged, it freely seeks targets and is not slaved to the aircraft's radar.

Antenna Elevation Knob	This rotary knob is used to set the elevation angle for the radar antenna. This can be used to scan different altitudes for enemy aircraft. There is generally a detent at the central position to allow the pilot to easily re-center the antenna.
Dogfight/Missile Override Switch	This is a three-way switch which is used to select the dogfight and missile override modes. If the switch is in the center position, neither override mode is selected.
Cursor Control	This joystick-type control is used to move the cursor on the FCR and HSD MFD pages. It is also used to slew the radar antenna in the ACM 30x20 mode.

COMMUNICATION SYSTEM

Communications connect the flight deck to the ground and the flight deck to the passengers. On-board communications are provided by public address systems and aircraft intercoms.The primary purpose of the communication system is Air traffic control. Airborne communication systems vary considerabily in size, weight, range, power requirements, quality of operation and cost, depending upon the desired operation.

The VHF aviation communication system works on the air band of 108.000 MHz to 136.975 MHz each channel is spaced from the adjacent ones by 8.33 kHz in Europe, 25 kHz elsewhere. VHF is also used for line of sight communication such as aircraft-to-aircraft and aircraft-to-ATC. Amplitude modulation (AM) is used, and the conversation is performed in simplex mode. Aircraft communication can also take place using HF (especially for trans-oceanic flights) or satellite communication.

The needs of communication system in airline are;

- Renders a clear picture of aircrafts health during the complete mission
- Ensures safety landing and take-off guidance
- Provides suitable environment awareness to the crew members of flight to direct the flying machine
- Acts as primary interfacing unit between pilot and the ATC or ground station.

RADIO COMMUNICATION SYSTEMS

Radio communication systems for aircrafts are primarily for the purpose of air traffic control; however, commercial aircraft also utilize a range of high frequencies for communicating with ground stations and other aircraft for business and operational purposes.
The Radio Communications System (RCS) consists of several exterior communications subsystems which, in combination, provide all exterior communications requirements for the ship with the exception of the Special Intelligence Communications requirements. The RCS subsystems are turnkey installations and consist of the following subsystems: High Frequency Communications System, Very High Frequency Communications (VHF Comms) System, Ultra High Frequency Line-of-Sight Communications (UHF LOS Comms) System, Ultra High Frequency Satellite Communications (UHF SATCOM) System, Extremely High Frequency Satellite Communications (EHF SATCOM) System, Super High Frequency Satellite Communications (SHF SATCOM) System, Communications Support Segment (CSS), Naval Modular Automated Communications System (NAVMACS) II, and the Bridge To Bridge Communications System.

Basic components

The basic components of a communication system are; Microphone, Transmitter, Transmitting Antenna, Receiving antenna, Receiver and a Head set or Loud speaker as shown in the figure.

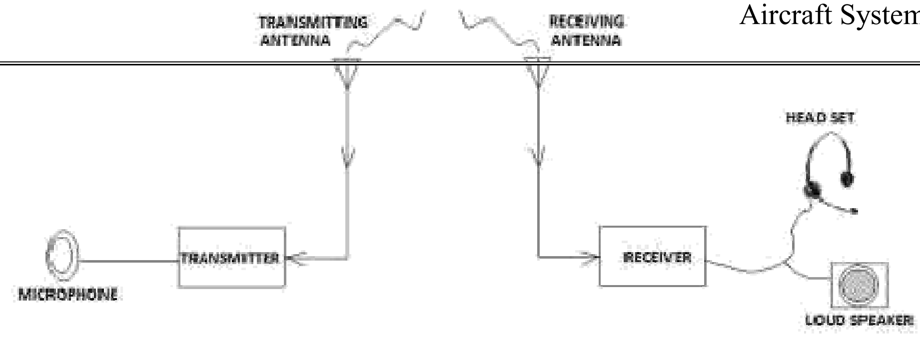


Fig: Basic communication equipment

A **microphone** is essentially an energy convertor that changes acoustical (sound) energy into corresponding electrical energy. The power supply furnishes the correct voltages and current needed to operate the communication. A **transmitter** may be considered as a generator which changes electrical power into radio waves. Radio waves of many frequencies are present in the air. A **receiver** must be able to select the desired frequency from all these present and amplify the small AC signal voltage**. Antenna** is a special type of electrical circuit designed to radiate and receive electromagnetic energy..

The radio frequency bands proven most useful and presently in use are;

Frequency range	**Band**
Low frequency	30 to 300 KHz
Medium frequency	300 to 3000 KHz
High Frequency	3000 KHz to 30 MHz
Very High Frequency	30 to 300 MHz
Ultra High Frequency	300 to 3000 MHz
Super High Frequency	3000 to 30000 MHz

In practice, radio equipment usually covers only a portion of the designated band; ex: Civil High frequency equipment normally operate 2 to 30 MHz frequency range and VHF equipment will be in between 108 MHz and 135.95 MHz

The various communication frequency systems used in aircrafts are;

- High-frequency (HF) communications
- Very high-frequency (VHF) communications
- Ultrahigh-frequency (UHF) communications
- Satellite communications (SATCOM)
- Data links

Difference between HF and VHF communication systems

High frequency (HF) covers the communications band between 3 and 30 MHz and is a very common communications means for land, sea and air. The utilized band is HF SSB/AM over the frequency range 2.000–29.999 MHz using 1 kHz (0.001 MHz) channel spacing. The primary advantage of HF

communications is that this system offers communication beyond the line of sight.

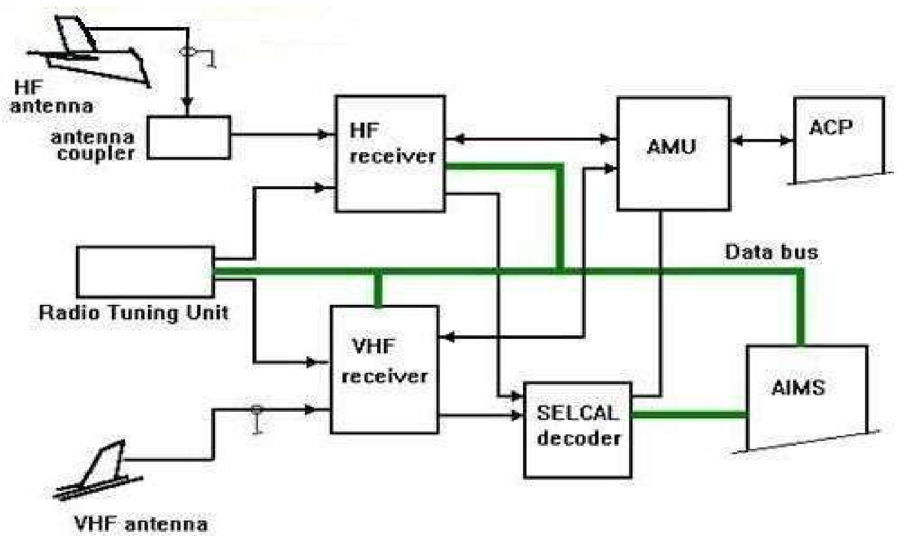


Fig: HF and VHF radio installation

In recent years, to overcome frequency congestion and taking advantage of digital radio technology, channel spacing has been reduced to 8.33 kHz (0.00833 MHz) which permits 3 times more radio channels in the available spectrum. VHF signals will only propagate over line of sight. That is, the signal will only be detected by the receiver when it has line of sight or can 'see' the transmitter. This line-of-sight property is affected by the relative heights of the radio tower and aircraft.

TRANSPORT AIRCRAFT COMMUNICATION SYSTEMS

A transport aviation communication system has a satellite subsystem including a constellation of satellites. A ground subsystem communicates with the satellite subsystem. The ground subsystem includes a number of networked ground stations at selected locations. An airborne communication subsystem is included in the aircraft. The airborne subsystem transmits to the satellite subsystem in a first frequency band. The airborne subsystem receives transmissions from the satellite subsystem in a second frequency band. The airborne subsystem communicates with a ground based system in a third frequency band. The third frequency band is between the first frequency band and the second frequency band.

Typically, the communications system on a Transport Aircraft is as follows:

VHF1 : Used for ATC communications
VHF2 : Used for all NON-ATC communications, and Emergency frequency monitoring.
VHF3: Typically used for Data transmissions (ACARS)

All VHF can be used interchangeably for any VHF purposes.

HF1: Typically used for Long-Range ATC communications

HF2: Back up to HF1. (Frequently used to listen to the BBC to overcome boredom on longer flights)

AIRCOM: AIRCOM allows ground to aircraft communications for operational flight information, such as fuel status, flight delays, Gate changes and departure times.

ACARS: Aeronautic Communications and Reporting System. (Data and Text based system for weather retrieval, communications and flight data).

SATCOM: Satellite communications to a land based telephone system.

SSR: Secondary Surveillance radar. System that communicates with ATC radar to provide position, speed and altitude information.

TCAS: System that communicates with other suitably equipped aircraft to provide separation against collision.

The ACARS (ARINC Communication Addressing and Reporting System) is a digital system that operates using the VHF communication equipment on a frequency of 131.550 MHz . The ACARS airborne equipment contains a control unit located on the flight deck and a management unit located in an equipment bay.

ACARS operates in two modes: (i) Demand mode and the (ii) Polled mode.

- The Demand mode allows the flight crew or airborne equipment to initiate communication. To transmit a message, the management unit (MU) of the airborne system determines if the ACARS channel is free from other communications.

- In the Polled mode, the system operates only when interrogated by the ground facility. The ground facility routinely up links "questions" to the MU responds with a transmitted message.

Information for ACARS is collected from several aircraft systems, including the flight management system (FMS), the aircraft integrated data system (AIDS) and the central maintenance computer system (CMCS).

Satellite communication systems

A communications satellite or comsat is an artificial satellite sent to space for the purpose of telecommunications. Modern communications satellites use a variety of orbits including geostationary orbits, Molniya orbits, elliptical orbits and low (polar and non-polar Earth orbits).

For fixed (point-to-point) services, communications satellites provide a microwave radio relay technology complementary to that of communication cables. They are also used for mobile applications such as communications to ships, vehicles, planes and hand-held terminals, and for TV and radio broadcasting.

Satellite communications provide a more reliable method of communications using the International Maritime Satellite Organization (INMARSAT) satellite constellation. The aircraft communicates via the INMARSAT constellation and remote ground earth station by means of C-band uplinks and downlinks to/from the ground stations and L-band links to/from the aircraft. In this way, communications are routed from the aircraft via the satellite to the ground station and on to the destination. Conversely, communications to the aircraft are routed in the reverse fashion. The airborne SATCOM terminal transmits on frequencies in the range 1626.5– 1660.5 MHz and receives messages on frequencies in the range 1530.0– 1559.0 MHz.These codes are known as ‘gold codes’. The coverage offered by the INMARSAT constellation was a total of four satellites in 2001. Further satellites are planned to be launched in the near future. The INMARSAT satellites are placed in earth geostationary orbit above the equator.

