Fundamentals
M5
DIGITAL TECHNIQUES/EIS

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Training Manual

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M5 DIGITAL TECHNIQUES/EIS

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M5.1 ELECTRONIC INSTRUMENT SYSTEMS

INTRODUCTION

Name

For the indication, all modern aircraft use electronic display devices.

The names of the specific system may vary between manufacturers.

Usually, the name is Electronic Instrument System, or in short EIS.

Advantages

The advantages that make them superior to analogue meters are:

- Variability and Variety
- Coloured Displays

Operation

All modern aircraft uses digital technology in a number of ways:

- Pilot operation of a push button on a cockpit control panel will be acted on by the processor and transmitted via the data bus to the receiver systems.
- Calculations in the system are made by CPUs (central processing units).
- The interconnection between the electronic units is realized by digital data buses.
- Necessary parameters are fed
  - via display data buses to CPU–controlled CRT– or LCD– displays
  - via digital data busses to an on-board maintenance system (if installed).
- Data is filtered: Important Data is accentuated, temporarily unimportant is suppressed.
- If one monitor fails its information can be transferred to an other monitor.
- Less Components needed: monitors for EIS are same type in an aircraft.

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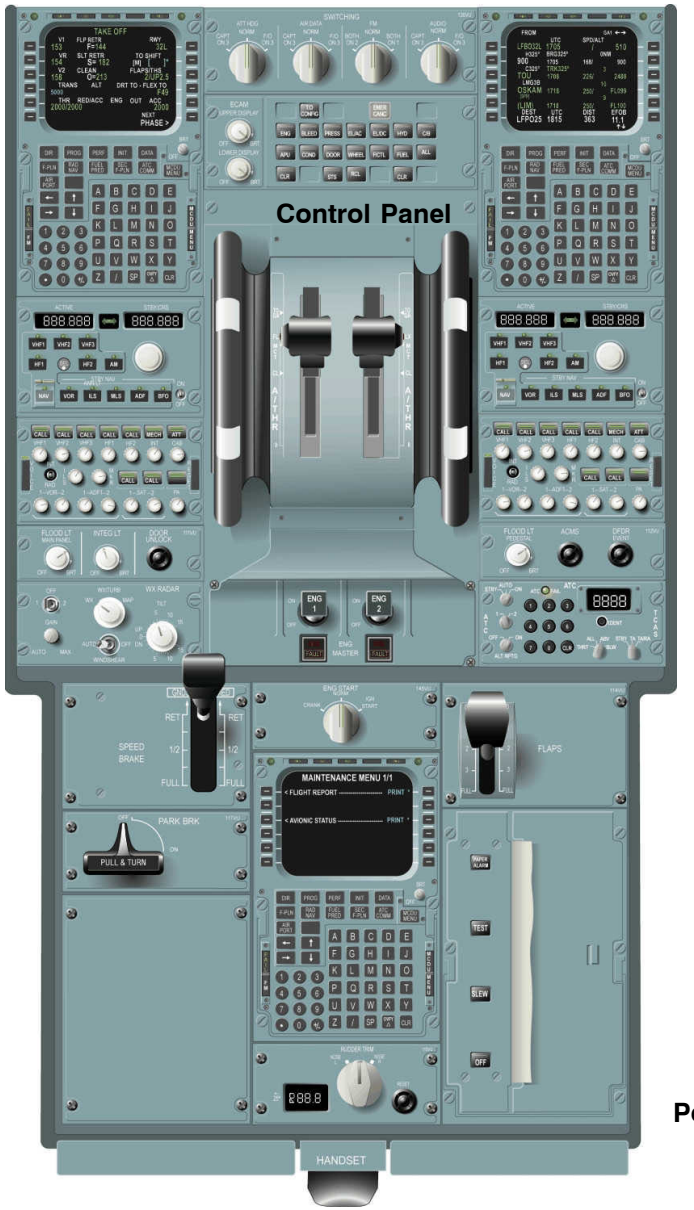

Pedestal



First Officer's Panel

Figure 1 Cockpit Layout

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SYSTEM ARRANGEMENT

Components

A typical Electronic Instrument System has the following components:

- Display Computers
- Display Units
- Control Panels.

Display Computers

Display computers receive various inputs from many aircraft systems and send these data to the Displays.

The inputs are:

- Navigation data (digital)
- Auto Flight System data (digital)
- Engine data (digital)
- Data from various aircraft systems (digital and analogue)

There are at least two display computers. Large aircraft have a third display computer for redundancy.

The arrangement which computer supplies which display unit depends on the type specific engineering.

EFIS

EFIS is the Electronic Flight Instrument System. It is a part of the Electronic Instrument System EIS and shows navigation data.

Some manufacturers use the name EFIS for the complete EIS system.

Control Panels

Since there are many data from the navigation systems each pilot can select on a related EFIS Control Panel what he wants to see on his navigation display (ND).

For the centre displays there is one control panel. It is used to select the system which is appropriate to be monitored.

Additionally, there are features to handle the alerts.

Displays

Displays are mainly used for two purposes:

- Navigation
- Information about the aircraft

There are three generation of display units:

- In the early 80's simple cathode ray tubes were installed as displays. They received video signals from the display computers.
- In the late 80's display units were installed. They received data and had an integrated symbol generator. Cathode ray tube and symbol generator form a display unit.
- Since the 90's LCD display units are installed in new aircraft.

Navigation

The navigation data and the information about the activities of the auto flight system are displayed on the Electronic Flight Instruments.

Each pilot has two Display Units:

- Primary Flight Display (PFD)
- Navigation Display (ND)

Technical Information

Most aircraft types have two display units which show engine data and some data from aircraft systems like the air conditioning system, the hydraulic system and some others.

One of these displays additionally shows alerts from various aircraft systems if something is out of limit.

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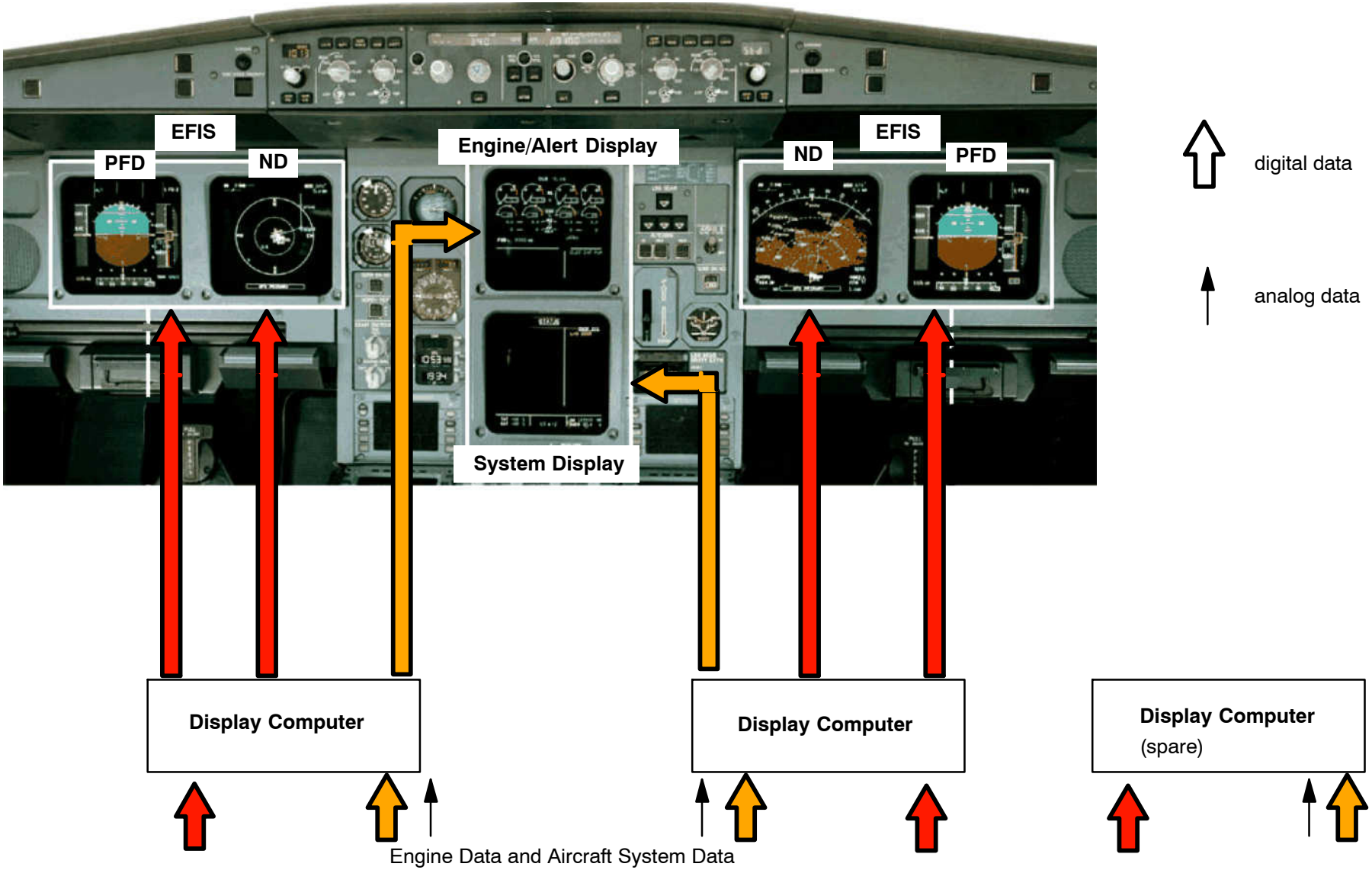

Figure 2 Electronic Instrument System Arrangement

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CLASSIFICATION OF THE INDICATORS

General

Despite the massive amount of indicators in the cockpit the indicators could be assigned to two groups:

- Flight surveillance and
- Aircraft surveillance

Flight Surveillance

Flight surveillance is:

- Artificial Horizon
- Heading Indicator
- Altimeter
- Speed Indicator
- Machmeter
- Variometer
- Rate of Turn Indicator
- Magnetic Compass

The EFIS Indicators display the most important information for flying.

One may derive between:

- Information on the Primary Flight Display (PFD, which in general represents the look ahead
- and Information on the Navigation Display (ND), which is a look from above.

Aircraft Surveillance

Aircraft surveillance consists of

Surface Indicators like

- Position indication
- Pressure indication and

Engine surveillance like

- RPM indicators
- Exhaust Gas Temperature indicators
- Fuel indicators.

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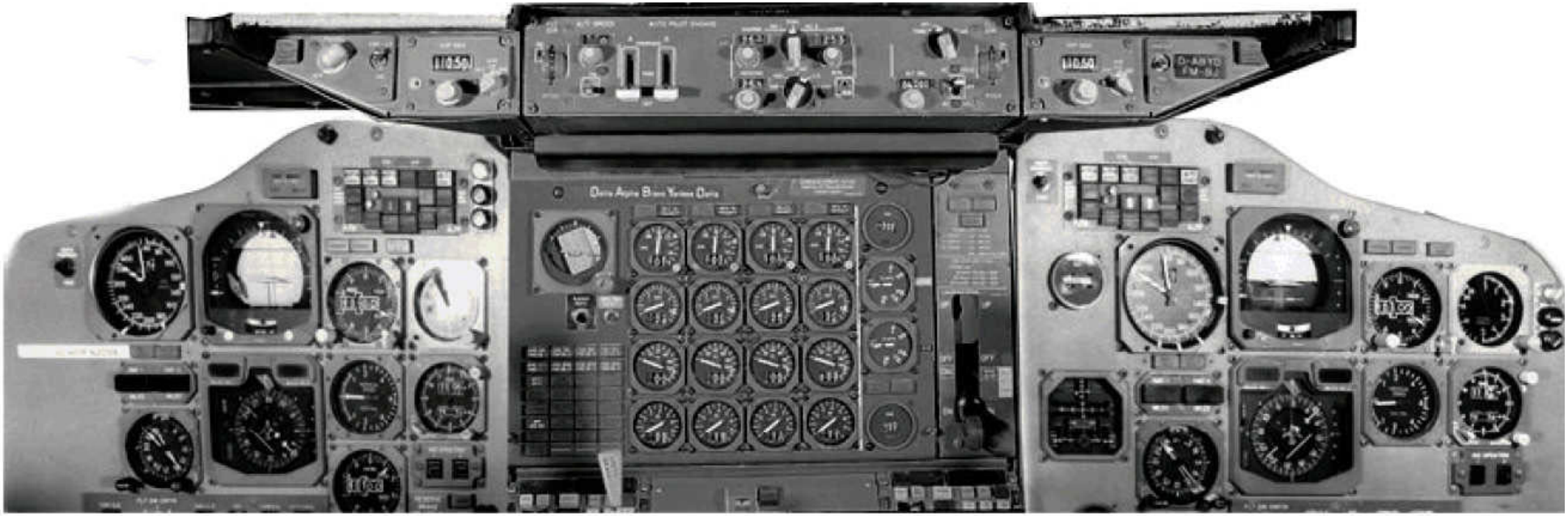

Captain's Flight Instruments

Engine Indications

First Officer's Flight Instruments

Figure 3 Cockpit Layout Boeing 747–100

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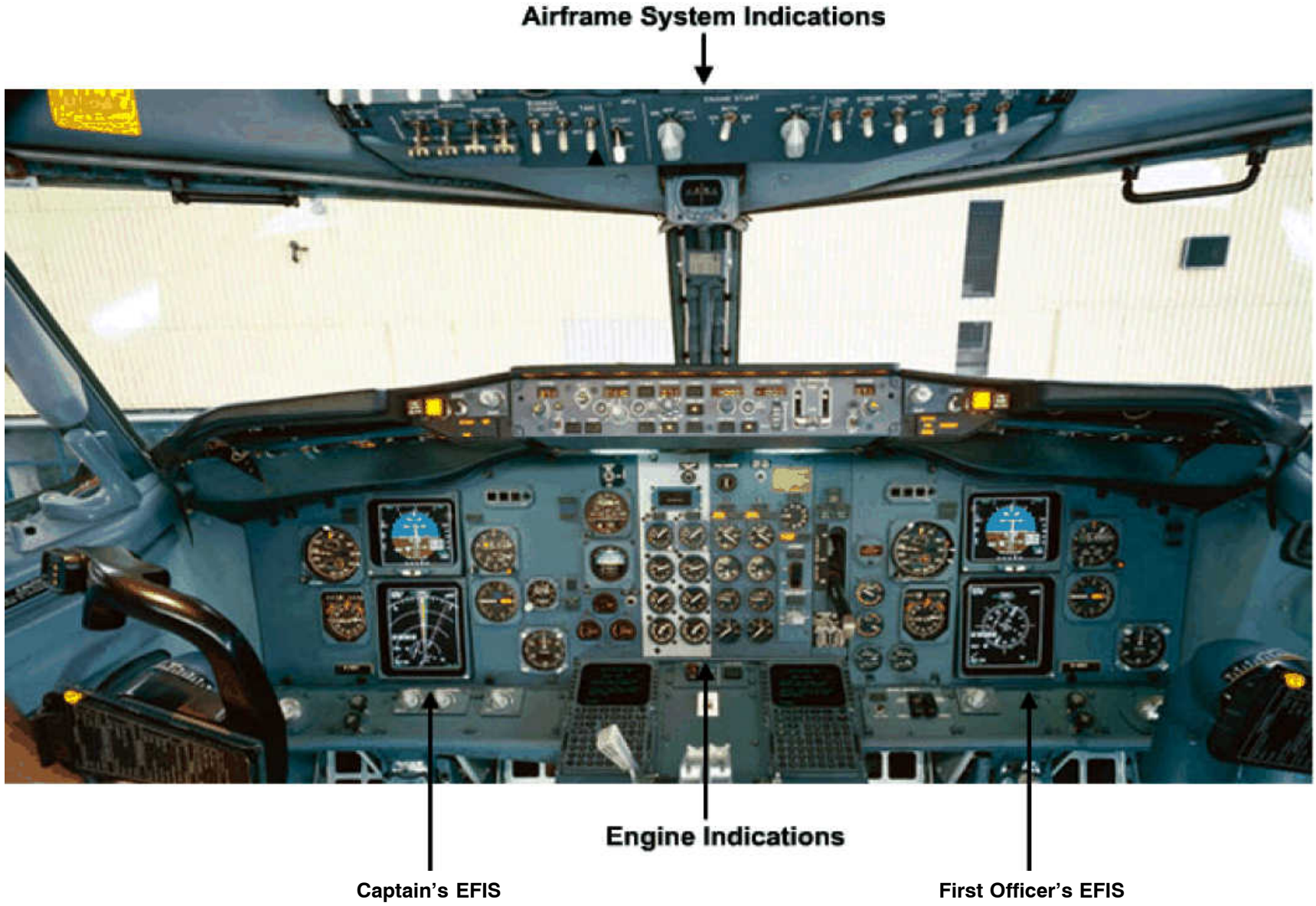

Figure 4 Cockpit Layout Boeing 737–300

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Figure 5 Cockpit Layout Airbus A340

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CONTROL

Name

The indication system for the aircraft surveillance may have different names.

Boeing names it EICAS. This means Engine Indicating and Crew Alerting System.

Airbus names it ECAM. This means Electronic Centralized Aircraft Monitor.

EICAS or ECAM are part of the EIS.

Display Controls

The position of the brightness control knob usually is besides the displays in a vertical position.

Brightness can be set by rotary knobs. In addition brightness is controlled automatically by light sensors attached to the displays.

The brightness control for the Navigational Display consists of two knobs.

A separate control is available for the basic indication on the ND and for the weather radar indication, which is an overlay to the navigation information.

In bright sunlight it may be more difficult to read the indication on glass cockpit screens than on analogue indicators because of the limitation in brightness of the screens.

OFF Position

On Airbus aircraft the control knobs have a dedicated OFF position, displays are switched off if set to the extreme left.

On Boeing aircraft an OFF position is not available. If brightness control is set to minimum the displays are still active as long as power supply is available.

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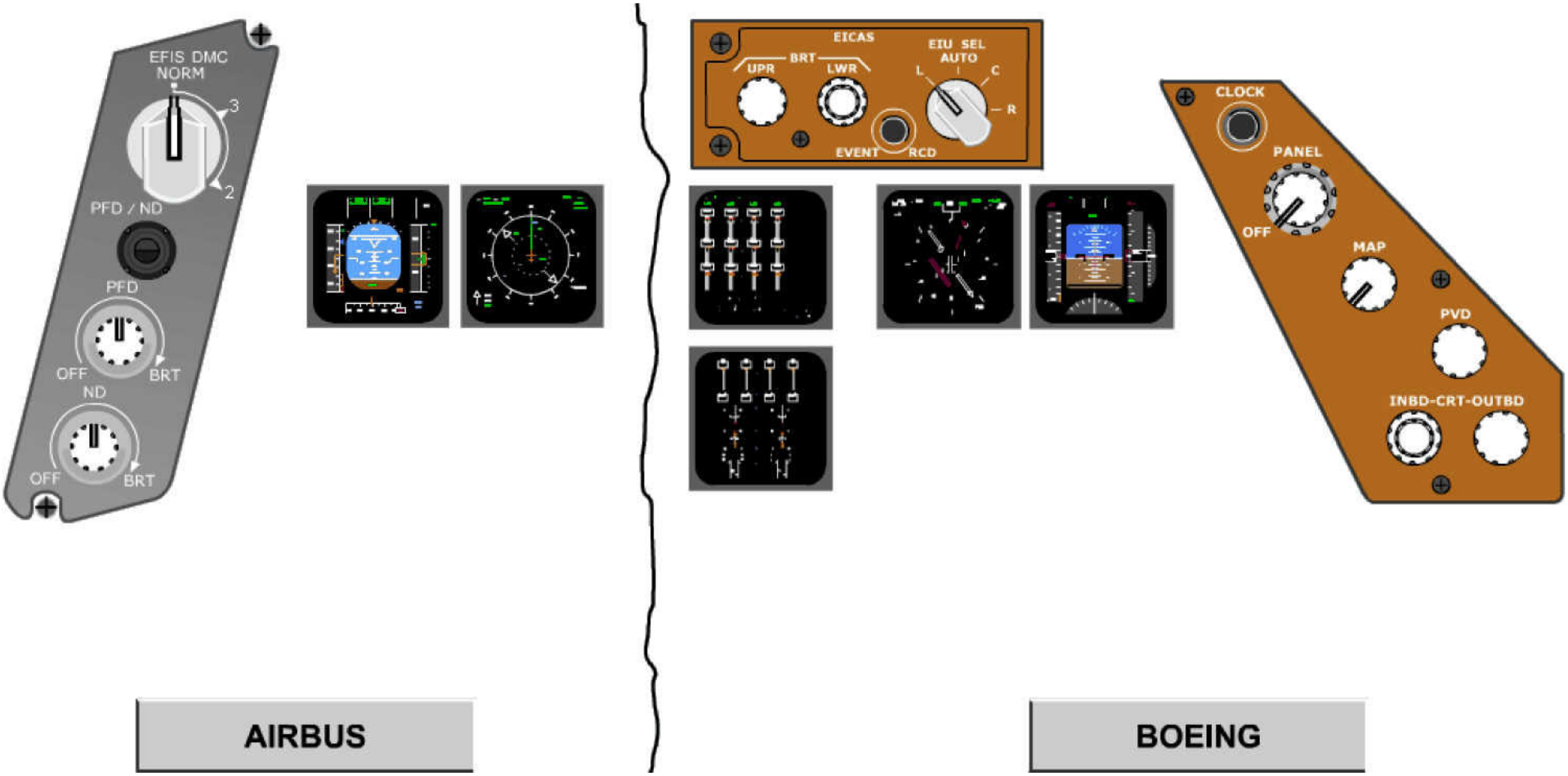

Figure 6 EIS Brightness Control

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INDICATION IN CASE OF A COMPUTER FAILURE

General

If a computer fails the indication changes.

On Airbus aircraft a white line is displayed.

On Boeing aircraft the screen turns dark.

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Figure 7 Display in case of a Computer Failure

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M5.2 NUMBERING SYSTEMS

INTRODUCTION

General

A knowledge of numbering systems is essential for understanding computers and their operation.

Digital Techniques have components which calculate by numbers. The numbering system they use is not the numbering system which is commonly used by us in everyday life.

All numbering systems are used to count objects or perform mathematical calculations and each consists of a set of symbols and characters, commonly referred to as digits.

Base

Every numbering system has a base which describes the system and is equal to the number of values a digit can have.

A subscript is often added to a number to indicate its base. An example of this is 101_2, which indicates the number 101 is a base 2 or binary number.

The value of the largest digit of a numbering system is one less than the base and the value of the smallest digit of a numbering system is zero. Each digit is multiplied by the base raised to the appropriate power for the digit position.

Positional Notation

The standard shorthand form of writing numbers is known as positional notation. The value of a particular digit depends not only on the digit value, but also on the position of the digit within the number.

The digit at the far right is called the Least Significant Digit (LSD) and the digit at the far left is called the Most Significant Digit (MSD).

Identification of the System

For the usual numbering systems there is a letter code.

Numbering System	Base	Designation
Binary	2	B
Octal	8	Q (instead of O)
Decimal	10	D
Hexadecimal	16	H

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DECIMAL NUMBER SYSTEM

General

The decimal number system (base 10) is the most familiar, and is used for everyday counting and mathematical calculations. This numbering system contains ten digits from 0 to 9.

Example 1

For example, the decimal number 4738 is standard shorthand form for the quantity four thousand seven hundred thirty-eight.

If the base 10 shall be indicated, the writing is 4738_{10}.

Each position has a ”value” or “weight”. Starting at the right is the units position, next the tens, then hundreds, and at the left is the thousands position.

The decimal number 4738 is equal to

$(4 \times 10^3) + (7 \times 10^2) + (3 \times 10^1) + (8 \times 10^0)$

$$4738 = 4 \times 10^3 + 7 \times 10^2 + 3 \times 10^1 + 8 \times 10^0$$

Example 2

10^5	10^4	10^3	10^2	10^1	10^0	10^{-1}	10^{-2}	Weighted Value
6	5	8	9	1	2	3	3	Number
600.000	50.000	8.000	900	10	2	0.3	0.03	

The total result is 600.000 + 50.000 + 8.000 + 900 + 10 + 2 + 0.3 + 0.03 = 658912.33

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BINARY NUMBER SYSTEM

INTRODUCTION

General

The simplest number system employing positional notation is the binary system. As the name implies, the system has a base of 2. The two binary digits used are 0 and 1.

In a digital computer, only two distinct states exist. Therefore, all inputs to a digital computer must be converted to a series of 1's and 0's (binary) before the computer can make use of the data.

These 1's and 0's can be used to describe the status of a system, e.g.:

Voltage applied: = 1

No voltage applied: = 0

Digit	...	5th	4rd	3rd	2nd	1st
Weighted Value		2^4	2^3	2^2	2^1	2^0
Base 10 Value		16	8	4	2	1

Bit

A digit is also called a bit.

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CONVERSIONS

Binary to Decimal Conversions

Conversion from binary to decimal is straightforward and easily performed using positional notation.

In the example, the weighted value of each bit position (2^0 , 2^1 ,2^2 ...) and the base 10 equivalent for each bit position is shown.

To convert 1011 (base 2) to base 10 add together the base 10 value for each bit position containing a 1.

The bit at the far right is the Least Significant Digit (LSD) and the bit at the far left is the Most Significant Digit (MSD).

Values of Digits:	8 4 2 1
Given:	$1\ 0\ 1\ 1_2$
Decimal number	$8 + 0 + 2 + 1 = 11_{10}$

The digit for the value four is disregarded because there are zero of these values to be added.

Decimal to Binary Conversions

A mathematical method of conversion is to repeatedly divide the decimal number by the base number, and by keeping track of the remainders, the new numbering base equivalent is obtained.

In the case of decimal to binary conversions, the decimal number is successively divided by the base number 2. The first remainder obtained is the least significant digit (LSD), and the last remainder is the most significant digit (MSD).

Decimal Number: $1\ 0\ 5_D$
Equivalent Binary Number $1\ 1\ 0\ 1\ 0\ 0\ 1_B$

LSB

```
105 : 2 =  52 Rem. 1
 52 : 2 =  26 Rem. 0
 26 : 2 =  13 Rem. 0
 13 : 2 =   6 Rem. 1
  6 : 2 =   3 Rem. 0
  3 : 2 =   1 Rem. 1
  1 : 2 =   0 Rem. 1
```

MSB

MSB means **M**ost **S**ignificant **B**it

LSB means **L**east **S**ignificant **B**it

This principle can be used for each and every numbering system. It can easily be used for computer programs.

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Examples

Example 1

Convert 1001 to a Decimal

Write down the powers of 2 and add them to a sum.

$$\begin{array}{ll} & 1 \times 2^3 = 8 \\ + & 0 \times 2^2 = 0 \\ + & 0 \times 2^1 = 0 \\ + & 1 \times 2^0 = 1 \\ \hline & 9 \end{array}$$

Thus

1001_2 is equal to 9_{10}

Example 2

Convert 1001001 to a Decimal

Write down the powers of 2, and the number to be converted below them, as follows:

64	32	16	8	4	2	1
1	0	0	1	0	0	1

Then add all the numbers above the 1's

i.e. 64 + 8 + 1 = 73

Example 3

Convert 271 to Binary

Every figure in the decimal numeral system can be broken down into powers of 2 and thus can be transferred to the binary numeral system.

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Method 1

Find the powers of two which is equal or smaller than the number to be converted.

For **271** this is 2^8, that equals 256_{10}.

256 128 64 32 16 8 4 2 1

2^8 = 256 fits one time in the **271**.

Write a **1** under the 256.

Subtract 256 from **271**.

271 – 256 = 15

2^7 doesn't fit into the remaining in the 15, so note a **0**.

The same is with 2^6, 2^5 and 2^4. Here you also note a **0** for each.

Then 2^3 = 8 fits one time in the 15, so you note a **1**, please.

Subtract 8 from 15.

15 - 8 = 7

2^2 = 4 fits one time in the 7, so you note a **1**.

Subtract 4 from 7.

7 - 4 = 3

2^1 = 2 fits one time in the 3, so you note a **1**.

Subtract 2 from 3.

3 - 2 = 1

2^0 = 1 fits one time in the 1, so you note a **1**.

The result of all the **1** and **0** is: **100001111**

Method 2

If you write all the powers of 2 in a line and then the zeros and ones below, you get the following result:

First write all powers of two, beginning with the highest number which has to be used for the calculation. Again, 256 in this case.

