Part 66 Cat. B1 Module 5

Digital Techniques / Electronic Instrument Systems

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5.1 ELECTRONIC INSTRUMENT SYSTEMS

Analog Cockpit

For many years of aviation, the standards for cockpit layout were established. Aircraft started with a few instruments, they changed with the number of devices growing.

Historically the modern typical systems arrangements and cockpit layout of electronic instrument systems could be started with Boeing 737-200 aircraft (**Fig. 1-1**). It flight deck could be divided into parts according captain's (pilot), Central and 1st officer's (co-pilot) places.



Figure 1-1. The Boeing 737-200 flight deck

On the top there is glareshield panel combined of Mode Control panel with autopilot and Master Caution lights. The master caution lights accompanied by annunciators are located on the left- and right-end of the glare shield panel. They are arranged as two-button systems with yellow and red lights with buzzer. Each annunciator group is different for pilot and co-pilot, accordingly to the instruments arrangement. The autopilot is in between.

The Glareshield panel is like a dock shelter, which shields Captain's, Central and 1st officer instrumental panels from the direct sunlights.

The main catching one's eye instruments on the Captain's and 1st officer instrumental panels are analog flight instruments. The Central panel instruments give the information on engine parameters (compressor speeds, etc.) and oil pressure, fuel quantity and consumption.

In the middle down of the Central panel, there are two Central display units (CDU) of Flight management computers (FMC) and digital color weather radar monitor in between.

Evolution to Completely Digitized Instruments Arrangement¹

In the NG and Airbus aircrafts (**Fig. 1-15**), the larger Primary Flight Display / Navigation Display (PFD/ND – formerly known as Electronic Flight Instrument System - EFIS/MAP) are now side by side to fit into the space available, controls for these are located on either side of the Mode Control Panel (MCP). The Electronic Instrument System (EIS) and fuel gauges are both on the central Common Display System (CDS) with a 6" screen below that, between the CDUs. The flat panel displays have the advantage over CRTs of being lighter, more reliable and consume less power.



Figure 1-15. Airbus flight deck schematic

The main difference in Boeing and Airbus flight decks is due to different ideology used. According to Boeing, the requirements from the airlines for the new cockpit were:

- To be easy for current 737 pilots to operate;
- To anticipate future requirements e.g. transitioning to 777 style flight decks;
- To accommodate emerging navigation and communication technologies.

In the case of Airbus aircrafts started from A-300 in 1972, the newest achievements were involved from the very beginning combining CRT displays with classic control column. This ideology helped later in launching the A320 family, pioneered the use of digital fly-by-wire flight control systems, as well as side-stick controls, in commercial aircraft.

The Boeing B737NG main and glareshield panels are presented on **Fig. 1-16**. Comparing with Fig. 1-15 the composition of the main monitors is classic for that of narrow-body aircrafts glass cockpit.

¹ As the "glass cockpit" is very similar for both Boeing and Airbus aircrafts, only one type is chosen to simplify discussion. Boeing preveals as in the very beginning of Basic Training in Lithuania this was the only one complex turbine aircraft type the maintenance organizations were approved and available for basic maintenance practice

Fig. 1-23A is of the Control Display Unit (CDU), which is the pilot interface to the FMC, and its layout (**Fig. 1-23B**).



Figure 1-23. Control Display Unit (A), its possible layout (B) and FMC in avionics bay (C)

This is only one of possible but rather common layouts. There are normally 2 CDUs but only one FMC used (if more than one, they are back-up FMC). Think of it as having two keyboards connected to the one PC. The CDU has a DIR INTC key at the beginning of the second row but some have a MENU key. This key gives access to the sub-systems such as FMC, ACARS, DFDMU, etc. The Control Display Unit (CDU) is the pilot interface to the FMC. The FMC (**Fig. 1-23C**) is located in avionics bay (**Fig. 1-24**). For control purposes, the information being input to FMCS is seen on the so-called Scratch Pad.



Figure 1-24. FMC in an avionics bay

5.2 NUMBERING SYSTEMS

The counting systems starting from the simplest one, related to the fingers changed to more sophisticated and the oldest known system is that used in Babylon about 5100 years before the 21st century.

The Babylonians, who are known for their astronomical observations and calculations, used a sexagesimal (base-60) numeral system. It was the first positional system, in which the value of the particular digit depends both on the digits itself and its position within the number.

The legacy of sexagesimal system survived until nowadays, in the form of angle degrees (360° in a circle) and in time measurement.

The everyday use of this system was of little use so since approximately 2300 years before the 21st century the Hindu-Arabic numeral system slowly became the main system used. The numeral concept, developed in India spread to other surrounding countries and, after adaptation and modification by Arabs, spread to the Western world due to trade links with them. The Western world modified them once again and called them Arabic numerals. Hence, the current Western numeral system is the modified version of the Hindu numeral system developed in India.

The Decimal (Denary) System

This is the familiar, everyday system in which the base or "radix" of the number is 10: this means that each digit in a decimal number is effectively multiplied by a power of 10.

In other words the value (for example **754**) is formed by the sum of each digit, multiplied by the *base* (in this case it is **10** because there are 10 digits in decimal system) in power of digit position (counting from zero) as is shown on **Fig. 2-1**.



Figure 2-1. Number 754 formation

Position of each digit is very important! Placing "7" to the end as in **547** (**Fig. 2-2**) it will be another value:



Figure 2-2. Number 547 formation

One's Complement

The one's complement of a binary number is formed by *inverting* the value of each digit of the original binary number (i.e. replacing 1's with 0's and 0's with 1's).

For example, the one's complement of the binary number 1010 is simply 0101. Similarly, the one's complement of 01110001 is 10001110. If the one's complement of a number is added to the original number, the result will be all 1's.

Original binary number: 10110101 One's complement: + 01001010 Sum: 11111111

<u>Two's Complement</u>

Two's complement notation is frequently used to represent negative numbers in computer mathematics (with only one possible code for zero-unlike one's complement notation). The two's complement of a binary number is formed by inverting the digits of the original binary number and then adding 1 to the result. Repeating the process of finding the one's complement:

Original binary number: 10110101 One s complement: + 01001010

and going to the two's compliment:

One's complement: + 01001010 Adding1: + 00000001 Two's complement: 01001011

Another example is:

Original binary number: 10011100 One's complement: 01100011 Adding1:+ 00000001 Two's complement: 01100110

When two's complement notation is used to represent negative numbers, the most significant digit (MSD) is always a 1.

Octal Numbering System

The octal numeral system, or *oct* for short, is the base-8 number system, and uses the digits 0 to 7. Octal numerals can be made from binary numerals by grouping consecutive digits into groups of three (starting from the right) and converting each group into decimal counterpart. For example, the binary One advantage of hexadecimal is that every unique 2-digit pair (or octet) always represents the same byte value. To "translate" a hexadecimal value into bytes, one needs only to separate the value into individual 2-digit groups, translate each group into its respective byte value, and then combine the results together to form an accurate translation of the entire original hexadecimal word. Conversely, bytes can also be easily translated into hexadecimal values by translating each byte individually into its hexadecimal 2-digit value, and then recombining the hexadecimal values into a "word". The resulting "word" will be an accurate hexadecimal representation of the original string of bytes.

There is a convention to add "h" in the end of a hexadecimal number, this way we can determine that 5Fh is a hexadecimal number with decimal value of 95. "0" (zero) is added in the beginning of hexadecimal numbers that begin with a letter (A...F), for example 0E120h.

Example: The hexadecimal number *1234h* is equal to decimal value of 4660:



Converting Decimals to Hexadecimals

In order to convert from decimal system, to any other system, it is required to divide the decimal value by the *base* of the desired system, each time you should remember the *result* and keep the *remainder*, the divide process continues until the *result* is zero.

The *remainders* are then used to represent a value in that system.

Example: Convert the value of **39** (base <u>10</u>) to *Hexadecimal System* (base <u>16</u>):



The hexadecimal number is 27_h . All remainders were below 10 in the above example, so any letters were used.

5.3. DATA CONVERSION

Analog Data

Analog data is data that can be considered to be an analog signal, as opposed to a digital signal, which is either on or off (1 or 0), or a series of discrete steps made from 1's and 0's, with no intermediate steps. Analog data is used by a wide variety of analog instruments, such as seismometers, sound level meters, and others. It can be changed to digital data.

Analog Signal

An analog signal is any variable signal continuous in both time and amplitude (Fig. 3-1).



Figure 3-1. Analog signal

It differs from a digital signal in that small fluctuations in the signal are meaningful. Analog is usually thought of in an electrical context, however mechanical, pneumatic, hydraulic, and other systems may also convey analog signals.

An analog signal uses some property of the medium to convey the signal's information. For example, an aneroid barometer uses rotary position as the signal to convey pressure information. Electrically, the property most commonly used is voltage followed closely by frequency, current, and charge.