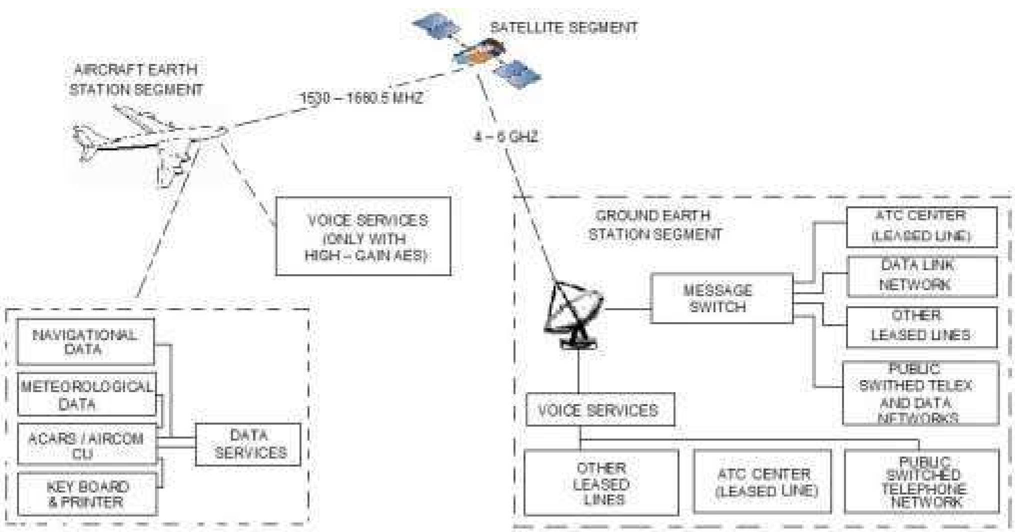


Fig: The SATCOM system segments (Collins Division; Rockwell International)

Data links

Many of the data links are limited to line-of-sight operation owing to the transmission characteristics of the RF frequencies being employed. However, the use of communications satellites to perform a relay function permits transmission of data over the horizon (OTH), thereby enabling intra- and inter-theatre communications. Typical data packages that may be delivered by data links include:

- Present position reporting
- Surveillance
- Aircraft survival, EW and intelligence information
- Information management
- Mission management
- Status.

The primary data links used for communications between airborne platforms and space and surface platforms are;

Link-16 - This is the most commonly used avionics data link and is usually manifested in avionics systems as the joint tactical information distribution system (JTIDS).

Link-11 - a data link commonly used by naval forces.

NAVIGATION SYSTEMS

Navigation

Navigation is the process of reading, and controlling the movement of a craft or vehicle from one place to another. It is also the term of art used for the specialized knowledge used by navigators to perform navigation tasks. The word navigate is derived from the Latin "navigare", meaning "to sail". All navigational techniques involve locating the navigator's position compared to known locations or patterns.

The *main categories* are Ground based and Satellite Navigations. In Ground based systems, High frequency radio waves can provide accurate position localized area. Lower frequency radio waves can cover a longer area, but are not a good yard stick to tell the position exactly. Satellite Navigation depends on the establishing of loci on which the craft is located.

The five basic forms of navigation

- ***Pilotage,*** is the use of fixed visual references on the ground or sea by means of sight or radar to guide oneself to a destination, sometimes with the help of a map or nautical chart.
- ***Dead reckoning***, (also ded (for deduced) reckoning or DR) is the process of calculating one's current position by using a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time, and course.
- ***Celestial navigation***, using time and the angles between local vertical and known celestial objects (e.g., sun, moon, or stars).
- ***Radio navigation***, which relies on radio-frequency sources with known locations (including GNSS satellites, LORAN-C, Omega, Tacan, US Army Position Location and Reporting System…)

- ***Inertial navigation***, which relies on knowing your initial position, velocity, and attitude and thereafter measuring your attitude rates and accelerations. The operation of inertial navigation systems (INS) depends upon Newton's laws of classical mechanics. It is the only form of navigation that does not rely on external references.

These forms of navigation can be used in combination as well.

Navigation systems

A navigation system is a (usually electronic) system that aids in navigation. Navigation systems may be entirely on board a vehicle or vessel, or they may be located elsewhere and communicate via radio or other signals with a vehicle or vessel, or they may use a combination of these methods.

Navigation systems may be capable of:

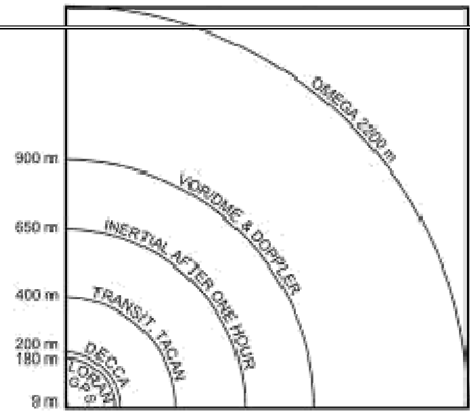
- containing maps, which may be displayed in human readable format via text or in a graphical format
- determining a vehicle or vessel's location via sensors, maps, or information from external sources
- providing suggested directions to a human in charge of a vehicle or vessel via text or speech
- providing directions directly to an autonomous vehicle such as a robotic probe or guided missile
- providing information on nearby vehicles or vessels, or other hazards or obstacles
- providing information on traffic conditions and suggesting alternative directions

Accuracy of Navigation systems

Accuracy is the essential factor for any type of navigation for the effective operation of any a/c automatically because of the speed and density of air traffic on major air routes to fly in a specified corridor defined by ATC authorities. High accuracy NAV is essential & forms part of FMS For military operation to enable the a/c to fly low & take advantage of terrain screening from enemy radar Use of

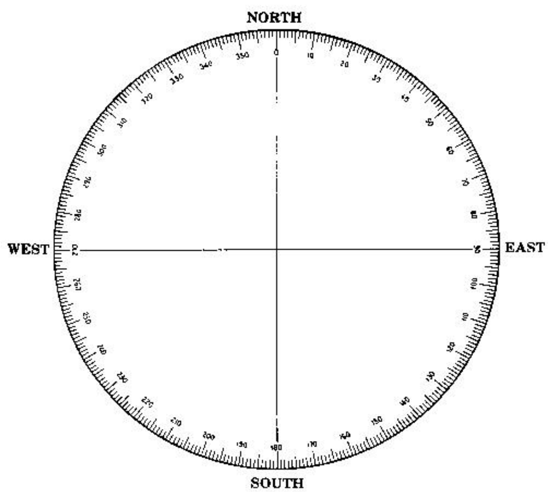
weapon released from several Kms away from target also requires an accurate knowledge of the a/c position in order to indicate the mid-course inertial guidance of the missile.

ACCURACY OF NAVIGATION SYSTEMS
(2-dimensional)



COMPASS

The circle is one of the three basic shapes in geometry. A **compass** is a circular device used for many purposes, but we know it primarily for its use in navigation. Airplanes and ships have relied on the compass for directional information (called a "heading") for many decades. A magnetic compass is designed so that the needle points North. The other directions are known in relation to North. For a compass to be a useful instrument, it must measure any direction. The circle was divided into 360 equal parts, each part called a degree. Consequently, the modern compass has 360 degrees.



Magnetic compass:

The magnetic compass used in airplanes is a simple self-contained instrument. A "compass card" is mounted on a floating ring which has two magnetized needles, which always point to magnetic North. The compass card has letters for cardinal headings, that is N (north), S (south), E (east) and W (west). Each 30º (30 degrees) interval of direction is represented by a number from which the last zero is omitted. Between the numbers, the card is graduated for each 5º (5 degrees). For example, on the compass 240º would look like 24. On the left, the compass indicates 96º (E is the same as 90º, the line to the left of E is a 5º line and the vertical line is a little to the left of that line).

EMERGENCY LOCATOR TRANSMITTER

An emergency locator transmitter (ELT), also referred to as a locator beacon, is required on aircraft to provide a signal or locator beacon, is required on aircraft to provide a signal or signals that will enable search aircraft or ground stations to find aircraft that will have made crash landings in remote or mountainous areas.

A typical ELT locator consists of a self-contained dual frequency radio transmitter and battery power supply with a suitable whip antenna. When armed, it will be activated by an impact force of 5g or more, as may be experienced in a crash landing. The ELT emits an Omni directional signal on the frequencies of 121.5 & 243.0 MHz The fixed ELT must be installed securely in the aircraft at a location where a rush damage will be minimum.

The location selected is usually in the area of the tail cone; however, in some cabin type aircraft, the unit is installed in the aft, top part of the cabin. Access is provided in either case, so the unit can be controlled manually.

ATC Transponder

A transponder is an automatic receiver and transmitter that can receive a signal from a ground station and then send a reply back to station. It can receive an interrogation from a ground radar station and sends a reply signal for identification.

Traffic alert and Collision avoidance system (TCAS)

TCAS works in conjunction with an aircraft's ATC Transponder to inform the flight crew of aircraft that pose a potential mid-air collision threat.

PERFORMANCE-BASED NAVIGATION **(PBN)**

Performance-based navigation (PBN) represents a shift from sensor-based to performance-based navigation. PBN specifies that aircraft RNP and RNAV systems performance requirements be defined in terms of accuracy, integrity, availability, continuity and functionality required for the proposed operations in the context of a particular airspace, when supported by the appropriate navigation infrastructure.

(a) AREA NAVIGATION (RNAV)

Area Navigation (RNAV) can be defined as a method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self contained system capability, or a combination of these.

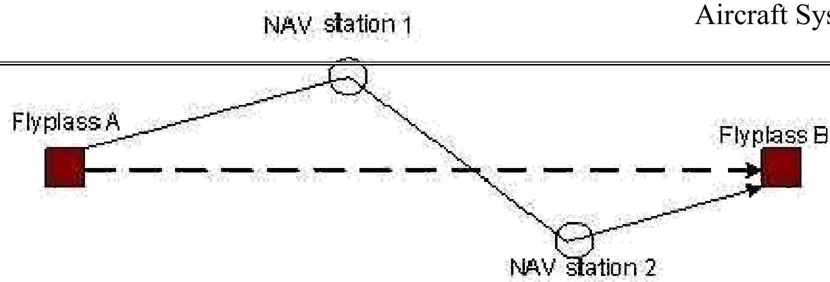


Fig: Area navigation (R NAV)

RNAV can be defined as a method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self-contained system capability, or a combination of these.

Functional Requirements

RNAV specifications include requirements for certain navigation functions. These functional requirements include:

1. continuous indication of aircraft position relative to track to be displayed to the pilot flying on a navigation display situated in his primary field of view;
2. display of distance and bearing to the active (To) waypoint;
3. display of ground speed or time to the active (To) waypoint;
4. navigation data storage function; and
5. Appropriate failure indication of the RNAV system including its sensors.

RNAV was developed to provide more lateral freedom and thus more complete use of available airspace. This method of navigation does not require a track directly to or from any specific radio navigation aid, and has three principal applications:

1. A route structure can be organized between any given departure and arrival point to reduce flight distance and traffic separation;
2. Aircraft can be flown into terminal areas on varied pre-programmed arrival and departure paths to expedite traffic flow; and
3. Instrument approaches can be developed and certified at certain airports, without local instrument landing aids at that airport.

Navigation systems which provide RNAV capability include VOR/DME, DME/DME, LORAN C (phased out in February 2010), GPS, OMEGA (no longer in use) and self-contained Inertial Navigation Systems (INS) or Inertial Reference Systems (IRS).

RADIO NAVIGATION

Radio navigation or radio navigation is the application of radio frequencies to determine a position on the Earth. Like radiolocation, it is a type of radio determination.

The basic principles are measurements from/to electric beacons, especially
Directions, e.g. by bearing, radio phases or interferometry,
Distances, e.g. ranging by measurement of travel times,
Partly also velocity, e.g. by means of radio Doppler shift.