256	**128**	**64**	**32**	**16**	**8**	**4**	**2**	**1**
1	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**

The decimal number 271_{10} therefore is 100001111_2

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OCTAL NUMBER SYSTEM

INTRODUCTION

General

Numerical operations in microcomputers are performed by binary numbers, when used to represent large quantities many 0's and 1's are needed. This is cumbersome and time−consuming; therefore, other systems are often used as a shorthand notation for binary numbers.

One popular system is the octal system which was very common until the mid 70ties.

The octal system base is 8.

The digits 0 through 7 are available, 8 and 9 do not exist.

As a result, frequent binary−to−octal conversions are necessary.

Powers of 8

Powers of 8;	8^4	8^3	8^2	8^1	8^0
Decimal No:	4096	512	64	8	1

It is possible to show values which are smaller than 1:

8^{-1} equals 0.125 in the decimal system.

8^{-2} equals 0.015625 in the decimal system.

In the positional notation example, the weighted value of each bit position (8^0, 8^1, 8^2...) and the base 10 equivalent are shown.

To convert 4522 (base 8) to base 10, multiply each octal digit by its corresponding base 10 value, then add together the computed base 10 values.

Digit	...	5th	4rd	3rd	2nd	1st
Weighted Value		8^4	8^3	8^2	8^1	8^0
Base 10 Value		4096	512	64	8	1

CONVERSIONS

Octal to Decimal Conversion

As in the case of decimal to binary conversions, decimal to octal conversions can also be accomplished by successive division. The decimal number to be converted to octal is repeatedly divided by the base 8 and again the remainders are used for the decimal to octal equivalent number.

Successive division by Base Number:

Example

Convert 2386_{10} to octal by using successive division.

2386 / 8 = 298R 2

298 / 8 = 37 R 2

37 / 8 = 4 R 5

4 / 8 = 0 R 4

$2386_{10} = 4522_8$

Binary to Octal Conversion

In binary, three−bit positions represent exactly eight combinations (000 through 111). Therefore, octal numbers can be directly substituted for 3−bit binary numbers. The binary number is separated into groups of three bits beginning at the right with the least significant digit (LSD) and proceeding to the most significant digit (MSD) at the left. Each group of three bits is then replaced by an octal equivalent.

In forming the 3−bit groupings, 0's may need to be added to complete the most significant digit (MSD).

Octal−to−binary conversion is the reverse of the above procedure. This is easily accomplished by replacing each octal digit by its 3−bit binary equivalent.

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Converting Binary to Octal

To convert a binary number to an octal number, construct a 3–bit binary / octal look-up table like the one below. Starting at the binary decimal point of the binary number, take the first 3 bits and find the corresponding octal value from the table.

3–bit binary / octal table

3–bit Binary	Octal
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

3–bit Binary/Octal table

Start with the 3 most right bits and find the related octal value in the table.

Repeat this with the next 3 bits and so on. If there are less than 3 bits left, fill with zeroes until you have 3 bits. Again, use the table.

Example:

Convert 11010010 to octal.

1. Take the 3 most right bits, 010 and find the corresponding octal value in the above look–up table. The octal value is 2.
2. Take the next 3 bits, 010. The corresponding octal value from the look–up table is 2 again.
3. Now only 2 bits, 11 of the binary number remain. Pad the left hand side with a 0 to get 011. The corresponding octal from the look–up table is 3.

so, $11010010_2 = 322_8$

Converting Octal to Binary

For the conversion of octal numbers to binary numbers, just use the table in a reverse manner.

To convert from octal to binary, write down the binary representation of each octal digit. Note that each octal digit should take up 3 bits.

Example:

Convert 322_8 to binary

3 = 011

2 = 010

2 = 010

so, $322_8 = 011010010_2$

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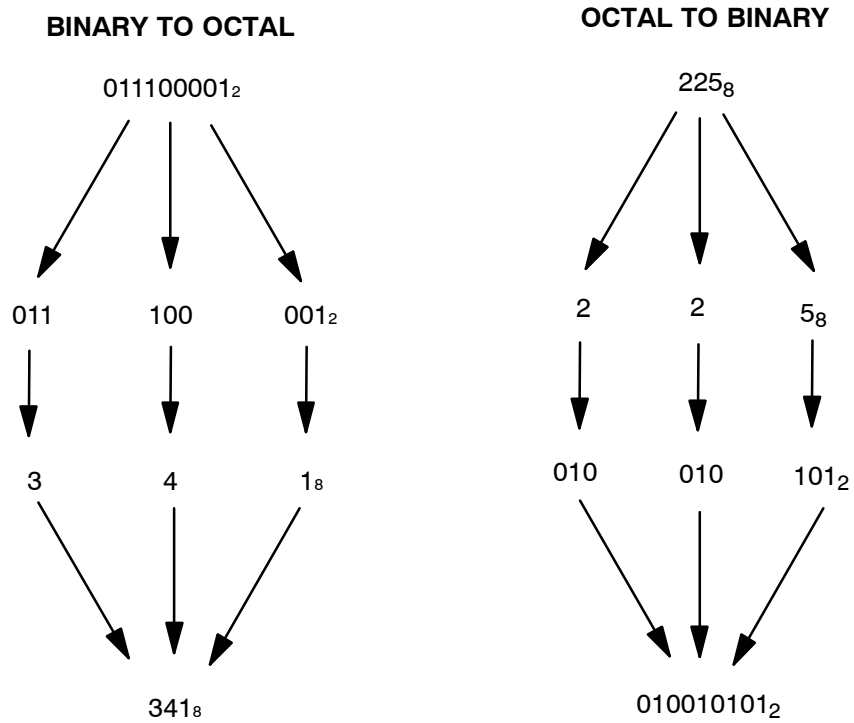

Figure 8 Binary to Octal / Octal to Binary

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HEXADECIMAL NUMBER SYSTEM

INTRODUCTION

General

The hexadecimal number system is another system often used in micro-computers. It has a base of 16 which requires sixteen digits. The digits used are 0 through 9 and A through F. The symbols A through F represent the equivalent decimal numbers of 10 through 15, respectively.

This system is called an alphanumeric number system since numbers and letters are used to represent its digits.

In the positional notation example, the weighted value of each digit's position (16^0,16^1,16^2...) and the base 10 equivalent is shown.

A → 10
B → 11
C → 12
D → 13
E → 14
F → 15

Often hexadecimal numbers are written with an "H" following the number to denote they are hexadecimal numbers.

Hexadecimal Number	Decimal Equivalent
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
A	10
B	11
C	12
D	13
E	14
F	15

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CONVERSIONS

Decimal / Hexadecimal Conversion

Decimal to hexadecimal conversions may be done by successive division

In this case, the decimal number is divided by the base number of 16. If the remainder is greater than 9, it should be changed to the hexadecimal equivalent of the remainder.

For example, if the remainder is 10, It should be changed to ”A”; if the remainder is 11, it should be changed to ”B”, and so on, up to 15, which is ”F”.

Example

Convert 43258_{10} to hexadecimal by using successive division.

43253/ 16 = 2703 R 5

2703 / 16 = 168 R F (15)

168 / 16 = 10 R 8

10 / 16 = 0 R A (10)

$43253_{10} = A8F5_{16}$

Digit	...	5th	4rd	3rd	2nd	1st
Weighted Value		16^4	16^3	16^2	16^1	16^0
Base 10 Value		65536	4096	256	16	1
Number to be converted			**A**	**8**	**F**	**5**
Equivalent Base 10 Number			40960	2048	240	5

To convert A8F5 (base 16) to base 10, multiply each hexadecimal digit by its corresponding base 10 value then add together the computed base 10 values.
40960 + 2048 + 240 + 5 = 4325310

$A8F5_{16} = 43253_{10}$

Figure 9 Hexadecimal Number System

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Binary / Hexadecimal Conversion

The hexadecimal number system is used as a shorthand notation for binary numbers. In binary, 4– bit positions are necessary to obtain sixteen combinations (0000 to 1111). As a result of this, hexadecimal numbers can be directly substituted for 4–bit binary numbers.

The binary number is separated into groups of four bits beginning at the LSD and preceding to the left. Each group of four bits is then replaced by hexadecimal equivalent.

In forming the 4–bit groupings, 0's may be required to complete the first (MSD) group.

Hexadecimal–to–binary conversion is the inverse of the above procedure. This is easily performed by replacing each hexadecimal digit by its 4–bit binary equivalent.

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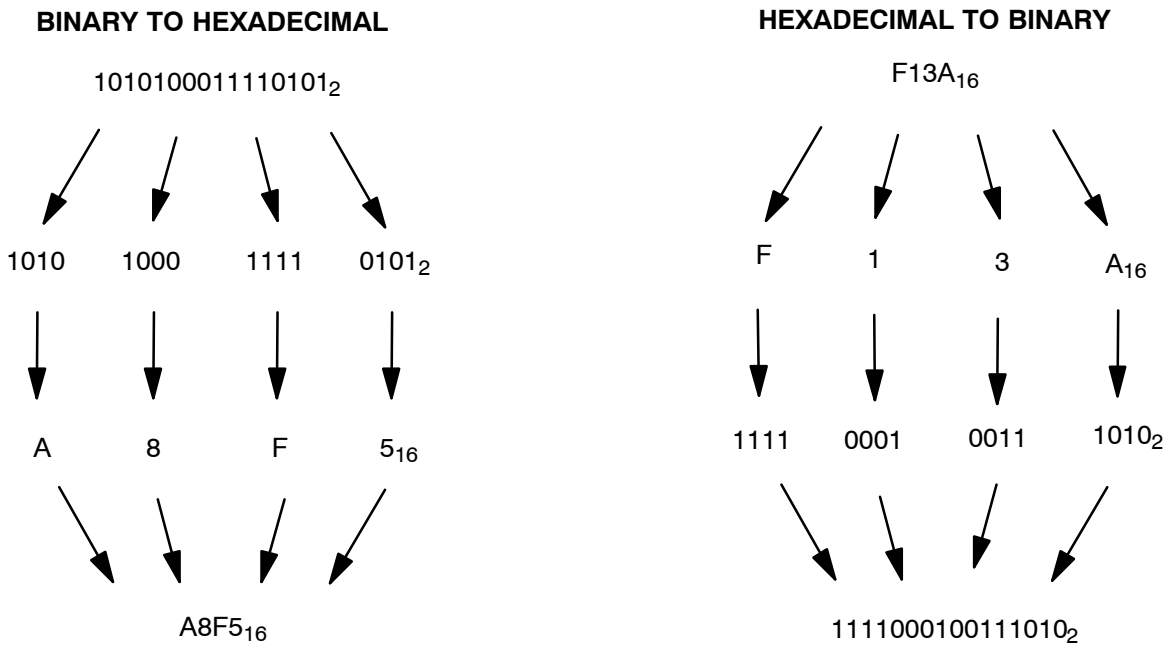

Figure 10 Binary and Hexadecimal Conversions

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OVERVIEW

Binary-, Octal-, Hexadecimal Numbering System

In case we count in the binary system a specific arrangement will be the result. This arrangement shows the relation between the numbers from the different numbering systems.

As the octal system is a grouping of 3 bit, the hexadecimal system is a grouping of 4 bit octal-hexadecimal conversions are very simple:

Example

The octal 123 is to be converted into hexadecimal.

123_8 as a binary is 001 010 011_2

As a hexadecimal is a re-grouping into groups of 4:

0 0101 0011_2 as a hex is 053_{16}.

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OVERVIEW DECIMAL, BINARY, OCTAL AND HEXADECIMAL NUMBERING SYSTEM

Decimal		Binary					Octal		Hexadecimal	
10^1	10^0	2^4	2^3	2^2	2^1	2^0	8^1	8^0	16^1	16^0
0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	1	0	1	0	1
0	2	0	0	0	1	0	0	2	0	2
0	3	0	0	0	1	1	0	3	0	3
0	4	0	0	1	0	0	0	4	0	4
0	5	0	0	1	0	1	0	5	0	5
0	6	0	0	1	1	0	0	6	0	6
0	7	0	0	1	1	1	0	7	0	7
0	8	0	1	0	0	0	1	0	0	8
0	9	0	1	0	0	1	1	1	0	9
1	0	0	1	0	1	0	1	2	0	A
1	1	0	1	0	1	1	1	3	0	B
1	2	0	1	1	0	0	1	4	0	C
1	3	0	1	1	0	1	1	5	0	D
1	4	0	1	1	1	0	1	6	0	E
1	5	0	1	1	1	1	1	7	0	F
1	6	1	0	0	0	0	2	0	1	0
1	7	1	0	0	0	1	2	1	1	1
1	8	1	0	0	1	0	2	2	1	2
1	9	1	0	0	1	1	2	3	1	3
2	0	1	0	1	0	0	2	4	1	4
2	1	1	0	1	0	1	2	5	1	5
2	2	1	0	1	1	0	2	6	1	6
2	3	1	0	1	1	1	2	7	1	7

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M5.5 LOGIC CIRCUITS

INTRODUCTION

General

Digital Computers and Central Processor Units must be able to realize arithmetic processes and logical combinations, which are both made in a so called ALU (Arithmetic Logic Unit), the heart of each CPU (Central Processor Unit).

This ALU needs the inputs in digital form:

- logic 1 (also known as logic ''True''),
- logic 0 (also known as logic ''False'').

Bit

The single item of information (logic 1 or logic 0) is known as a ''bit'' (binary digit).

Level Assignment

A binary signal is a digital signal with only two different values. A special meaning is assigned to these two values (voltages):

Example

Voltage applied → U = 1.

No voltage applied → U = 0.

A fulfilled condition is considered to be logic „1“, otherwise it is logical „0“. This is just a logic state, not a value or Voltage.

An assignment has to be made in accordance with the hardware requirements. Usually we say: the voltage level that is more positive is seen as „“1“, the voltage level that more negative is to be seen logic „0“.

Positive and Negative Logic

The assignment depends on the technology used, you can say „it is at will“. This assignment gives us the so called positive Logic and negative Logic.

Positive Logic	Negative Logic
1 » H	1 » L
0 » L	0 » H

Usually the H-Level is seen as „1“, L-Level is to be seen as „0“.

H means 1 L means 0

H means high voltage, L means low voltage. However, the voltages used in digital techniques are relatively low since no power needs to be applied on mechanical devices.

Operators

Operators are signs in mathematics. In logic circuits, they show how the input signals are combined to calculate the output signal.

For logic's, the following operators are used:

- AND ∧
- OR ∨
- NOT ¬

Mixed Logic

Individual assignments may be used. We call them mixed logic.

This system has the disadvantage that some inverted gates are not available.

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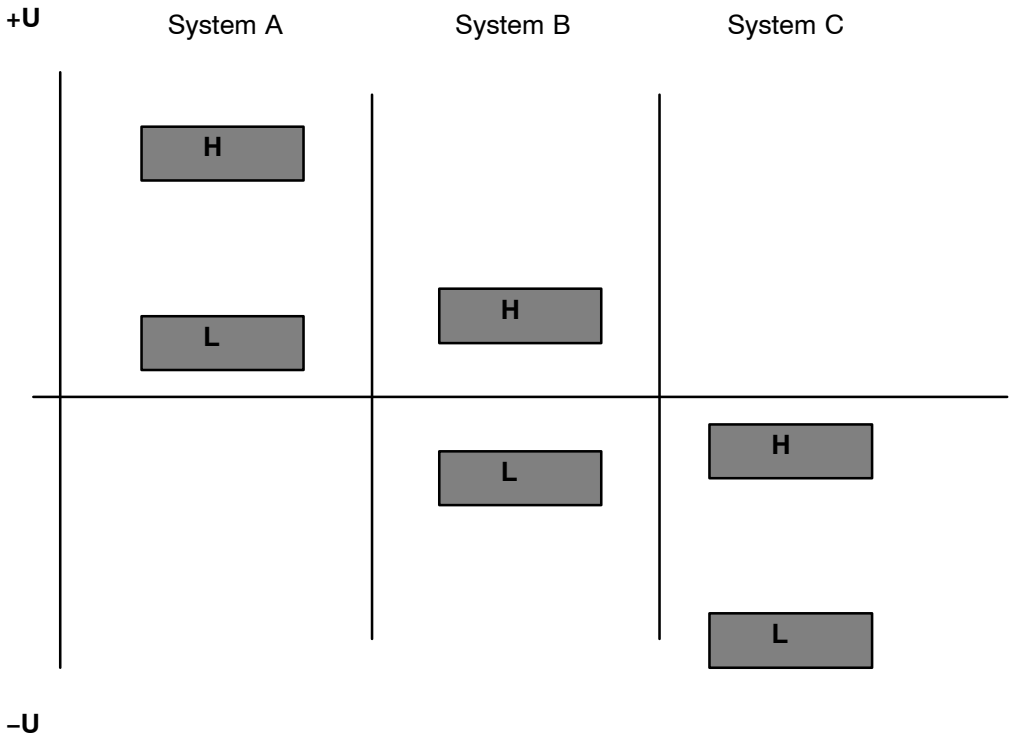

Figure 11 Level Assignment

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BASIC FUNCTIONS

General

The illustration with the logic symbols is completely independent from the technology used. It just states the function but not the „contents“.

For logical combination there are only three basic functions:

- AND Function
- OR Function
- INVERTER Function.

AND Gate

An AND-Gate may have two or more inputs (E_1 to E_n) and one output (A).

The output has only a logical 1, if all inputs have a logic 1.

If one or more inputs have a logic 0, the output has a logic 0.

Switching Function

$A = E_1 \times E_2 \times ..... \times E_n$ or $A = E_1 \wedge E_2 \wedge ..... \wedge E_n$

A equals E_1 and E_2 and ..... and E_n

Truth Table (for two Inputs)

E_2	E_1	A
0	0	0
0	1	0
1	0	0
1	1	1

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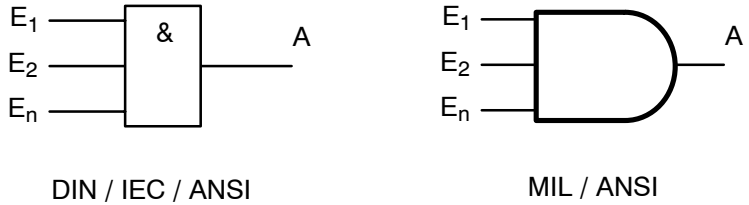
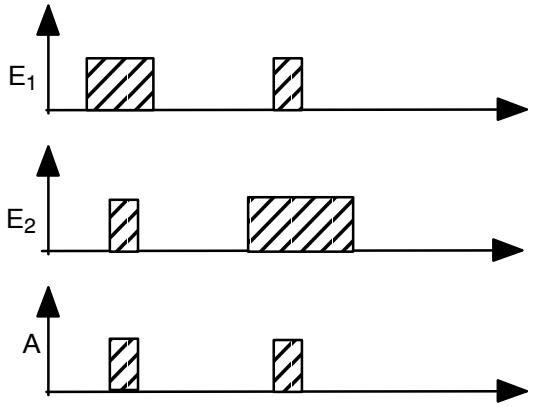
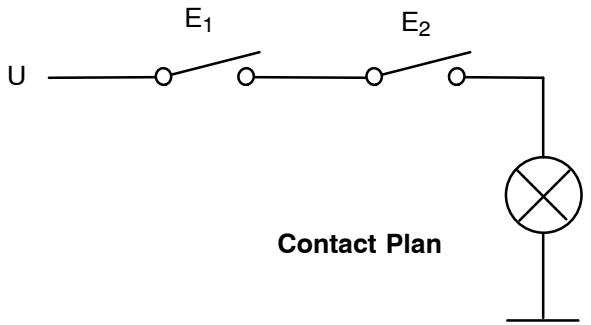


AND Symbols



Impulse Diagram



Contact Plan

Figure 12 AND Gate

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OR Gate

An OR-Gate may have two or more inputs (E_1 to E_n) and one output (A).
The output has only a logical 1, if one or more inputs have a logic 1.
The out put has only a logic 0, if all inputs have a logic 0.

Switching Function

$A = E_1 + E_2 + ... + E_n$ or $A = E_1 \vee E_2 \vee ... \vee E_n$

A equals E_1 or E_2 or..... or E_n

Truth Table (for two Inputs)

E_2	E_1	A
0	0	0
0	1	1
1	0	1
1	1	1

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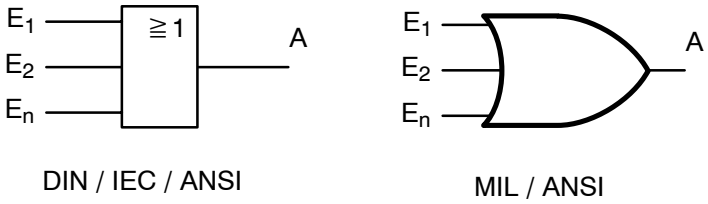
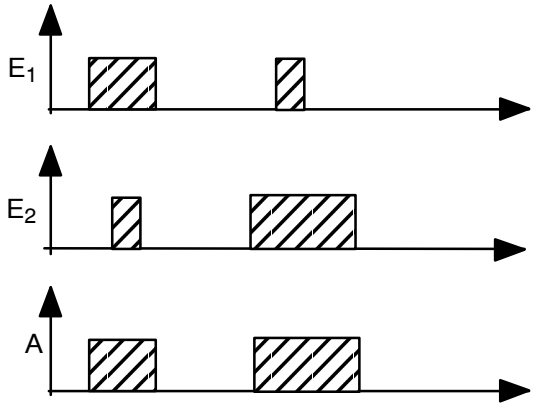
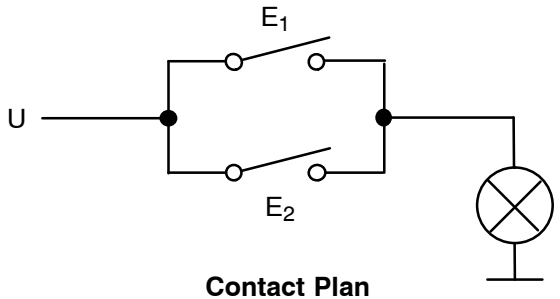


OR Symbols



Impulse Diagram



Contact Plan

Figure 13 OR Gate

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Inverter

The Inverter (NOT-Function) inverts the input signal. It is also called a Boolean complement.

If the input signal is a logical 1, the output signal is a logical 0 and vice versa.

Switching Function:

$A = \overline{E}$

A is inverse to E

Truth Table

E	A
0	1
1	0

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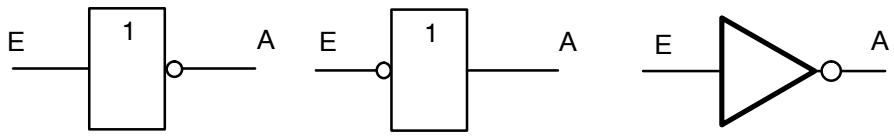
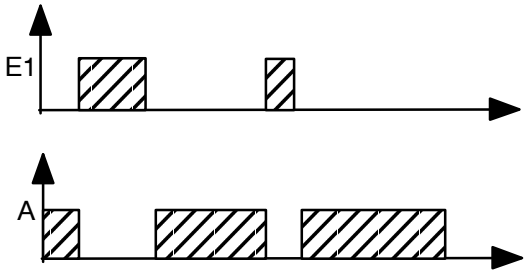


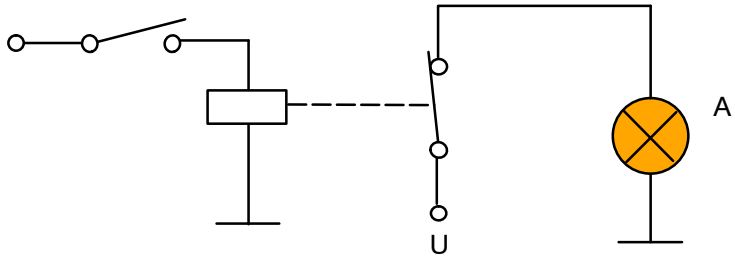
DIN / IEC / ANSI

MIL / ANSI

Inverter Symbols



Impulse Diagram



Contact Plan

Figure 14 Inverter

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UPPER FUNCTIONS

NAND Gate

A NAND-Gate (Not-AND-Gate) may have two or more inputs (E1 to En) and one output (A).

The output has only a logic 1, if one input (one of E1 to En) has a logic 0.

The output has a logic 0, if all inputs (E1 to En) have a logic 1.

Switching Function

$A = \overline{E_1 \times E_2 \times .... \times E_n}$ or $A = \overline{E_1 \wedge E_2 \wedge .... \wedge E_n}$

To be read as: $A = E_1$ and E_2 and..... and E_n not

A NOT spoken at the end of a term means that the complete term is to be inverted.

Truth Table (two inputs)

E_2	E_1	A
0	0	1
0	1	1
1	0	1
1	1	0

Inversion with NAND Gate

If all input gates but one are provided with a constant 1 as an input, the gate works as an inverter for the remaining input signal.

AND from NAND

If an inverter is set at the output of the NAND-gate, the total result is a AND gate.

OR from NAND

If all input gates are inverted, the total result is an OR-gate.

NAND for all Basic Functions

Since it is possible to create AND-gates, OR-gates and inverters with NAND-gates, it is possible to create all basic functions by using NAND-gates.

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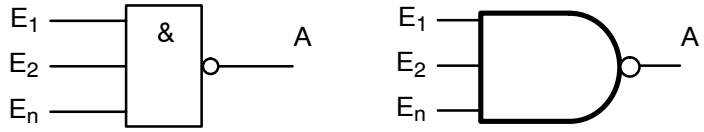
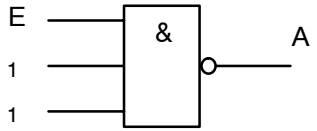
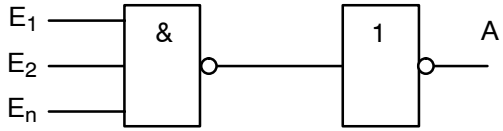


DIN / IEC / ANSI MIL / ANSI

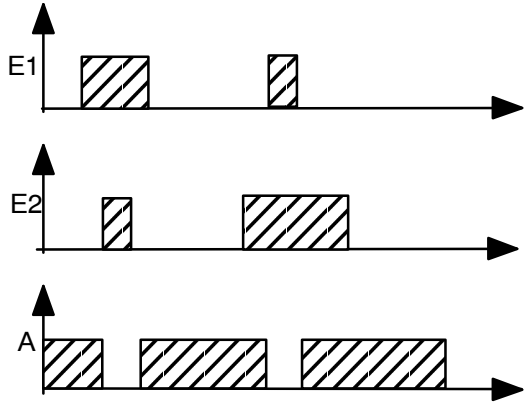
NAND Symbols



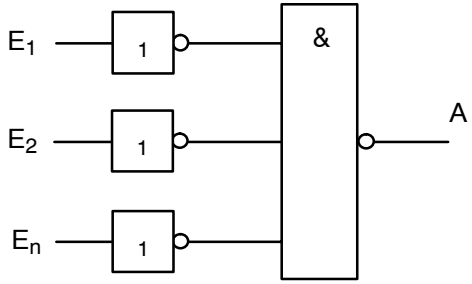
Inverter from NAND Gate



AND from NAND



Impulse Diagram



OR from NAND

Figure 15 NAND Gate

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NOR Gate

A NOR-Gate (Not-OR) may have two or more inputs (E1 to En) and one output (A).

The output has only a logic 1, if all inputs (E1 to En) have a logic 0.

The output has a logic 0, if one or more inputs have a logic 1

Switching Function

$A = \overline{E_1 + E_2 + ... + E_n}$ or $A = \overline{E_1 \text{ v } E_2 \text{ v } .... \text{ v } E_n}$

To be read as: $A = E_1$ or E_2 or..... or E_n not

A NOT spoken at the end of a term means that the complete term is to be inverted.

Truth Table

E_2	E_1	A
0	0	1
0	1	0
1	0	0
1	1	0

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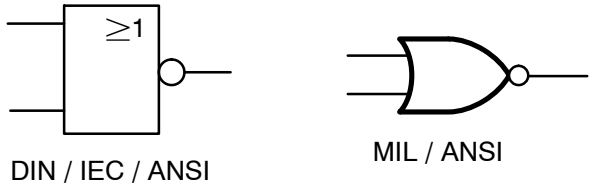
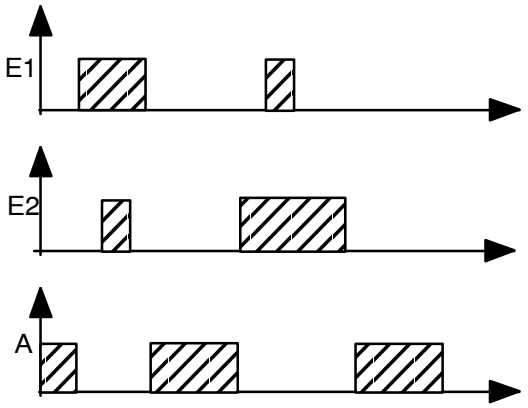


NOR Symbols



Impulse Diagram

Figure 16 NOR Gate

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Exclusive OR

An Exclusive OR has two inputs (E_1 and E_2) and one output A.