Any information may be conveyed by an analog signal, often such a signal is a measured response to changes in physical phenomena, such as sound, light, temperature, position, or pressure, and is achieved using a transducer.

For example, in an analog sound recording, the variation in pressure of a sound striking a microphone creates a corresponding variation in the voltage amplitude of a current passing through it. An increase in the volume of the sound causes the fluctuation of the current's voltage amplitude to increase while keeping the same rhythm.

Disadvantage of Analog Signal

The primary disadvantage of analog signaling is that any system has noise - i.e., random variation. As the signal is copied and re-copied, or transmitted over long distances, these random variations Resolution can be defined electrically, in volts. The voltage resolution of an ADC is equal to its overall voltage measurement range divided by the number of discrete intervals as in the formula:

$$Q = \frac{E_{FSRV}}{2^M} = \frac{E_{FSRV}}{N}$$

where:

Q - Resolution in volts per step (volts per output code);

$$E_{FSVR} = V_{Ref}(Hi) - V_{Ref}(Lo)$$
 - the full scale voltage range;

M - the ADC's resolution in bits, and

N - the number of intervals, where $N = 2^{M}$.

Example: Full-scale measurement range is from 0.0 to 8.0V; 3-bit ADC resolution is $2^3 = 8$.

$$Q = \frac{E_{FSRV}}{2^M} = \frac{8 - 0}{2^3} = \frac{1V}{1(code)} = 1\ 000 \frac{mV}{code}$$

The codes used are not equal. The smallest output code ("0") represents a voltage range, which is of the ADC voltage resolution:

 $0.5 \times Q$

In 3-bit resolution and full-scale measurement range from 0 to 8V this gives the 1st code ("0") to be

$$0 \ code = 0.5 \times Q = 0.5 \times \frac{E_{FSRV}}{2^{M}} = 0.5 \times \frac{8 - 0}{2^{3}} = 0.5 \left(\frac{V}{code}\right) = 500 \frac{mV}{code}$$

The largest output code ("7") represents a voltage range, which is

$$7 \ code = 0.5 \times Q = 1.5 \times \frac{E_{FSRV}}{2^M} = 1.5 \times \frac{8-0}{2^3} = 1.5 \left(\frac{V}{code}\right) = 1\ 500 \frac{mV}{code}$$

The other codes (N - 2 in number) are equal in width and represent 1V. The "1" code has a voltage from 0.5 to 1.5 V, the "2" code has a voltage from 1.5 to 2.5 V and so on up to the last.

Problems with Analog-to-digital Conversion

<u>Aliasing</u>

ADCs work by sampling their input at discrete intervals of time. Their output is therefore an incomplete picture of the behavior of the input.

If the input signal is changing much faster than the sample rate, then this will not be the case, and spurious signals called *aliases* will be produced at the output of the DAC.

To avoid aliasing, the input to an ADC must be low-pass filtered to remove frequencies above half the sampling rate.

The actual output curve (**Fig. 3-16B**) should be linear. It loses its linearity from 3.9 volt. The "Error zone" is where the output of the DAC no longer mathematically the relative binary input.

This problem could be solved by increasing the supply voltage of the Op-Amp (**Fig. 3-17**). Supplying 6.5 volts or more, there will be neat linear output from 0V to 5V.



Figure 3-17. Solving the problem of non-linearity of op-amp

DAC Applications

Audio

Most modern audio signals are stored in digital form (for example MP3s and CDs / DVDs) and in order to be heard through speakers they must be converted into an analog signal. DACs are therefore found in CD / DVD players, digital music players, PC and mobiles sound cards.

Specialist stand-alone DACs can also be found in high-end Hi-Fi systems. These normally take the digital output of a CD / DVD player (or dedicated transport) and convert the signal into a line-level output that can then be fed into a pre-amplifier stage. Some of these can also be made to interface with computers using a USB interface.

<u>Video</u>

Video signals from a digital source, such as a computer, must be converted to analog form if they are to be displayed on an analog monitor. As of 2007, analog inputs were more commonly used than digital, but later this changed as flat panel displays with DVI and/or HDMI connections become more widespread. However, a video DAC is incorporated in any Digital Video Player with analog outputs. The DAC is usually integrated with some memory (RAM), which contains conversion tables for gamma correction, contrast and brightness, to make a device called a RAMDAC.

5.4 DATA BUSES

Buses are designed to connect more than two devices together in a system. Computer buses are backplane devices - that is, the physical implementation is a circuit board with parallel connectors into which other boards are plugged perpendicularly.

A *bus* may be defined as subsystem that transfers data between system components inside a system or between different systems. Each bus is defined by set of connectors to plug devices, cards or cables together (**Fig. 4-1**).



Figure 4-1. PCI Express bus on Personal computer motherboard

What makes an Avionics bus? The important factors of avionics buses include:

- Deterministic behavior,
- Fault tolerance, and
- Redundancy.

Most avionics buses are serial in nature. A serial bus using only a few sets of wires keeps the pointto-point wiring and weight down to a minimum.

Buses transfer three types of signals:

(1) Data;
 (2) Address and
 (3) Control.

Bus Topology

The devices, line replaceable units or LRUs, are most commonly configured in a star (**Fig. 4-2**) or bus-drop (**Fig. 4-3**) topology. Each LRU may contain multiple transmitters and receivers communicating on different buses. This simple architecture, almost point-to-point wiring, provides a highly reliable transfer of data. Buses that are more complex may be of mixed type (**Fig. 4-4**).

Other ARINC Formats

ARINC 573

ARINC 573 is a Flight Data Recorder output format. This device sends a continuous data stream of Harvard Bi-Phase encoded 12-bit words, which are encoded in frames (**Fig. 4-30**).



Figure 4-30. Harvard bit encoding

The data in a frame consists of a snapshot of the many avionics subsystems on the aircraft. Each frame contains the same data at a different snapshot in time.

<u>ARINC 629</u>

A system similar to MIL-STD-1553 but with significant improvements is ARING 629 operating at 2 Mb/s, twice the data rate of 1553. ARINC 629 is used on the new Boeing 777 Aircraft. It uses a high-speed bi-directional bus capable of either periodic or aperiodic transmissions. Access to the bus is controlled by a sophisticated protocol involving wait periods, quiet periods and other rules.

The important difference between ARING 629 and MIL-STD-1553 is that ARING 629 is defined for both voltage and current modes of operation. The ARINC 429 discussed before use voltage coupling; receivers are high impedance and respond to voltage across the line. During a transmission, a voltage is placed on the bus. To prevent the bus from being loaded by RT's or receivers in the case of ARING 429, there are series resistors between the terminal and bus for isolation. This is a problem because significant signal is lost in the resistors. An alternate to the voltage mode is the current mode.



Figure 4-31. ARINC 629 data bus in current (A) and voltage (B) mode

An example of current mode is shown in **Fig. 4-31A.** In this technique, the bus passes through the primary of a transformer. The impedance of the transformer is very low so there is no signal loss. In

pairs or strands for transmit and receiving data. AFDX extends standard Ethernet to provide high data integrity and deterministic timing.

The Main Elements of an AFDX Network

The AFDX Network (Fig. 4-38) comprises the following components:

- Avionics Subsystem;
- AFDX End Systems;
- AFDX Interconnect (Switches) and
- AFDX Links.



Figure 4-38. AFDX Network.

Two End Systems provide communication interfaces for three avionics subsystems and the third End System supplies an interface for a gateway application. It, in turn, provides a communication path between the Avionics Subsystems and the external IP network and is used for data loading and logging.

<u>Avionics Subsystem</u>

The traditional Avionics Subsystems on board an aircraft, such as the flight control computer, global positioning system, tire pressure monitoring system, etc.

An Avionics Computer System provides a computational environment for the Avionics Subsystems. Each Avionics Computer System contains an embedded End System that connects the Avionics Subsystems to an AFDX Interconnect.

AFDX End System

That system provides an "interface" between the Avionics Subsystems and AFDX Interconnect. In each Avionics Subsystem the End System interface guarantee a secure and reliable data interchange with other Avionics Subsystems. This interface exports an application program interface (API) to the

Ethernet Header	IP Header	UDP Header	UDP Payload Avionics Subsystem Message	Seq. No.	FCS
byte 14	20	8	UDP Header and Payload	1	4
Fthernet Frame					

Figure 4-50. AFDX Frame and Sequence Number

Fig. 4-50 applies when the UDP payload is between 17 and 1 471 bytes. If the UDP payload is smaller than 17 bytes, then a Pad field is introduced between the UDP payload and the Sequence Number fields.

On a per-virtual link and per-network port basis, the receiving End System checks that the sequence numbers on successive frames are in order. This is referred to as "Integrity Checking". After Integrity Checking is complete, the End System determines whether to pass the packet along or drop it because its replica has already been sent along. This is called Redundancy Management (**Fig. 4-51**).