Radio propagation:

Depending upon the frequency of the radiated signal, radio energy is most efficiently propagated by only one of the three main methods - *ground, space or sky waves*. The following general rules apply:

a. Up to about 3 MHz (VLF, LF and MF) ground wave transmission predominates, although sky waves arc used for longer distances;
b. from 3 to 30 MHz (HF) the range of the ground wave decreases rapidly and sky waves are the primary method;
c. above 30 MHz (VHF, UHF, SHF and EHF) propagation is line-of-sight (space waves), modified by the reflecting effects of various objects on the earth. The transmission path is generally predictable. Ground waves rapidly attenuate, the sky waves rarely exist;
d. from l 00 MHz (upper VHF and UHF) the transmission path is highly predictable and not affected by time of day, season, precipitation or atmospheric conditions; and
e. above 3 GHz (SHF and EHF), some attenuation and scattering is caused by precipitation and the atmosphere.

Radio frequency categories:

Table of Radio Frequencies

Description	Abbreviation	Frequency	Wavelength
Very Low Frequency	VLF	3 KHz - 30 KHz	100,000m - 10,000m
Low Frequency	LF	30 KHz - 300 KHz	10,000m - 1,000
Medium Frequency	MF	300 KHz - 3 MHz	1,000m - 100m
High Frequency	HF	3 MHz - 30 MHz	100m - 10m
Very High Frequency	VHF	30 MHz - 300 MHz	10m - 1m
Ultra High Frequency	UHF	300 MHz - 3 GHz	1m - 0.10m
Super High Frequency	SHF	3 GHz - 30 GHz	0.10m - 0.01m
Extremely High Frequency	EHF	30 GHz - 300 GHz	0.01m - 0.001m

RADIO NAVIGATION SYSTEMS

Radio navigation is the application of radio frequencies to determine a position on the Earth. Two types of radio navigation systems are position fixing systems and hyperbolic radio navigation systems

POSITION FIXING SYSTEMS

- Range and bearing (R/θ) radio navigation aids
    - VOR/DME
    - TACAN- Accuracy of 1-2 miles

HYPERBOLIC RADIO NAVIGATION SYSTEMS

- LORAN C - positional accuracy of around 150 m. (8 LORAN C chains comprising 34 ground station transmitters)
- OMEGA - accuracy around 2 NM -VLF at 10 khz using 8 ground stations

(a) <u>VHF Omni Directional Range (VOR)</u>

VOR (VHF Omni-Range) is the basic Electronic navigation that in use today. This VHF Omni-Range navigation method relies on the ground based transmitters which emitted signals to VOR receiver. The VOR system operates in the VHF frequency band, from 108.0 to 117.95 MHz The reception of VHF signals is a line of sight situation. You must be on the minimum altitude of 1000 feet (AGL) above ground level in order to pick up an Omni signals service range.

VOR is a type of short-range radio navigation system for aircraft, enabling aircraft to determine their position and stay on course by receiving radio signals transmitted by a network of fixed ground radio beacons, with a receiver unit.

Basic principle

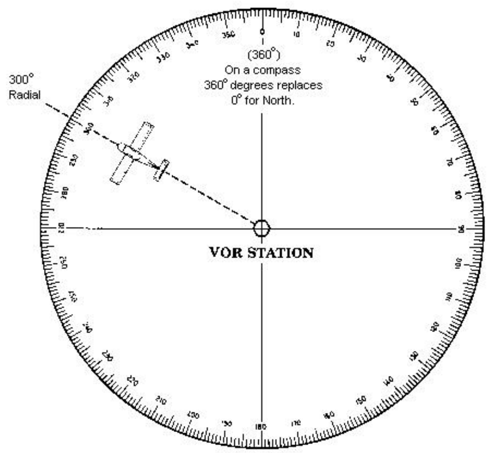
As the name implies, the Omni-directional or all directional range station provides the pilot with courses from any point with in its service range. It produces 360 usable radials or courses, any one of which is a radio path connected to the station. The radials can be considered as lines that extend from the transmitter antenna like spokes of a wheel. The navigational information is visually displayed on an instrument in the cockpit.

Components

It consists of a receiver, visual indicator, antenna and a power supply. In addition, a unit frequency selector is required and in some cases located on the receiver unit front panel. Some manufacturers design a remote control frequency selector, so the equipment may be installed in some other area of the aircraft. This frequency selector is used to tune the receiver to a selected VOR ground station.

The VOR receiver mounted in an airplane may be an independent unit, or it may operate in conjunction with the VHF communication radio. Light aircrafts typically use the combined unit, known as VHF NAV / COM radio.

Usage of campus in VOR



However, today most airplanes use special ground based radio transmitters which are designed to aid air navigation. These transmitters are called **VOR stations**. On an aerial navigation map, the VOR station is indicated by a small hexagon with a compass around it.

The aircraft pilot may choose the magnetic heading desired to fly to or from a VOR station. This heading is now called a **course** because it will be along a specific path over the ground. The exact magnetic direction which is flown away from a VOR station is called a **radial**. This term (radial) is used because the navigational radio signal is being "radiated" out from the station in a specific magnetic direction.

In the above figure, the airplane's course (or heading) is on the 300 degree radial away from the VOR. If the airplane were headed the opposite direction, toward the VOR, it would still be on the 300 degree radial from the VOR, but the plane's course would be 120 degrees.

(b) <u>Tactical Air Navigation (TACAN)</u>

The Tactical Air Navigation System (TACAN) is an ultra-high-frequency (UHF) Omni-directional navigational aid that provides slant distance, in nautical miles from a ground station to an aircraft, and the azimuth in degrees from the station. Stations are normally referenced to magnetic north. Equipment consists of a ground station transponder and an airborne receiver/transmitter. The system has a range of up to 200 NM, depending on aircraft altitude.

TACAN Principles

The distance measuring concept used in TACAN equipment is an outgrowth of radar-ranging techniques. Radar-ranging determines distance by measuring the round-trip travel time of pulsed RF energy. The return signal (echo) of the radiated energy depends on the natural reflection of the radio waves. However, TACAN beacon-transponders generate artificial replies instead of depending on natural reflection.

This system was developed by the Navy for use on aircraft carriers and other navy installations. The TACAN distance measuring facility is now utilized for civilian air navigation, as well as for the Military. The low TACAN band has receiving frequencies from 1025 to 1087 MHz and transmitting frequencies from 962 to 1024 MHz. The high TACAN band has receiving frequencies from 1088 to 1140 MHz and transmitting frequencies from 1115 to 1213 MHz.

(c) <u>Distance Measuring Equipment (DME)</u>

The purpose of distance measuring equipment (DME) is to provide a constant visual indication of the distance to the aircraft is from a ground. A DME reading is not a true indication of point to point distance as measured over the ground. DME indicates the slant range between the aircraft and the ground station. Slant range error increases as the aircraft approaches the station. At a distance of 30 to 60 nautical miles the slant range error is negligible.

Principle

The DME operates by transmitting to and receiving paired pulses from the ground station. The transmitter in the aircraft sends out very narrow pulses at a frequency of about 1,000 MHz. These signals are received at the ground station and trigger a second transmission on a different frequency. These reply pulses are sensed by timing circuits in the aircraft's receiver that measure the elapsed time between transmission and reception. Electronic circuits within the radio convert this measurement to electrical signals that operate the distance and ground speed indicators.

DME operation

DME operates in the UHF range of the radio frequency spectrum. The transmitting frequencies are in two groups between 962 MHz to 1024 MHz and 1151 MHz to 1212 MHz; the receiving frequencies are between 1025 MHz to 1149 MHz. Transmitting and receiving frequencies are given a channel number which is paired with a VOR channel.

In some aircraft installations the DME channel selector is ganged with the VOR channel selector to simplify the radio operation. The aircraft is equipped with a DME transceiver which is tuned to a selected DME ground station. Usually DME ground stations are collocated with a VOR facility.

The airborne transceiver transmits a pair of spaced pulses to the ground station. The pulses spacing serves to identify the signal as a valid DME interrogation. After reception of the challenging pulses, the ground station responds with a pulses transmission on a separate frequency to send a reply to the aircraft. Upon reception of the signal by the airborne transceiver, the elapsed time between the challenges and the reply is measured, this time interval is measure of the distance separating the aircraft and the ground station.

VORTAC and VOR-DME

In many cases, VOR stations have co-located DME (Distance Measuring Equipment) or military TACAN (TACtical Air Navigation) — the latter includes both the DME distance feature and a separate TACAN azimuth feature that provides military pilots data similar to the civilian VOR.

VORTAC is a combination of a VOR and TACAN at one location. VORTAC provides azimuth navigational information on VHF, and azimuth and distance information on UHF. Separate TACAN airborne equipment is needed to obtain azimuth data from the TACAN part of the system.

A VOR co-located only with DME is called a VOR-DME. A VOR radial with a DME distance allows a one-station position fix. Both VOR-DMEs and TACANs share the same DME system.

VORTACs and VOR-DMEs use a standardized scheme of VOR frequency to TACAN/DME channel pairing so that a specific VOR frequency is always paired with a specific co-located TACAN or DME channel. On civilian equipment, the VHF frequency is tuned and the appropriate TACAN/DME channel is automatically selected.

(d) <u>Long Range Navigation (LORAN)</u>

LORAN (Long Range Navigation) The latest system known as LORAN-C .This system will be discontinued due to cost not effective. The US will continue to operate the LORAN-C system beyond the previously planned December 31, 2000. The termination date is continuing to evaluate the long term need for continuation of the system. User will be given reasonable notice so that they will have the opportunity to transfer to alternative navigation aids. At this time we will talking about this system a little because they might keep this system as a backup system.

LOng RAnge Navigation (LORAN) is a terrestrial radio navigation system which enables ships and aircraft to determine their position and speed from low frequency radio signals transmitted by fixed land based radio beacons, using a receiver unit.

The most recent version of LORAN in use is LORAN-C, which operates in the low frequency (LF) portion of the radio spectrum from 90 to 110 KHz.

Principle

The navigational method provided by LORAN is based on measuring the time difference between the receipt of signals from a pair of radio transmitters. A given constant time difference between the signals from the two stations can be represented by a hyperbolic line of position (LOP).

If the positions of the two synchronized stations are known, then the position of the receiver can be determined as being somewhere on a particular hyperbolic curve where the time difference between the received signals is constant. In ideal conditions, this is proportionally equivalent to the difference of the distances from the receiver to each of the two stations.

So a LORAN receiver which only receives two LORAN stations cannot fully fix its position - it only narrows it down to being somewhere on a curved line. Therefore the receiver must receive and calculate the time difference between a second pair of stations. This allows to be calculated a second hyperbolic line on which the receiver is located. Where these two lines cross is the location of the receiver.

In practice, one of the stations in the second pair also may be — and frequently is — in the first pair. This means signals must be received from at least three LORAN transmitters to pinpoint the receiver's location. By determining the intersection of the two hyperbolic curves identified by this method, a geographic fix can be determined.