The output has a logic 1, if input E_1 has a logic 1 and input E_2 a logic 0 or vice versa.

The output has a logic 0, if both inputs (E_1 and E_2) have a logic 1, or both inputs have a logic 0.

Switching Function

$A = E_1 \times \overline{E_2} + \overline{E_1} \times E_2$

Truth table

E_2	E_1	A
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive NOR

An Exclusive NOR has two inputs (E_1 and E_2) and one output A.

The output has a logic 1, if inputs E_1 and E_2 have a logic 1, or E_1 and E_2 have a logic 0.

The output has a logic 0, if input E_1 has a logic 1 and input E_2 a logic 0 or vice versa.

Switching Function

$A = \overline{E_1} \times \overline{E_2} + E_1 \times E_2$

Truth table

E_2	E_1	A
0	0	1
0	1	0
1	0	0
1	1	1

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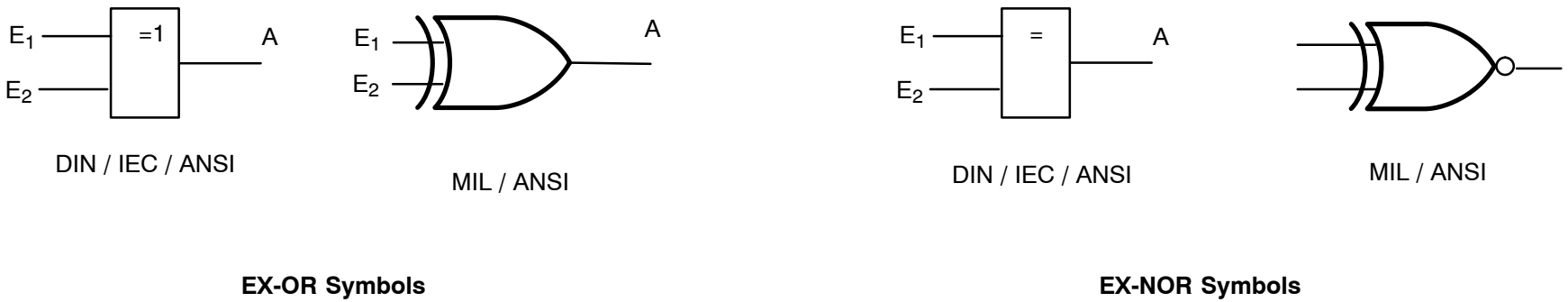

EX-OR Symbols

EX-NOR Symbols



EX-OR Impulse Diagram

EX-NOR Impulse Diagram

Figure 17 EX-OR/EX-NOR Gate

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POSSIBLE FUNCTIONS

General

The number of possible input combinations: Ic = 2^n
with n being the number of input variables.

Number of possible switching functions: SF = 2^{2^n}

Not all possible functions are always sensible.

With 2 inputs in total 16 functions are possible.

Function No	A = 0101 B = 0011	$Q_i = f(A, B)$	Name of Function
0	0000	0	Null
1	0001	A x B	AND
2	0010	$\overline{A}$ x B	Not A and B
3	0011	B	1. Identity
4	0100	A x $\overline{B}$	A and not B
5	0101	A	2. Identity
6	0110	A $\oplus$ B	Exclusive OR
7	0111	A + B	OR
8	1000	$\overline{A + B}$	Not OR
9	1001	$\overline{A \oplus B}$	Exclusive NOR
10	1010	$\overline{A}$	Not A
11	1011	$\overline{A}$ + B	Not A or B
12	1100	$\overline{B}$	Not B
13	1101	A + $\overline{B}$	A or not B
14	1110	$\overline{A \times B}$	A and B not
15	1111	1	One

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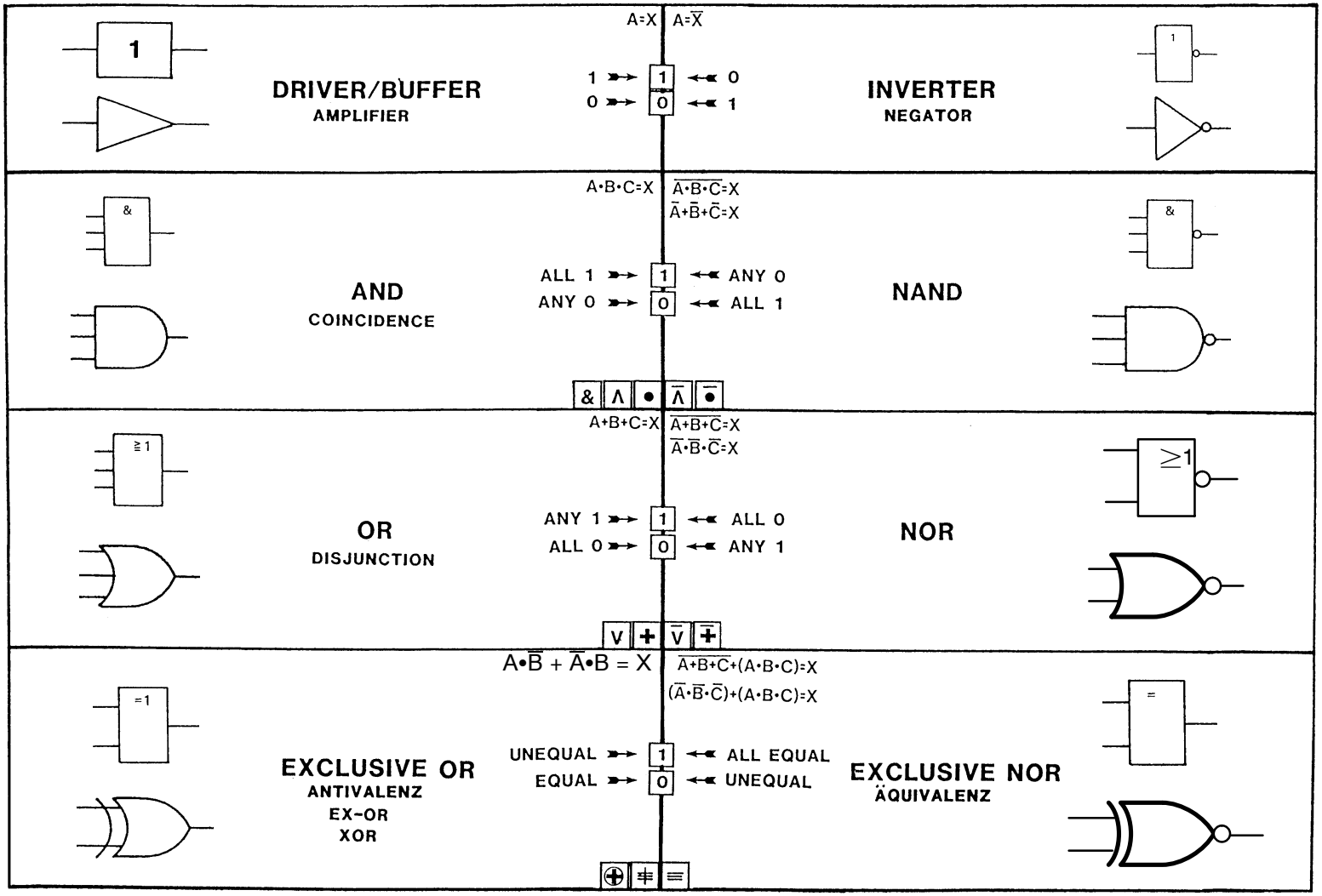

Figure 18 Summary Logic Gates

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EXAMPLE

General

The figure shows a logic which is shown with logic symbols.

If at least one Main Gear is not up and the aircraft is in the air an alert for the pilots is triggered.

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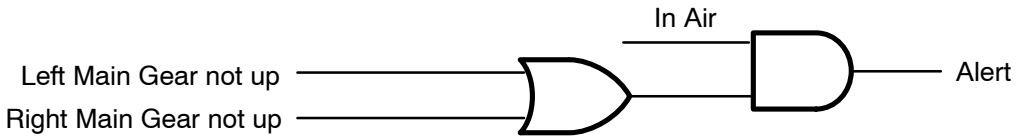

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Figure 19 Example for Logic Circuits

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BOOLEAN ALGEBRA

General

Technical operations can be expressed with the so called „Boolean Algebra“ by using the binary 0 and 1.

This is what we call switching function (e.g. F = A v B Λ C, or A+B x C)

Boolean Algebra deals with combinations of logic 0 and logic 1. It uses the binary number system.

Also Truth Tables, Impulse Diagrams and Logic Symbols may be used to describe a technical operation.

Definition of Function

With implementing the binary symbols 0 and 1 we can describe technical processes by means of the Boolean Algebra.

The 0–1 decisions at Inputs (E_1, E_2, ..., E_n) are the independent variables.

The Output (A) is the so called dependant variable as it depends on the input states.

Output A depends on the inputs (E_1, E_2 ..., E_n). This can be described with a switching function A = f (E_1, E_2 E_n).

Number of Possible Functions

With n Variables on the input side there are 2^n Variations on the output side and 2^{2^n} possible switching functions.

n	possible input variations	possible switching functions
1	2	4
2	4	16
3	8	256

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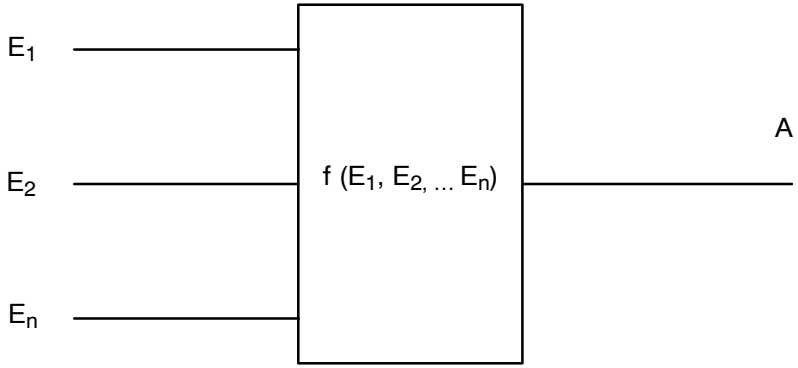

Figure 20 Functional Block

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RULES OF BOOLEAN ALGEBRA

Priority

When realizing equations, there is a rule for prioritizing combinations of operations (AND/OR).

It is: $(A + B) \cdot C \neq A + (B \cdot C)$!

A	B	C	$(A + B) \cdot C$	$A + (B \cdot C)$
0	0	0	0	0
0	0	1	0	0
0	1	0	0	0
0	1	1	1	1
1	0	0	0	1
1	0	1	1	1
1	1	0	0	1
1	1	1	1	1

The long inversion bar treats everything below it as if in brackets.

If there are several operations in one equation, the following sequence should be kept:

4. Negation $\overline{\quad}$
5. AND x , $\wedge$
6. OR + , $\vee$

In accordance with the operator precedence rules: AND operations preced OR operations.

De Morgan Theorem

A practical operational way to look at DeMorgan's Theorem is that an AND may be replaced by an OR with all inputs and the output inverted.

AND can replace an OR or vice versa.

Shannon Theorem

In accordance with the Shannon Theorem, a NAND can be replaced by an OR with inverted inputs.

A long inversion bar can be split into several smaller ones when replacing an AND by an OR or vice versa.

Calculation Rules

The following table shows the logical connection between input variants and output in accordance to the boolean algebra using constants, variables and combinations of them.

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Name	Calculation Rule	
Functions with Constants (Postulates)	$\overline{0} = 1$ $\overline{1} = 0$ $0 \cdot 0 = 0$ $0 + 0 = 0$ $1 \cdot 1 = 1$ $1 + 1 = 1$ $1 \cdot 0 = 0$ $1 + 0 = 1$	(1) (2) (3) (4) (5) (6) (7) (8)
Functions with one Constant and one Variable	$0 \cdot A = 0$ $1 \cdot A = A$ $A \cdot \overline{A} = 0$ $A \cdot A = A$ $0 + A = A$ $1 + A = 1$ $A + \overline{A} = 1$ $A + A = A$ $\overline{\overline{A}} = A$	(9) (10) (11) (12) (13) (14) (15) (16) (17)
Commutativity	$A \cdot B \cdot C = A \cdot C \cdot B = C \cdot B \cdot A = ...$ $A + B + C = A + C + B = C + B + A = ...$	(18) (19)
Associativity	$A \cdot B \cdot C = (A \cdot B) \cdot C = A \cdot (B \cdot C) = ...$ $A + B + C = (A + B) + C = A + (B + C) = ...$	(20) (21)
Distributivity	$A \cdot (B + C) = (A \cdot B) + (A \cdot C)$ $A + (B \cdot C) = (A + B) \cdot (A + C)$	(22) (23)
Priority	$(A + B) \cdot C \neq A + (B \cdot C)$	(24)
Cancelling	$A + (A \cdot B) = A$ $A \cdot (A + B) = A$ $A + (\overline{A} \cdot B) = A + B$ $A \cdot (\overline{A} + B) = A \cdot B$ $A \cdot B + A \cdot \overline{B} = A$ $(A + B) \cdot (A + \overline{B}) = A$	(25) (26) (27) (28) (29) (30)
de Morgans Theorem	$\overline{(A \cdot B \cdot C \cdot ...)} = \overline{A} + \overline{B} + \overline{C} + ...$ $\overline{(A + B + C + ...)} = \overline{A} \cdot \overline{B} \cdot \overline{C} \cdot ....$	(31) (32)
Shannon Theorem	$\overline{f(A, \overline{B}, \cdot, +, \equiv, \neq)} = f(\overline{A}, B, +, \cdot, \neq, \equiv)$	(33)

Figure 21 Overview Calculation Rules

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M5.3 DATA CONVERSION

ANALOGUE DATA

General

A lot of information is given in the way we normally can see, hear or feel.

The easiest way is language. Signs can also be given with the hands.

An example for analog data are letters. At first in handwriting, then in printing.

Physical Quantities

Analog information represents physical quantities. The values can change permanently.

The value of the difference may be large or small, dependent on time. These are linear signals which are analogue to the represented physical quantity.

These physical quantities are e.g.:

- length
- mass
- current
- voltage.

Analogue Signal

Analogue signals are signals which have a correlated amplitude for each value in a given moment.

The number of values is non-finite within the technical limits.

Analogue Technology without Electricity

Analogue technology was without electricity first.

Examples are the gramophone and the camera.

Data was stored on a gramophone record (this is a kind of disc) or on a filmstrip.

Gramophone

In a gramophone, a disc has a spiralled groove on each side. This groove was formed according to a sound. When the disc rotates, a needle (pick-up) will move according the form of the groove.

When a diaphragm is linked to the needle, it will move synchronously and generate a sound which is similar to the sound which is stored on the disc. A cone can focus the sound to one direction.

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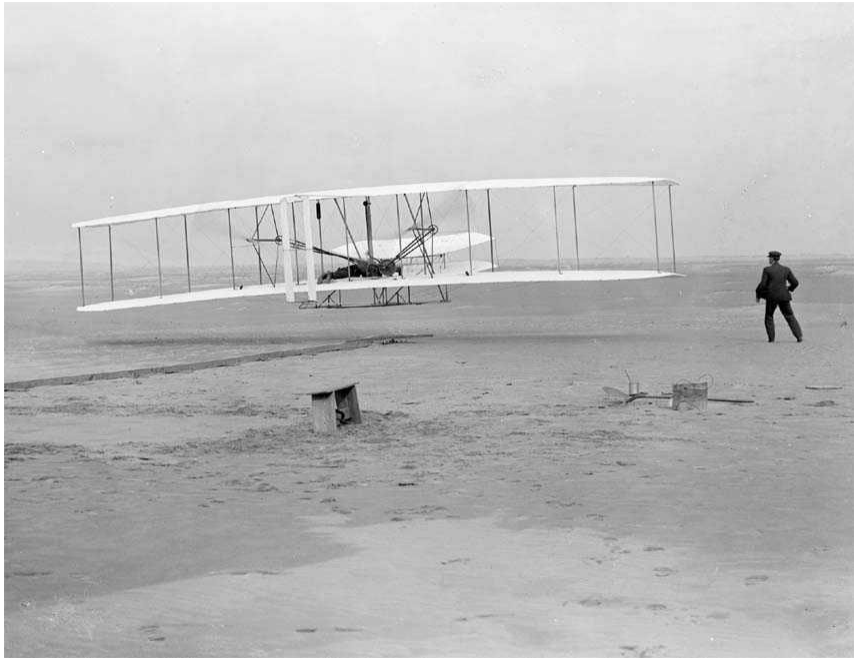
Grammophone



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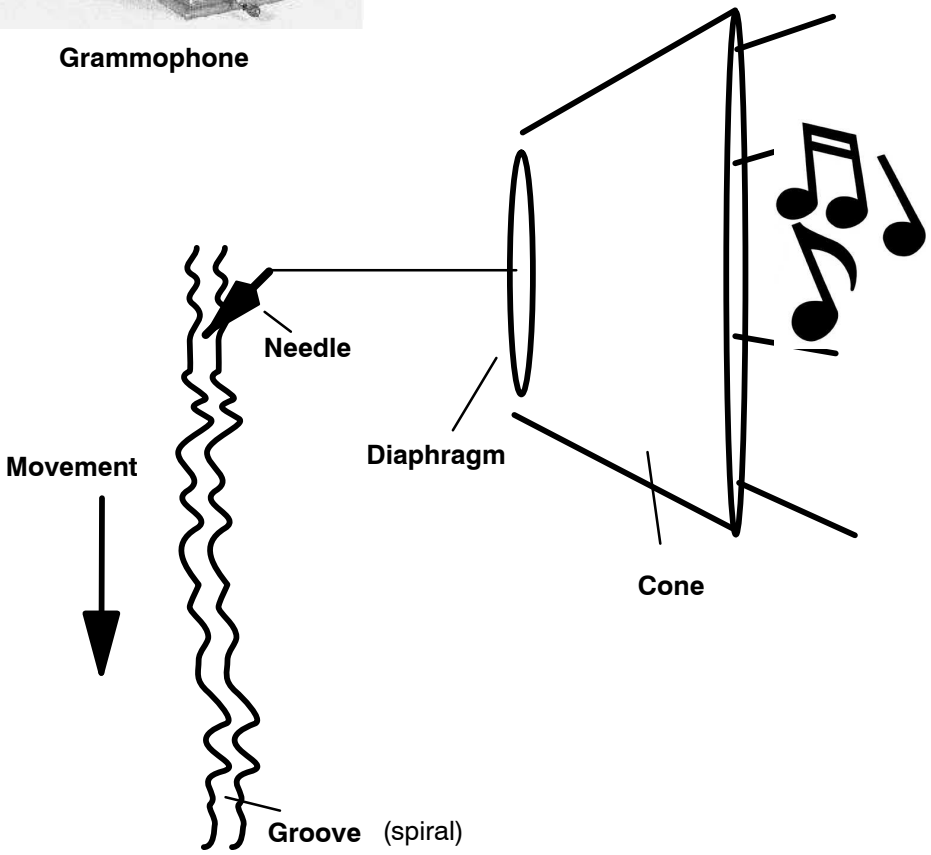

Figure 22 Analogue Technology without Electricity

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Analogue Technology with Electricity

Various technologies are used to write and read analogue data.

Electricity is used to sense and to amplify the movements of the needle in a record player.

Using electromagnetism, it is possible to record sound on magnetic tapes.

Electricity can be used to transmit signals over long distances via wires or via radio waves.

Components

In electronics, various active and passive components are used.

Active components are transistors and operational amplifiers.

Passive components are resistors, capacitors.

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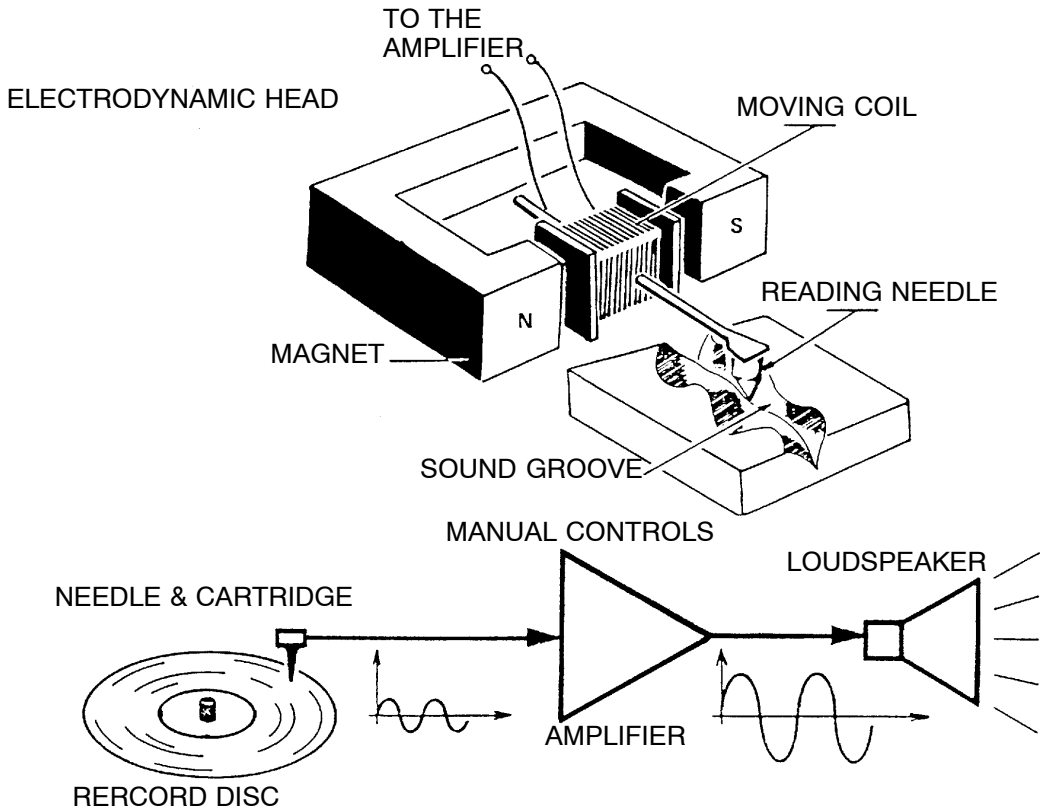

Figure 23 Record Player

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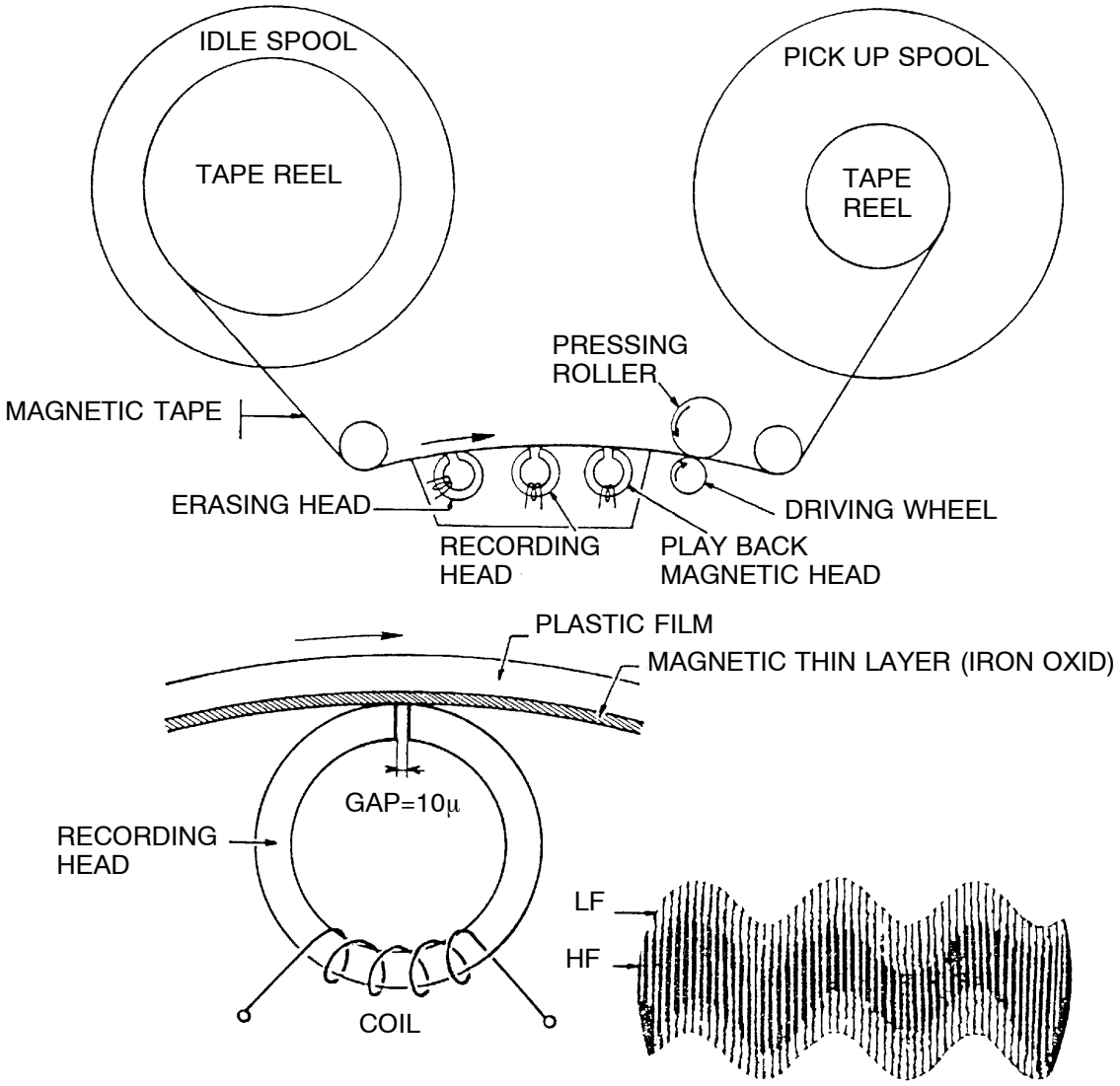

Figure 24 Magnetic Tape

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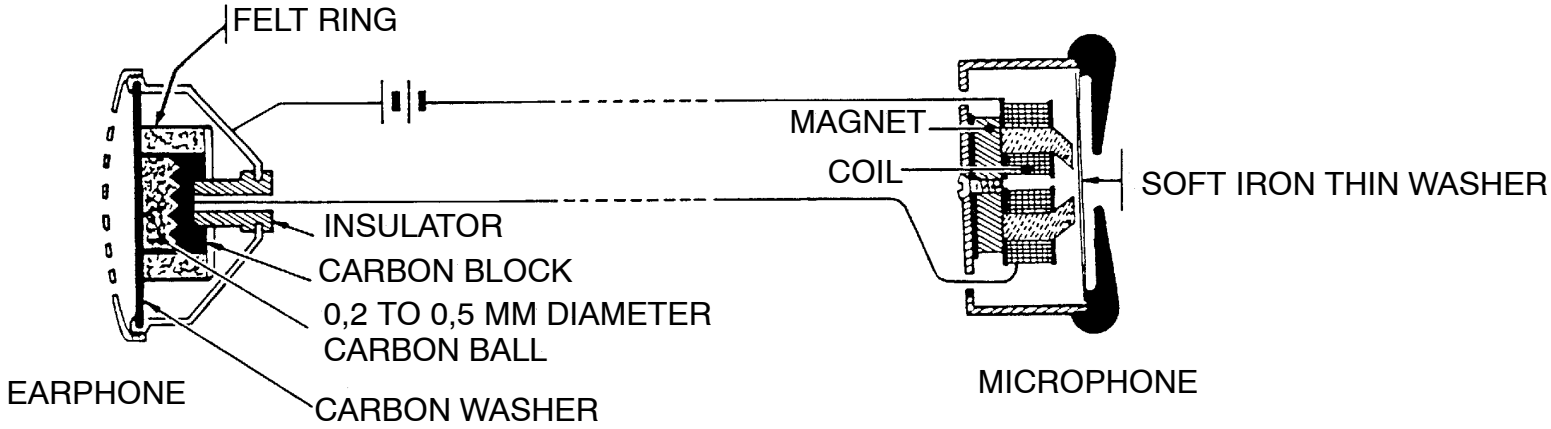

Figure 25 One-Way Telephone

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Signal Transmission

As for analogue signals, electricity can be used to transmit signals over long distances via wires or via radio waves.