Figure 4-51. Receive processing of Ethernet Fames

Virtual Link Isolation

The 100 Mbps link of an End System can support multiple virtual links. These virtual links share the 100 Mbps bandwidth of the physical link. **Fig. 4-52** shows three virtual links being carried by a single 100 Mbps physical link.



Figure 4-52. Three virtual links connected by a physical link

5.5A LOGIC CIRCUITS

An ability to make decisions based on a variety of different factors is crucial to the safe operation of a modern aircraft. Logic systems are widely used in aircraft.

Logic is the development of

a reasonable or logical conclusion based on known information

Digital equipment and systems make use of logic circuits to direct binary information in the form of voltage levels and pulses to various locations in the system. With logic circuitry, the point of interest is somewhat different in that rather than considering each individual component, entire circuits are accepted as individual packages. It is not necessary to know the exact circuit configuration of any particular device, but only to understand the function of the device in terms of input and output.

Before starting some basic statement are needed. In meaning content, they are:

- In digital circuits, binary bit values of 0 and 1 are represented by voltage signals measured in reference to a common circuit point called *ground*. An absence of voltage represents a binary "0" and the presence of full DC supply voltage represents a binary "1";
- A *logic gate*, or simply *gate*, is a special form of amplifier circuit designed to input and output *logic level* voltages (voltages intended to represent binary bits). Gate circuits are most commonly represented in a schematic by their own unique symbols rather than by their constituent transistors and resistors;
- Just as with operational amplifiers, the power supply connections to gates are often omitted in schematic diagrams for the sake of simplicity;
- A *truth table* is a standard way of representing the input/output relationships of a gate circuit, listing all the possible input logic level combinations with their respective output logic levels.

Logic Level Representation

Computers and aircraft logic decision systems use the *TRUE* and *FALSE* logic conditions of a logical statement to make a programmed decision. Electronic circuits operating in two LOGIC STATES represent these two conditions. These logic states are 0 (*zero*) and 1 (*one*). Respectively, 0 and 1 represent the *FALSE* and *TRUE* conditions of a statement.

When the TRUE and FALSE conditions are converted to electrical signals, they are referred to as *LOGIC LEVELS* called *HIGH* and *LOW*. The 1 state might be represented by the presence of an electrical signal (*HIGH*), while the 0 state might be represented by the absence of an electrical signal (*LOW*).

At T₁, *Input A* goes *HIGH* (logic 1); *Input B* remains *LOW*; and as a result, *Output* remains *LOW*. At T₂, *Input A* goes *LOW* (logic 0); *Input B* goes *HIGH*; and as a result, *Output* is still *LOW*.

This is because the proper input conditions have not been satisfied (*Input A* and *Input B* both HIGH at the same time).

At T₄, both *Input A* and *Input B* are *HIGH*. As a result, *Output* is *HIGH*.

AND logic gate could be modeled by electronic circuit as well (**Fig. 5.5.7**). This circuit uses solid-state components to produce the gate.



Figure 5-7. AND logic gate electronic model

In this circuit, each diode is reverse-biased by a positive signal at *Input A* and *Input B*, respectively. If both inputs are positive (1), the diodes are both reverse-biased and no current flows through R_1 ; therefore, there is no voltage drop over R_1 and point C is positive. If either input is negative (0), current will flow through R_1 and point C will be negative (0) owing to the voltage drop across R_1 . In this circuit the only way to produce a positive at point C (a 1 output) is to provide both diodes with a positive voltage (both inputs are 1); therefore, the circuit performs an *AND* function.

To describe the AND gate and display relationship between inputs and output shown on **Fig. 5-7** the *Truth table* is used (**Fig. 5-8**).

Input		Output
Input1	Input2	o mp m
0	0	0
0	1	0
1	0	0
1	1	1

Figure 5-8. Truth table for digital logic AND gate

The first combination (A = 0, B = 0) corresponds to T₀; the second to T₁; the third to T₂; and the last to T₄. When constructing a *Truth table*, all possible combinations of the inputs must be included, including the all 0s' combination.

5.5B LOGIC CIRCUITS

Combinational Logic as the Base for Applications Used for Aircraft Systems

By using a standard range of logic levels (i.e. voltage levels used to represent the logic 1 and logic 0 states) logic circuits can be combined together in order to solve more complex logic functions. As an example, assume that a logic circuit is to be constructed that will produce a logic 1 output whenever two, or more, of its three inputs are at logic 1. This circuit is referred to as a majority vote circuit (**Fig. 5-34A**). Its truth table is shown in **Fig. 5-34B**.



А	В	С	Out
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Figure 5-34. Majority vote circuit (A) and its Truth table (B)

В

The Typical Aircraft Systems

Frequently logic circuits are used to monitor system functions. The examination of such systems will be started from simplified Flight Director Indicator and Landing Gear Position Indicator systems.

Flight Director Indicator

In the Flight Director, the gyro flag provides an indication of an invalid roll / pitch display. The flag is retracted when the system is functioning properly.

The gyro flag circuit (**Fig. 5-35**) uses a four-input *AND* gate with two of the inputs inverted. As long as the horizon indicator roll and pitch motors are following input commands, the input at A and D should be at a low level (but not grounded). They are inverted to provide logic 1 inputs to the *AND* gate.

The DC power for both amplifiers is being monitored at inputs B and C and should normally be logic 1. When these four conditions met, a voltage output (logic 1) is sent to the flag coil to retract it from view provided the ground return for the gyro flag is available through the vertical gyro monitor circuit (Vertical Gyro Valid).



Figure 5-35. Flight Director Indicator simplified circuit

Landing Gear Position Indicator

Various circuits are used to indicate landing gear positions. These circuits activate panel lights, which indicate gear position. **Fig. 5-36** shows a simplified typical circuit.



Figure 5-36. Landing gear position indicator schematics

This circuit utilizes two solid-state switches, an inverter, a six-input *NAND* gate, and *OR* gate and a light circuit. To illuminate the gear down light, a ground is provided to the light circuit through solid-state switch "B". With the gear down lock sensor activated (solid-state switch "A"), logic 0 (ground) is inverted and applied as logic 1 at the *NAND* gate input. As long as all gear sensor inputs to the *NAND* gate are logic 1, the *NAND* gate output will be logic 0.

This output is inverted at the OR gate to solid-state switch "B", thus providing a ground to illuminate the gear down light.

5.6A BASIC COMPUTER STRUCTURE

Computer

A computer is a machine for manipulating data according to a list of instructions. Computers take numerous physical forms. Early electronic computers were the size of a very large room, consuming as much power as several hundred modern personal computers. Today, computers can be made small enough to fit into a wristwatch and be powered from a watch battery.

However, the most common form of computer in use today is by far the embedded computer. Embedded computers are small, simple devices that are often used to control other devices—for example; they may be found in machines ranging from aircraft to industrial robots, digital cameras, and even children's toys.

Computer Systems

A general-purpose computer has three main sections:

- 1. Central processing unit (CPU);
- Memory, comprising both "read/write" and "read only" devices, commonly called RAM and ROM respectively, and
- 3. Input and output devices (collectively termed I/O).

Busses, often made of groups of wires (Fig. 6-1), interconnect these parts.



Figure 6-1. Basic computer structure

The basic components of the system (CPU, RAM, ROM and I/O) are linked together using multiplewire connecting systems know as a bus. Three different buses are present, these are:

- 1. Address bus used to specify memory locations;
- 2. Data bus on which data is transferred between devices; and
- 3. Control bus that provides timing and control signals throughout the system.

is disconnected. They are thus said to be non-volatile memories (NVM). Most RAM devices, unless battery-backed, are volatile memories and the stored data will be lost when the supply is disconnected.

Computer Storage

Computer storage, computer memory, and often casually memory refer to computer components, devices and recording media that retain data for some interval of time. Computer storage provides one of the core functions of the modern computer, that of information retention. It is one of the fundamental components of all modern computers.

In contemporary usage, memory usually refers to a form of solid-state storage known as random access memory (RAM) and sometimes-other forms of fast but temporary storage. Similarly, storage more commonly refers to mass storage - optical discs, forms of magnetic storage like hard disks, and other types of storage, which are slower than RAM, but of a more permanent nature (**Fig. 6-4**).



Figure 6-4. Computer storage hierarchy

These contemporary distinctions are helpful, because they are also fundamental to the architecture of computers in general. As well, they reflect an important and significant technical difference between memory and mass storage devices.

5.10 FIBRE OPTICS

An optical fiber (or fibre) is a glass or plastic fiber (**Fig. 10-1**) designed to guide light along its length by total internal reflection.