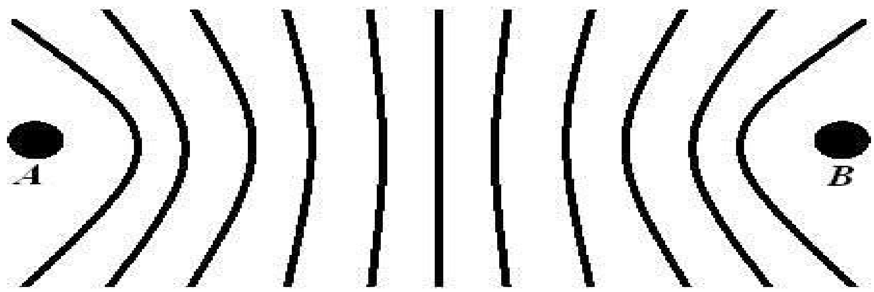


Fig: A crude diagram of the LORAN principle

In the above figure, the difference between the time of reception of synchronized signals from radio stations A and B is constant along each hyperbolic curve; when demarcated on a map, such curves are known as "TD lines"

Limitations

LORAN suffers from electronic effects of weather and the ionospheric effects of sunrise and sunset. The most accurate signal is the ground wave that follows the Earth's surface, ideally over seawater. At night the indirect sky wave, bent back to the surface by the ionosphere, is a problem as multiple signals may arrive via different paths (multipath interference). The ionosphere's reaction to sunrise and sunset accounts for the particular disturbance during those periods. Magnetic storms have serious effects as with any radio based system.

LORAN uses ground based transmitters that only cover certain regions. Coverage is quite good in North America, Europe, and the Pacific Rim.

The absolute accuracy of LORAN-C varies from 0.10–0.25-nautical-mile (185–463 m). Repeatable accuracy is much greater, typically from 60–300-foot (18–91 m).

- **LORAN-C**

LORAN-C is a pulsed hyperbolic system operating in the 90 to 110 kilohertz (kHz) frequency band which is used for marine and air navigation where signal coverage is available. The system is based upon the measurement of the time difference in the arrival of signal pulses from a group or chain of stations. A chain consists of a master station linked to a maximum of four secondary stations with all of the signals synchronized with the master. The LORAN-C receiver measures the time difference between the master and at least two of the secondaries to provide a position fix.

(e) OMEGA

OMEGA was the first truly global radio navigation system for aircraft, operated by the United States in cooperation with six partner nations. It enabled ships and aircraft to determine their position by receiving very low frequency (VLF) radio signals transmitted by a network of fixed terrestrial radio beacons, using a receiver unit.

Working principle

Omega had eight stations around the world. The stations transmitted a Very Low Frequency (VLF) signal, consisting of four musical tones. Each station had a unique four-note phrase, transmitted every 10 seconds.

If an Omega receiver picked up signals from three stations, it would compute a vessel's location by phase comparison. This means that the receiver determined what direction each signal from was coming from; the vessel was at the point where the bearing to Station A intersected the bearings to Stations B and C.

Accuracy with Omega

Omega was very accurate for its time. In the late 1960s, when Omega began operation, navigation was generally the result of a comparison of a dead reckoning position (the computed position of the vessel) with the results of "shooting a star" with a preset sextant. Navigators had to compute the difference between the position preset from the dead reckoning position and the position obtained by observation. This method was accurate, with errors of not more than 1 nautical mile, but required about 20 minutes to take three "star shots" and do the math for each.

Omega could have the information within a few seconds--if three stations were received by the Omega unit. The error with Omega ranged from 2,200 yards to 4 nautical miles.

(f) DECCA

Hyperbolic systems other than Loran and Omega exist and are used for navigation. One such example is the Decca system developed by the British and used extensively during the later stages of World War II. In 1996, its major area of implementation is in north Western Europe where it is primarily used by shipping companies.

Decca is based on the measurement of differential arrival times (at the vehicular receiver) of transmission from two or more synchronized stations (typically 70 mi apart). As an illustration, consider two stations (A and B) 10 mi apart and each radiating synchronized radio-frequency carriers of 100 KHz. Assume that there is some way by which each station can be identified.

The wave length at this frequency is 3000 meters or about 2 mi. On a line between the stations, the movement of a vehicle D one mile toward one station and one mile away from the other station will cause the vehicle to traverse one cycle of differential radio-frequency phase. There will, therefore, be 10 places along the line AB where the signals from the two stations will be in phase. As the vehicle moves laterally away from this line, isophase LOPs can be formed (each line being a hyperbola) with the stations as foci and BD – AD as a constant for each LOP.

Site error virtually vanishes in such a system, and the accuracy depends entirely on the constancy of propagation between the stations and the vehicle. In an effort to avoid line-of-sight limitations, Decca uses a low frequency (70 to 130 KHz), which is subject to sky-wave contamination, and uses continuous waves, which preclude the separation of ground waves from sky waves. Thus, despite the low frequency (whose ground-wave range is on the order of 1000 mi), practical decca coverage is limited to areas where sky-wave strength does not exceed about 50% of ground-wave strength. This is typically 200 mi.

DEAD RECKONING NAVIGATION

Dead reckoning (DR) is the process of estimating one's current position based upon a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time, and course. While traditional methods of dead reckoning are no longer considered primary means of navigation, modern inertial navigation systems, which also depend upon dead reckoning, are very widely used.

The various dead reckoning navigation systems used in aircraft are;

- Air data/heading reference system - lower accuracy
- Doppler/heading reference systems - widely used in helicopters
- Inertial Navigation systems - most accurate and widely used systems
- Doppler/Inertial navigation system - combination

(a) <u>DOPPLER NAVIGATION</u>

The Doppler navigation system is so named because it utilizes the ‘Doppler shift’ principle. The <u>Doppler shift</u> is the difference in frequency that occurs between a radar signals emitted from an aircraft radar antenna and the signal returned to the aircraft.

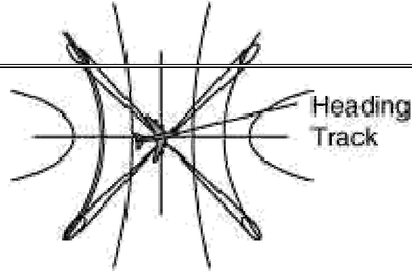


Fig: diagram of Doppler radar beams from an airborne transmitter

Working Principle

If the signal is sent forward from an aircraft in flight, the returning signal will be at a higher frequency than the signal emitted. The difference in the frequencies makes it possible to measure the speed and direction of movement of the aircraft; thus information is provided from which one can computes the exact position of the aircraft at all times with respect to a particular reference point and the selected course.

In the Doppler navigation system, flight information is obtained by sending four radar beams of continuous wave 8800 MHz energy from the aircraft to the ground and measuring the changes in frequencies of the energy returned to the aircraft. The change in frequency for any beam signal is proportional to the speed of the aircraft in the direction of the beam.

Description

The radar beams are pointed forward and down at an angle of approximately 45^0 to the right and left of a center of the aircraft and rearward and down at a similar angle. When the airplane is flying with no drift, the forward signals will be equal. The rearward signals will be equal to the forward signals, but opposite value.

The difference between the frequencies of the forward and rearward signals will be proportional to the ground speed; hence this difference is used to compute the ground speed, and the value is displayed on the Doppler indicator. If the airplane drifts, there will be differences in frequency between the right and left beam signals, and these differences are transmitted into drift angle and displayed on the Doppler indicator.

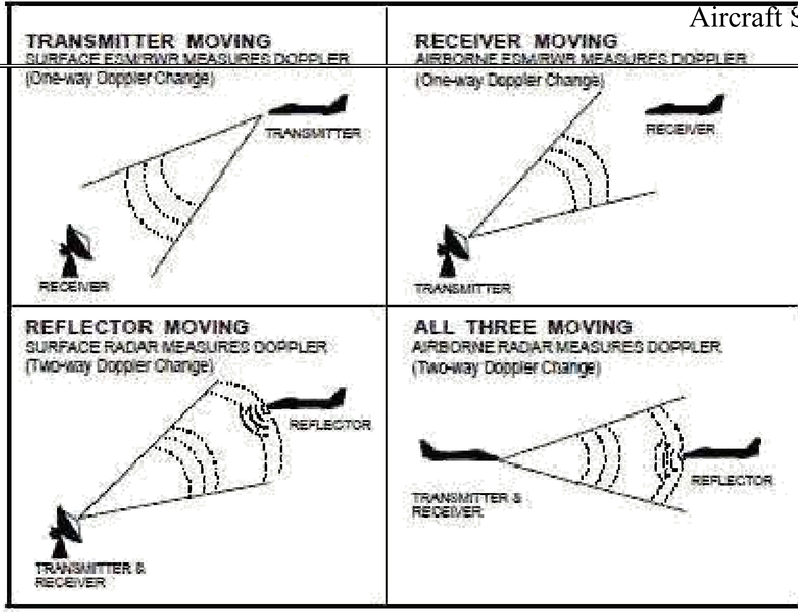


Fig: Methods of Doppler creation

The figure shows how the radar beams are aimed with respected to the aircraft. The advantage of a Doppler system is that it is completely contained in the aircraft and requires no external signals. At the start of a flight, the course or courses to be flown are programmed into the system. Therefore, continuous information regarding the position of the aircraft will be displayed on the Doppler indicator and the computer controller.

(b) INERTIAL NAVIGATION SYSTEM (INS)

An Inertial Navigation System (INS) is a navigation aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate via dead reckoning the position, orientation, and velocity (direction and speed of movement) of a moving object without the need for external references. It is used on vehicles such as ships, aircraft, submarines, guided missiles, and spacecraft.

Basic principle of inertial navigation

- Given the ability to measure the acceleration of vehicle it would be possible to calculate the change in velocity and position by performing successive mathematical integrations of the acceleration with respect to time.
- In order to navigate with respect to our inertial reference frame, it is necessary to keep track of the direction in which the accelerometers are pointing.
- Rotational motion of the body with respect to inertial reference frame may be sensed using gyroscopic sensors that are used to determine the orientation of the accelerometers at all times. Given this information it is possible to resolve the accelerations into the reference frame before the integration process takes place.

An INS consists of the following;

- *An IMU*
- *Instrument support electronics*
- *Navigation computers* (one or more) calculate the gravitational acceleration (not measured by accelerometers) and doubly integrate the net acceleration to maintain an estimate of the position of the host vehicle.

Different types of INS

It is of two different configurations based on the inertial sensor placement. They are;

a. Stable or Gimballed platform.
b. Strap down platform

The original applications of INS technology used stable platform techniques. In such systems, the inertial sensors are mounted on a stable platform and mechanically isolated from the rotational motion of the vehicle. Platform systems are still in use, particularly for those applications requiring very accurate estimates of navigation data, such as ships and submarines.

Modern systems have removed most of the mechanical complexity of platform systems by having the sensors attached rigidly, or "strapped down", to the body of the host vehicle. The potential benefits of this approach are lower cost, reduced size, and greater reliability compared with equivalent platform systems. The major disadvantage is a substantial increase in computing complexity.

GIMBALED SYSTEMS

A gimbal is a rigid with rotation bearings for isolating the inside of the frame from external rotations about the bearing axes. At least three gimbals are required to isolate a subsystem from host vehicle rotations about three axes, typically labeled roll, pitch, and yaw axes.

The gimbals in an INS are mounted inside one another. Gimbals and torque servos are used to null out the rotation of stable platform on which the inertial sensors are mounted.