Examples

A stereo equipment can give signals to loudspeakers which are some meters away. The signal is transported via wires.

A radio transmitter is used to radio a signal via an antenna. The signal is transported to the antenna via a special wire for high frequencies.

A camera can transport its picture as a signal to a monitor via a special wire.

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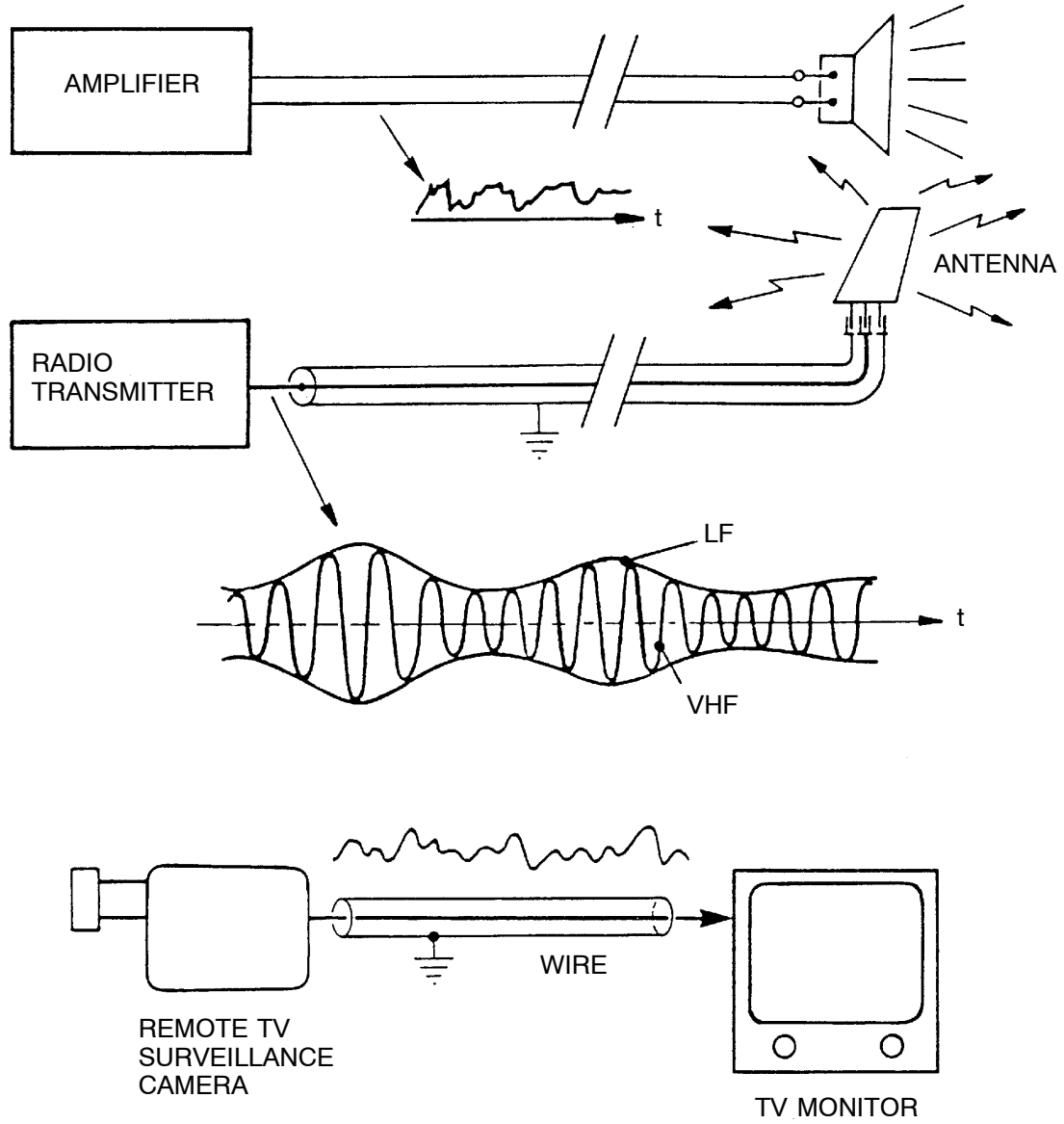

Figure 26 Analogue Signal Transmission

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DIGITAL DATA

General

It is possible to store information in form of digits.

Since logic's work with 0 and 1, only these numbers are used. The binary numbering system also uses 0 and 1 only, so it is used for calculations.

Storage

The bits can be stored in various ways which can be read by machines:

- punched paper in cards or stripes
- magnetic tapes or disks
- optical disks
- electrical circuits with flip-flops.

Handling

All these storage technologies require machines which are able to read the storage format.

Conversion

Whatever shall be stored in digital form must be converted to digital data.

There are two possibilities:

- Sensors are coupled with digital technology
- Analog Data is converted to digital data.

Digital Information

The computation of information which is given in bits can be done with simple electrical circuits since they must handle only two signals.

This allows the construction of integrated circuits.

Binary Signal

Binary signals are signals which have one dedicated binary code for a defined range of values in a given moment.

The number of different signals for the total range of values is limited.

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Punched Paper Tape



Magnetic Tape



Magnetic Disc



Compact Disc
(Optical Disc)

Figure 27 Storage Possibilities for Digital Data

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Computing

An ancestor of modern digital computers is the chinese abacus.

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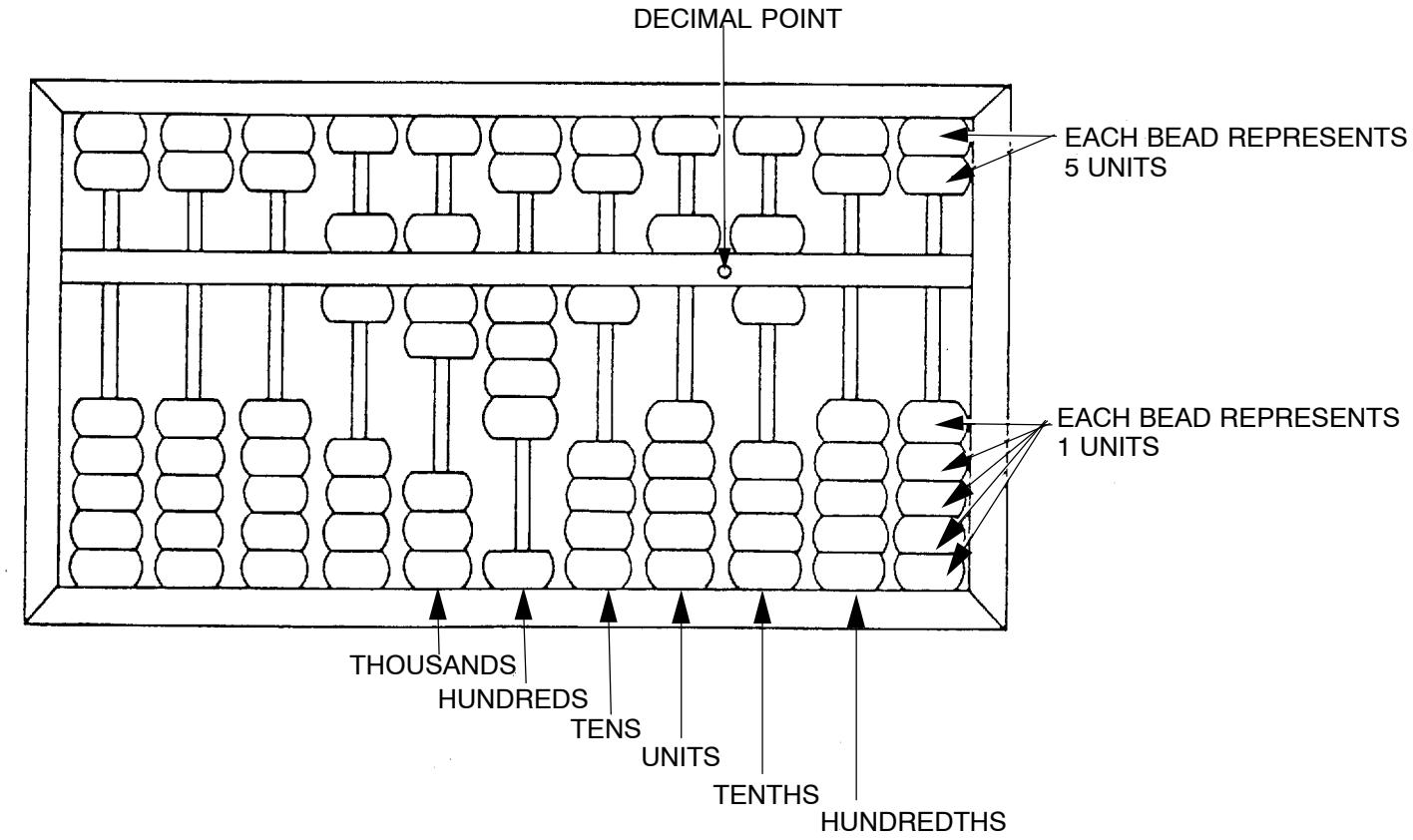

Figure 28 Chinese Abacus

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Signal Transmission

Electricity must be used to transmit signals over long distances via wires or via radio waves.

Example

A camera which is not the latest model works with analog technique but has a digital output. An A/D-converter provides the digital signal.

A cable with at least two leads for data and synchronization is used to transport the signal to the receiving component.

A monitor with a digital input is used. Since analogue technique is needed to control the generation of the picture a D/A-converter must be installed in this monitor.

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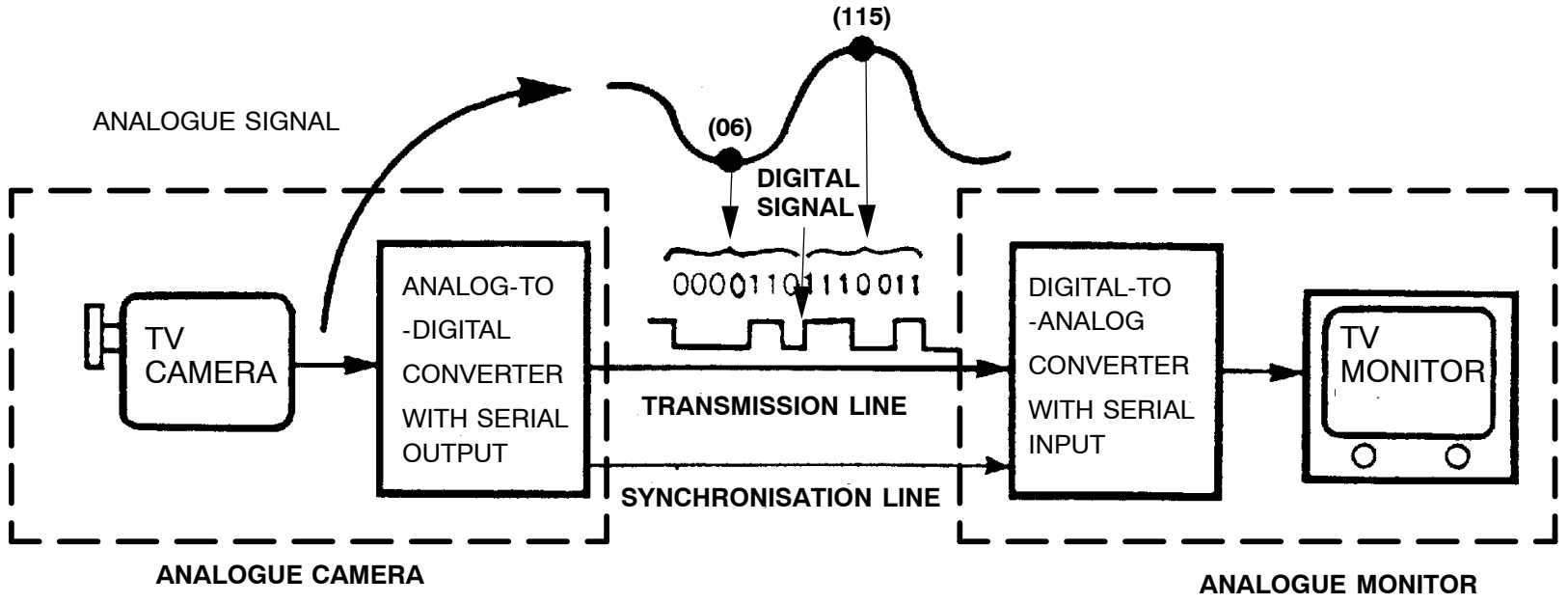

Figure 29 Digital Signal Transmission

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DATA CONVERSION

General

While digital computers process information faster and more efficiently than analog computers they do have somewhat of a disadvantage in that they only understand 1's and 0's.

The real world is analog in nature.

Temperature

Temperature does not change in discrete steps. It is a continuously varying quantity.

In order for digital computers to use temperature information, the analog quantity must be converted to a digital representation of temperature.

Control Surfaces

Aeroplane control surfaces do not move in discrete steps but rather in continuous motion.

A digital computer may be able to determine where a control surface must be positioned, but the signal to the surface must be in analog form to drive the surface.

Converters

The circuits used to interface digital computers to the analog world are referred to as Digital to Analog (or D/A) Converters and Analog to Digital (or A/D) Converters.

Input

The signal which is given to a converter is called input.

The terminals for that signals may also be named input.

Output

The signal which is generated by the converter is called output.

The terminals for that signals may also be named output.

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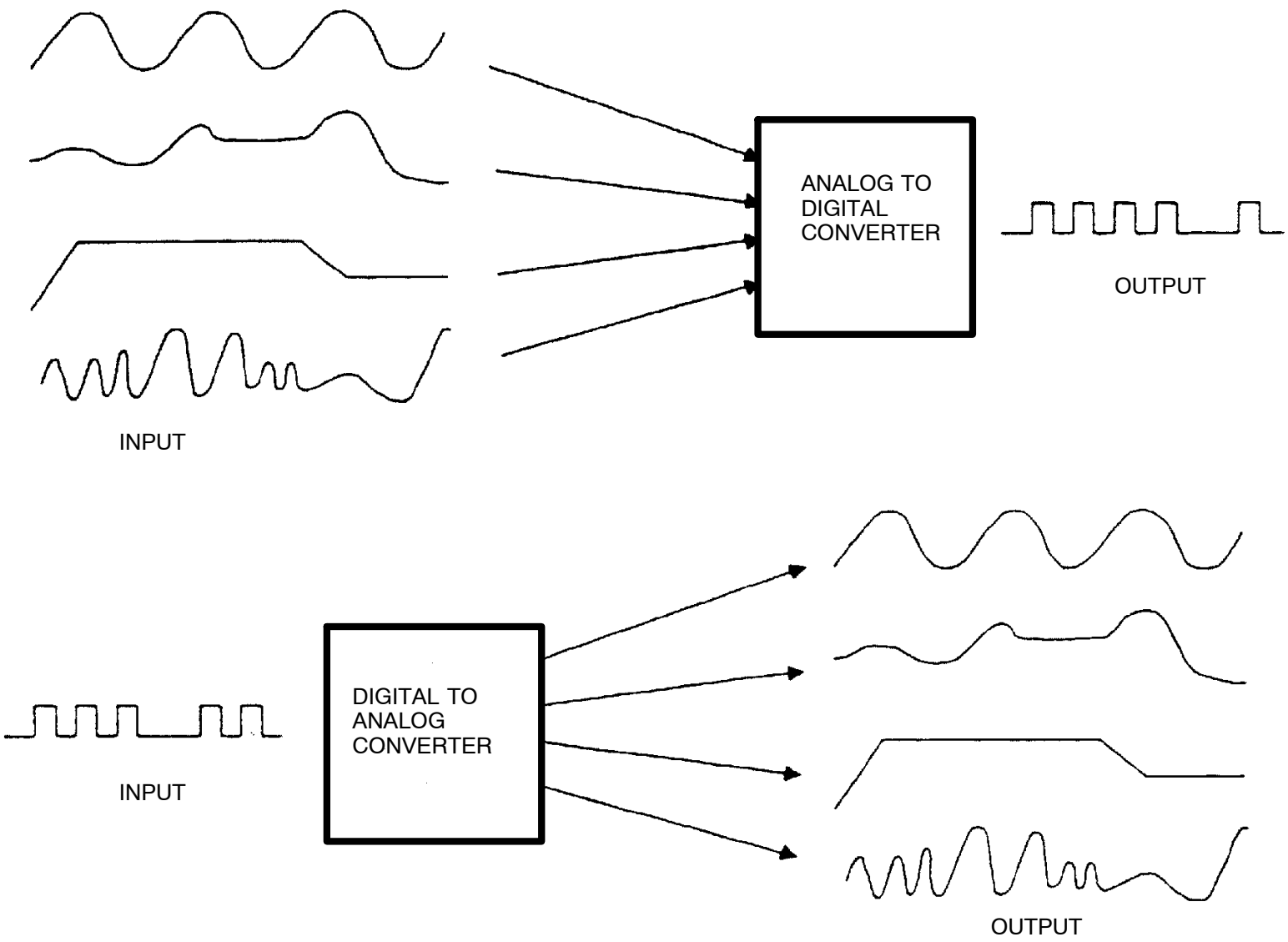

Figure 30 Digital/Analog Conversions

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ANALOG TO DIGITAL CONVERTER

Purpose

Almost all ”real world” applications are analog in nature. Therefore, analog to digital (A/D) converters are quite common in computer systems, and especially in those systems dedicated to monitoring or controlling ”real world” events.

An A/D converter converts a continuous voltage signal, or analog signal into a multi-bit digital word.

Principles

A/D-Conversion may use various principles:

- Sawtooth-principle
- Dual-Slope-principle
- Ramp Generation A/D
- Successive Ramp A/D
- ...

The Sawtooth Principle

The schematics below shows the Sawtooth principle.

The Input voltage U_M to be evaluated will be compared with a sawtooth voltage Uref created inside the converter itself. The time the sawtooth requires to reach the voltage level of the input voltage will be evaluated.

This time will be measured by pulses from the Pules Generator.

The amount of pulses counted is a reference for the input voltage. The Time T from ,,START” (sawtooth voltage is 0) until ,,STOP” (sawtooth voltage Uref = U_M) the gate is open so pulses from the pulse generator can pass it and access the binary counter.

A Buffer stores that binary number and applies it to a data bus activated by a signal on the Control–Bus.

The advantage of that principle is the quite simple arrangement but is usually temperature-sensitive as the pulse generators are not temperature-compensated. They can only be used for slow changing voltages as they are pretty slow, quick changes don’t influence the output result.

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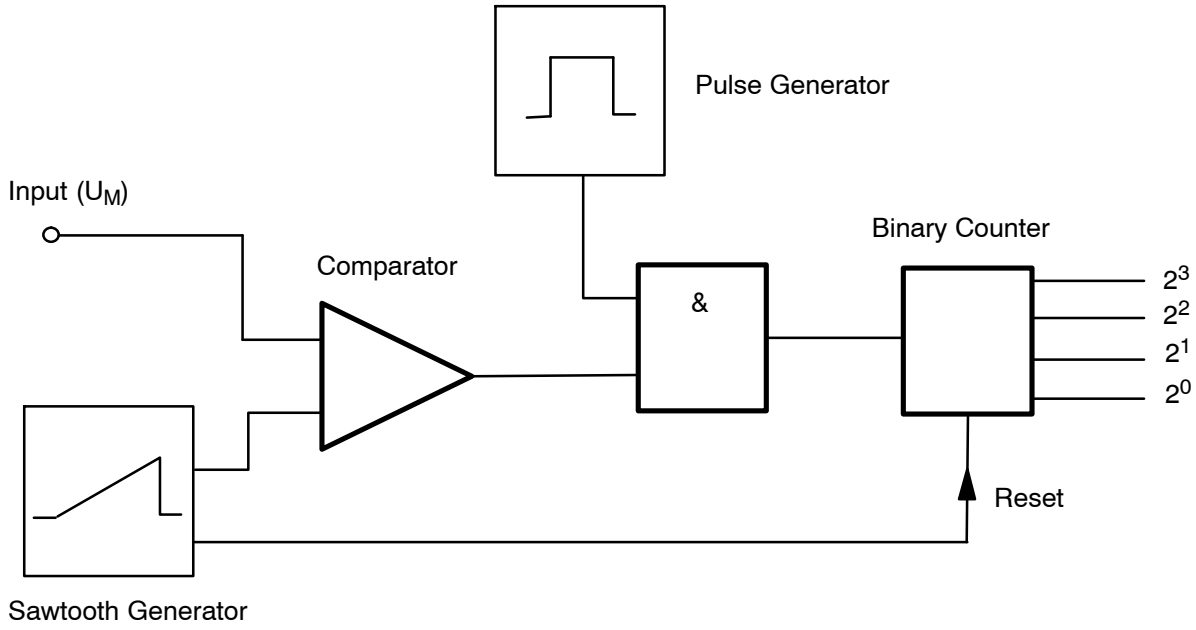

Figure 31 A/D Converter

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How the Sawtooth Principle works

The sawtooth principle uses a sawtooth created by the converter and compares it with the input voltage.

The input voltage must be less or equal to the sawtooth voltage. Higher input voltages can not be converted properly. In case the input voltage is higher always the maximum (in this example: 10 Volts) would be indicated.

The analogue input voltage ① and the sawtooth ② will be applied to an OpAmp acting as a comparator. As long as the sawtooth voltage is less than the input voltage the comparator will provide „1“ (equals 5 Volts) at its output. As soon as the sawtooth voltage reaches the voltage level of the input voltage the output will toggle to „0“ (equals 0 Volts). It will remain in that state for the rest of the sawtooth.

The output voltage from the comparator ③ is applied to an AND gate as well as a clock or pulse created by a pulse generator.

In case the output voltage of the comparator is „1“, the pulses from the pulse generator can pass the AND gate. In case the output voltage from the comparator is „0“ the pulses from the pulse generator will be blocked, they can’t pass the AND gate any more.

The pulses that passed the AND gate ④ are applied to a binary counter which will count them and the count will be applied to its output section.

The binary counter therefore provides a binary number that is proportional to the analogue input voltage.

At the end of each count (sawtooth) the binary counter will be reset and a new count may start.

In order to create a continuous indication on the display the count from the binary counter will be buffered and handed over to the data bus only during the falling flange of the sawtooth (where the output voltage toggles from 10 Volts to 0 Volts).

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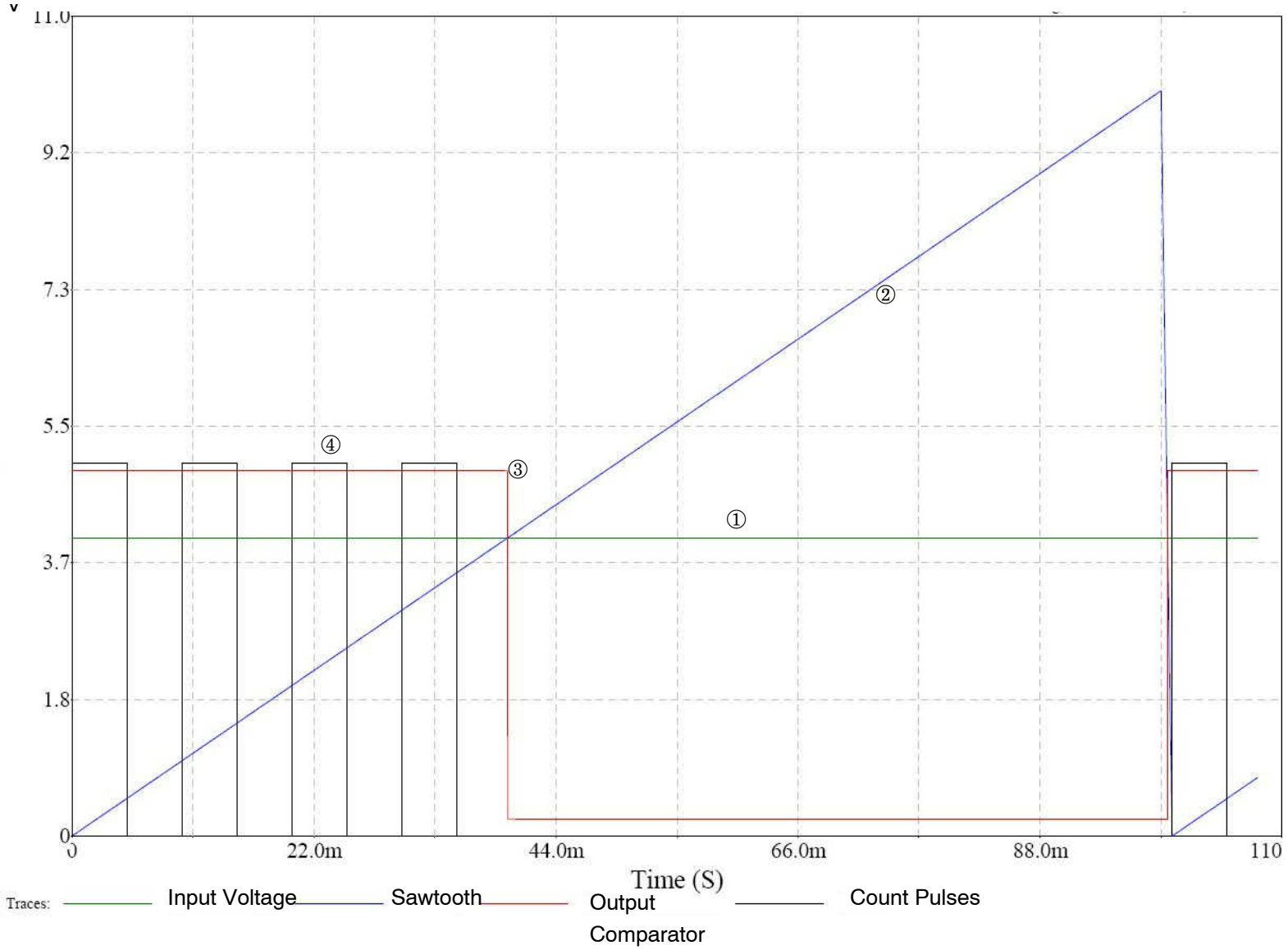

Figure 32 A/D Conversion: Sawtooth Principle

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OPAMS FOR D/A CONVERTER

Purpose

D/A Converters convert binary input information into an analogue output voltage.

Operation

Usually OpAms are used to convert binary numbers into analogue output voltages. The OpAmp will act as an adder. The output voltage of the OpAmp is the sum of the input voltages where every input will have an individual voltage amplification in accordance with its binary value. This amplification is set by the ratio of the resistors on the input side.

The more Bit (switches) the higher the accuracy (resolution) of the output voltage will be.

It is one of the fastest conversion methods but suffers from poor accuracy because of the high precision required for each individual voltage or current. Such high−precision resistors and current sources are expensive, so this type of converter is usually limited to 8−bit resolution or less.

The schematics below indicate the basic principle: Data from a data bus is applied to to a register (buffer) that controls the (electronic) switches.

In case all four bits are „0“ the analogue output voltage will be 0 Volts.

In case only the least significant bit (LSB) is „1“ a voltage will be provided at the output depending on the ratio of R_L over R.

The bit with the next higher significance has a resistor wit half the resistance of the input from the LSB. As the ratio of R_L over R in this case has been doubled the output voltage will be doubled as well.

The resistance of the input resistors will be inverse proportional to the significance of the bits.

Output Voltage

The output voltage will not be really analogue but can be altered in steps depending on the voltage from the LSB.

Example

A binary input 0111 will be converted in an analogue output voltage of 7 Volts.