Figure 5.10.1. Optical fibers

Fiber optics is the branch of applied science and engineering concerned with such optical fibers. Optical fibers are widely used in fiber-optic communication, which permits digital data transmission over longer distances and at higher data rates than other forms of wired and wireless communications. They are also used to form sensors, and in a variety of other applications.

The operating principle of optical fibers applies to a number of variants including multi-mode optical fibers, single-mode optical fibers, graded-index optical fibers, and step-index optical fibers. Because of the physics of the optical fiber, special methods of splicing fibers and of connecting them to other equipment are needed. A variety of methods is used to manufacture optical fibers, and the fibers are built into different kinds of cables depending on how they will be used.

The modern optical fibers were developed beginning in the 1950s. Optical fibers became practical for use in communications in the late 1970s, and since then several technical advances have been made to extend the reach and speed capability of optical fibers, and lower the cost of fiber communications systems.

Uses of Optical Fibers

Optical Fiber Communication

The optical fiber can be used as a medium for telecommunication and networking because it is flexible and can be bundled as cables. Although fibers can be made out of transparent plastic, glass, or a combination of the two, the fibers used in long-distance telecommunications applications are always glass, because of the lower optical attenuation. Both multi-mode and single-mode fibers are used in communications, with multi-mode fiber used mostly for short distances (up to 500 m), and singlemode fiber used for longer distance links. Because of the tighter tolerances required to couple light into and between single-mode fibers, single-mode transmitters, receivers, amplifiers and other components are generally more expensive than multi-mode components. The reflected waves at point A and point B are in phase if the total amount of phase collected is an integer multiple of 2π radian. If propagating wave fronts are not in phase, they eventually disappear. Wave fronts disappear because of destructive interference. The wave fronts that are in phase interfere with the wave fronts that are out of phase. The destructive interference is the reason why only a finite number of modes can propagate along the fiber.

For a given mode, a change in wavelength can prevent the mode from propagating along the fiber. The mode is no longer bound to the fiber. The mode is said to be cut off.

However, an optical fiber is always able to propagate at least one mode. This mode is referred to as the fundamental mode of the fiber. The fundamental mode can never be cut off. The wavelength that prevents the next higher mode from propagating is called the cutoff wavelength of the fiber.

An optical fiber that operates above the cutoff wavelength (at a longer wavelength) is called a *single mode fiber*. An optical fiber that operates below the cutoff wavelength is called a *multimode fiber*.

<u>Modes</u>

A set of guided electromagnetic waves is called the modes of an optical fiber. Maxwell's equations describe electromagnetic waves or modes as having two components. The two components are the electric field, E(x, y, z), and the magnetic field, H(x, y, z). The electric field, E, and the magnetic field, H, are at right angles to each other. Modes traveling in an optical fiber are said to be transverse. The transverse modes (**Fig. 10-13**) propagate along the axis of the fiber. The mode field patterns are said to be transverse electric (TE). In TE modes, the electric field is perpendicular to the direction of propagation. The magnetic field is in the direction of propagation.



Figure 10-13. Mode propagated through a fiber. Only TE modes are shown

Another type of transverse mode is the transverse magnetic (TM) mode. TM modes are opposite to TE modes. In TM modes, the magnetic field is perpendicular to the direction of propagation. The electric field is in the direction of propagation.

The TE mode field patterns shown in **Fig. 10-13** indicate the order of each mode. The order of each mode is indicated by the number of field maxima within the core of the fiber. For example, TE₀ has one field maxima. The electric field is a maximum at the center of the waveguide and decays toward the core cladding boundary. TE₀ is considered the fundamental mode or the lowest order standing



Figure 10-27. Optical X-coupler

Couplers

Star and *tree couplers* (**Fig. 10-28**) are multiport couplers that have more than two input or two output ports. A *star coupler* is a passive device that distributes optical power from more than two input ports among several output ports.



Figure 10-28. 1×M (A), N×1 (B) tree and star (C) couplers and

Fiber Fuse

At high optical intensities, above 2 megawatts per square centimeter, when a fiber is subjected to a shock or is otherwise suddenly damaged, a fiber fuse can occur. The reflection from the damage vaporizes the fiber immediately before the break, and this new defect remains reflective so that the damage propagates back toward the transmitter at 1-3 meters per second. The open fiber control system, which ensures laser eye safety in the event of a broken fiber, can also effectively halt propagation of the fiber fuse. In situations, such as undersea cables, where high power levels might be used without the need for open fiber control, a "fiber fuse" protection device at the transmitter can break the circuit to prevent any damage.

Fiber Optical Cable Construction

The construction of a typical fiber optic cable (Fig. 10-30) comprises:

- Five optical fibers and two filler strands;
- Separator tape;
- Aramid yam strength member;
- An outer jacket.

The cable has an overall diameter of about 0.2 inches and the individual optical fiber strands have a diameter of 140 μ m (approx. 0.0055 inches). A protective buffer covers each fiber and protects it during manufacture, increases mechanical strength and diameter in order to make handling and assembly easier.



Figure 10-30. Typical fiber optic cable

The buffers are coded in order to identity the fibers using colors (blue, red, green, yellow and white). The filler strands are made from polyester and are approximately 0.035 inches in diameter. A polyester separator tape covers the group of five fibers and two filler strands. This tape is manufactured from low-friction polyester and it serves to make the cable more flexible.

A layer of woven Aramid (or Kevlar) yarn provides added mechanical strength and protection for the cable assembly. The outer thermoplastic jacket (usually purple in color) is fitted to prevent moisture ingress and to provide insulation.

5.11 ELECTRONIC DISPLAYS

Modern passenger aircraft employ a variety of different display technologies on the flight deck, including those based on conventional cathode ray tubes (CRT), light emitting diodes (LED) and liquid crystal displays (LCD).

Cathode Ray Tube

The cathode ray tube (CRT), invented by German physicist Karl Ferdinand Braun in 1897, is the display device that was first used for computer displays, video monitors, televisions, radar displays and oscilloscopes.

A cathode ray tube technically refers to any electronic vacuum tube employing a focused beam of electrons. The main family of cathode ray tubes is used as displays for television, radar, oscilloscopes etc.

General Description

Cathode rays exist in the form of streams of high-speed electrons emitted from the heating of a cathode inside a vacuum tube, at its rear end (**Fig. 11-1**).



Figure 11-1. Cathode ray tube of oscilloscope

The cathode, heater, grid and anode assembly forms an electron gun, which produces a beam of electrons within the tube. The heated cathode produces an electron cloud, which is accelerated due to the positive potential applied across anodes. The beam is then perturbed (deflected) by electric field applied to vertical deflection plates (Y-plates) and horizontal deflection plates (X-plates), to trace over ("scan") the inside surface of the screen. The screen is covered with a phosphorescent coating (often transition metals or rare earth elements), which emits visible light when excited by the electrons.

When LCDs are used as optical (light) modulators, they are actually changing polarization rather than transparency (at least this is true for the most popular type of LCD called *Super-twisted Nematic Liquid crystals*). In their unexcited or crystalline state, the LCDs rotate the polarization of light by 90 degrees. In the presence of an electric field, LCDs behave like a liquid and align the small electrostatic charges of the molecules with the impinging E field.

The LCD's transition between crystalline and liquid states is a slow process. This has both good and bad side effects. LCDs, like phosphors, remain "on" for some time after the E field is applied. Thus the image is *persistent* like a CRT's, but this lasts just until the crystals can realign themselves, thus they must be constantly refreshed, again, like a CRT.

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector.

Each pixel of an LCD consists of a layer of perpendicular molecules aligned between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. With no liquid crystal between the polarizing filters, light passing through one filter would be blocked by the other.

The surfaces of the electrodes that are in contact with the liquid crystal material are treated to align the liquid crystal molecules in a particular direction. This treatment typically consists of a thin polymer layer that is unidirectionally rubbed using a cloth (the direction of the liquid crystal alignment is defined by the direction of rubbing).

Before applying an electric field, the orientation of the liquid crystal molecules is determined by the alignment at the surfaces. In a twisted nematic device (the most common liquid crystal device), the surface alignment directions at the two electrodes are perpendicular, and so the molecules arrange themselves in a <u>helical</u> structure, or twist (**Fig. 11-14**).



Figure 11-14. Light passing through the polarizers and twisted nematic device without electric field applied

Because the liquid crystal material is birefringent, light passing through one polarizing filter is rotated by the liquid crystal helix as it passes through the liquid crystal layer, allowing it to pass through the

5.12 ELECTROSTATIC SENSITIVE DEVICES

Electrostatic discharge or ESD is caused by the buildup of electrical charge on one surface that is suddenly transferred to another surface when it is touched. This discharge could be up to several thousand volts with very little currents. Notwithstanding that, it can certainly destroy semiconductor devices in electronic equipment. Especially sensitive to ESD are integrated circuits, processors, memory chips, MOSFETs, and circuit cards. Extensive (and permanent) damage to static sensitive devices can result from mishandling and inappropriate methods of storage and transportation.