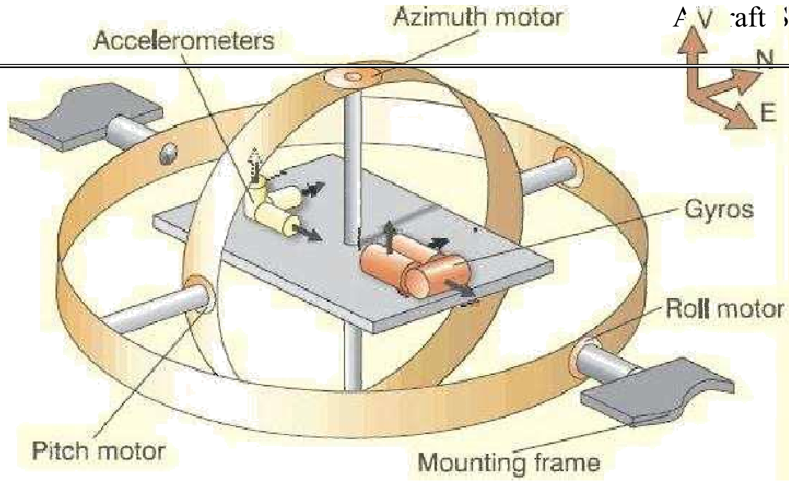


Fig: Gimbaled inertial platform

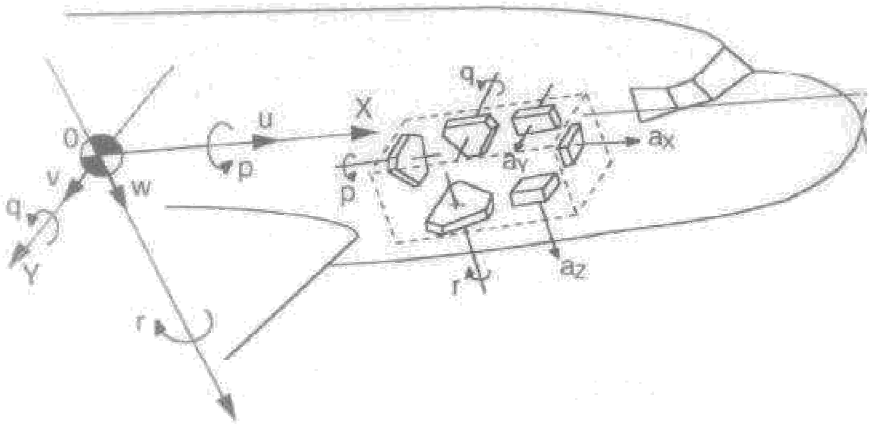
Gimbaled systems have a platform in the device that is mounted in gimbals. This device has 2 or more mechanical gyroscopes (not likely there are more than 3) that keep this platform level. On the platform, in addition to the gyroscopes, are usually three accelerometers, one in each direction. This was the earlier type of INS. It does not need accurate gyroscope orientation sensing, they only need mechanical gyroscopes to keep a platform level -- a much less demanding task for the gyroscopes. Additionally, since the accelerometers are already oriented (usually north/south, east/west, and up/down) the actual integration to obtain velocity and then position can be done by simpler, analog electronics.

Working principle

The gyros of a type known as “integrating gyros” give an output proportional to the angle through which they have been rotated. Output of each gyro connected to a servo-motor driving the appropriate gimbal, thus keeping the gimbal in a constant orientation in inertial space. The gyros also contain electrical torque generators which can be used to create a fictitious input rate to the gyros. Applications of electrical input to the gyro torque generators cause the gimbal torque motors/servos to null the difference between the true gyro input rate and the electrically applied bias rate. This forms a convenient means of cancelling out any drift errors in the gyro.

STRAP DOWN INS

Strap down systems have all their sensors mounted on a platform that changes orientation like the plane. Instead of mechanical gyros to hold it level, it has three more accurate gyros that sense the orientation of the system. Additionally, it has the same three acceleration sensors.



Basic concept

Accelerometers mounted directly to airframe (strap down) and measure "body" acceleration. Horizontal/vertical accelerations computed analytically using direction cosine matrix (DCM) relating body coordinated and local level navigation coordinates. DCM computed using strap down body mounted gyro outputs

Whereas the gimballed system just senses the orientation of the platform to get the aircraft's attitude, the strap down systems have three gyroscopes that sense the rate of roll, pitch, and yaw. It integrates them to get the orientation, then calculates the acceleration in each of the same axes as the gimballed system. Due to the sensing of the rate of rotation, rather than just holding a platform level, very accurate and sensitive gyroscopes are needed.

Specific advantages of INS

- It is the self contained, autonomous and unjammable.
- It is faster than the data given by the GPS.
- INS is very accurate over the short distance.
- It is autonomous and does not rely on any external aids or visibility conditions. It can operate in tunnels or underwater as well as anywhere else.
- It is inherently well suited for integrated navigation, guidance, and control of the host vehicle. Its IMU measures the derivatives of the variables to be controlled (e.g., position, velocity, and attitude).
- It is immune to jamming and inherently stealthy. It neither receivers nor emits detectable radiation and requires no external antenna that might be detectable by radar.

Disadvantages of INS

- Mean-squared navigation errors increase with time.
- Cost, including:

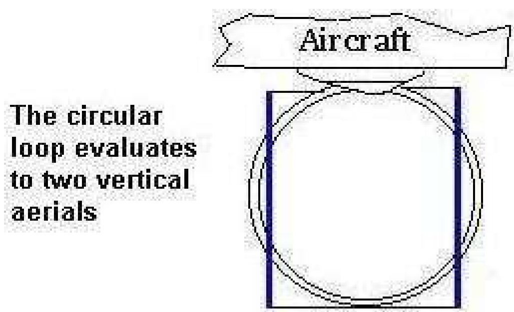
- Acquisition cost, which can be an order of magnitude (or more) higher than GPS receivers.
- Operations cost, including the crew actions and time required for initializing position and attitude. Time required for initializing INS attitude by gyrocompass alignment is measured in minutes. TTFF for GPS receivers is measured in seconds.
- Maintenance cost. Electromechanical avionics systems (e.g., INS) tend to have higher failure rates and repair cost than purely electronic avionics systems (e.g., GPS).

- Size and weight, which have been shrinking
- Power requirements, which have been shrinking along with size and weight but are still higher than those for GPS receivers.
- Heat dissipation, which is proportional to and shrinking with power requirements.

AUTOMATIC DIRECTION FINDER (ADF)

ADF (Automatic Direction Finder) is the radio signals in the low to medium frequency band of 190 Khz. to 1750 Khz. It was widely used today. It has the major advantage over VOR navigation in the reception is not limited to line of sight distance. The ADF signals follow the curvature of the earth. The maximum of distance is depending on the power of the beacon. The ADF can receive on both AM radio station and NDB (Non-Directional Beacon). Commercial AM radio stations broadcast on 540 to 1620 Khz. Non-Directional Beacon operate in the frequency band of 190 to 535 Khz.

ADF (Automatic Direction Finder) are radio receivers equipped with directional antennas which are used to determine the direction from which signal are received. The ADF system operates on a frequency range of 90 to 1800 KHz, a range that makes it possible for the system to receive radio range stations in the LF band and standard board cast stations.



Rotating Loop Aerial

By use of the ADF system, a pilot can determine the aircrafts position or the pilot can “home-in” on a radio broad cast station or a radio beacon station by flying directly toward that station station using the indication of the radio campus or radio magnetic indicator. ADF systems utilize the directional characteristics of a loop antenna to determine the direction of a radio station.

Principle

A simple direction finder may be made by using a loop antenna with an ordinary radio receiver. By rotating the antenna, the strongest reception can be determined and also the point at which the signal fades out. This point is called the 'null position' and from it a fairly accurate indication of the station direction can be determined.

ADF components

The principal components of an ADF system are a radio receiver, which includes the amplifiers and various other electronic components: a loop antenna; a sense antenna; a radio magnetic indicator (RMI); and a remote control unit or control panel.

Theory of operation

Radio waves are propagated in the form of electromagnetic and electro static lines of that travel at a speed of approximately 186300 mi/s (300000000 m/s) from the radio transmitter. When these lines of force weight across a radio antenna, a voltage is induced in the antenna. This voltage is amplified and demodulated, so that the intelligence contained on the radio wave may be determined.

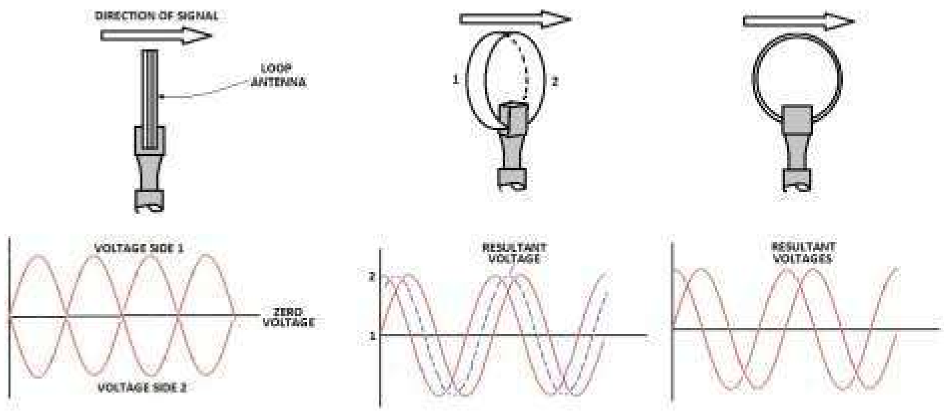


Fig: Operation of an ADF loop antenna

If a loop antenna is placed in such a position that it is at 90^0 to the direction of wave travel, equal and opposite voltages will be induced in the sides of the antenna. The voltages thus induced in the loop will cancel each other, with the result that the loop will have no output. If the loop is connected to a radio receiver, the signal will disappear at this point.

If the loop is turned either one way or the other, a voltage will be induced in one side slightly before it is induced in the other, with the result that there will be difference between the two that will provide a signal that may be fed to the receiver.

When the plane of the loop is parallel to the direction of wave propagation, the strongest signal will be developed. ADF receiver units for large aircraft are typically located in equipment racks with digital data links to the antennas, control panels and RMI.

INSTRUMENT LANDING SYSTEM (ILS)

An instrument landing system (ILS) is a ground-based instrument approach system that provides precision guidance to an aircraft approaching and landing on a runway, using a combination of radio signals and, in many cases, high-intensity lighting arrays to enable a safe landing during instrument meteorological conditions (IMC), such as low ceilings or reduced visibility due to fog, rain, or blowing snow.

The ILS is designed to allow pilots the opportunity to land their aircraft with the aid of instrument references. The ILS can be visualized as a slide made of radio signals on which the aircraft can be brought safety to the runway.
A typical ILS system will allow the pilot to bring an aircraft to within ½ mi of the runway and less than 200 ft above the runway without any external visual references. At these minimums (the decision height), the pilot must identify the runway environment in order to continue the Landing process. If the runway environment cannot be identified, the pilot must execute a missed approach procedure.

Components

The entire system consists of a runway localizer, a glide slope signal and marker beacons for position location. The total system consists of:

a. the localizer transmitter;
b. the glide path transmitter;
c. the outer marker (can be replaced by an NDB or other fix);
d. the approach lighting system.

- **Runway localizer**

The localizer equipment produces a radio course aligned with the center of an airport runway. The on course signals result from equal reception of two signal; one containing 90 Hz modulation and the other containing 150 Hz modulation. On one side of the runway center line the radio receiver develops an output in which the 150 Hz tone predominates. This area is called the blue sector. On the other side of the center line the 90 Hz output is greater. This area is the yellow sector.