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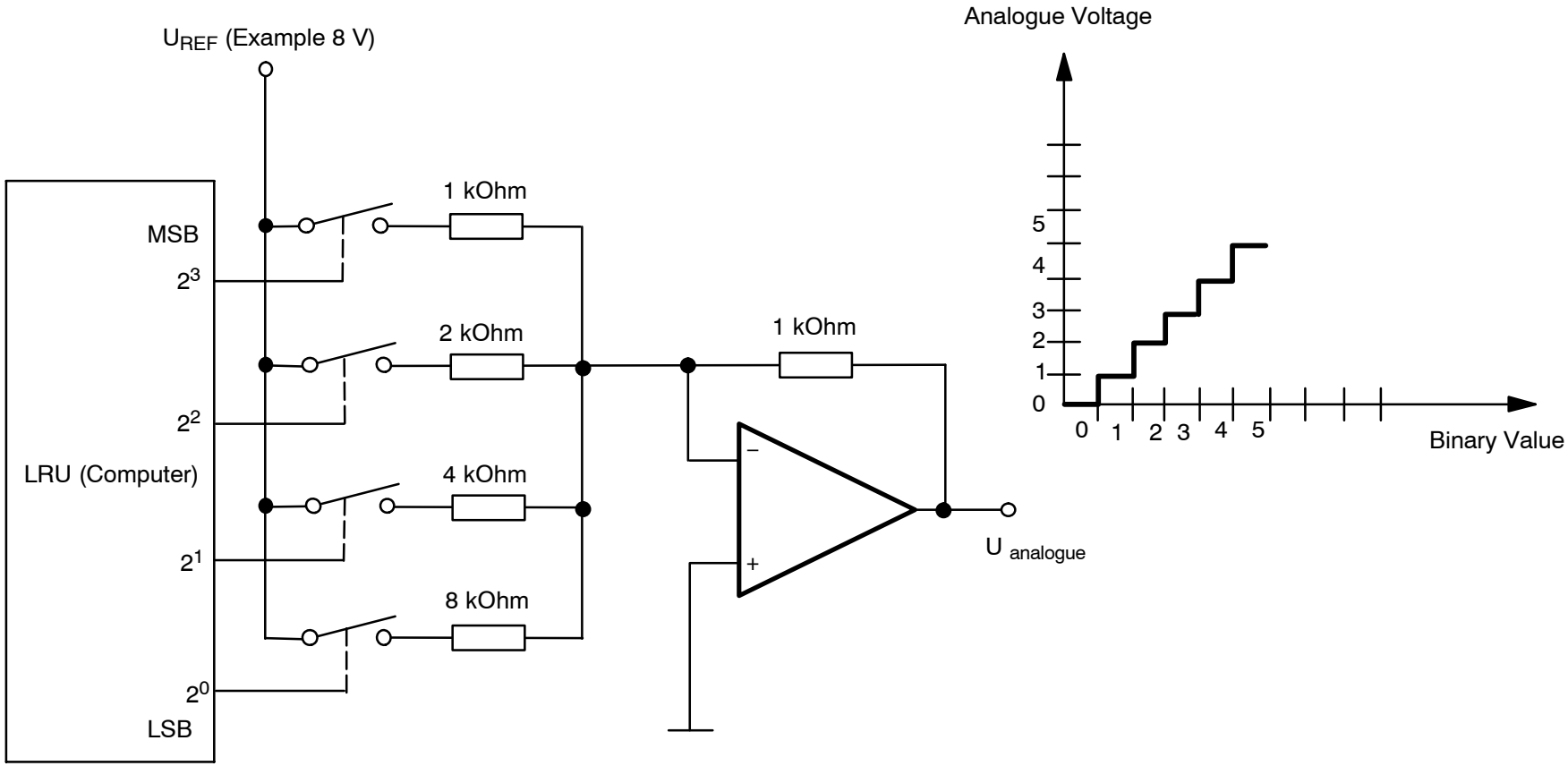

Figure 33 D/A Converter

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COMPARISON BETWEEN ANALOGUE AND DIGITAL TECHNOLOGY

General

Here the advantages and disadvantages of analogue and digital technology are shown.

Analogue Technology

Advantages

- Much information in a period of time
- Processing of information is simple and sometimes cost-effective
- Electronic circuits are well adapted to their task.

Disadvantages

- Difficult long-time storage
- Dynamic is limited
- Drift factors like temperature, environment and age
- Difficult procedures for adjustment.

Digital Technology

Advantages

- Storage is easy to handle
- High stability
- No drift factors
- No procedures for adjustment
- Precise and with higher resolution than analogue technology
- Numerical indication is easy to realize
- Processing of information is faster than working with analogue technology
- Easy to integrate because it needs little space. This reduces weight, power consumption and costs
- Highly reliable
- realization of the system is easy and requires no experimental setup
- large scale for dynamic
- low susceptibility to trouble.

Disadvantages

- In most cases an analogue/digital data conversion is needed
- The information must be updated constantly
- Time must be taken account of.

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Record Player



Computer
"Black Box"



Tape Recorder

Figure 34 Analogue and Digital Machines

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M5.6 BASIC COMPUTER STRUCTURE

INTRODUCTION

General

Automatic data processing deals with processing information without errors. This data could be numbers, letters or even complete sentences.

Processing is done by computers.

Computer

A computer is a machine that processes data by means of digital technologies. All information are reduced to simple Yes/No decisions. Electronic circuits (Hardware) is controlled with specific instructions (Software).

Both, Hardware and Software, form a Computer.

Hardware

Hardware means all devices and components that are required to process binary data in digital systems.

Program

A program is an order of instructions that tells how to process data. This could be logic operations or arithmetic operations as well.

Data could be changed, sorted or decisions could be made. It also controls where (if) information is stored, displayed or printed.

Software

Software is a common word which is used to describe all kinds of programs. This could be an application like Word or a device driver as well.

System Architecture

A computer system requires the computer itself and the devices which send inputs or which receive outputs.

Input

A computer needs to be operated. For this reason a keyboard is used to enter letters and numbers.

Input is also available on memory devices, e.g. compact disks.

Computers can also receive signals and information from other computers.

Output

A computer can give signals or information to a monitor or a printer.

It is also possible to control memory devices. For example, data can be stored on a compact disk.

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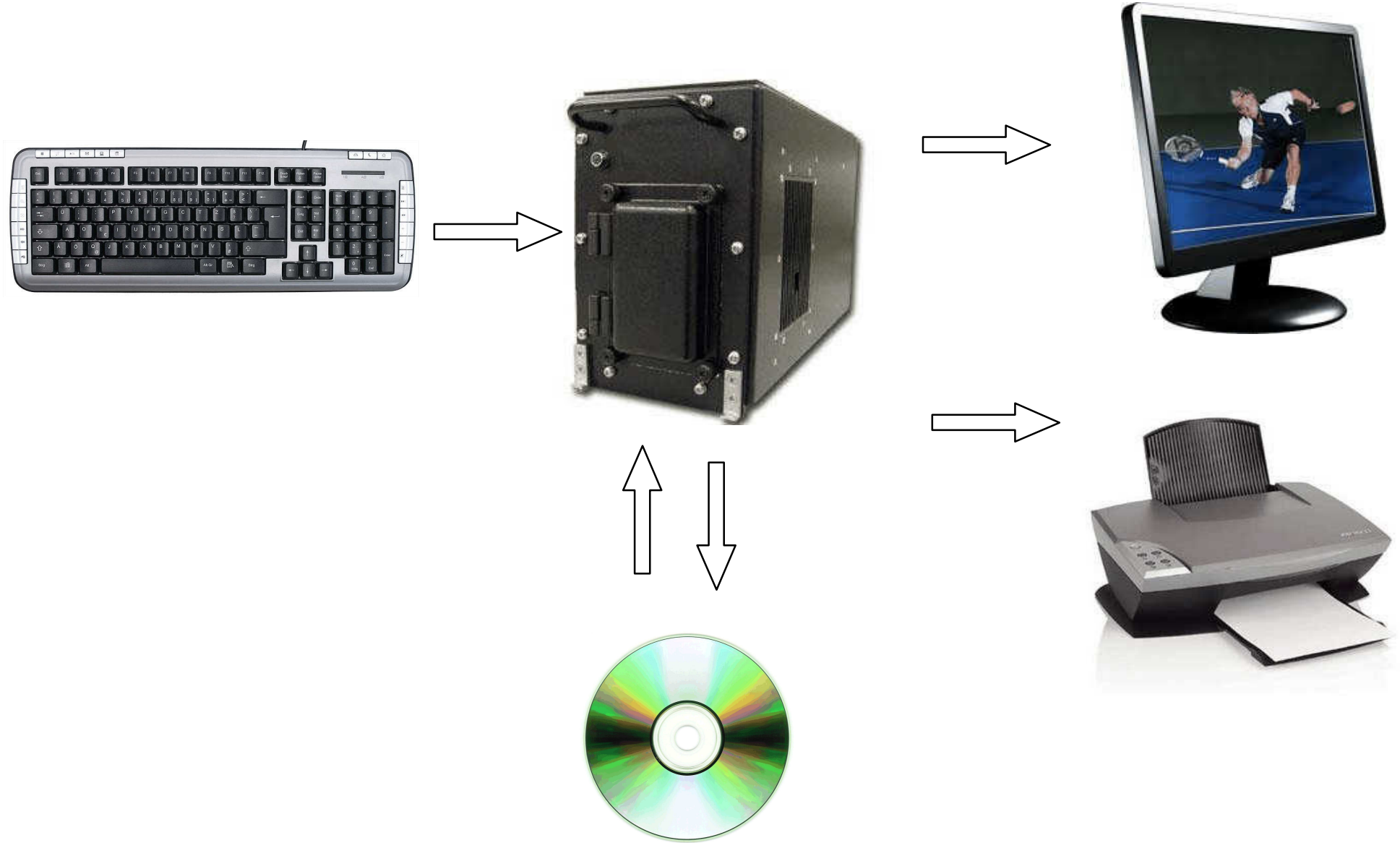

LTT

Figure 35 Basic Computer System Structure

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TERMINOLOGY

CPU

CPU stands for Central Processor Unit. You can call it the operation centre of the computer.

A CPU is an integrated circuit, it is an IC device.

A CPU for example contains various sections:

- the ALU (Arithmetic-Logic Unit) in order to execute calculations,
- register as temporary memory,
- instruction decoder and
- timing/logic control.

IC

Nowadays computer contain a large set of Integrated Circuits, each with a special function.

Integrated Circuits are arrangements of several electronic components in a common housing.

A CPU is one single IC or an assembly of IC's on a common circuit board.

Memory

A computer requires memory to perform calculations. Memory is also required to store software and data.

Memory devices are installed inside the computer, but it is also possible to have additional memory devices in the computer periphery.

Bit

The smallest amount of information that is possible is a Bit. This is just a single „0“ or „1“-Information.

Byte

Usually bits are used in groups. This is what we call Byte.

A byte always consists of eight bits. Since more powerful computers use wider data busses 16, 32 or even more bit are in use.

Examples:

- Nibble 4 Bit
- Byte 8 Bit
- Word 16 Bit
- Double-Word 32 Bit
- Quad Word 64 Bit

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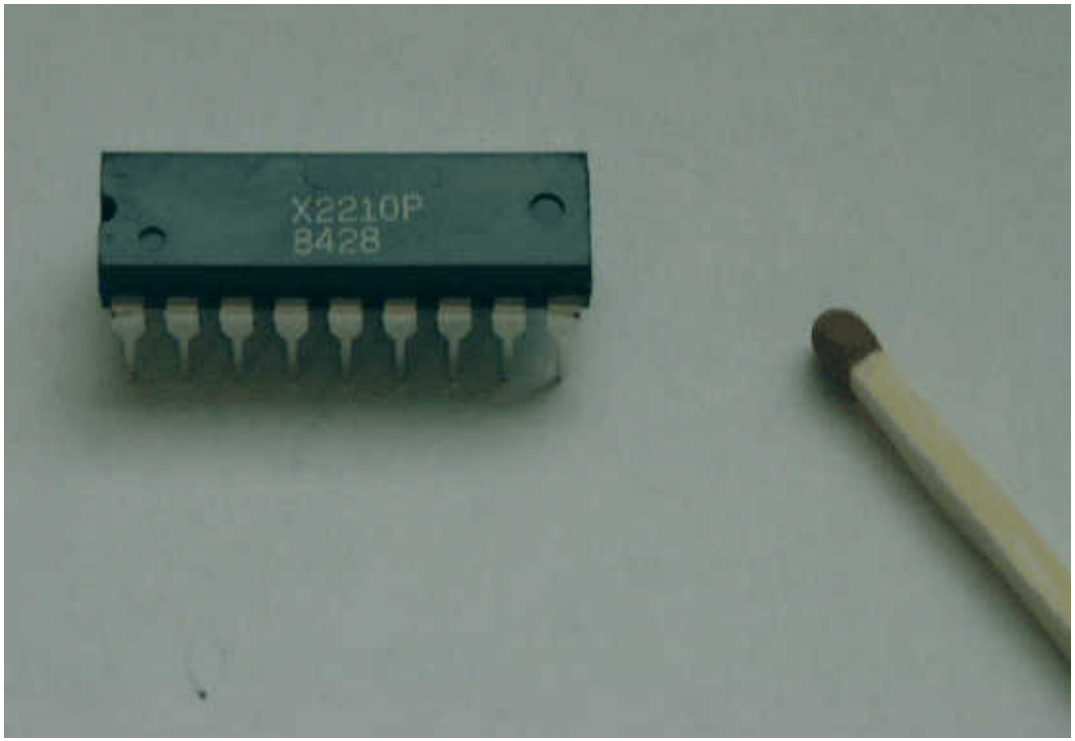
CPU Shapes



IC Shape

Figure 36 Shapes of IC and CPU

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Circuit Board

In the figure below, you can see a circuit board.

Boards like this are used to connect the various components in a computer. However, many computers have more than one circuit board. Then the boards are interconnected by a wiring. This is mainly done by the use of connectors.

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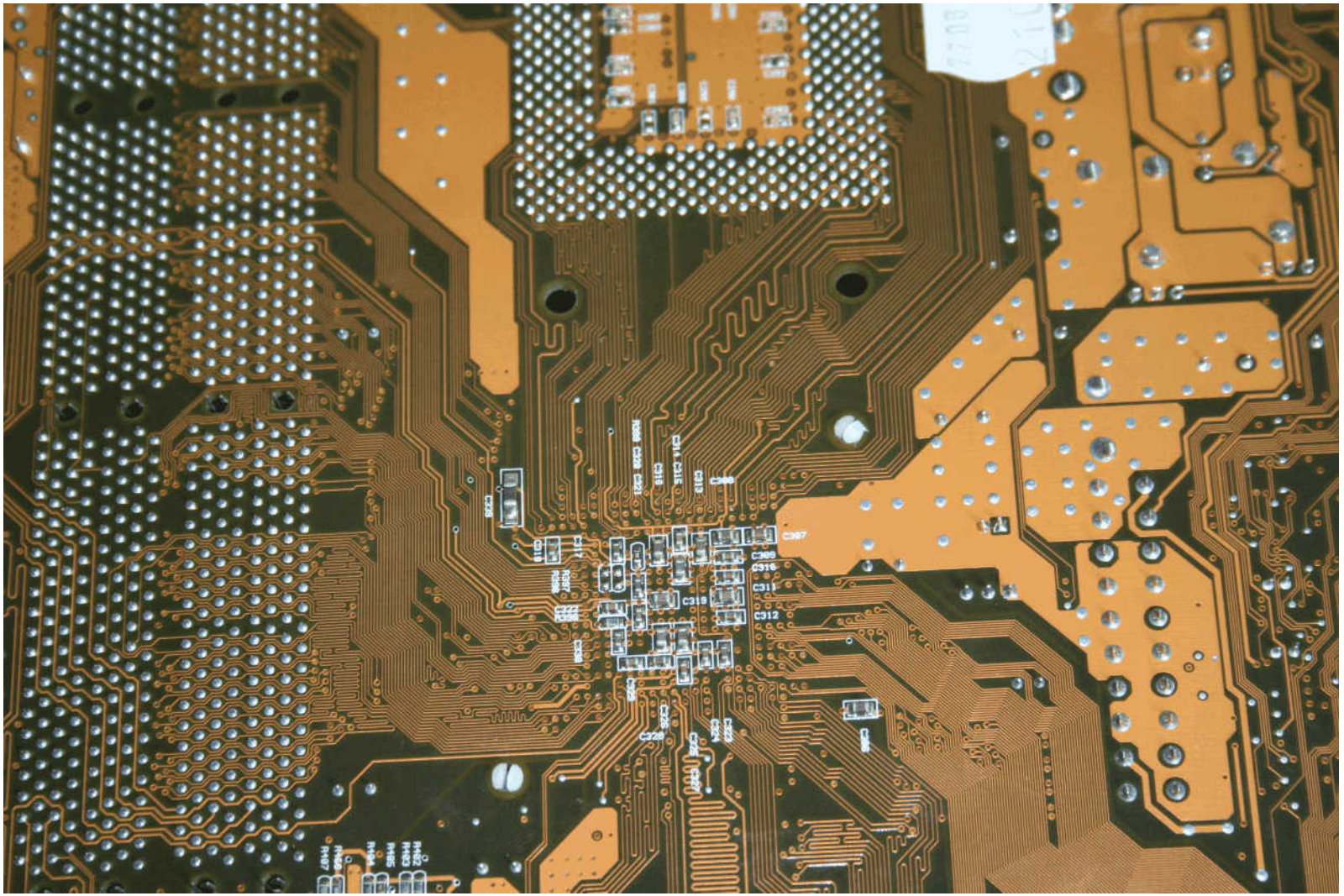

Figure 37 Circuit Board

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MEMORY DEVICES

General

Memories nowadays are high-integrated components that can store many Giga−Bit and have a size of only few square-millimetres. In the top processor of the Intel Core 2 family in 0,032 µm Technologies, 1 billion transistors are installed with approximately 4.000.000 transistors per square-millimetre. The scale of integration of memory devices is quite similar.

Basically Memory consists of a matrix of conducting wires. The lines could be connected by semiconductors. Every crossing of two wires is a memory able to store one Bit.

The semiconductors could be conductive in case a „0“ is stored or non-conductive if a „1“ is stored. Depending on the technology used a memory could consist of diodes or MOS-Transistors.

With specific control circuits (selectors/address decoder) the bits stored could be retrieved one by one or in groups (data words). With two address lines four data words are accessible. Every data word could consist of e.g. four or eight bit (1 Byte).

Every single section of the memory could be accessed directly. This is called random access. In earlier times memory had to be accessed in a sequence until the desired information was found. This is no longer necessary.

With n address lines 2^n addresses could be selected.

NVM

NVM stands for Non-Volatile Memory.

If a computer stores data in a NVM, the data will be stored even when the system has no power.

Types of Memories

During the years, various types of memories were developed, one after the other.

These are

- RAM
- ROM
- PROM
- EPROM
- EEPROM
- EAPROM

Reasons for Failures

Though the memory devices are integrated circuits without any mechanic parts a kind of erosion is possible.

One reason is the cosmic radiation. This is mainly particles from outer space. 89% are protons. As an effect, they ionize some atoms of the memory device. Since the material is doped silicon, there may be effects on the function of the memory. An aircraft in cruise altitude is exposed to the cosmic radiation much more than on ground, and so are the computers which are installed inside.

An other reason is that the memory devices are ageing. Depending on the type of memory, this process can be accelerated by changing the values in the memory elements.

Fault Protection

The Hamming Code is used to detect faults within the memory device. If one bit is faulty, this can be corrected. If more bits are faulty, this can be detected only, but not corrected.

If the Hamming Code is used, parity bits are added to the data word: 7 parity bits for a 32 bit word, 8 parity bits for a 64 bit word.

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Amount of Transistors in CPU over the Years

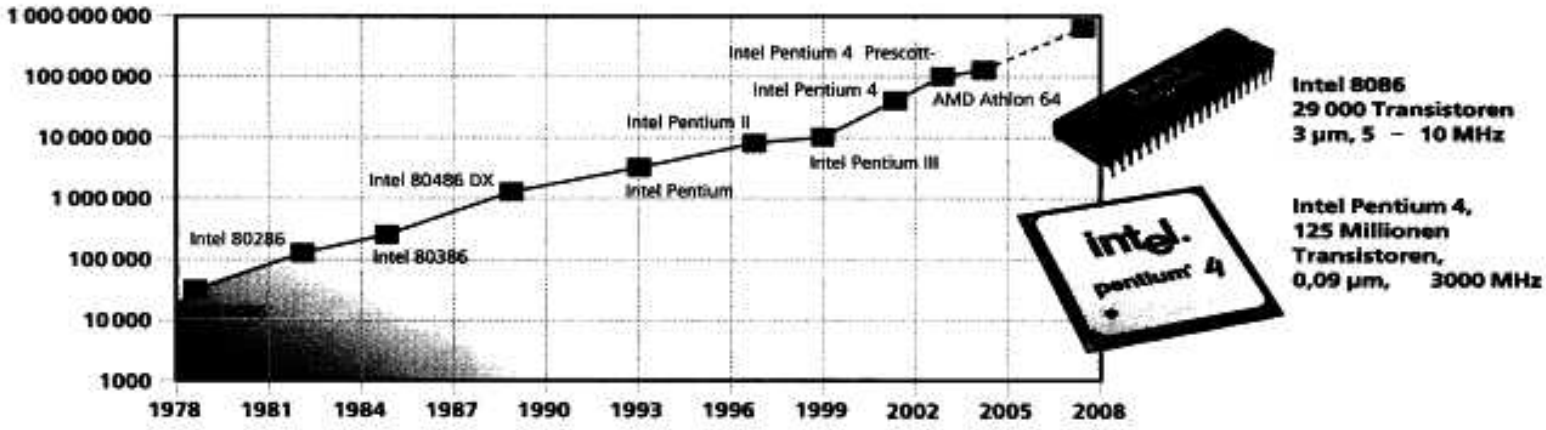

Figure 38 History of Processors

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Capacity of Memory

The smallest amount of information that is possible is a Bit.

Usually bits are used in groups which form bytes. The number of bits depends on the programming language.

The capacity of memory devices is stated in the same format:

Capacity = Amount of addresses x Amount of bit/address

Example: 2048 × 8

This means: The memory has 2048 Addresses. Each address can store 8 Bit.

Usually one can see the letter ”K“ for Kilo. Here K doesn’t mean 1.000 but 1.024 (this is a power of 2).

Example: 256K × 1

This memory has 256 times 1024 addresses. Each address can store 1 Bit.

In aircraft software sometimes is stored on so-called OBRMs. An OBRM (On Board Replaceable Memory) is a memory card that can be replaced without opening the computer case.

RAM

Read / Write-Memory (Random Access Memory, RAM) usually consists of 4 - 6 MOS-Transistors per bit. This memory can store information provided via a bus-system and data can be retrieved as well.

Static RAMs keep the information stored as long as the power supply is not switched off.

Dynamic RAMs have to be refreshed within a few milliseconds by reading the information and writing it back (Refresh cycle). This is because they use very small capacitors that have quite high leakage currents.

The advantage of dynamic RAM is that they are smaller so that their integration scale can be larger than the static ones. But static RAM is faster as it doesn’t need a refresh.

Both types have in common that the information stored is lost as soon as the power supply is switched off. When switching on the power supply the contents of the memory is unknown, the state is accidental.

If a RAM shall be used for a NVM, a small power source is needed to keep the memory. This may be a storage-battery or a capacitor.

ROM

Fixed Memory (Read-Only-Memory, ROM) don’t have the option of writing information into it. Usually they are produced in large amounts. The programming is a part of the production process (Gameboy Software) and can not be changed.

All ROM keep their information even if the power supply is switched off.

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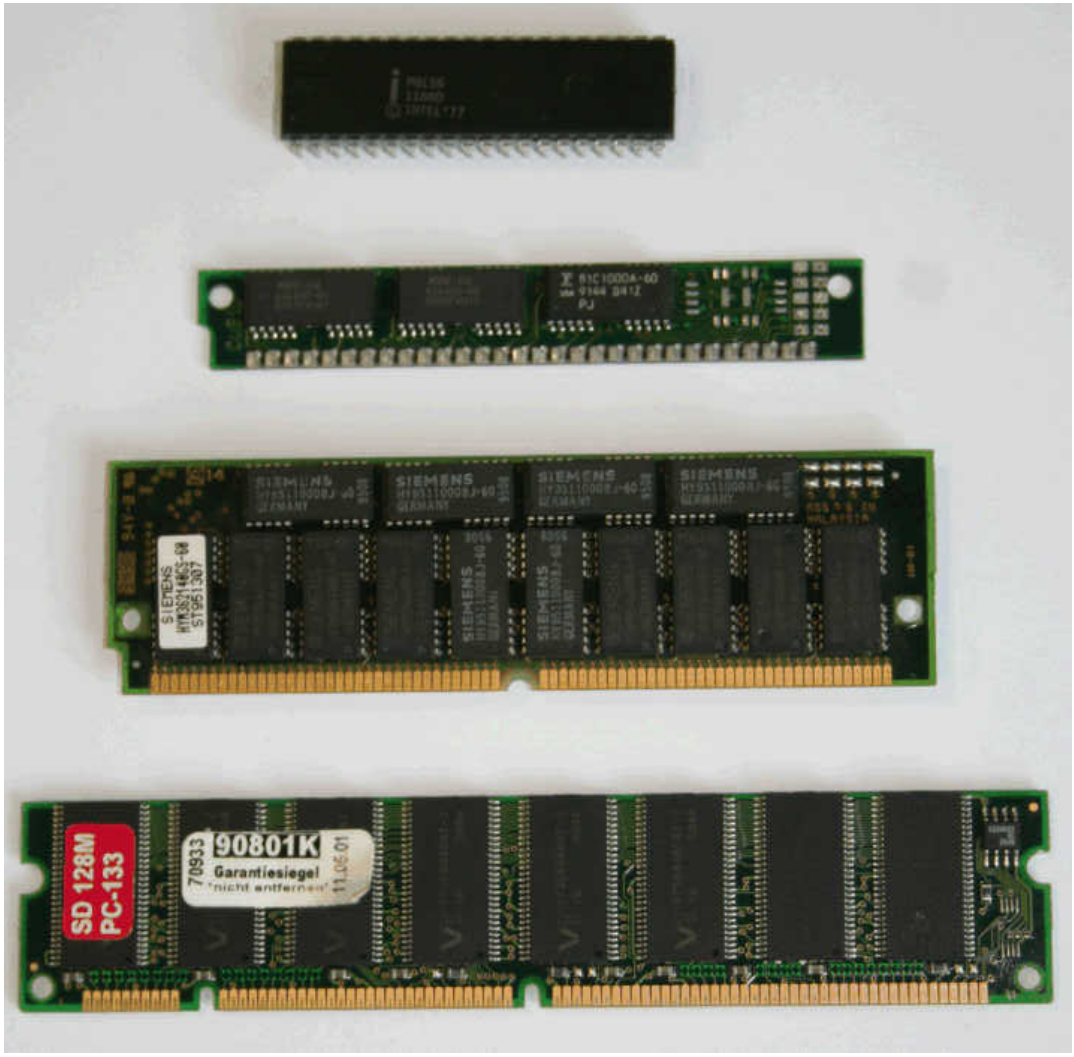

Figure 39 Shapes of Memory Devices

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PROM

Programable ROM (PROM) is programmed by short bursts of current. This will cause a gap in the current paths which then could mean 1 or 0.

They are programmed with a specific device called programmer.

This programming is irreversible! They are used for small series.

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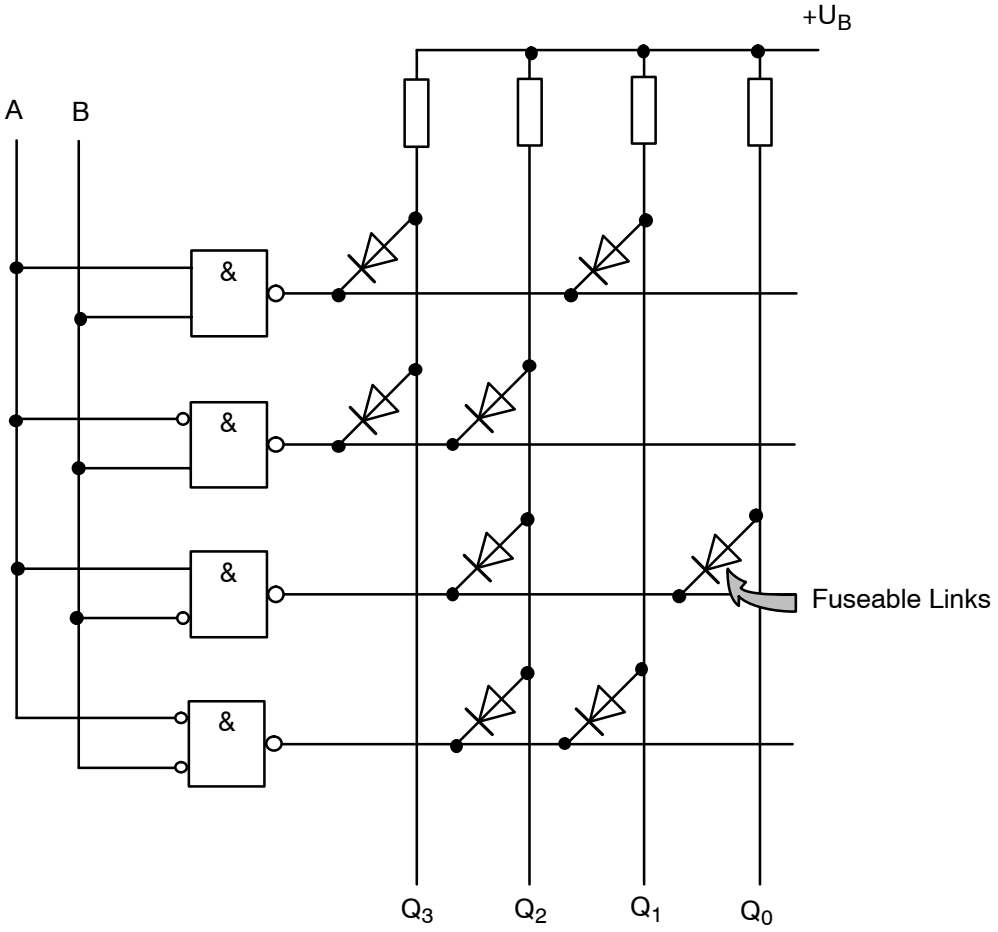

Basic Principle of a PROM

Figure 40 PROM

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EPROM

Erasable and **P**rogramable **ROM** (EPROM) can be programmed with a specific device, a programmer just like PROM.