Identification of ESD sensitivity

Many electronic line replaceable units (L.R.U's) contain microcircuits and other sensitive devices, which can easily be damaged by an electrostatic discharge. These units are identified as being Electrostatic Discharge Sensitive (ESDS).



Figure 12-1. ESD decal

Decals (**Fig. 12-1**) are installed on ESDS LRU's to indicate that special handling is required. Personnel who remove, install and transport ESDS LRU's should have an understanding of static electricity including its generation and the protection required from static discharges.

Electrostatic charges are generated and stored in a variety of ways. Human bodies, hair, clothing, floors, equipment racks and equipment may be electrostatically charged by friction, magnetic induction or by being in contact with a substance, which is at a higher electrical potential. Once charged the substance will retain the electrostatic charge unless it comes into electrical contact with a substance of lower potential. Insulating materials loose charge very slowly, because of these electrostatic charges can build up to very high levels and its discharge is often dramatic when connected through a low resistance contact. Packaging and containers, particularly those made from insulating materials such as plastic, can produce very large electrostatic charge levels when moved and handled.

cone or wing tip. Currents flow through the conductive structure, and then leave the aircraft at another extremity (**Fig. 12-14**).

This can cause short-term interference with systems, but there should be no permanent damage. Some currents could enter the structure due to the high voltages; the energy will normally be conducted through bonding leads and back into the fuselage skin.



Figure 12-14. Lightning energy dissipation through aircraft

The majority of physical damage on the aircraft occurs at the exit point of the lightning strike. For better protection, the aircraft is categorized into specific areas when planning system and equipment locations (**Fig. 12-15**):

Zone 1 - where lightning can be expected to enter and exit the aircraft;

Zone 2 and Zone 3 - provide the conductive paths through the aircraft.

This categorization is especially useful for aircraft visual inspection after crossing lightning front in flight.



Figure 12-15. Risk areas for lightning strikes: aerials and protrusions (A), sharp corners of fuselage and control surfaces (B)

5.13 SOFTWARE MANAGEMENT CONTROL

Airworthiness is a term used to dictate whether an aircraft is worthy of safe flight It is illegal in most countries to fly an aircraft without first obtaining an airworthiness certificate from the responsible government agency. The airworthiness usually must be maintained by a program of inspections by an authorized aircraft maintenance engineer, typically performed annually, or after a fixed elapsed flight time, such as every 100 hours.

A more generic and non-process orientated definition of airworthiness is:

The ability of an aircraft or other airborne equipment or system to operate without significant hazard to aircrew, ground crew, passengers (where relevant) or to the general public over which such airborne systems are flown

This definition applies equally to civil and military aircraft.

Aviation Software as a Part of Airworthiness

Aircraft software is something that you cannot see and you cannot touch yet it must be treated with the same care and consideration as any other aircraft part. Maintenance of the safety-critical software found in modern aircraft is very important.

The software encompasses both the executable code (i.e. the programs) run on aircraft computers as well as the data that these programs use. The term also covers the operating systems (i.e. system software) embedded in aircraft computer systems.

All of these software parts require periodic upgrading as well as modification to rectify problems and faults that may arise because of operational experience (**Fig. 13-1**).

The consequences of software failure (**Fig. 13-2**) can range from insignificant (no effect on aircraft performance) to catastrophic (e.g. major avionic system failure, engine faults, etc.). Because of this, it is important that maintenance engineer should have an understanding of the importance of following correct procedures for software modification and upgrading. Once again, this is an area of rapidly evolving technology, which brings with it many new challenges.

Each digital LRU (Line Replaceable Unit) consists of Hardware (the electronic devices), and Software (instructions that tell a computer what to do). Software comprises the entire set of programs, procedures, and routines associated with the operation of a computer system.

With the considerable use of software on modern aircraft used in essential systems such as flight controls, engine controls, electrical generation, navigation flight instruments and auto-flight it is essential that the software design must be investigated and control of its certification maintained.

EASA	AIRWORTHINESS DIRECTIVE			
X	AD No.: 2010-0137			
	Date: 30 June 20	10		
E.	Note: This Airworthiness Directive (AD) is issued by EASA, acting in accordance with Regulation (EC) No 2162008 on behalf of the European Community, its Member States of the European third countries that participate in the activities of EASA under Article 65 that Regulation.			
This AD is issued in accordant continuing airworthiness of an operate an aircraft to which an Agency (EC 2042/2003 Annes exemption).	This AD is issued in accordance with EC 1702/2003, Part 21A.38. In accordance with EC 2042/2003 Annex I, Part M.A.301, the continuing silvorthiness of an alroad shall be ensured by accomplishing any applicable ADs. Consequently, no person may operate an alroad to which an AD applies, except in accordance with the requirements of that AD, unless otherwise specified by the Agency (EC 2042/2003 Annex I, Part M.A.303) or agreed with the Authority of the State of Registry (EC 216/2008, Article 14(4) exemption).			
Type Approval H	older's Name :	Type/Model designation(s) :		
Thielert Aircraft Er	ngines GmbH	TAE 125 series engines		
TCDS Number :	EA8A E.055			
Foreign AD :	Not applicable			
Supersedure :	LBA AD D-2005-145 (EA8	A approval N*2005-2921 dated 01 April 2005)		
AIA /2	Engine - FADEC So	rtware - Modification		
Manufacturer(s):	Thielert Alrcraft Engines (TAE) GmbH.			
	TAE125-01, TAE 125-	12-99, TAE 125-02-114, all serial numbers		
Applicability:	These engines are known to be installed, but not limited to, Diamond DA 40, DA 42, DA 42M, Apex DR-400, Cessna C172 and Piper PA28.			
Response	Service experience has shown that a case of FADEC channel B manifold a pressure (MAP) sensor hose permeability is not always recognised as fault by the FADEC. The MAP value measured by the sensor may be lower than the actual pressure value in the engine manifold, and limits the amount of fi injected into the combustion chamber and thus the available power of the engine. A change in FADEC software version 2.91 will change the logic in failure detection and in switching to channel B (no automatic switch to channel B if MAP difference between channel A and B is detected and lowe MAP is at channel B).			
Ricason.	In addition, previous software versions allow – under certain conditions and on DA42 aircraft only – the initiation of a FADEC self test during flight that causes an engine in-flight shutdown.			
These conditions, if not corrected, could lead to in-flight case power loss or ultimately shutdown. To address and correct this situation, TAE has developed a version 2.91.		t corrected, could lead to in-flight cases of engine y shutdown.		
		t this situation, TAE has developed a new software		
	This AD requires the installation of software version 2.91.			

Figure 13-1. AD identifying the need for software modification

Level	Type of failure	Failure description	Probability	Value
А	Catastrophic failure	Aircraft loss and/or fatalities	Extremely improbable	< 10 ⁻⁹
В	Hazardous/severe major failure	Flight crew cannot perform their tasks; serious or fatal injuries to some occupants	Extremely remote	< 10 ⁻⁷ >10 ⁻⁹
С	Major failure	Workload impairs flight crew efficiency; occupant discomfort including injuries	Remote	<10 ⁻⁵ > 10 ⁻⁷
D	Minor failure	Workload within flight crew capabilities; some inconvenience to occupants	Probable	> 10 ⁻⁵
Е	No effect	No effect	Not applicable	

Figure 13-2. Level of failure

The basis for the certification of software in aircraft equipment and systems is RTCA (Radio Technical Commission for Aeronautics) document D0-178B, and EUROCAE (European Organization for Civil Aviation Equipment) document ED-12/12B entitled "Software Considerations in Airborne Systems and Equipment Certification".

These documents provide guidelines for the production of airborne systems equipment software. They describe techniques and methods appropriate to ensure the integrity and reliability of such software and are used internationally to specify the safety and airworthiness of software for avionics systems.

Software Definition

LRU's of new generation often contains their software in different packages, which can be divided into different categories:

- Core Software or System Software;
- Operational Software or Application Software;
- Data Base Software.

The Core Software refers to the operating system and all utility programs that manage computer resources at a low level. It also defines the interface of this specific LRU to other LRU's.

The Operational Software, or Application Software, defines the part of a computer program that varies for different aircraft configuration or changes for each different airline.

By implementing a new Data Base Software, only parameter values will be changed. Therefore, it is not a program change. An example would be the navigation database that contains flight plan information such as runway direction or landing system frequency etc.

Black Box and Acceptance Testing

Meanwhile, the test engineers usually begin assembling a test rig, and releasing preliminary tests for use by the software engineers. At some point, the tests cover all of the functions of the engineering specification. At this point, testing of the entire avionic unit begins. The object of the acceptance testing is to prove that the unit is safe and reliable in operation.