- **Glide slope**

The glide slope is a radio beam which provides vertical guidance to the pilot, assisting him in making the correct angle of descent to the runway. Glide slope signals are radiated from two antennas located adjacent to the touchdown point of the runway. Each glide slope facility operates in the UHF range from 329.3 MHz to 335.0 MHz.

The above figure shows the radiation pattern from the glide slope transmitter. If an airplane is approaching the runway and is above the glide path, the 90 Hz signal will pre dominate; and if the airplane is below the glide path, the 150 Hz signal will pre dominate.

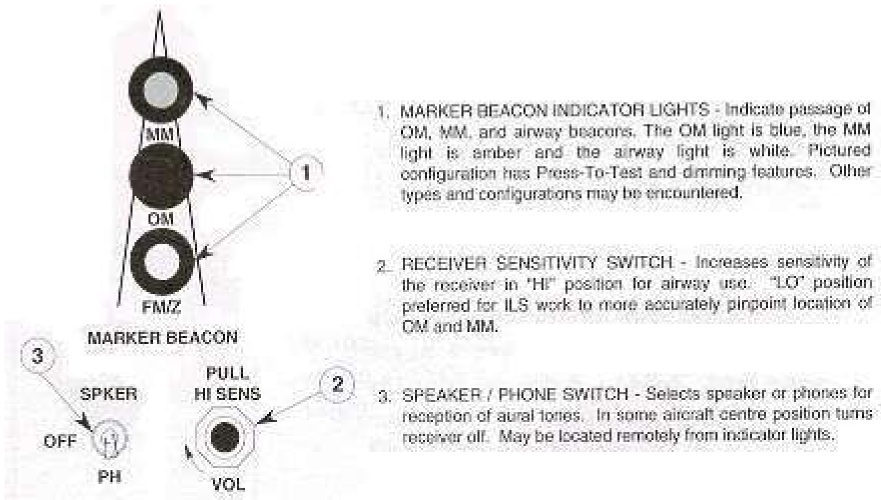
- **Antenna**

Two antennas are usually required for ILS operation. One for the localizer receiver, also used for VOR navigation, and one for the glide slope. Some of the small aircraft use a single multi element antenna for both glide slope and VOR operation.

The VOR / localizer antenna is normally installed on the top of the aircraft fuselage or flush mounted in the vertical stabilizer. The glide slope antenna is, in most cases, installed on the nose of the aircraft.

- **Marker Beacons**

Beacon is a system of visual lights indicating fixed features. The markers are signals which indicate the position of the aircraft along the approach to the runway. Radio beacons can be of any frequency but are normally in VHF and omni directional or of directional beam type. Marker beacons are used in connection with the ILS.



Two markers are used in each installation. The location of each marker is identified by both radio signals and a signal lamp. The marker beacon transmitters operating on a fixed 75 MHz frequency are placed at specific locations long the approach pattern of an ILS facility.

MICRO WAVE LANDING SYSTEM

The MLS provides precision navigation guidance for exact alignment and descent of aircraft on approach to a runway. It provides azimuth, elevation, and distance.

Both lateral and vertical guidance may be displayed on conventional course deviation indicators or incorporated into multipurpose cockpit displays. Range information can be displayed by conventional DME indicators and also incorporated into multipurpose displays.

The MLS supplements the ILS as the standard landing system in the U.S. for civil, military, and international civil aviation. At international airports, ILS service is protected to 2010.

Function

The system may be divided into five functions:

a) Approach azimuth;
b) Back azimuth;
c) Approach elevation;
d) Range; and
e) Data communications.

Configuration

The standard configuration of MLS ground equipment includes:

a) An azimuth station to perform functions (a) and (e) above. In addition to providing azimuth navigation guidance, the station transmits basic data which consists of information associated directly with the operation of the landing system, as well as advisory data on the performance of the ground equipment.
b) An elevation station to perform function (c).
c) Distance Measuring Equipment (DME) to perform range guidance, both standard DME (DME/N) and precision DME (DME/P).

MLS Expansion Capabilities

The standard configuration can be expanded by adding one or more of the following functions or characteristics.

a) <u>Back azimuth;</u> Provides lateral guidance for missed approach and departure navigation.
b) <u>Auxiliary data transmissions</u>**;** Provides additional data, including refined airborne positioning, meteorological information, runway status, and other supplementary information.
c) <u>Expanded Service Volume (ESV)</u> proportional guidance to 60 degrees.

MLS identification is a four-letter designation starting with the letter M. It is transmitted in International Morse Code at least six times per minute by the approach azimuth (and back azimuth) ground equipment.

Approach Azimuth Guidance

a) The azimuth station transmits MLS angle and data on one of 200 channels within the frequency range of 5031 to 5091 MHz.
b) The equipment is normally located about 1,000 feet beyond the stop end of the runway, but there is considerable flexibility in selecting sites. For example, for heliport operations the azimuth transmitter can be collocated with the elevation transmitter.
c) The azimuth coverage extends:
   i. Laterally, at least 40 degrees on either side of the runway centerline in a standard configuration,
   ii. In elevation, up to an angle of 15 degrees and to at least 20,000 feet, and
   iii. In range, to at least 20 NM.

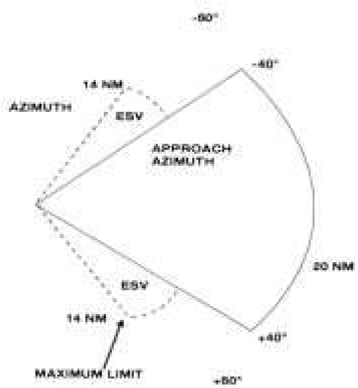


Fig: Coverage Volume Azimuth

Elevation Guidance

a) The elevation station transmits signals on the same frequency as the azimuth station. A single frequency is time-shared between angle and data functions.
b) The elevation transmitter is normally located about 400 feet from the side of the runway between runway threshold and the touchdown zone.
c) Elevation coverage is provided in the same airspace as the azimuth guidance signals:
   i. In elevation, to at least +15 degrees;
   ii. Laterally, to fill the Azimuth lateral coverage; and
   iii. In range, to at least 20 NM.

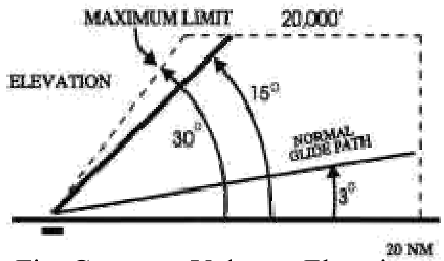


Fig: Coverage Volumes Elevation

Range Guidance

a) The MLS Precision Distance Measuring Equipment (DME/P) functions the same as the navigation DME (Distance Measuring Equipment), but there are some technical differences. The beacon transponder operates in the frequency band 962 to 1105 MHz and responds to an aircraft interrogator. The MLS DME/P accuracy is improved to be consistent with the accuracy provided by the MLS azimuth and elevation stations.
b) A DME/P channel is paired with the azimuth and elevation channel. A complete listing of the 200 paired channels of the DME/P with the angle functions is contained in FAA Standard 022 (MLS Interoperability and Performance Requirements).
c) The DME/N or DME/P is an integral part of the MLS and is installed at all MLS facilities unless a waiver is obtained. This occurs infrequently and only at outlying, low density airports where marker beacons or compass locators are already in place.

Data Communications

a) The data transmission can include both the basic and auxiliary data words. All MLS facilities transmit basic data. Where needed, auxiliary data can be transmitted.
b) Coverage limits; MLS data are transmitted throughout the azimuth (and back azimuth when provided) coverage sectors.
c) Basic data content; Representative data include:
    a. Station identification;
    b. Exact locations of azimuth, elevation and DME/P stations (for MLS receiver processing functions);
    c. Ground equipment performance level; and
    d. DME/P channel and status.

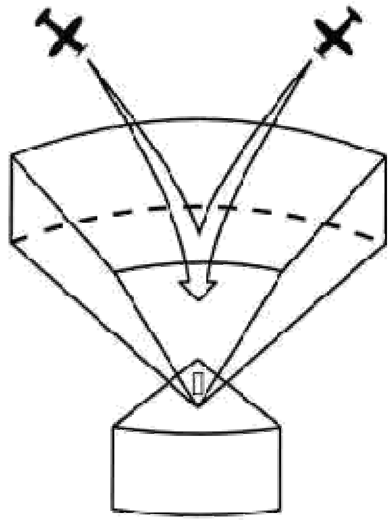


Fig: Coverage Volumes 3-D Representation

4. <u>Auxiliary data content</u>; Representative data include:
   a) 3-D locations of MLS equipment;
   b) Waypoint coordinates;
   c) Runway conditions; and
   d) Weather (e.g., RVR, ceiling, altimeter setting, wind, wake vortex, wind shear).

Operational Flexibility

1. The MLS has the capability to fulfill a variety of needs in the approach, landing, missed approach and departure phases of flight. For example:
   a. Curved and segmented approaches;
   b. Selectable glide path angles;
   c. Accurate 3-D positioning of the aircraft in space; and
   d. The establishment of boundaries to ensure clearance from obstructions in the terminal area.
2. While many of these capabilities are available to any MLS-equipped aircraft, the more sophisticated capabilities (such as curved and segmented approaches) are dependent upon the particular capabilities of the airborne equipment.

SATELLITE NAVIGATION

A satellite navigation or sat nav system is a system of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few meters using time signals transmitted along a line-of-sight by radio from satellites. Receivers calculate the precise time as well as position, which can be used as a reference for scientific experiments. A satellite navigation system with global coverage may be termed a global navigation satellite system or GNSS.

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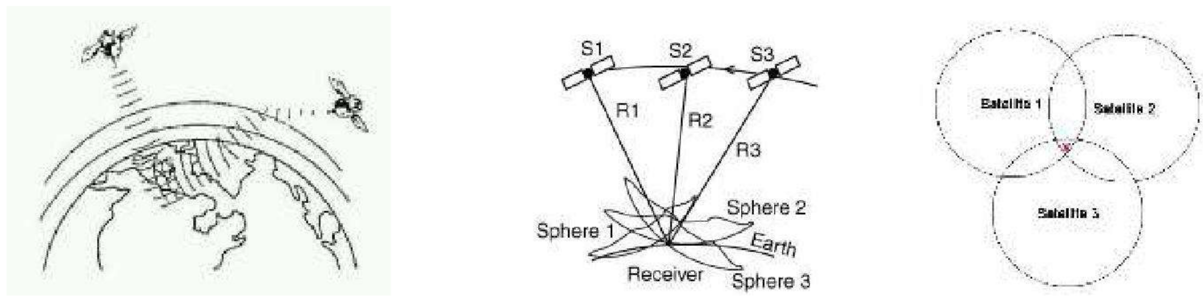


Fig: Satellite Navigation concept

Satellite navigation is based on a global network of satellites that transmit radio signals from approximately eleven thousand miles in high earth orbit. Global coverage for each system is generally achieved by a satellite constellation of 20–30 medium Earth orbit (MEO) satellites spread between several orbital planes. The actual systems vary, but use orbit inclinations of >50° and orbital periods of roughly twelve hours (at an altitude of about 20,000 kilometers (12,000 mi)).