They have a small transparent „window“. Below lies the silicon memory which is erased when exposed to UV light. As daylight also contains a small amount of UV the window is covered by a label that has to be removed in order to erase the memory.

So EPROM can be erased, the programming is reversible.

Typical application is experimental programming. In aircraft it had been used for software (e.g. FMS) and nav data base.

EEPROM and EAPROM

EEPROM is erasable memory that can be erased electrical and then be reprogrammed (computer BIOS).

EAPROM is erasable memory where information also can be altered. So no erasing is required.

Both, EAPROM and EEPROM, nowadays replace PROM and EPROM because they can be reprogrammed in a running system, no components have to be exchanged, no opening of LRU is required.

Re-writing is possible many times, but not limitless.

With the system de-energized data can be stored some 10 years.

Overview: Types of Memory

Type	Volatile	Programmable
RAM	Yes	YES
ROM	NO	NO
PROM	NO	Once
EPROM (UV-PROM)	NO	Numerous times, but not in system
EEPROM EAPROM	NO	Numerous times in the system

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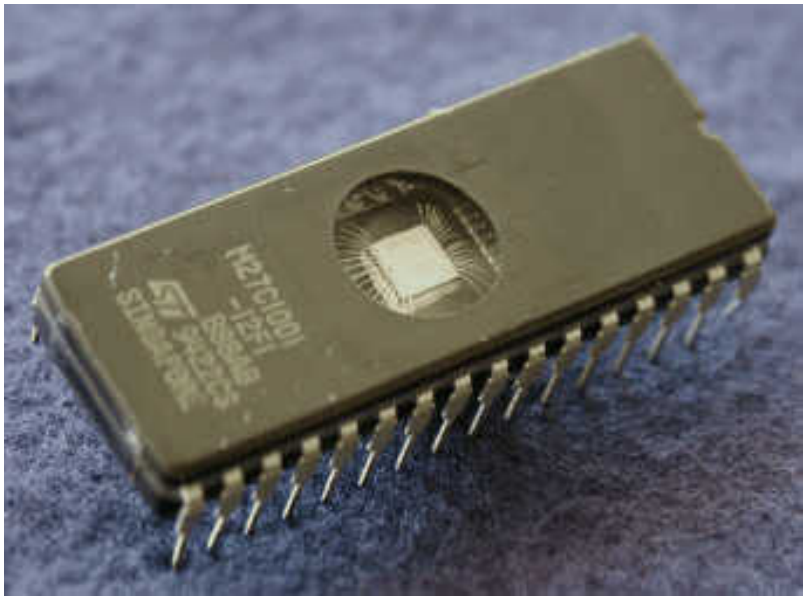
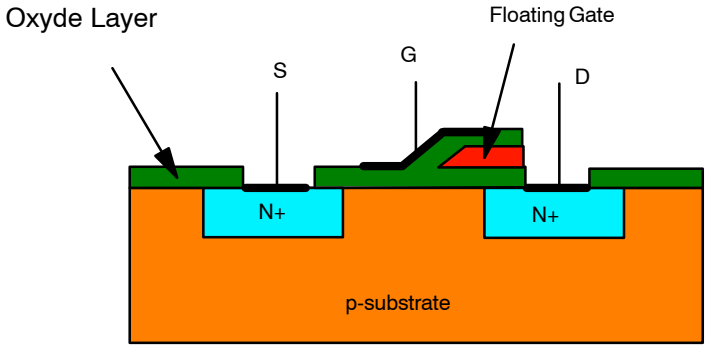


EPROM



EEPROM Principle

Figure 41 EPROM / EEPROM

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ARCHITECTURE

General

As with the purpose of a basic computer, the structure of a basic computer does not vary between computers.

Each computer is comprised of an input section, output section, central processing unit, a memory section and a bus−system.

The differences in the computers are in the characteristics of devices used to make up each section of the computer, and the instruction steps used to control the operation of the computer.

The minimum requirements for computer operation is:

- CPU
- Memory
- Input-/Output Interfaces
- Bus System.

These requirements do not meet our standards for comfort and convenience but they are sufficient for basic functioning.

Some devices could contain several components.

CPU

CPU stands for Central Processor Unit. You can call it the operation centre of the computer.

Memory

A computer requires memory to perform calculations. Memory is also required to store software and data.

Memory devices are installed inside the computer, but it is also possible to have additional memory devices in the computer peripherals.

Input Interface

Signals and data to the computer are received by the input interface.

The CPU decides where these inputs go to.

Output Interface

If any signals or data shall be given out of the computer, the CPU decides where this information comes from. This information is guided to the Output section.

Peripheral devices which receive anything for the computer are connected to the output interface by wires or radio technology.

Clock

The clock is a beat generator. Since all components in a computer work step by step, the steps must be synchronized by a beat signal.

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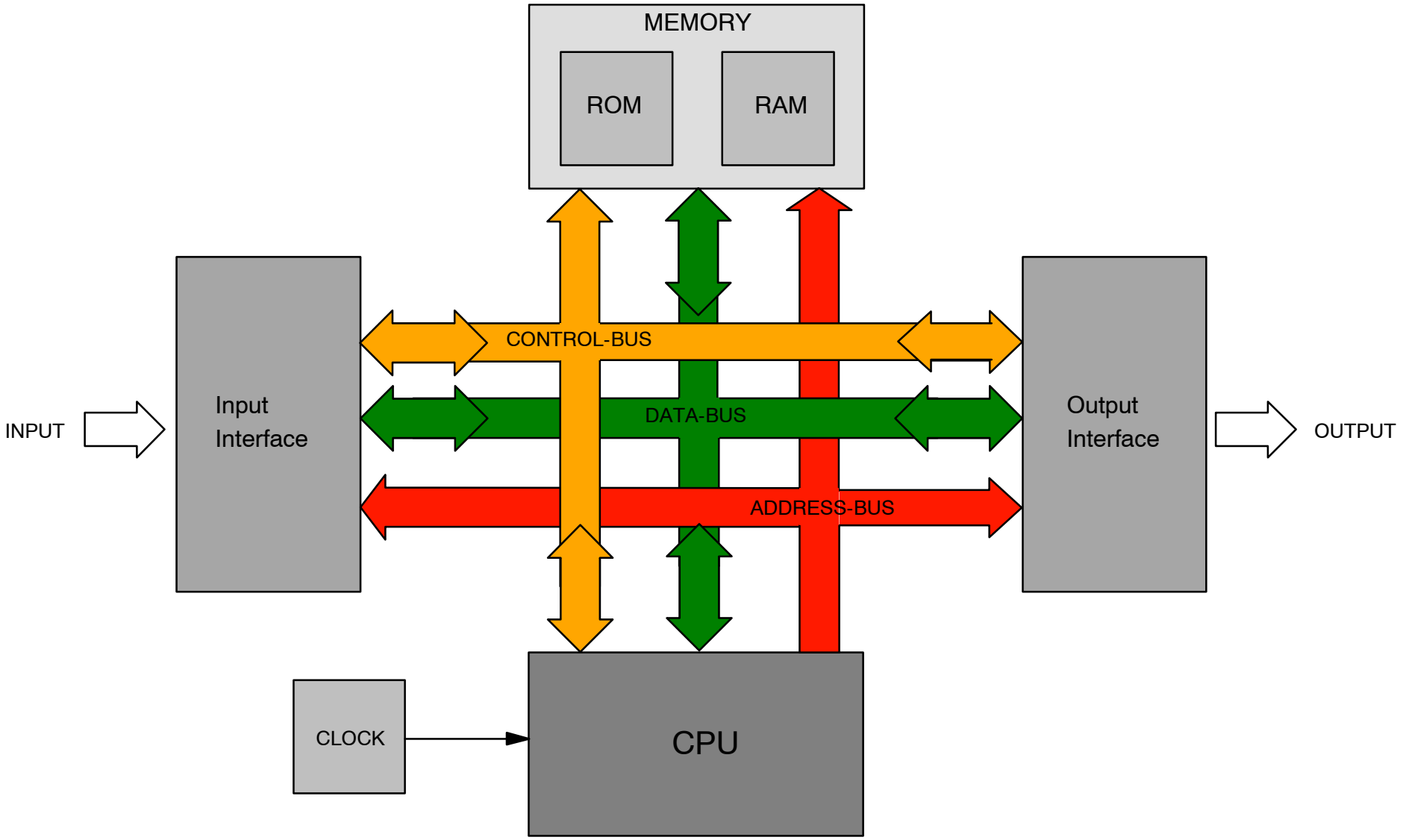

Figure 42 Computer Architecture

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COMPUTER TECHNOLOGY IN AIRCRAFT SYSTEMS

General

Although computers can be classified by hardware as analog, digital, or hybrid, they are more often classified by their tasks or application.

Analogue computer use analogue voltages only.

A hybrid computer calculates as a digital computer, but its outputs are available in analogue and digital form.

Digital computer can only handle digital data, they sometimes require ADM (Air Data Modules) which are close to the sensor and convert analogue voltages into digital data.

Mainly people are interested in the application of the computer but not in the techniques used.

Air Data Computer

The Air Data Computer System measures static pressure, total pressure and air temperature.

The central component is the Air Data Computer.

With the input data it calculates altitude, airspeed and Mach number.

The sensors for the input are

- Pitot Probe
- Static Port
- Temperature Probe.

The output is used by air data indicators and computers of various other aircraft systems.

A/D Converter

In the system shown below the sensors provide analogue signals to the computer. Therefore, A/D converters are used in the input section of the computer.

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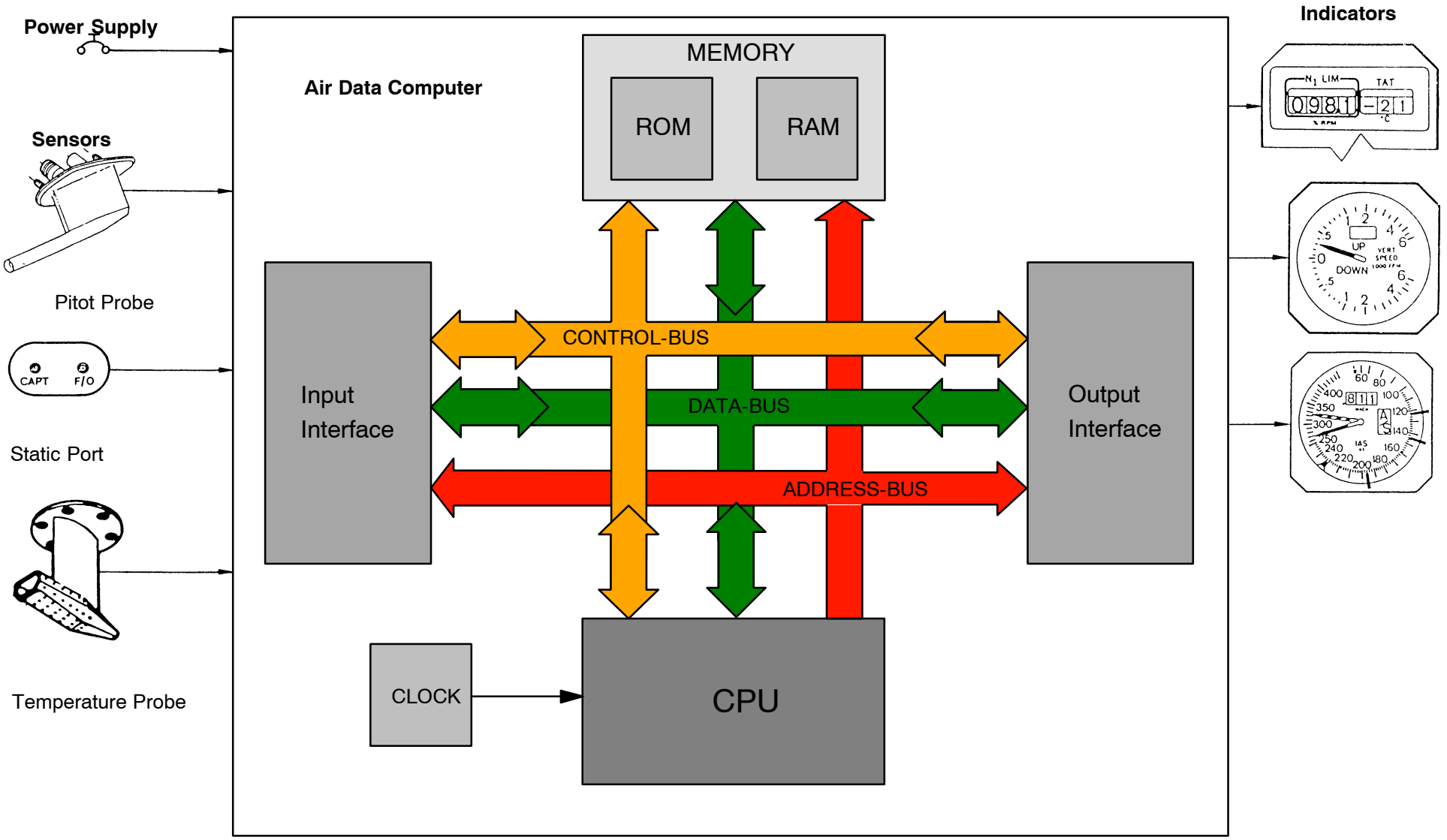

Figure 43 Air Data System

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Reference Computer

A computer which may be used for a source of information or data can be called a reference computer. Reference signals from this computer may be self–contained and only provides outputs.

An Inertial Reference System (IRS) is one example of a reference computer. This system is a laser gyro and accelerometer based reference system used to generate such outputs as airplane attitude, heading, acceleration and angular information. Other than for initialization purposes, the IRS needs no inputs to perform its task.

Some of the units utilizing this information as a reference are the Autothrottle Computer, the flight Control Computers, the pilot's Horizontal Situation Indicators and the Flight Management Computer.

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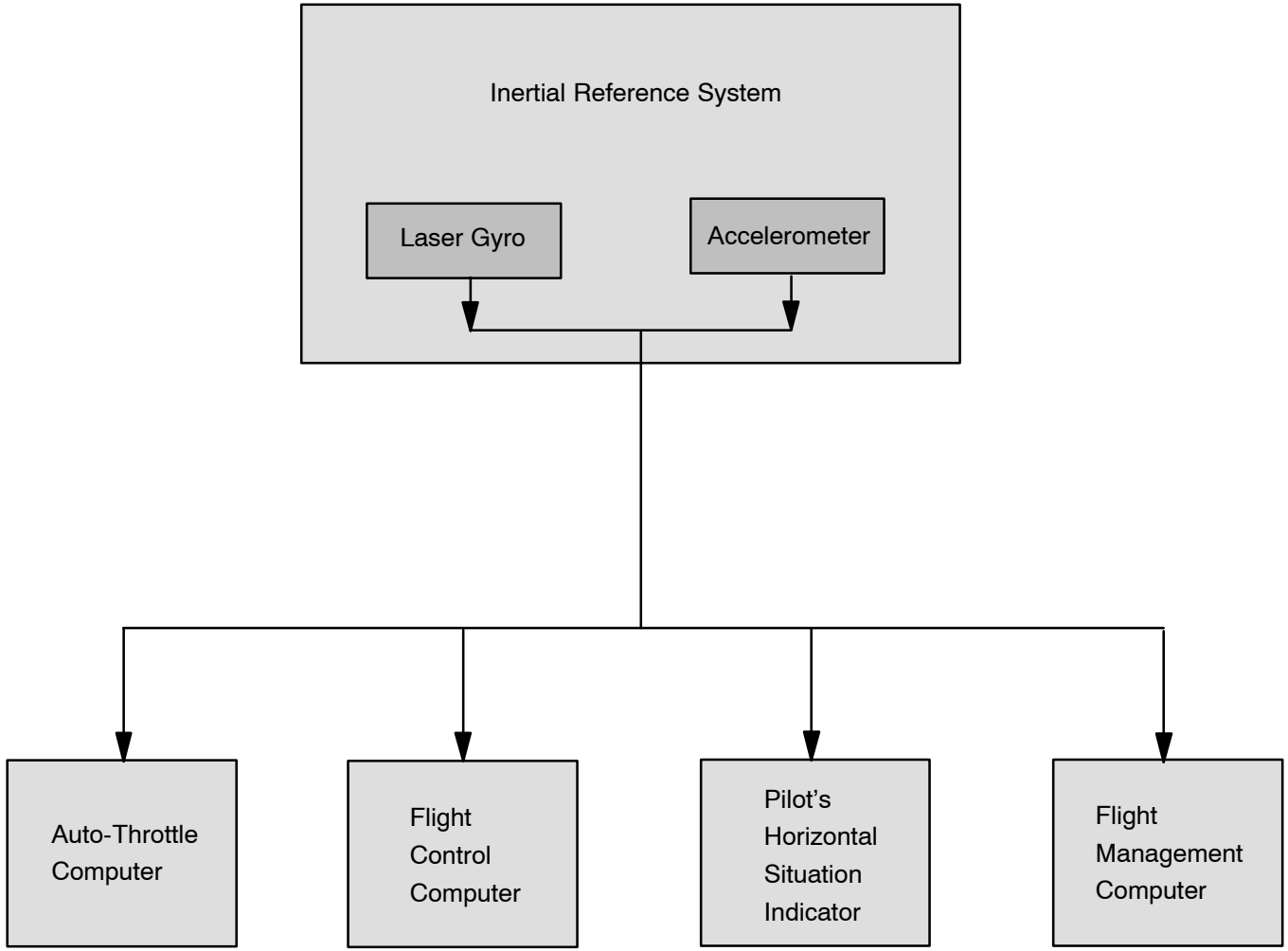

Figure 44 Reference Computers

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Informational Computers

A computer that collects data from various places, processes it, and formats it for display can be called an informational computer.

The main task of an informational computer is to collect data and display it in a central place.

During the different phases of a flight, from power up through touchdown, the flight crew is often in need of information concerning a certain airplane system. Information needed may include

- total air temperature,
- engine oil levels,
- hydraulic pressures, and
- engine vibration levels.

On the ground, the maintenance personnel often need to recall certain events that occurred during the flight, such as

- out of normal parameters on an engine (overspeed), or
- Auxiliary Power Unit voltage information.

ECAM/EICAS

An ECAM/EICAS is one type of informational computer. The flight crew has various types of information available to them before, during and after a flight. Parameters used to set and monitor engine thrust are displayed on a cathode ray tube (CRT) full time and the remaining engine parameters may be selected for display by the crew.

Maintenance information can be displayed when required by maintenance personnel.

Airplane configuration, equipment cooling and status, electrical / hydraulic parameters, performance data and engine exceedance are some of the types of maintenance information available.

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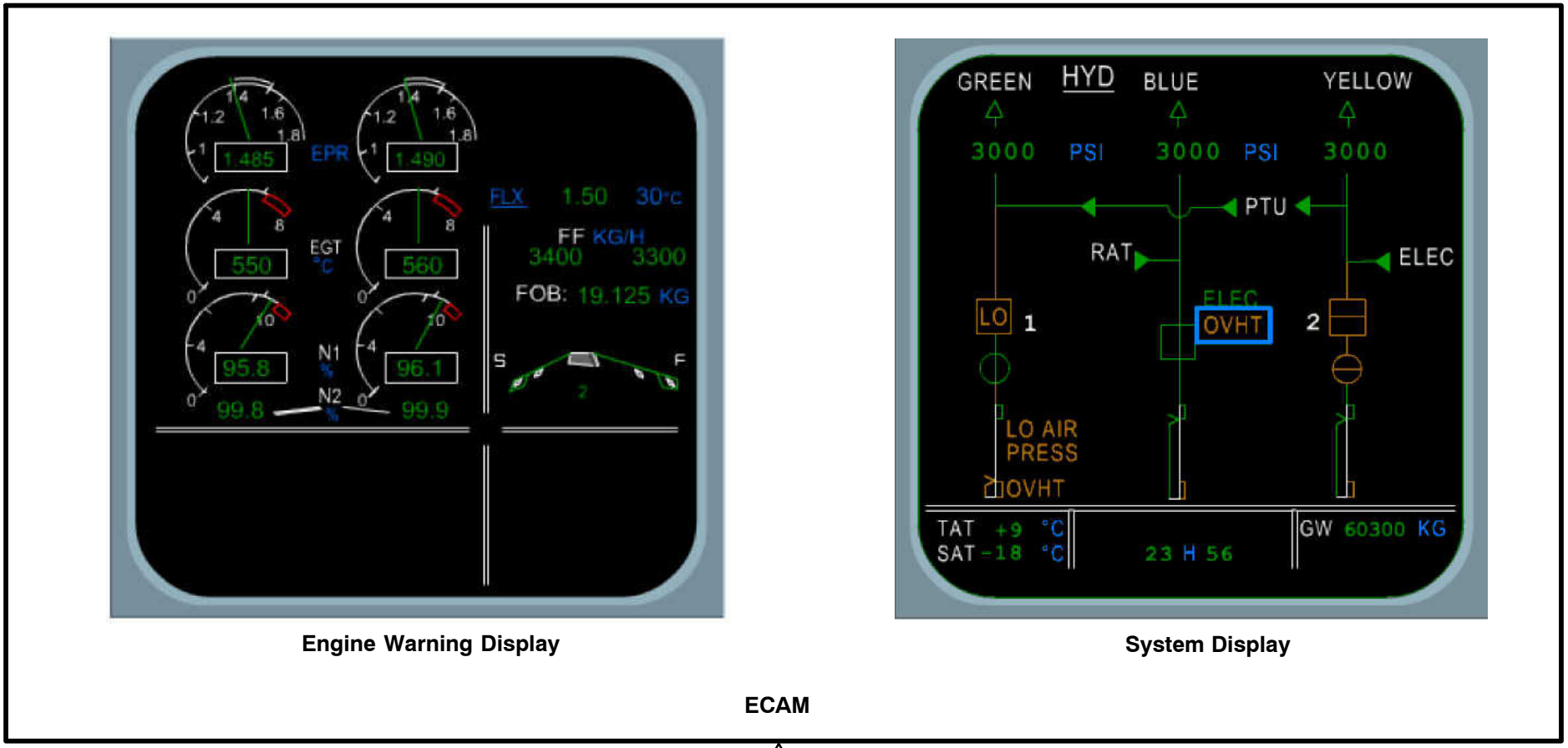

Engine Warning Display

System Display

ECAM

AIRPLANE SYSTEMS AND SENSORS

B757 AMM 31-41-00

Figure 45 Informational Computers

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Storage/Monitor Computers

Storage/monitor computers retain information provided to them by other systems, by other computers or by monitoring other systems or sections of the storage/ monitor computer unit. The information stored may be used by other computers, by the flight crew or by the maintenance crew. Typically storage/monitor computers do very little signal processing. Their main task is to monitor and store data for later retrieval.

An Electronic Engine Control Monitor (EECM) is a type of storage computer which stores fault data from the Electronic Engine Control (EEC) system. When an abnormality occurs on an engine during flight, the data pertaining to that fault is stored within the EECM. When the EEC systems indicate a failure has occurred, the maintenance personnel can recall the faults from the EECM to determine what maintenance action needs to be completed.

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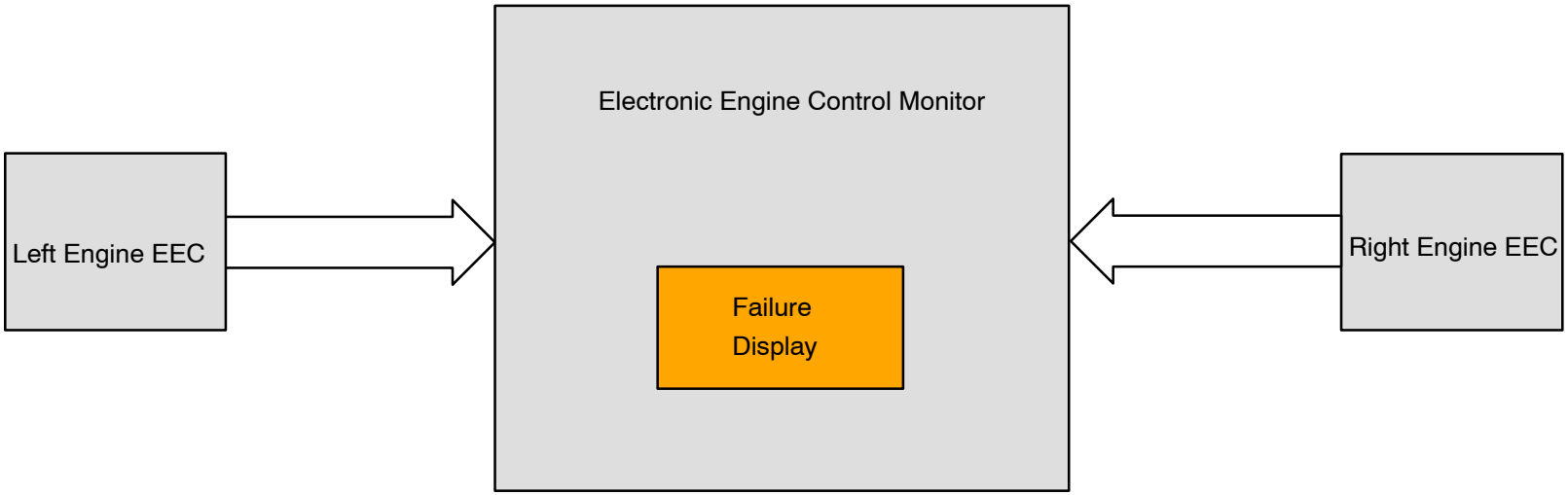

Figure 46 Storage/Monitor Computers

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Controlling Computers

A computer with the primary task of controlling something can be called a controlling computer or controller. this is one of the largest categories of computers. In industry today nearly anything that can be controlled can be controlled by a computer. Computerized controllers range from simple temperature controllers to entire systems for controlling a complete factory.

Aeroplanes have a myriad of systems, surfaces, and devices needing control during operation, both in the air and on the ground. It is impractical to have the flight crew manually control all of the necessary systems, so computers are used to lighten the crew's workload by providing automatic control.

The Flap/Slat Electronic Unit (FSEU) computer provides a means to monitor the flap lever position and to control the flap position on the wings. The FSEU can control the flaps automatically during take–off and landing by utilizing information from other systems such as the Flap / Slat position Module, the Proximity Switch Electronics Unit, and Flap Lever.

If the flight crew selects to extend the flaps at an unsafe air speed, the FSEU will monitor the air speed and control the flap extension when airspeed is within allowable parameters.

FCC

The Flight Control Computer (FCC) is a "controlling computer".