The first test of the software, and one of the most difficult to meet in a tight schedule, is a realistic test of the unit's radio emissions. This usually must be started early in the project to assure that there is time to make any necessary changes to the design of the electronics.

Software Initial Certification

Each step produces either a deliverable, a document, code, or a test report. When the software passes all of its tests (or enough to be sold safely), these are bound into a certification report, that can literally have thousands of pages. The designated engineering representative, who has been striving for completion, then decides if the result is acceptable. If it is, he signs it, and the avionic software is certified.

The initial certification of an aircraft requires that the Design Organization (DO) shall provide evidence that the software has been designed, tested and integrated with the associated hardware in a manner that satisfies standard D0-1788 or ED-128 (or an agreed equivalent standard). In order to provide an effective means of software identification and change control, a Software Configuration Management Plan (SCMP) (e.g. as defined in Part 7 of D0-1788 or ED-128) is required to be effective throughout the life of the equipment (the SCMP must be devised and maintained by the relevant DO).

General Principles of Software Configuration Management

Software Configuration Management (SCM) is part of configuration management (CM)

SCM is a set of activities designed to control change by identifying the work products that are likely to change, establishing relationships among them, defining mechanisms for managing different versions of these work products, controlling the changes imposed, and auditing and reporting on the changes made

In other words, SCM is a methodology to control and manage a software development or handling project.

SCM concerns itself with answering the question:

Somebody did something, how can one reproduce it?

Often the problem involves not reproducing ,,it" identically, but with controlled, incremental changes.

Database Field Loadable Data

Database Field Loadable Data (DFLD) is data that is field loadable into target hardware databases. Note that it is important to be aware that the database itself is an embedded item that resides within the target hardware and is not, itself, field loadable and that the process of "loading a database" is merely one of writing new data or over-writing old data from a supplied data file.

DFLD is usually modified or updated by overwriting it using data from a data file which is field loaded. The data tile can contain data in various formats, including natural binary, binary coded decimal, or hexadecimal formats. Of these, natural binary code produces the most compact and efficient data files but the data is not readable by humans and, for this reason, binary coded decimal or hexadecimal formats are sometimes preferred.

It is important to note that the updating of an aircraft database will usually have an impact on aspects of the aircraft's performance. However, if the data used by a program is invalid or has become corrupt, this may result in erratic or out of range conditions. Because of this, it is necessary to treat DFLD in much the same manner as the executable code or LSAP that makes use of it. Hence a DFLD must be given its own unique part number and release documentation.

Typical examples of the target hardware with databases that can be field loaded with DFLD (and that need to be tracked in the same manner as other aircraft parts) include:

- Flight Management Computers (FMC);
- Terrain Awareness Warning System (TAWS) Computers;
- Integrated Modular Avionics (IMA) units.

Operators should maintain a register (documentation) which provides the following information:

- The current version of the FLS and DFLD installed;
- Which aircraft the FLS and DFLD are installed on;
- The aircraft, systems and equipment that they are applicable to;
- The functions that the recorded FLS or DFLD performs;
- Where (including on or off aircraft location), and in what format it is stored (i.e. storage media type), the name of the person who is responsible for it, and the names of those who may have access to it;
- Who can decide whether an upgrade is needed and then perform that upgrade, and
- A record of all replicated FLSIDFLD, traceable to the original source.

5.14 ELECTROMAGNETIC ENVIRONMENT

The operation of electrical and electronic equipment can potentially disturb the operation of other nearby items of electronic equipment. Such influence has prompted the introduction of legislation that sets strict standards for the design of electrical and electronic equipment.

This type of disturbance is named Electromagnetic Interference (EMI) and the property of an electrical or electronic product (in terms of its immunity to the effects of electromagnetic fields generated by other equipment and its susceptibility to the generation and radiation of its own electromagnetic field) is known as Electromagnetic Compatibility (EMC).

EMI (and the need for strict EMC control) can be quickly demonstrated by placing a mobile close to a laptop and switching it to Bluetooth mode. In many cases (depends on mobile and laptop) wideband noise and stray EMI radiation should be detected.

EMC - Electromagnetic Compatibility

The term electromagnetic compatibility (EMC) is used in the field of electrical engineering and is the ability of an electrical device to work satisfactorily in its electromagnetic environment without influencing the surrounding devices.

Consequently, the two main aspects of EMC arise:

- Electromagnetic emission (Radiated or Conducted Emission)
 Devices have to be designed in a way that emitting electromagnetic disturbances do not interfere with the operation of radio and telecommunication and other devices in accordance with their purpose.
- Electromagnetic interference (Radiated or Conducted Susceptibility)
 Devices have to be designed in a way that they have adequate immunity to electromagnetic interferences and operation in accordance with their purpose is possible.

EMI Generation

As an example of how EMI can be produced from even the most basic of electronic circuits, consider the simple DC power supply consisting of nothing more than a transformer, bridge rectifier, and reservoir capacitor and load resistor (**Fig. 14-1**).

The waveforms produced by such circuit (**Fig. 14-2**) are both sinusoidal for the primary and secondary voltage and, the load voltage, comprises a DC level (just less than the peak secondary voltage) onto which is superimposed a ripple component at 800 Hz.

The most significant in terms of EMC and EMI is the waveform of the current that flows in both the secondary and primary circuits. Rather than being sinusoidal, this current comprises a series of fast rise-time rectangular pulses as each pair of diodes conducts alternately in order to replace the lost

NASA scientists have also found the radio waves created by lightning clear a safe zone in the radiation belt surrounding the earth. This zone, known as the Van Allen Belt slot, can potentially be a safe haven for satellites, offering them protection from the Sun's radiation.

The first process in the generation of lightning is still a matter of debate: scientists have studied root causes ranging from atmospheric perturbations (wind, humidity, and atmospheric pressure), to the impact of solar wind and accumulation of charged solar particles. Large quantities of ice in the clouds are suspected to enhance lightning development. This charge will neutralize itself through any available path. This may assist in the forcible separation of positive and negative charge carriers within a cloud or air, and thus help in the formation of lightning.

Description of Some Lightning Accidents in Aviation

<u> Accident A – Flight from Lima Airport</u>

24.12.71 (12.36) Lockheed L-188A Electra
OB-R- 941 (1086) LANSA [year built: 1959]
Occupants: 6 crew + 86 passengers
Fatalities: 6 crew + 85 passengers
Accident Occurred: Cruise
Location: Puerto Inca (Peru)
Flight: Lima-Jorge Chavez IAP - Flightnr.: 508

About forty minutes after take-off, the aircraft entered a zone of strong turbulence and lightning. After flying for twenty minutes in this weather at FL210 lightning struck the aircraft, causing fire on the right wing, which separated, along with part of the left wing. The aircraft crashed in flames into mountainous terrain. Structural failure occurred because of the loads imposed on the aircraft flying through a severe thunderstorm, but also because of stresses resulting from the maneuver to level out the aircraft.

<u> Accident B – Flight Tehran-Madrid</u>

09.05.76 (14.35 GMT) Boeing 747-131F

5-8104 (19677/73) Islamic Republic of Iran Air Force [year built: 1970]
Occupants: 10 crew + 7 passengers
Fatalities: 10 crew + 7 passengers (Freight loss)
Accident Occurred: Descent
Location: Madrid (Spain)
Flight: Tehran-Mehrabad IAP - Madrid-Torrejon AFB Flightnr.: 48

direction canceling and reducing the magnitude of the overall electromagnetic field that links the shielded cable.

Grounding and Bonding as Means of Reducing EMI and HIRF Impact

The electrical integrity of the aircraft structure is extremely important as a means of reducing EMI and protecting the aircraft, its passengers, crew and systems, from the effects of lightning strikes and static discharge. Grounding and bonding are specific techniques that are used to achieve this (**Fig. 14-6**).



Figure 14-6. Bonding straps

Grounding and bonding can also be instrumental in minimizing the effects of high intensity radio frequency fields (HIRF) emanating from high power radio transmitters and radar equipment. Grounding and bonding resistances of less than 0.0001Ω to 0.003Ω are usually required.

Grounding

Grounding is defined as the process of electrically connecting conductive objects to either a conductive structure or some other conductive return path for safely completing either a normal or a fault circuit. Bonding and grounding connections are made in an aircraft in order to accomplish the following:

- Protect aircraft, crew and passengers against the effects of lightning discharge;
- Provide return paths for current;
- Prevent the development of RF voltages and currents;
- Protect personnel from shock hazards;
- Maintain an effective radio transmission and reception capability;
- Prevent accumulation of static charge.

5.15A TYPICAL ELECTRONIC / DIGITAL AIRCRAFT SYSTEMS

In most modern aircraft Onboard Maintenance Systems are installed named in a whole Built-in Test Equipment (BITE) systems, which collect failure reports from each system computer and shows the failures on a display in the cockpit or allows printing of the failures on an on board printer.