Classification

Satellite navigation systems that provide enhanced accuracy and integrity monitoring usable for civil navigation are classified as follows:

The major classifications are;

- GNSS-1 is the first generation system and is the combination of existing satellite navigation systems (GPS and GLONASS), with Satellite Based Augmentation Systems (SBAS) or Ground Based Augmentation Systems (GBAS). In the United States, the satellite based component is the Wide Area Augmentation System (WAAS), in Europe it is the European Geostationary Navigation Overlay Service (EGNOS), and in Japan it is the Multi-Functional Satellite Augmentation System (MSAS). Ground based augmentation is provided by systems like the Local Area Augmentation System (LAAS).
- GNSS-2 is the second generation of systems that independently provides a full civilian satellite navigation system, exemplified by the European Galileo positioning system. These systems will provide the accuracy and integrity monitoring necessary for civil navigation. This system consists of L1 and L2 frequencies for civil use and L5 for system integrity. Development is also in progress

to provide GPS with civil use L2 and L5 frequencies, making it a GNSS-2 system.

- Core Satellite navigation systems, currently GPS (U.S.), GLONASS (Russia), Compass (China), and Galileo (EU).

Other important classifications are;

- Global Satellite Based Augmentation Systems (SBAS) such as Omnistar and Star Fire.
- Regional SBAS including WAAS (U.S.), EGNOS (EU), MSAS (Japan) and GAGAN (India).
- Regional Satellite Navigation Systems such as China's Beidou, India's yet-to-be-operational IRNSS, and Japan's proposed QZSS.
- Continental scale Ground Based Augmentation Systems (GBAS) for example the Australian GRAS and the US Department of Transportation National Differential GPS (DGPS) service.
- Regional scale GBAS such as CORS networks.
- Local GBAS typified by a single GPS reference station operating Real Time Kinematic (RTK) corrections.

Application

Aircraft navigation systems usually display a "moving map" and are often connected to the autopilot for en-route navigation. Cockpit-mounted GNSS receivers and glass cockpits are appearing in general aviation aircraft of all sizes, using technologies such as WAAS or LAAS to increase accuracy. Many of these systems may be certified for instrument flight rules navigation, and some can also be used for final approach and landing operations. Glider pilots use GNSS Flight Recorders to log GNSS data verifying their arrival at turn points in gliding competitions. Flight computers installed in many gliders also use GNSS to compute wind speed aloft, and glide paths to waypoints such as alternate airports or mountain passes, to aid en route decision making for cross-country soaring.

Spacecraft are now beginning to use GNSS as a navigational tool. The addition of a GNSS receiver to a spacecraft allows precise orbit determination without ground tracking. This, in turn, enables autonomous spacecraft navigation, formation flying, and autonomous rendezvous. The use of GNSS in MEO, GEO, HEO, and highly elliptical orbits is feasible only if the receiver can acquire and track the much weaker (15 - 20 dB) GNSS side-lobe signals. This design constraint, and the radiation environment found in space, prevents the use of COTS receivers. Low earth orbit satellite constellations such as the one operated by Orbcomm uses GPS receivers on all satellites.

Aircraft passengers — most airlines allow passenger use of GNSS units on their flights, except during landing and take-off when other electronic devices are also restricted. Even though consumer GNSS receivers have a minimal risk of interference, a few airlines disallow use of hand-held receivers during flight. Other airlines integrate aircraft tracking into the seat-back television entertainment system, available to all passengers even during takeoff and landing.

(a) GLOBAL POSITIONING SYSTEM (GPS)

GPS (Global Positioning System) is the only system today able to show you where you’re exactly position on the earth at any time and any weather condition. 24 satellites are all orbit around the earth at 11,000 nautical miles or approximately 20,200 kms. Above the earth. The satellites are placed into six different orbital planes and 55 degree inclination. They are continuously monitored by ground stations located worldwide.

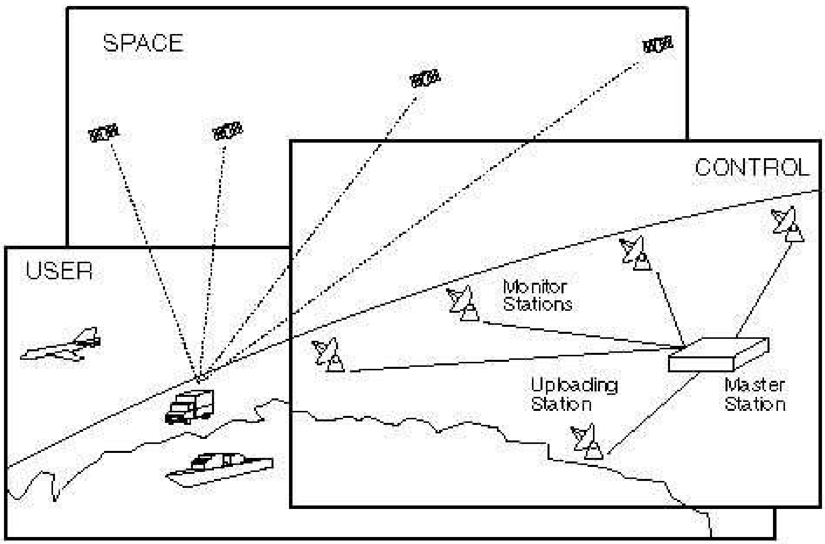
The Global Positioning System (GPS) is currently the U.S. space-based world's most utilized global navigation satellite system. It provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth.

Segments

GPS is made up of three parts: between 24 and 32 satellites orbiting the Earth, four control and monitoring stations on Earth, and the GPS receivers owned by users. GPS satellites broadcast signals from space that are used by GPS receivers to provide three-dimensional location (latitude, longitude, and altitude) plus the time.

So the overall system configuration for GPS consists of three segments;

- Space segment
- Control segment
- User segment



The Space segment is comprised of the satellite constellation made up multiple satellites, each in its own orbit 11000 nautical miles above earth. The Control segment consists of three major elements;

- Monitor stations that track the satellites transmitted signals and collect measurements similar to those that the users collect for their navigation.
- A master control station that uses these measurement to determine and predict the satellite's information and time history, and subsequently to upload parameters that the satellites modulate on the transmitted signals.
- Ground antennas that perform the upload and general of the satellites.

The User segment is comprised of the receiving equipment and processors that perform the navigation solution.

Basic concept

The basic principle of position determination using the GPS system is to measure the spherical range of the user from a minimum of 3 or 4 GPS satellites. The basis of GPS is 'triangulation' from satellites. To triangulate, a GPS receiver measures distance using the travel time of radio signals. To measure travel time, GPS needs very accurate timing. A long with distance, we need to know exactly where the satellites are in space and must correct for any delays the signals experiences as it travels through the atmosphere.

Constellation of satellites

An orbit is one trip in space around earth. GPS satellite each take 12 hours to orbit earth. Each satellite is equipped with an atomic clock, so accurate that it keeps time to within three billionths of a second (ie., 0.000000003) to let it broadcast signals that are synchronize with those from other satellites.

The signal travels to the ground at the speed of light. Even at this speed, the signal takes a measureable amount of time to reach the receiver. The difference between the time when the signal is received and the time when it was sent, multiplied by the speed of light, enables the receiver to calculate the distance to the satellite.

To make this measurement as accurate as possible the GPS navigation signals are specially designed to make it easy for GPS receivers to measure the time of arrival and to allow all the satellites to operate on the same frequency without interfering with each other. By using four satellites, the receiver calculates both its position and the time and doesn't need an expensive atomic clock like those on the satellites.

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

- the time the message was transmitted
- satellite position at time of message transmission

The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite. These distances along with the satellites' locations are used with the possible aid of trilateration, depending on which algorithm is used, to compute the position of the receiver. This position is then displayed, perhaps with a moving map display or latitude and longitude; elevation information may be included. Many GPS units show derived information such as direction and speed, calculated from position changes.

Binary data that is modulated or "superimposed" on the carrier signal is referred to as Code. Two main forms of code are used with NAVSTAR GPS: C/A or Coarse/Acquisition Code (also known as the civilian code), is modulated and repeated on the L1 wave every millisecond; the P-Code, or Precise Code, is modulated on both the L1 and L2 waves and is repeated every seven days. The (Y) code is a special form of P code used to protect against false transmissions; special hardware, available only to the U.S.government, must be used to decrypt the P(Y) code.

Three satellites might seem enough to solve for position since space has three dimensions and a position near the Earth's surface can be assumed. However, even a very small clock error multiplied by the very large speed of light — the speed at which satellite signals propagate — results in a large positional error. Therefore receivers use four or more satellites to solve for both the receiver's location and time. The very accurately computed time is effectively hidden by most GPS applications, which use only the location.

GPS Aircraft tracking

GPS (Global Position System) aircraft tracking are systems installed on aircraft to give position reports over a satellite and/or cellular network. This information is typically accessed from a web-based mapping interface where current and historical information can be viewed. These devices come in many different forms: some are portable devices that can be moved between aircraft and others are fixed installations.

There are varying degrees of fixed installations: some with only the antenna permanently installed and others where the electronics must be installed in the dash of the cockpit.

GPS aircraft tracking systems report aircraft-specific information such as speed, bearing and altitude and sometimes have built in voice or data communications capabilities. These systems have varying configurations for reporting intervals, typically from one-minute to fifteen-minute time intervals but cellular based systems can also report at shorter intervals. Some devices also have the ability to report for AFF.

Some common satellite networks include the Iridium satellite constellation, Global star, and Inmarsat. Data networks such as Aircraft Communications Addressing and Reporting System (ACARS) can also be used for periodic transmission of GPS positions of aircraft.

DIFFERENTIAL GLOBAL POSITIONING SYSTEM

Differential Global Positioning System (DGPS) is an enhancement to Global Positioning System that provides improved location accuracy, from the 15-meter nominal GPS accuracy to about 10 cm in case of the best implementations.

DGPS uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudo ranges and actual (internally computed) pseudo ranges, and receiver stations may correct their pseudo ranges by the same amount. The digital correction signal is typically broadcast locally over ground-based transmitters of shorter range.

Advantage of GPS over conventional navigation

- Global coverage and assessment
- More precise
- High integrity and portable simple system
- Augments the accuracy of the self-contained systems

GPS/INS

GPS/INS refers to the use of GPS satellite signals to correct or calibrate a solution from an Inertial Navigation System (INS). The benefits of using GPS with an INS are that the INS may be calibrated by the GPS signals and that the INS can provide position and angle updates at a quicker rate than GPS. For high dynamic vehicles such as missiles and aircraft, INS fills in the gaps between GPS positions. Additionally, GPS may lose its signal and the INS can continue to compute the position and angle during the period of lost GPS signal. The two systems are complementary and are often employed together

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FACULTY OF ENGINEERING
UG / B. Tech. Aerospace Engineering

Subject Name: Aircraft Systems and Avionics **Subject Code:** 16BTAR403

PART A

1. Which engine system is more trouble free than piston engine?

   a. Jet b. Piston c. Electric d. Reciprocating

2. Oil from the system is also routed through ________ for control of pitch and engine rpm.

   a. Control surface b .**Propeller** c. Wing d. engine fan

3. In power assisted control system majority of work is done by the __________

   a. piston b. control rod c. fluid **d. actuators**

4. An automatic device that uses error-sensing negative feedback to correct the performance of a mechanism

   a. pump b. **servo mechanism** c. actuator d. undercarriage

5. Which of the following is a pressure measuring device?

   a. pitot tube b. altimeter c. Turn co ordinator d. attitude indicator

6. The purpose of spark plug is to conduct a short _______

   a. Spark b. Impulse c. **ignition** d. Inductance

7. The number of wheels in Tricycle type of landing gears is

   a. Three **b.** Four c. Five d. Six

8. Aircrafts are made statically and __________

   a. mechanically stable b. Statically unstable

   c. Dynamically unstable d. **Dynamically Stable**

9. A system for admitting fuel into an internal combustion engine

   a. shutter valve b. fuel valve c. hollow valve d. **Fuel injection**

10. Piston engine lubrication is classified into

    a. Wet sump lubrication b. Dry sump lubrication

    b. **wet and dry sump lubrication** d. None of the given

11. The other name of reciprocating engine is __________

a. jet engine b. **piston engine** c. turbo fan engine d. turbo prop engine

12. Air starting is used in which aircrafts?

a. **Commercial** b. Non-commercial c. Jet d. Trainers

13. ____________ is the largest fraction of units in a 1553 system.