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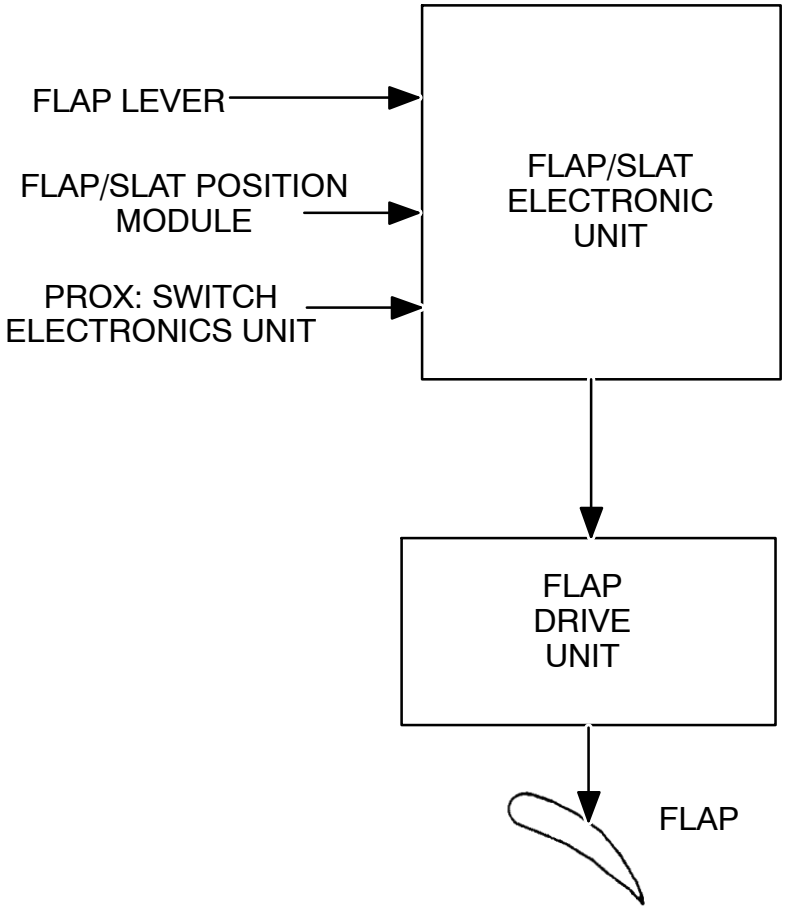

Figure 47 Controlling Computers

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Flight Control Computer

The figure below shows a Flight Control Computer (FCC) of a Boeing B757.

On the left side you can see various inputs to the computer. They are connected to the receiver of an Input/Output Interface (I/O).

On the right side you can see some outputs. These include analog signals to Autopilot Control Servos. Control Servos give inputs to the actuation of rudders like elevators, ailerons or rudder.

In the “Computation“ section of the FCC you can see

- Processor (This is the CPU)
- Memory

Right of the “Computation“-section you can see the

- Input-/Output Interfaces

Computation section and Input/Output Interface are connected via the

- Bus-System

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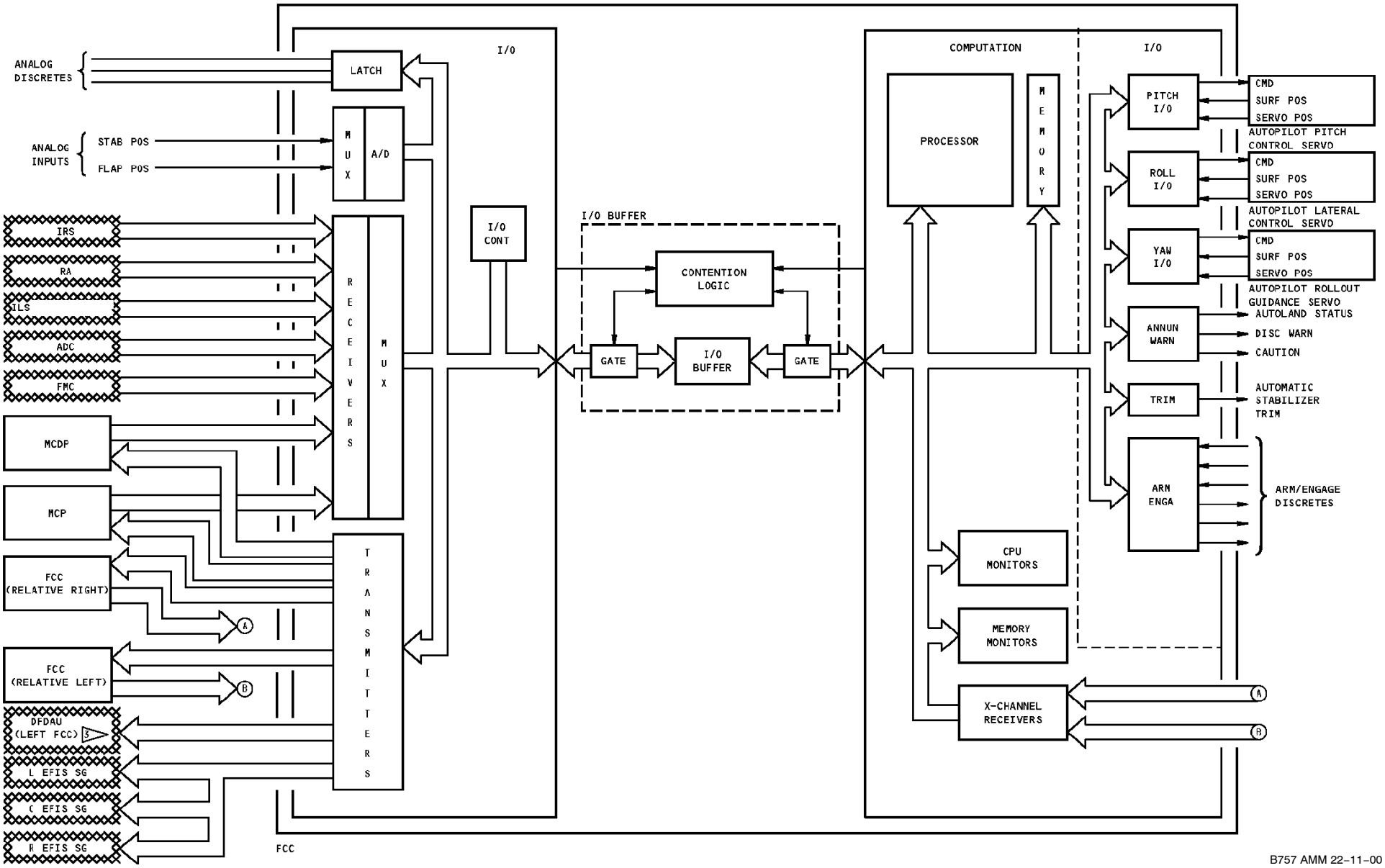

Figure 48 Flight Control Computer

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Interactive Computers

Some computers can perform several different tasks depending on operator inputs. Such a computer is called an interactive computer. Interactive computers typically display information to the operator and then manipulate the data based on the interaction between the operator and the computer.

The Flight Management Computer (FMC) is an example of an interactive computer. The flight crew interfaces with the computer by means of the

Control Display Unit (CDU) to input performance data, initialization data and route structure.

The computer calculates optimum cost profiles for climb, cruise and descent used by the autopilot and autothrottle for automatic flight control. All computed values are also automatically displayed allowing the crew to fly an optimum profile if using manual control.

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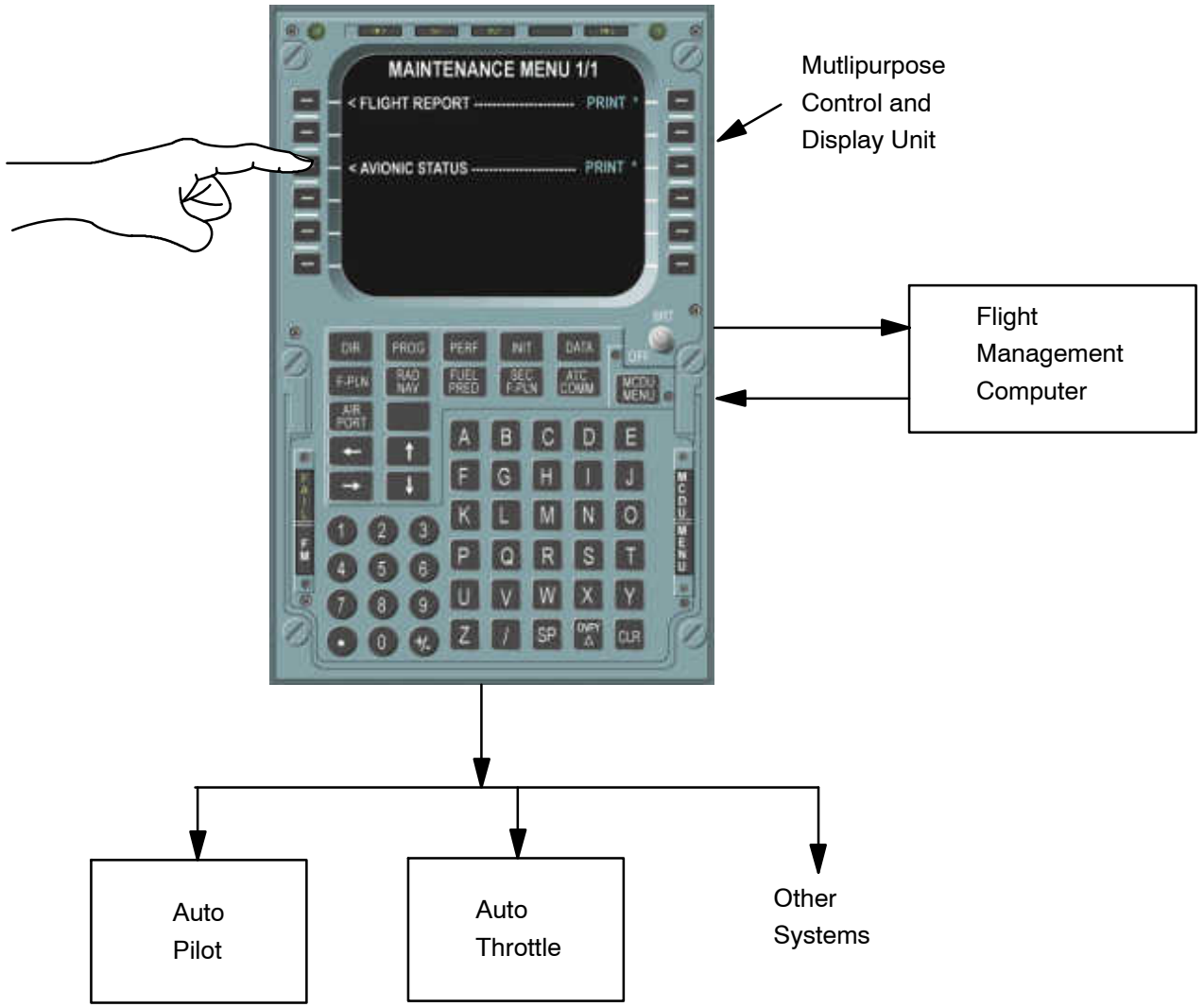

Figure 49 Interactive Computers

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Aircraft Digital Systems – Summary

Aeroplanes typically have many computers to control, monitor, provide references, and make available information. These computers can be either analog, digital or hybrid. It can also be noted that computers are typically different combinations of the five types of computers as categorized by application.

Those are interactive, reference, storage / monitor, controlling, and information computers.

As in the example of the interactive computer, the flight management computer is also used as a control computer by controlling the autopilot and other systems. It can be an Informational computer by providing the flight crew with route Information.

The flight management computer also acts as a storage computer by storing information to be used by other airplane systems. It also acts as a storage / monitor computer, in that it monitors many of its inputs and stores this information for further reference. Computer types and applications are as varied as their tasks.

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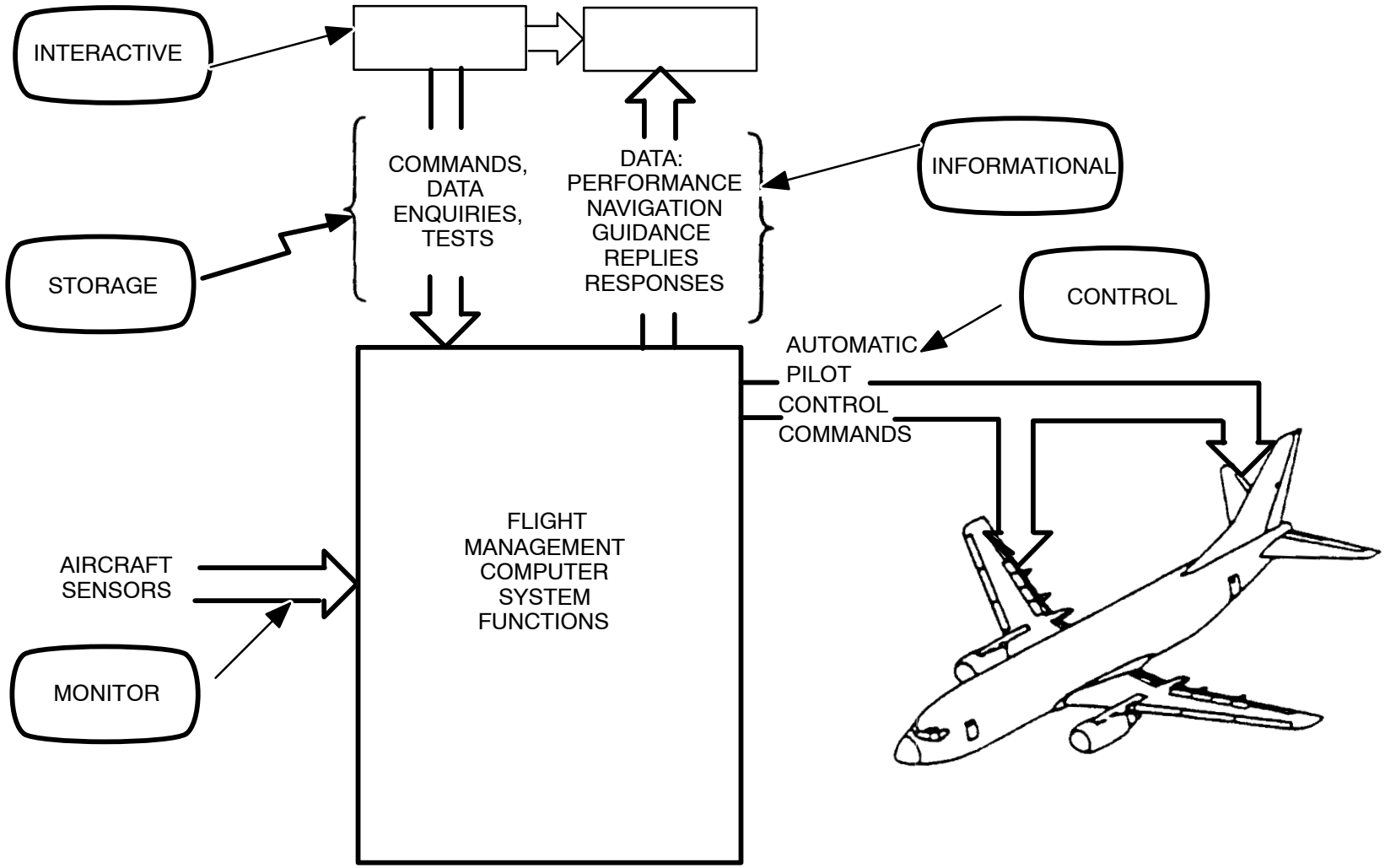

Figure 50 Airplane Digital Systems

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M5.13 SOFTWARE MANAGEMENT CONTROL

INTRODUCTION

Hardware Specification

Each digital LRU (Line Replaceable Unit) consists of the

- Hardware, the electronic devices and the
- Software, the program of the arithmetic and logic process in the computer.

The specification of an electronic unit does not detail the hardware the system should/does employ. The designer/engineer will decide which hardware, CPU memory IC's etc, will best meet the requirements of the unit. As long as the hardware chosen must meet requirements in terms of interfacing, environmental resistance and relevant international standards, then the specification of a unit will be guaranteed by the software of the system.

Software Specification

The software specifies the

- input– and output–parameters,
- their tolerances,
- refreshment–rates,
- fault detections and so on.

It is up to the manufacturer to meet all of the demands. It is usual for the hardware and the software to be developed together.

Memory Medium

Memory mediums are:

- Floppy Disk (diskette)
- Compact Disc (CD)
- Memory devices in a portable data loader
- PCMCIA-card (Personal Computer Memory Card International Association)

PROGRAM CHANGE

Reprogramming

Reprogramming may be done in different ways, each with different costs.

Beginning with the easiest way, a program change in an aircraft–LRU can be done

- by an ADL (Airborne Data Loader), a drive found in the cockpit. The software is loaded from a diskette or diskettes followed by the start–command.
- by a Portable Data Loader, which must be connected direct to the LRU–Front–Plug or to a transfer– plug, which can be located in the cockpit. In both cases, a disc or a magnetic tape may be the data transfer medium.
- by changing of OBRMs (On Board Replaceable Modules), which are implemented into the front face of the LRU.
- by using a special Programing Menu on the MCDU, located in the cockpit, usually accessed by the input of a security code.
- in the workshop.

The easier it is to re–program a device, the more quality controls have to be applied to ensure that the reprogramming is done correctly in a controlled manner.

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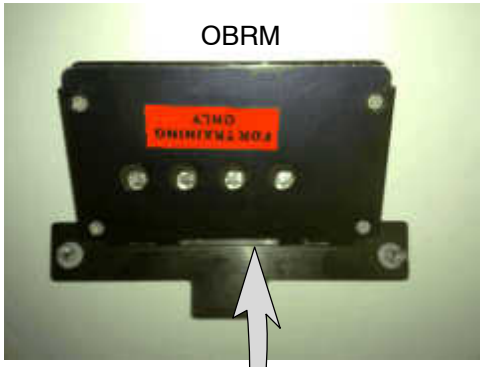
Diskette



Airborne Data Loader



Computer







Diskette



Portable Data Loader



Computer with PCMCIA Slot

Figure 51 Software Upload

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SOFTWARE DEFINITION

Packages

Modern LRUs contain their software in different packages, called:

- Core Software,
- Operational Software or Application Software and
- Data Base.

Core Software

The Core Software defines the individual system. It will interface one LRU, such as the air data computer, to another, such as the flight control system.

In defining each system it defines the function of the whole aircraft.

Operational Software

The Operational Software, also known as Application Software, defines for example the kind of display in the cockpit.

Data Base

By implementing a new Data Base Software, only parameter values will be changed, not strictly a program change.

For example the maximum aircraft take off weight can be increased because of the higher pressure in the tyres.

Software Separated into Three Blocks

If the software is separated in three separated blocks it is easy to alter one of these software's only. During modifications, only the block which is affected needs to be replaced.

If Core Software is replaced, this is a major change. This must be recorded in the documentation.

A change of the Data Base Software will be regarded as a minor item.

Software Separated into Two Blocks

If Core Software and Operational Software are one common block, any change in one of these software's must be specified like a change of the Core Software.

A change of the Data Base Software will be regarded as a minor item.

Software in One Single Block

In this configuration, all software's are one single block.

Any software change in one of these software's must be specified like a change of the Core Software.

This configuration is used for systems which are not subject for periodical updates.

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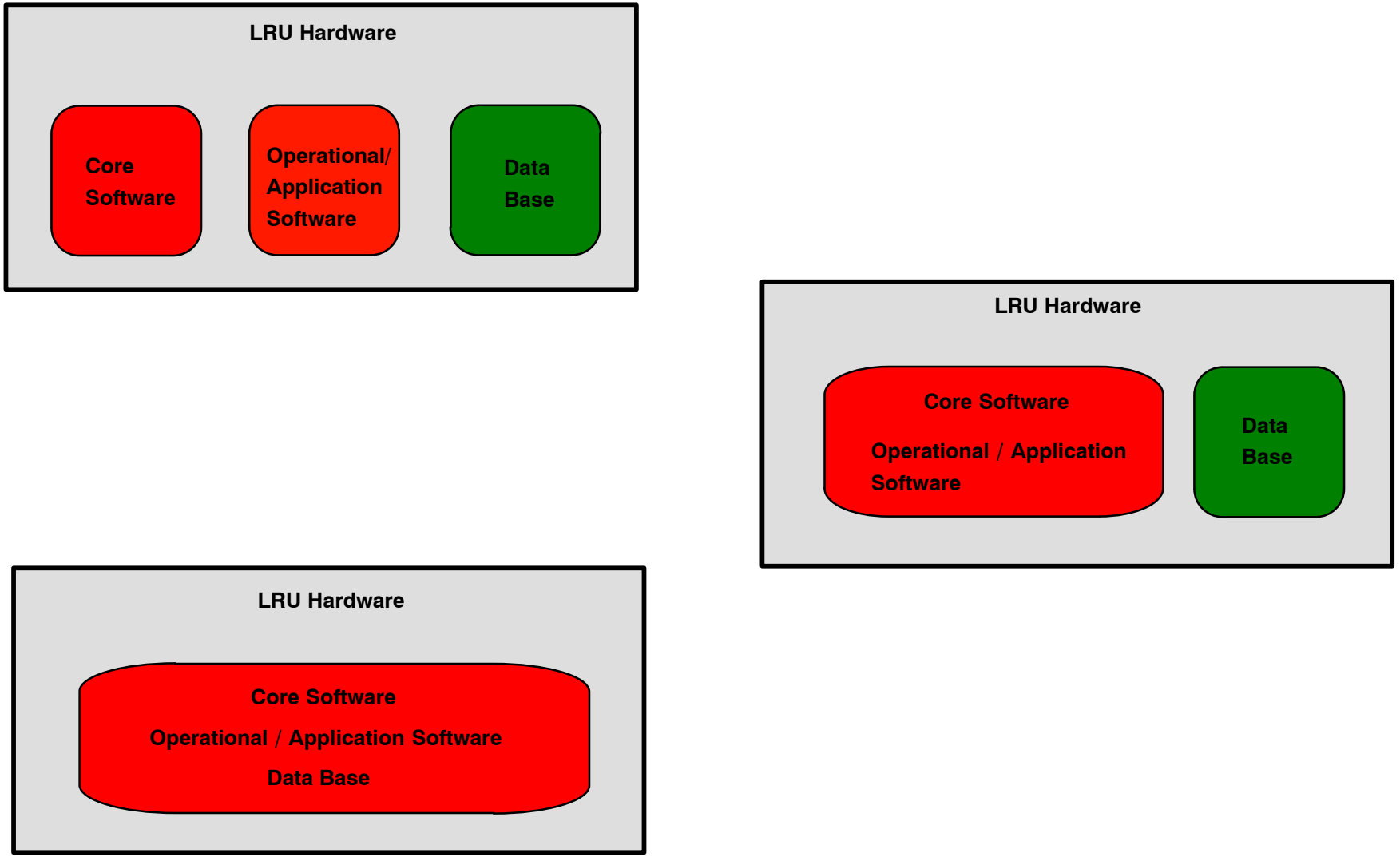

Figure 52 Software Layout

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SOFTWARE HANDLING

General

Depending on the Software Level, different levels of care must be taken in documentation and handling of the software. Only authorized personal may modify the software which is classified in level A. Software which is classified in level E can be done by maintenance personnel, but only if respective documentation is available.

In any case it must be guaranteed that

- only the authorized software will be influenced by re–loading,
- successful loading must be acknowledged,
- no other systems will be affected.

Core Software

The Core–Software should normally never be touched, because it is a part of the control loop of the aircraft. An uncontrolled change could be disastrous. A change of this software can only be made with the agreement of the aircraft manufacturer and the LRU–manufacturer. This is documented in authorized Service Bulletins (Cover–S/B) of the two manufacturers.

Operational Software

A change of the Operational/Application–Software also needs the agreement and documentation of both manufactures. However, the LRU–Manufacture can be bypassed, if the airline engineering guarantees an ‘equivalent–level–of–safety‘, this is a complicated process.

Data Base

A Data Base Software change can normally be done without involvement of the manufacturers if it is guaranteed that the software is classified in level E in accordance with RTCA Document No DO178B.

However, wrong data in a data base may of a navigation computer may result in navigation errors.

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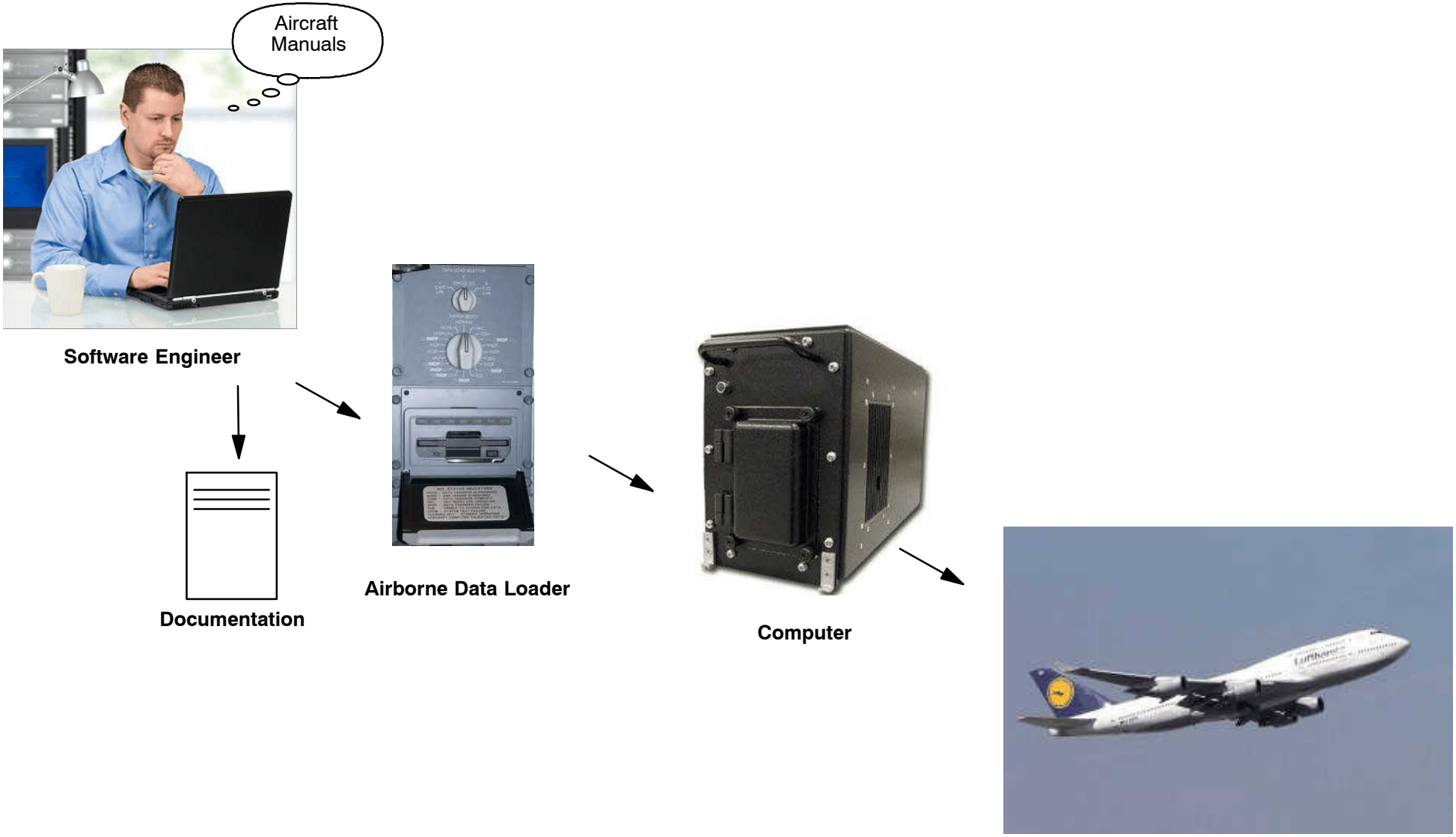

Figure 53 Software Update

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LEVELS

General

In the RTCA (Requirement and Technical Concepts for Aviation), Document DO 178B or EUROCAE Doc. ED 12B (Software Considerations in Airborne Systems and Equipment Certification) software levels are defined as:

- Level A: Catastrophic – Failure may cause a crash. Error or loss of critical function required to safely fly and land aircraft.
- Level B: Hazardous – Failure has a large negative impact on safety or performance, or reduces the ability of the crew to operate the aircraft due to physical distress or a higher workload, or causes serious or fatal injuries among the passengers (safety significant).
- Level C: Major – Failure is significant, but has a lesser impact than a Hazardous failure (for example, leads to passenger discomfort rather than injuries) or significantly increases crew workload (safety related).
- Level D: Minor – Failure is noticeable, but has a lesser impact than a Major failure (for example, causing passenger inconvenience or a routine flight plan change).
- Level E: No Effect – Failure has no impact on safety, aircraft operation, or crew workload.

Software Level Definitions Example

Level E: Software whose anomalous behavior, as shown by the System assessment process, would cause or contribute to a failure of System function with no effect on aircraft operational capability or pilot workload.

(Excerpt from RTCA Document No. DO178B)

Only a data base may be classified as Level E in some cases.