BITE Systems

Aircraft systems are composed of many components including Line Replaceable Units (LRU), which can be computers, sensors, actuators, probes, etc. Most of these LRU's are controlled by digital computers and, for safety reasons, are permanently monitored. In addition, they can be tested and troubleshooting can be performed on demand.

In each system, a part of computer resources functions, called Built-In Test Equipment is dedicated to monitoring, testing and troubleshooting. In multi-computer systems, individual computer may be dedicated to concentrate the BITE data of the system.

The permanent monitoring is carried out during normal operation. The permanent monitoring comprises of:

- Internal monitoring;
- Inputs / outputs monitoring;
- Links between LRU's within the system monitoring.

BITE Fundamentals

Due to sophistication of aircraft equipment, normally a noticeable failure occur only if many small malfunctions accumulate until their accumulated effect transforms into a failure. If a failure occurs, it can be classified as:

- Permanent (consolidated), or
- Intermittent (occurring at irregular intervals).

After failure was detected, the BITE system identifies the possible failed LRU's and gives a snapshot of the system environment when the failure occurred.

For detecting a failure, BITE needs a database of parameters allowing distinguishing between normal and failed performance. All the information necessary for maintenance and troubleshooting is memorized in a Non Volatile Memory (NVM).

time messages to an airline. Detailed engine reports could also be transmitted to the ground via ACARS. The airlines used these reports to automate engine trending activities. This capability enabled airlines to better monitor their engine performance, identify and plan repair and maintenance activities.

ACARS as Interactive Crew Interface

All of the processing described above is performed automatically by the ACARS MU and the associated other avionics systems, with action performed by the flight crew. As part of the growth of the ACARS functionality, the ACARS MUs also interfaced directly with a control display unit (CDU), located in the cockpit. This CDU, often referred to as an MCDU or MIDU, provides the flight crew with the ability send and receive messages similar to today's e-mail. To facilitate this communication, the airlines in partnership with their ACARS vendor, would define MCDU screens that could be presented to the flight crew and enable them to perform specific functions. This feature provided the flight crew flexibility in the types of information requested from the ground, and the types of reports sent to the ground.

As an example, the flight crew could pull up a MCDU screen that allowed them to send to the ground a request for weather information. Upon entering in the desired locations for the weather information and the type of weather information desired, the ACARS would then transmit the message to the ground. In response to this request message, ground computers would send the requested weather information back to the ACARS MU, which would be displayed and/or printed.

How it Works

A person or a system on board may create a message and send it via ACARS to a system or user on the ground, and vice versa. Messages may be sent either automatically or manually using various networks (**Fig. 15-3**).



Fig. 15-3. Ground-aircraft communication

The OSP transmits the message over their ground network to a VHF remote ground station near the aircraft. The remote ground station broadcasts the message over the VHF frequency. The onboard VHF radio receives the VHF signal and passes the message to the CMU (with the internal modem transforming the signal into a digital message). The CMU validates the aircraft registration number, and processes the message.

The processing performed on the uplink message by the CMU depends on the specific airline requirements. In general, an uplink either is forwarded to another avionics computer, such as an FMS or FOAMS, or is processed by the CMU. For messages, which the CMU is the destination, such as weather report uplink, the flight crew can go to a specific MCOU screen, which contains a list of all of the received uplink messages. The flight crew can then select the weather message, and have the message viewed on the MCOU. The ACARS unit may also print the message on the cockpit printer. Messages are sent to the ground from other on-board systems in a similar manner as the delay message example discussed previously. As an example, a FOAMS system may have a series of algorithms active to monitor engine exceedance conditions during flight (such as checking engine vibration or oil temperature exceeding normal operating conditions). The FOAMS system, upon detecting such an event, automatically creates an engine exceedance condition message, with applicable data contained within the body of the message.

The message is forwarded to the CMU, using what is referred to as ARING 619 data protocols. The CMU would then transmit the message to the ground. In this case, the service provider routing table for an engine exceedance message is typically defined to have the message routed directly to an airline's maintenance department. This enables airline maintenance personnel to be notified of a potential problem, in real time.

EICAS - Engine Indication and Crew Alerting System

The EICAS (Engine Indication and Crew Alerting System) furnishes the needed information to the flight crew. A typical EICAS senses the parameters listed in **Fig. 15-5**, and in addition it interfaces with such systems as the maintenance control display panel (MCDP) of the flight control computer (FCC), the thrust management system (TMS), the electronic engine control (EEC), the flight management computer (FMC), the radio altimeter, and the air data computer (ADC).

The EICAS (if installed) consists of two color CRT displays, mounted one above the other (**Fig. 15-6**). The right-hand side of the upper display shows the engine primary parameters such as EPR, EGT, and N_1 speed. These parameters are shown in the form of an analog display with the actual value in digits. The left-hand side of the display shows warnings and cautions.

The lower display shows engine secondary parameters such as N_2 and N_3 speeds, fuel flow, oil quantity, oil pressure, and oil temperature, and engine vibration. The status of systems other than engine systems may be displayed as well as maintenance data.

Engine sensors	System sensors
Compressor speeds	Hydraulic quantity
N1. N2, and N3	Hydraulic pressure
Engine pressure ratio	Control surface positions
Exhaust gas	Electrical voltage
temperature	Electrical system current
Fuel flow	Electrical system frequency
Oil pressure	Generator drive temperature
Oil quantity	Environmental control system
Oil temperature	Temperatures
Vibration	APU exhaust gas temperature APU speed
	Brake temperature

Figure 15-5. Parameters sensed by the EICAS

Caution and warning lights as well as aural signals back up the displays on the EICAS.



Figure 15-6. EICAS displays

The primary (upper) EICAS display presents primary engine indication instruments and relevant crew alerts.

Flight Control Electronic Modes

Aircraft with fly-by-wire flight controls require computer controlled flight control modes that are capable of determining the operational mode (computational law) of the aircraft.

A reduction of electronic flight control can be caused by the failure of a computational device, such as the flight control computer or an information-providing device, such as the ADIRU.

Electronic flight control systems (EFCS) also provide augmentation in normal flight, such as increased protection of the aircraft from overstress or providing a more comfortable flight for passengers by recognizing and correcting for turbulence and providing yaw damping.

Two aircraft manufacturers produce commercial passenger aircraft with primary flight computers that can perform under different flight control modes (or laws). The most well known are the Normal, Alternate, Direct and Mechanical Laws of the Airbus A320-A380.

Boeing's fly-by-wire system is used in the Boeing 777, Boeing 787 Dreamliner, and Boeing 747-8 Freighter. Boeing also has a passenger variant of the 747-8, the 747-8 Intercontinental that is still under development, and will too use fly-by-wire controls.

These newer generations of aircraft use the lighter weight electronic systems to increase safety and performance while lowering aircraft weight. Since these systems can also protect the aircraft from overstress situations, the designers can therefore reduce over-engineered components, further reducing weight.

Airbus Flight Control Laws

Airbus aircraft after the A300/A310 are almost completely fly-by-wire controlled (**Fig. 15-10**). The A320, A330, A340, A350 and A380 operate under Airbus flight control Laws. The flight controls on the Airbus A330, for example, are all electronically controlled and hydraulically activated. Some surfaces, such as the rudder, can also be mechanically controlled. While in normal flight the computers act to prevent excessive forces in the pitch and roll.



Figure 15-10. Airbus 320-100 Cockpit

The Software options database includes the operational program and its update, plus any company specific differences.

The MEDB holds all the performance data for V speeds, min & max speeds in climb, cruise & descent, fuel consumptions, altitude capability etc.

The NDB is comprised of:

- Permanent database;
- Supplemental (SUPP) database, and
- Temporary (REF) database.

The last database view on FMC screen is presented on **Fig. 15-13**. Crew cannot modify the Permanent database. There are four types of data: Waypoint, Navaid, Airport and Runway. Runway data is only held in the permanent database.

REF NAV DATA	REF NAV DATA
RUNWAY IDENT	RUNWAY IDENT
AIRPORT IDENT	RW27
EGGP	AIRPORT IDENT
LATITUDE	EGGP
N53°20.0	LATITUDE LONGITUDE
W002°51.0	N53°20.1 W002°50.0
ELEVATION	ELEVATION
81FT	77ET
MAG VAR	LENGTH
W 4°	7500FT2286M
KINDEX	KINDEX

Figure 15-13. Temporary (REF) navigation database FMC view

There is capacity in the SUPP and REF databases for up to 40 waypoints, 40 navaids and 6 airports. SUPP data can only be entered on the ground. It is then stored indefinitely but crew may delete individual data or the whole database. Any existing SUPP data should be checked for accuracy before flight using the SUMMARY option (U6+ only) or DELeted and re-entered, crosschecking any Lat & Longs between both crewmembers. All Temporary (REF) data is automatically deleted after flight completion.