a) Digital display b) Bus monitor **c) Remote terminal** d)Control bus

14. High frequency covers the communication band is between ____________

a) 3 – 30 MHz b)5 – 60 MHz c)2 – 40 MHz d)6 – 80 MHz

15. Energy gap for diode in LED is __________

a) 1.1 ev b) 2.2ev c)1.3ev d) 4.1ev

16. In LED energy is releases in the form of ____________

a) Photon b) neutron c) electron d) boron

17. AFCS stands for ___________

a) Automatic flight control systems b) Audio flight control systems

c) Automatic flight communication systems d) Audio flight communication systems

18. Following one is the type of navigation system

a) Medium frequency **b) pilot age** c) High frequency d) Low frequency

19. Electronic Warfare is mainly used to search the ___________

a) Communication signals b) Ultrasonic waves

c) Sound waves **d) Radio frequency band**

20. In communication system __________ is used as a transmitter links.

a) Fiber b) iron c) mica d) Silver

21. Aircrafts are made statically and dynamically stable in other words

a. laterally and normally stable b. normally and longitudinally stable

c. **longitudinally and laterally stable** d. directionally and laterally stable

22. The turbine is rotated by high pressure gases resulting from the combustion of

a. Hydrochloric acid b. **Nitrous acid** c. Alcoholic spirit d. Isopropyl nitrate

23. Air starting is used in which aircrafts

a. Commercial b. Non-commercial c. **Jet** d. Trainers

24. The purpose of autopilot is to reduce the work load of the

a. engine b. wings c. instruments d. **pilot**

25. Auto Pilot system can be used during

a. **Steady Flight** b.Unsteady Flight c.Moderate flight d.High flight

26. The Rigid landing gear system comes under ___________

a NALG b. NACA c. **NAGL** d. NAM

27. Teleflex can be operated from

a. Rudder b.Fuselage c.**Cockpit** d.Engine

28. Guidance in Poor Visibility condition can be done using

a. IFS b. IRS c. ISF d. **ILS**

29. Air starter motor transmits

a. Wave b. Frequency c. **power** d. current

30. If the battery current is cutoff and the plug does _________

a. Fire b. **Not fire** c. charge d. ignite

31. Fuel systems can be classified into

a. Gravity-Feed fuel systems b. Pressure-Feed fuel Systems

c. **gravity and pressure feed systems** d. None of the given

32. The heated air in Thermal anti-icing system is passed through the

a. vanes b. **Ducts** c. Pipes d. Manes

33. Materials like GaAs and GaAsP are used in _________

a) LED b) LCD c) CRT d)EL

34. LCD stands for __________

a) Light Crystal Display **b) Liquid Crystal Display**

c) Light Copper Display d) Liquid Cryptal Display

35. Single LED is used as _________

a) Indicator lights b) Induction lights c) Indicator switch d) Induction switch

36. The light of an LED comes when the diode is __________

a) Forward biased b) Backward biased c) unbiased d) over biased

37. Pilotage is used to find the direction with the help of ____________

a) Land marks b) Radio signals c) radar d) maps

38. RLG stands for __________

a) Real Laser Gyro b) Ring Laser Gas **c) Ring Laser Gyro** d) Ring large Gyro

39. Satellites are used in ____________

a) Global positioning system b) Global point system

c) Global plane system d) Galaxy positioning system

40. Localizer is used in ___________

a) ILS b) IOP c) IAP d) ISI

41. Components such as engine, propeller controls, trimming controls, fuel valves can be controlled by

a. engine system b. **tele flex control system** c. control unit d. hydraulic system

42. What is meant by NDB?

a **National direct radio beacon** b. Non disturbed radio beacon

c. Non directional radio beacon d. Natural disturbed radio beacon

43. The microphone converts acoustic energy to

a. mechanical energy b. **electric energy** c. kinetic d. sound waves

44. Which of the following is tubular in construction?

a. wheel drum b. **push pull rod** c. landing gear d. rudder pedal

45. Aircraft -cooling system, also called air-conditioning is used to reduce

a. Heat b. Air flow c. Humidity d. **Temperature**

46. The other name of landing gear is ___________

a. **undercarriage** b. wheels c. base d. stand

47. According to Newton's law, the gravitation is inversely proportional to

a geometric altitude b. Geo potential altitude

c. **absolute altitude** d. none of the given

48. NALG is usually

a Movable Landing Gear b. Non-Absorbing Landing Gear

c. **Rigid landing gear** d. Retractable landing gear

49. Aircraft propulsion systems is sub-divided into

a **fuel system & Engine system** b. Rocket fuel system

c. Jet fuel system d. Turbine fuel system

50. Simplex and Duplex are types of

a. **Spray nozzle** b. Flow divider c. Flow equalizerd. Dump valves

51. The number of wheels in Tricycle type of landing gears is

a. Three b. Four c. Five d. Six

52. Aircrafts are made statically and

a. Statically stable b. Statically unstable

c. Dynamically unstable d. **Dynamically Stable**

53. ____________ has twisted molecules.

a)LCD b)LED c)EL d)INS

54. CRT consist of ______________

a) Mirror b) Touch screen **c) Electron gun** d) signal band

55. Electronically generated display with the input controls is called ____________

a) Analog display **b) Touch screen** c) Manual display d) PLC display

56. Electroluminescent media is constructed in___________ layers

a) 5 b) 3 c) 2 d) 4

57. Dead reckoning method is used in _____________

a) Desert areas b) Fighter aircrafts c) Rush areas d) JET A

58. Radio method is used to find the position with the help of ______________

a) Radar **b) Radio frequencies** c) sounds d) Lights

59. VOR stands for____________

a) Very High Frequency Omni range b) Very High distance Omni range

c) Very High signal Omni range d) Very low Frequency Omni range

60. ADF is used in ____________

a) Communication system **b) Navigation system** c)ILS d)GPS

61. A special type of electrical circuit designed to radiate and receive the electromagnetic energy is

a. control unit b. system unit c. electric navigational system d. **antenna**

62. The full form of CCV is

a. **control configured vehicle** b. construction configured vehicle
c. control circuit vehicle d. control convertor vehicle

63. The primary heat exchanger is the first unit of

a. **Cooling packs** b. heating packs c. Thermal packs d Non Thermal packs

64. Choose the correct abbreviation for RB in aircraft systems.

a. **relative bearing** b. readable bandwidth c. reliable bandwidth d. readable bearding

65. The landing gear which do not dissipate the energy of the aircraft contacting the ground during landing is called

a. Movable Landing Gear b. **Non-Absorbing Landing Gear**

c. semi movable Landing Gear d. Retractable landing gear

66. Systems not essential to the actual operation of the aircraft are commonly called as

a. **Auxiliary units** b. Tertiary units c. terminal units d. Low subsidiary units

67. The outlet of Aneroid barometer serves as

a. **Vent** b. Vane c. nozzle d. diffuser

68. Which of the following is used during landing?

a. Cockpit b. **Landing Gear** c. Wings d. Tail

69. Drilled and cored passages carry oil from the oil cooler to all parts of the engine requiring________

a. Fluidity b. Contamination c. **Lubrication** d. Viscosity

70. Commercial aircraft requires the engine to be started with the minimum

a. Heat loss b. Heat transfer c. No disturbance d. **Disturbance**

71. The electric starter is usually ________

a. A.C supply b. **D.C supply** c. MESH d. NON-MESH

72. Gas Turbine starter is economical to operate and provides a high

a. **Power** b. Electricity c. Weight d. Ignition

73. EL stands for_____________

a. Electro Luminescence b. Electro Light c. Electro Laser d. Electronic Laser

74. Following one is the principle of touch screen________

a. Scanning infrared b. radar c. Radio d. Digital display

75. LED has_________ Junction

a. p-n b. n-p c. r-p d. s-p

76. CRT is coated inside with ___________

a. Phosphorous b. Sulfuric c. Teflon d. polymer

77. SELCAL is the ____________

a. Separate calling **b. Selective calling** c. Selective calculation d. Sensor calling

78. MLS stands for_______________

a. Microwave Landing System b. Micro control Landing System

c. Micronics Landing System d. Microwave Lane System

79. No. of cycles per seconds is known as _____________

a. Wave length **b. frequency** c. Sound d. Light

80. ADF is used in _______________

a. Communication system **b. Navigation system** c. ILS d. GPS

81. A radio wave is an

a. **electromagnetic wave** b. electric wave
c. sound wave d. magnetic wave

82. Which of the following is not a function of the ADF

a. plot your position b. **plot the pressure distribution**
c. track inbound and outbound d. intercept a bearing

83. The radio frequency portion of the electro-magnetic spectrum extends from approximately from 30 KHz to

a. 300 MHz b. 300 KHz c. **30,000 MHz** d. 30,000 KHz

84. As the gas enters the condenser, what is drawn from the refrigerant?

a. **Heat** b. Liquid c. Air d. Cooler

85. A device which displaces a volume by physical or mechanical action

a. servomechanism b. actuator c. **pump** d. air speed indicator

86. Torque links is often referred to as

a. scalar system b. **Scissors assembly** c. pitot assembly. d. torsion assembly

87. A hydraulic snubbing unit that reduces the tendency of the nose wheel to oscillator from side to side is called

a. Hydraulic Filter b. **Shimmy Damper** c. O-Rings d. Omni-Radial

88. ACT is called as

a. Advanced Control Technology b. **Active Control Technology**
c. Adaptive control technology d. all the given

89. Air starting is used for _____________ aircrafts

a. **Commercial** b. Non-commercial c. Jet d. trainer

90. The lack of oxygen causes a person to experience a condition called

a. Hycopothermia b. **Hypoxia** c. Dermatitis d. Asthma

91. Which of the following is used during landing?
a. Cockpit b. **Landing Gear** c. Wings d. Tail

92. Hydraulic filters use

a. **O-Rings** b. M-Rings c. T-Rings d. F-Rings

93. The entire group of instruction is called as ____________

a. Instruction decoder **b. Instruction set** c. Instruction data d. Instruction encoder

94. LED has ___________Junction

a. p-n b. n-p c. r-p d. s-p

95. How many types of antenna channels used for radio communication _______

a. 1 b. 6 **c. 5** d. 3

96. Automatic Direction Finder is used in ____________

a. Communication system **b. Navigation system** c. ILS d. GPS

97. RLG stands for_________

a. Real Laser Gyro b. Ring Laser Gas c. **Ring Laser Gyro** d. Ring large Gyro

98. Instruction which specifies the task to be performed by the computer is called _________

a. opcode b. encode c. operand d. operation

99. SELCAL is the __________

a. Separate calling **b. Selective calling** c. Selective calculation d. Sensor calling

100. VHF uses the range between_______________

a. 30 – 300 MHz b. 30 – 600 MHz c. 90 – 300 MHz d. 90 – 900 MHz

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