IRS – Inertial Reference System

The Inertial Reference System (IRS) and Inertial Navigation System (INS) are methods of very accurate navigation that do not require any external input such as ground radio information. They are passive systems that work entirely independently of any external input, a very useful characteristic, as the system cannot then be easily liable to interference. On modern aircraft, the IRS is separate and supplies data to the FMC (the latter performing the navigation function).

The basic IRS consists of:

- Gyroscopes;
- Linear accelerometers;
- A navigation computer and
- A clock.

The INS is an extremely accurate navigation system that does not depend upon outside navigation signals to direct the pilot to any chosen destination.



Figure 15-14. Principal scheme of a gimbaled inertial platform

Gyroscopes are instruments that sense directional deviation using the characteristics of a very fast spinning mass to resist turning. Three such spinning masses are mounted orthogonally in a structure known as a *gimbal* (**Fig. 15-14**). This frame allows the three rotating "gyros" to maintain their direction of spin during aircraft movement thereby indicating the "sensed" changes. In aircraft, they are used to sense angles of roll, pitch, and yaw.

The accelerometers sense speed deviations (acceleration) along each of the axes. This three dimensional accelerometer/gyro configuration gives three orthogonal acceleration components, which can be vectorially summed. Combining the gyro-sensed direction change with the summed accelerometer outputs yields the directional acceleration of the vehicle.

The system clock determines the rate the navigation computer time integrates directional accelerations in order to obtain the aircraft's velocity vector. The velocity vector is then integrated with time, to obtain the distance vector. These steps are continuously iterated throughout the navigation process giving accurate positional information.

Crucial to the accuracy of the IRS is the initialization of the system. This is the process of pre-flight gimbal and position alignment that gives a datum to measure all further in flight movement from.

The ND can also be operated in an approach format or an en-route format with or without weather radar information included in the display.

Operational display parameters (such as ground speed, time-to-go, time, and wind direction *I* speed) can be selected by means of the Display Select Panel (DSP).

The PFD and ND are multifunction display. Standard functions that can be displayed on ND include weather radar, pictorial navigation map, checklists and other operating data. In the event of a failure of any (including EICAS) displays, the required information can be shown on the displays that remain functional.

The Display Processor (DPU)/Multifunction Processor Unit (MPU) provides sensor input processing and switching for the necessary deflection and video signals, and power for the electronic flight displays. The DPU can drive up to two electronic flight displays with different deflection and video signals.

EFIS Operation

The simplified block schematic diagram of an EFIS system is shown in Fig. 15-17.



Figure 15-17. EFIS simplified block-diagram

The system is based on three symbol generators. These are simply three microprocessor-based computers that process data received from a wide variety of aircraft systems (VOR, DME, IRS, etc.) and generate the signals that drive the EFIS displays (and so generate the "symbols" that appear on the EFIS screens).



Figure 15-21. EHSI in Map mode

In the PLAN mode, the EHSI shows a static map with the active route of the flight plan drawn out on it. In the VOR (**Fig. 15-22**) mode, the display shows the compass rose with heading and course information.



Figure15-22. EHSI in VOR mode

In the ILS mode, the heading, localizer, and glide slope information are shown. Information furnished by the weather radar is shown on the EHSI when it is in the expanded scale format of both the VOR and ILS modes.

Radar Basics

One of the most important developments to come out of World War II was that of radar (RAdio Detection And Ranging). This system, brought to a high level of operation by the British, allowed ships and aircraft to be detected and tracked when they could not be seen because of distance or clouds.

Radar transmits a pulse of high-energy electromagnetic waves at a super high frequency from a directional antenna. This pulse travels from the antenna until it strikes an object, then part of the energy is reflected and it returns to the antenna and is directed into the receiver. The returned pulse is displayed as a light dot on a cathode-ray tube at a specific distance and direction from a reference on the tube.

A basic primary ground-based radar system can be explained by using the block diagram in **Fig. 15-33**.



Figure 15-33. A simplified block diagram of radar system

The synchronizer is the timing device that produces the signals that synchronize the functions of the transmitter, receiver, and indicator. The modulator produces pulses of high-voltage DC that are built up and stored until a timing, or trigger, pulse from the synchronizer releases them into the transmitter. In the transmitter, the high-voltage pulses are changed into pulses of SHF energy of extremely short duration. These pulses are directed into the duplexer, which acts as an automatic selector switch, connecting the transmitter to the antenna, and then disconnecting it and connecting the antenna to the receiver. The pulse of SHF energy is radiated from a short dipole antenna and is focused by a parabolic reflector into a beam. The beam of SHF electromagnetic energy travels in a straight line until it hits some object, and then some of it bounces back and is picked up by the reflector, focused on the antenna, and is carried into the duplexer. The duplexer, again acting as a switch, directs the returned energy into the receiver. The receiver manipulates this energy so it is usable by the indicator.

IMA Architecture

The IMA concept is shown in **Fig. 15-39**. The diagram depicts how the LRUs may be installed in an integrated rack or cabinet as Line Replaceable Modules (LRMs). The integration process specifies common modules and interleafing multiple processing tasks within common processor module.



Figure 15-39. LRU and Integrated Modular Cabinet Comparison

There are a number of obvious potential advantages to be realized by this integration:

- Volume and weight savings;
- Sharing of resources, such as power supplies, across a number of functional module;
- More unified approach to equipment design;
- LRMs are more reliable than LRUs.

These advantages must be weighed against the disadvantages:

- Possibly more expensive overall to procure;
- Possibly more risky;
- May pose proprietary problems by having differing vendors working more closely together;
- Segregation considerations (more eggs in one basket);
- Will an "open" or "closed" architecture prevail?
- What standards will?
- Possibly more difficult to certify;
- Who takes responsibility for systems integration?

<u>Mobile Phone</u>

Generally, mobile phone use while airborne is usually not just prohibited by the carrier but also by regulatory agencies in the relevant jurisdiction. However, with added technology, some carriers already allow the use of mobile phones on selected routes.

Emirates Airline became the first airline to allow mobile phones to be used during flight. Using the systems supplied by telecom company AeroMobile, Emirates launched the facility commercially on March 20, 2008.

Cabin Core System

The development of various cabin systems leaded to grow in cabling weight. This contradicted cost efficiency and simple operation requirements along with decrease in flexibility for customization and reconfiguration. These problems call for the need of decreasing the amount of individual networks and system components by means of higher integration level.

The Cabin Core System was firstly introduced on business jets. In the frame of such system, two subsystems (**Fig. 15-45**) are defined:

- 1. Cabin power system and
- 2. Data transmission system.



Figure 15-45. Cabin Core System platform with integrated data and power lines

Cabin Core Power

The Airbus A380 introduced a new concept of power distribution (**Fig. 15-46**). The primary electrical power distribution center in the avionics bay provides 115V AC and 28V DC to the secondary power

The Air Traffic and Information Management System (ATIMS) was developed as a first step to FANS to enable datalink communications and the exchange of complex data or specific reports between the aircraft and the ground centers (**Fig. 15-50**).



Figure 15-50. Air Traffic Information Management System

ATIMS enables:

- Controller-pilot datalink communications (HF voice in backup) for air traffic management;
- Automatic reporting (position, intention) for air traffic surveillance;
- Specific airline-aircraft communications (operational control) to improve airline operational costs and flexibility;

ATIMS enables data-link communication as:

- VHF Data radio;
- HF Data radio;
- SATCOM, and
- Exchange of specific data/reports between aircraft and the ground centers.

It provides the crew with Aircraft Communication Addressing and Reporting System (ACARS) equivalent functions and more, as for instance:

- Notice To AirMen (NOTAM), weather, winds and requests;
- Free text message exchanges;
- Diversion, delay, refueling, flight reports;
- Aircraft data from Centralized Fault Display System (CFDS), Aircraft Integrated Data System (AIDS), cabin terminal. .. etc.

<u>Flight Level Change</u>

In order to avoid potential conflicts, an airplane, which achieves a crossing airway, must be vertically separated from all other airplanes. This means that one of two airplanes must leave its actual altitude to an altitude up to 4 000 feet below its optimal flight altitude. If the air traffic controller has more accurate position data, and if the airplane can control its speed in such a way that the flight level change is achieved at a certain point in time, the vertical separation for this maneuver is used less often.

Transformation to Fans

There are three stages of FANS development (Fig. 15-52):

- Pre-FANS (Communications (COM) and AOC functions);
- FANS A (pre-FANS+ ATC functions);
- FANS B (FANS A + improved ground network + Traffic Alert and Collision Avoidance System (TCAS)).



Figure 15-52. Stages in FANS development

In this figure:

ACARS - Aircraft Communication Addressing and Reporting System;

AOC – Airline Operational Center;

ATC – Air Traffic Control;

FANS – Future Air Navigation System.