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Classification	Pilots	Passengers	Aircraft
Level A	unable to control aircraft	multiple death possible	loss of aircraft possible
Level B	heavy work load, physical distress	serious injuries possible	large reduced function
Level C	significant increased work load	injuries possible	significantly reduced function
Level D	slightly increased work load	some inconvenience	slightly reduced function
Level E	no effect	no effect	no effect

Figure 54 Levels for Software

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M5.4 DATA BUSES

INTRODUCTION

Codes

Codes are generally determined to specific rules. Determined input combinations will be converted to determined output combinations.

Binary Code

If the code consist only of binary digits (bits), with the condition 1 and 0, it is called Binary Code.

It is a so called Word Code because the number has to be converted as a single Word.

Data Bus

A data bus is made of cables which are made of several wires.

Data buses are used inside of computers or as as a connection between computers.

A data bus transports the code as an electrical pulse.

Interface

An interface is the connection between two or more “black boxes“.

This may be components inside a computer or two different computers.

There are two types of interface:

- parallel port
- serial port.

Parallel Port

In a parallel port each bit is transmitted via its own wire.

The speed of transmission depends on the type of microprocessor (4 bit, 8 bit, 16 bit, 32 bit or 64 bit) and the frequency of the clock generator.

The internal components like Central Processor Unit (CPU), memory and interface devices use parallel data buses. The number of links depends on the type of the processor.

Serial Port

Computers are commonly linked via serial data buses, but there are some exceptions.

The speed depends on the type of microprocessor, the type of link and the distance between the computers.

The bits are transmitted with only one electrical circuit, one after the other. This is why it is called a serial port.

The advantage is that only one wire is needed.

The disadvantage is that it is slower.

Link

The figure below shows the signal flow only. But complete electrical circuits are needed.

A serial port needs two leads. Normally, the housing is not used as a lead to prevent disturbances.

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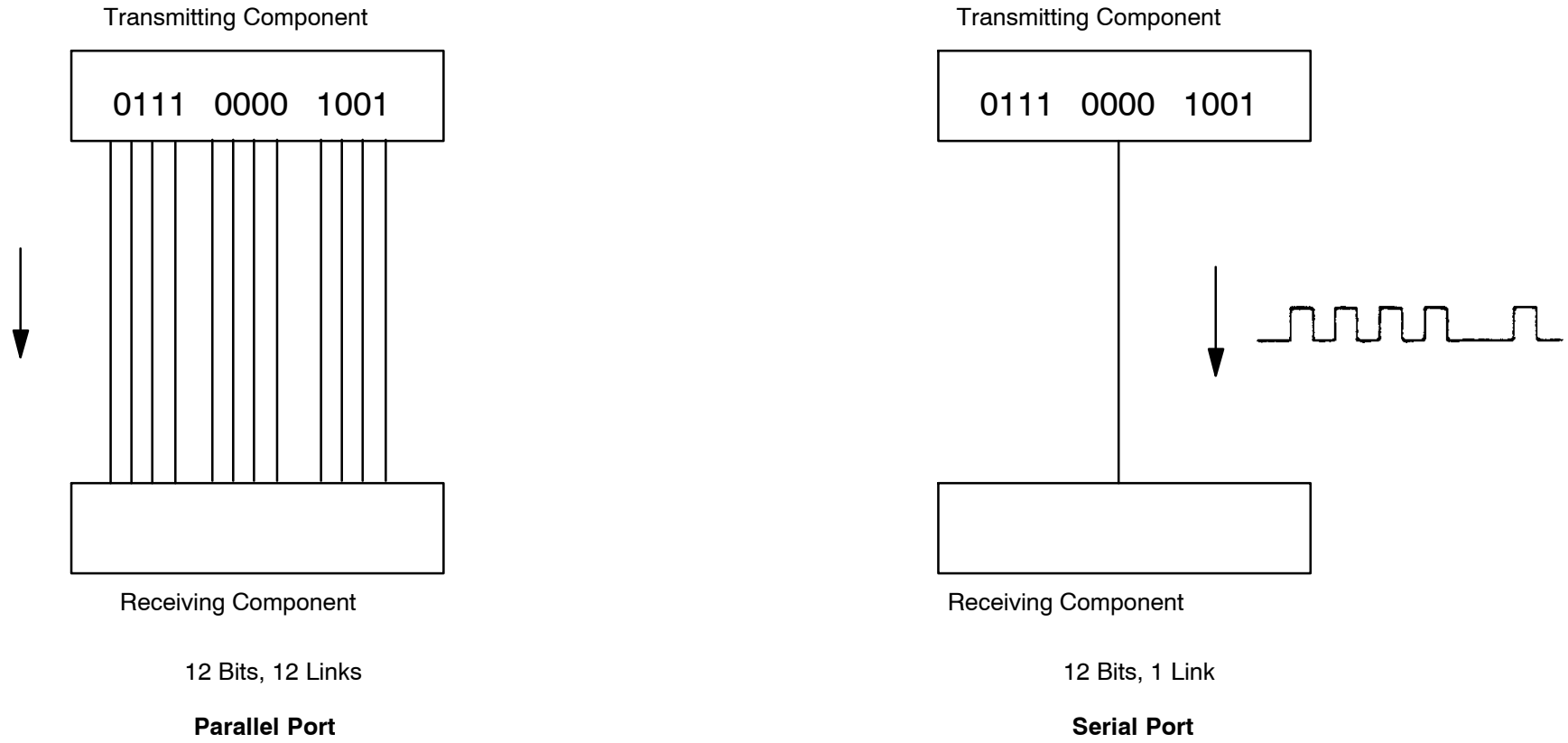

LTT

Figure 55 Interface

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ARINC

General

ARINC, **A**eronautical **R**adio **Inc**orporated is a corporation that was founded 1929 in the United States in order to simplify radio communication and find common standards. Nowadays some boards also deal with aviation.

From time to time there is an ARINC Meeting where representives from manufacturers, owners and avionics suppliers meet to redefine the standards if necessary.

Some ARINC-Specifications deal with digital data transmissions. Standard is ARINC 429 still, even in Boeings 777 and in Airbus A380 in some areas. But tendency goes to more reliable, fast databuses which can deal the enormous amount of digital data modern aircraft provide.

Data Exchange

There are different ways for digital data transmission:

- Simplex: one transmitter, one Receiver. One way only.
- Multiple Simplex: one transmitter, multiple receivers. One way only.
- Half-Duplex: one transmitter, one or several receiver(s). Both directions, but only one at a time.
- Full Duplex: one transmitter, one receiver. Both directions at the same time.

400 Series

400 Series ARINC Specifications and Reports provide a design foundation for equipment specified per the ARINC 700 and 500 Series.

They include guidelines for installation, wiring, data buses, databases, and general guidance.

500 Series

500 Series ARINC Characteristics define older analog avionics equipment still used widely on the B−727, DC−9, and DC−10, as well as on early models of B−737, B−747, and A−300 aircraft.

600 Series

600 Series ARINC Specifications and Reports define enabling technologies that provide a design foundation for equipment specified per the ARINC 700 Series of digital avionics systems.

Among the topics covered by Specifications are data link protocols.

700 Series

700 Series ARINC Characteristics define digital avionics systems and equipment installed on current−model production aircraft.

They include detailed definitions of form, fit, function, and interface.

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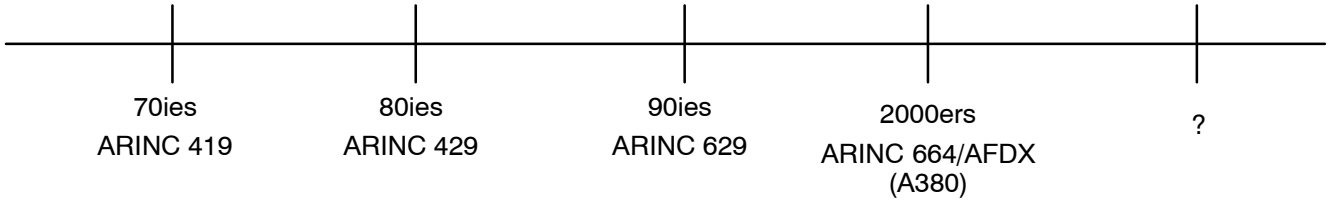

Figure 56 History of ARINC Standards

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ARINC 429

General

System data transfers in and out of an aircraft system and within the system occur in digital formats as defined by ARINC specification 429 Mark 33 Digital Information Transfer System (DITS).

This specification therefore defines encoding data of signals to be transmitted.

Aircraft Systems

The digital computers of the different aircraft systems process results in the form of messages or parallel binary words, i. e., information comprising several bits (0,1) available simultaneously.

However, to transmit digital information towards external receivers, it is preferable, for weight control and reliability reasons, to use a serial transmission system. Therefore, the parallel message is converted into a serial message. Then a line transmitter adapts this serial logic message into voltage levels which are compatible with the transmission standard. The message is thus sent in the form of a string of pulses.

Data Exchange

ARINC 429 defines Simplex-Operations as a standard.

One transmitter can supply data to up to 20 receivers.

Serial transmission of information in digital format is designed as defined by ARINC specification 429.

Data Cables

The hardware support providing serial transmission of information is a mono−directional bus composed of a pair of twisted and shielded wires (see figure below). This shielding is connected to ground, in particular at each branch.

Advantages of serial transmission:

- only a single line is required for transmission.
- only one set of digital circuitry is needed to process the data.

This is slower than parallel transmission but sufficient for ARINC 429 requirements.

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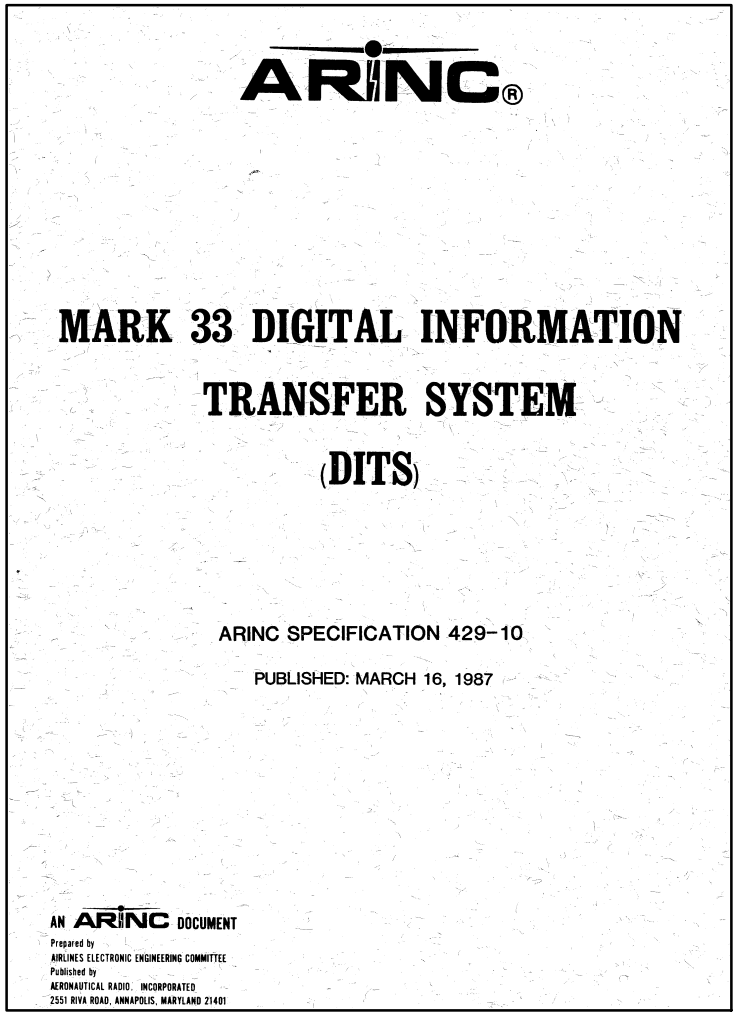

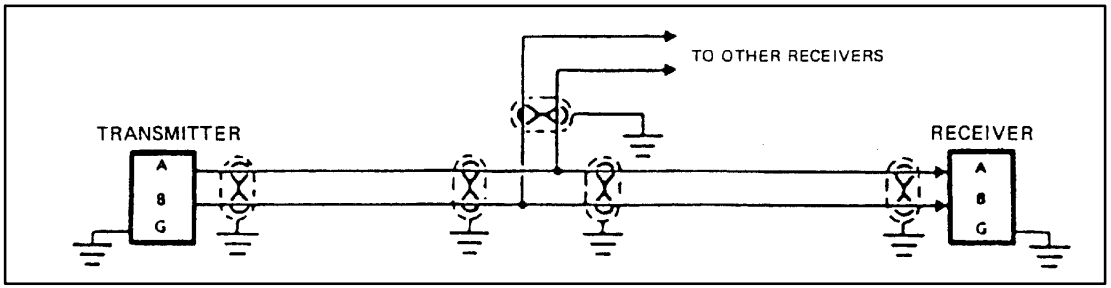

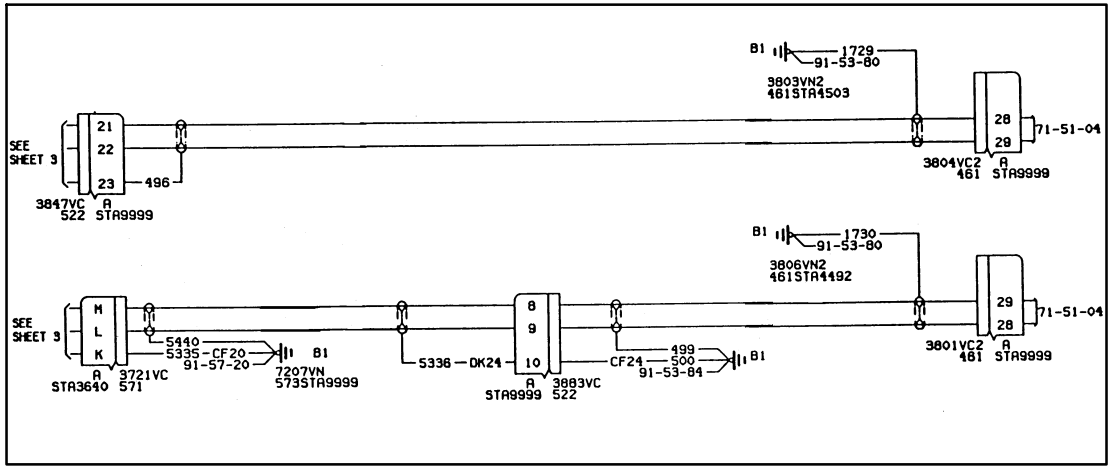

Serial Transfer

Figure 57 ARINC 429 Interconnection

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Transmission Speed

ARINC 429 defines two different transmission speeds:

- Low Speed (12 - 14 kBit)
- High Speed (100 kBit)

Low Speed and High Speed-Transmission may never occur on the same data bus it is either a low speed or high speed bus.

	HIGH SPEED	LOW SPEED
TRANSMISSION SIGNAL SPEED	100 kBit	12,5 kBit
BIT TIME T	10 µs	80 µs

Voltage Ranges

The voltage ranges for transmitter and receiver differ a little bit.

The receiver accepts a wider voltage range so it could read the data even if there are some minor disturbances on the bus.

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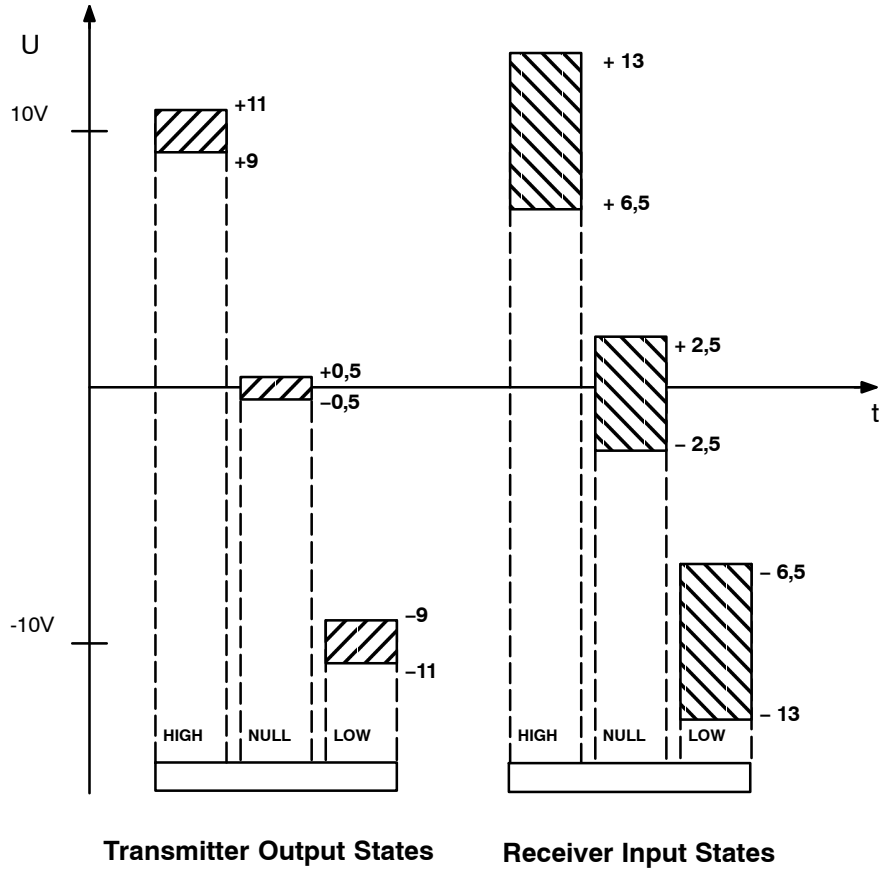

Figure 58 Voltage Ranges

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DATA SYNCHRONIZATION

Bit - Synchronization

ARINC 429 uses a bipolar RZ (Return to Zero) -Signal, which contains data and clock. Therefore three different voltage levels are required:

- + 10 Volts for the logic „1“
- 0 Volts for the clock
- - 10 Volts for the logic „0“

Word Synchronization

The data words are separated by a gap of 4 bit time minimum. Usually it is from 4 to 8 bit.

The Receiver recognizes the first bit of a new data word by the change in voltage (from 0 V to +10V or -10V).

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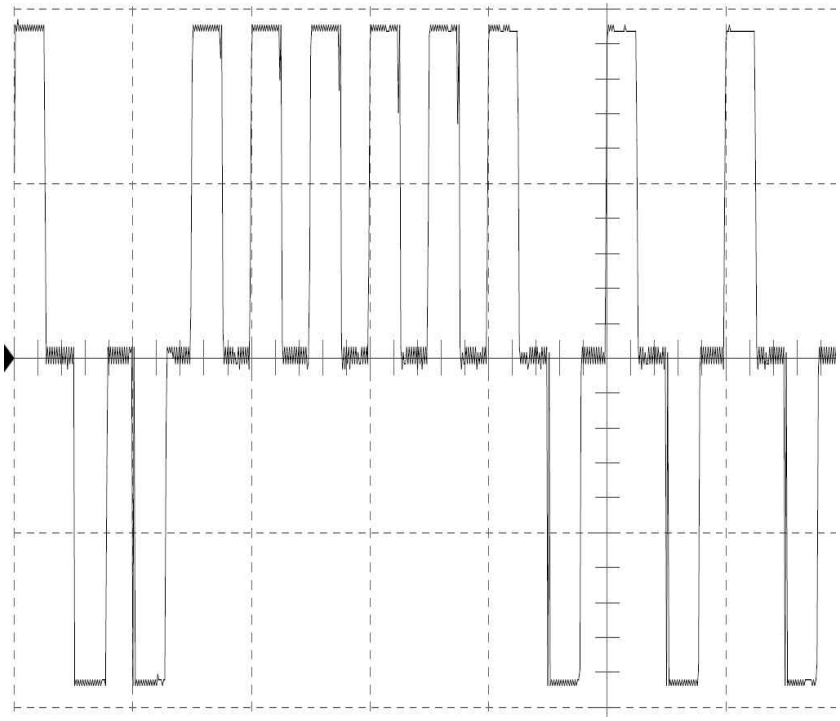
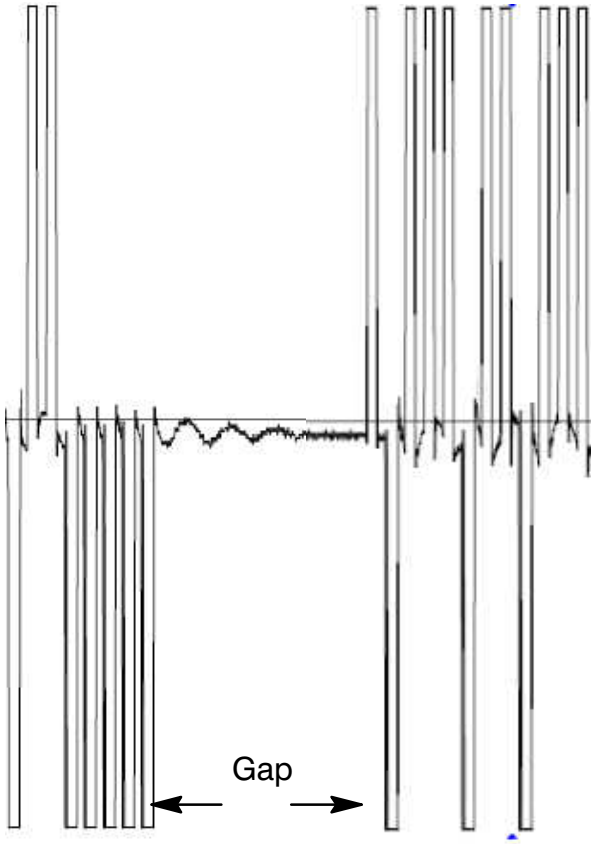


Bit Synchronization



Word Synchronization

Figure 59 Synchronisation

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INFORMATION-RATE

General

Important data is transmitted quite often, less important data is transmitted less often. This is what we call Information Rate.

As BCD-Data (Binary Coded Decimal) is used for displays only it is transmitted every 500 ms (average), BNR (Binary) is to be processed by other LRU's and therefore transmitted 6 to 20 times a second.

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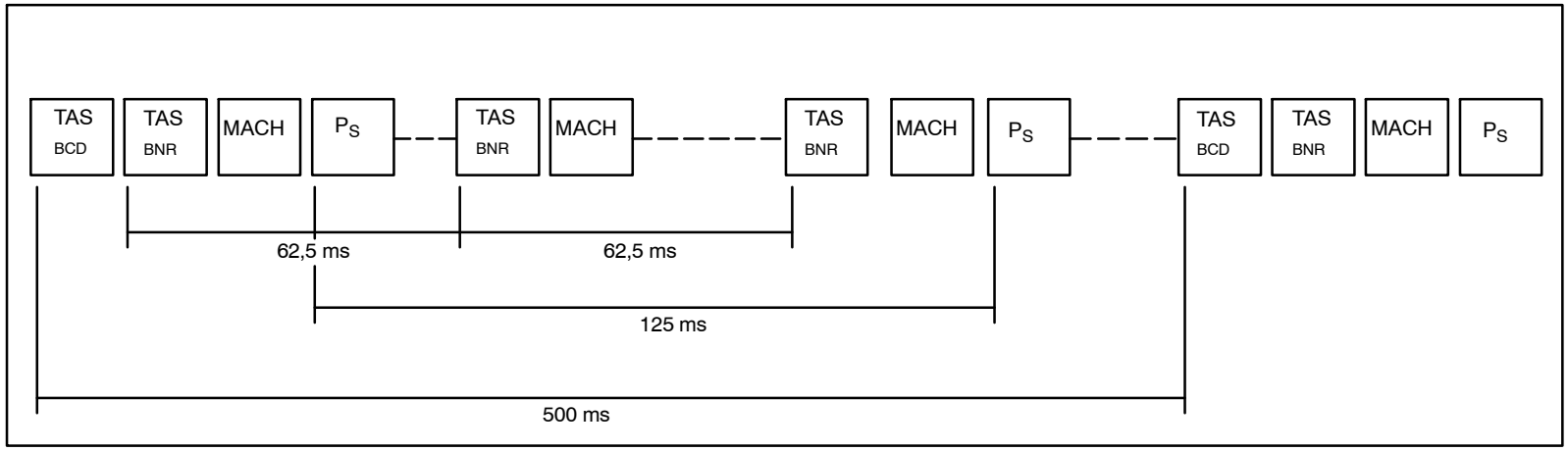

Figure 60 Information Rate

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DATA WORD

General

A Data Word is always composed of 32 Bits, even if not all of them are required for the information transferred.

Arrangement

These 32 Bits are split up in areas with a dedicated purpose:

- Bit 1-8: Label / Address
- Bit 9-10: Source / Destination Identifier (SDI)
- Bit 11-28 (29): Data
- Bit (29) 30-31: Sign/Status Matrix (SSM)
- Bit 32: Parity Bit

Variations for bits 29 to 31 are strictly in conjunction with some of the labels.

Label

The label takes up the first 8 bits (1 to 8) of a word.

It identifies the data word: the word may represent a radio frequency, the altitude, the air speed or any other parameter.

SDI

Various aircraft systems have two computers which have the same task. Sometimes two computers transmit the same type of data, sometimes two computers receive the same type of data from two different sources.

Bits 9 and 10 are used for two different purposes:

- they can tell from which data source the signal comes from (computer 1 or computer 2)
- they can indicate which receiving computer of a system shall use the data. The data may have the destination computer 1 or computer 2.

SSM

In the Sign/Status Matrix some additional information for the data is possible, for example an algebraic sign.

The status of a computer can also be transmitted, for example “computer is valid“.

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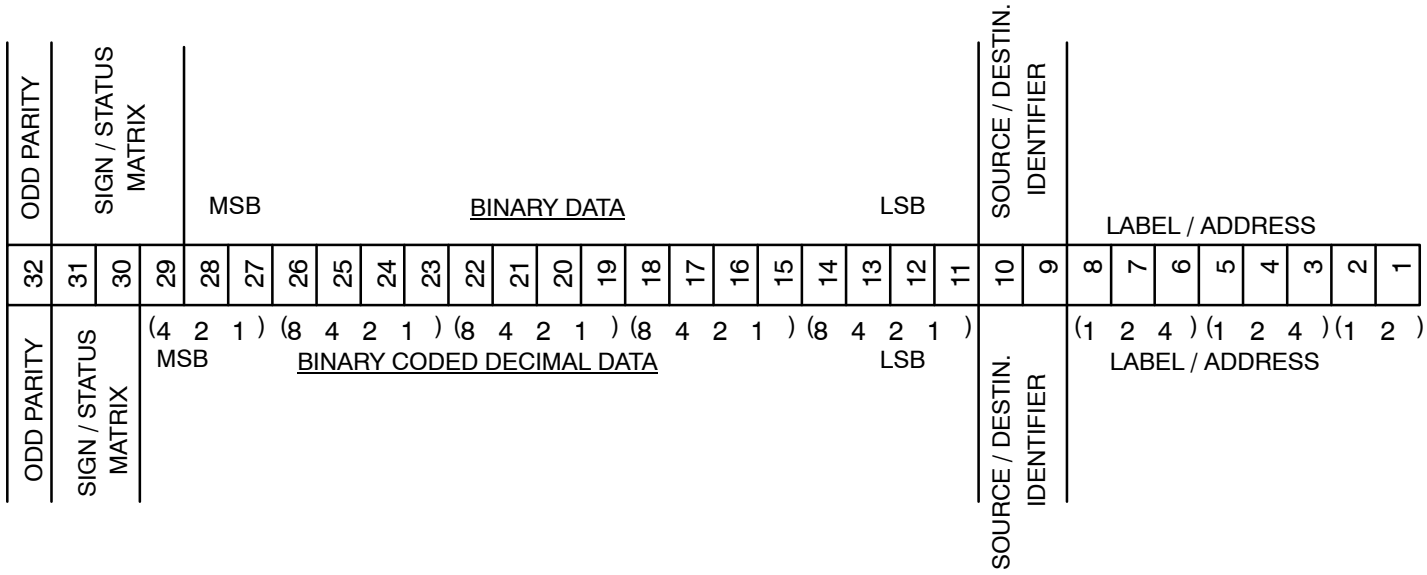

Figure 61 ARINC 429 Data Word

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LABEL

General

The label takes up the first 8 bits (1 to 8) of a word. It is octal coded (based 8 number system).

The following figure gives some examples of application to illustrate the selected coding system.

Each word is identified by a label which defines its function: A word may represent aerodynamic information, a radio frequency, or a series of binary data, each one of which controls the illumination of an inscription or controls a function, etc.

Equipment Identifier

As nowadays the total amount of labels (256) available is no longer sufficient they may be used for different parameters. To determine the correct parameter the equipment identifier is also needed.

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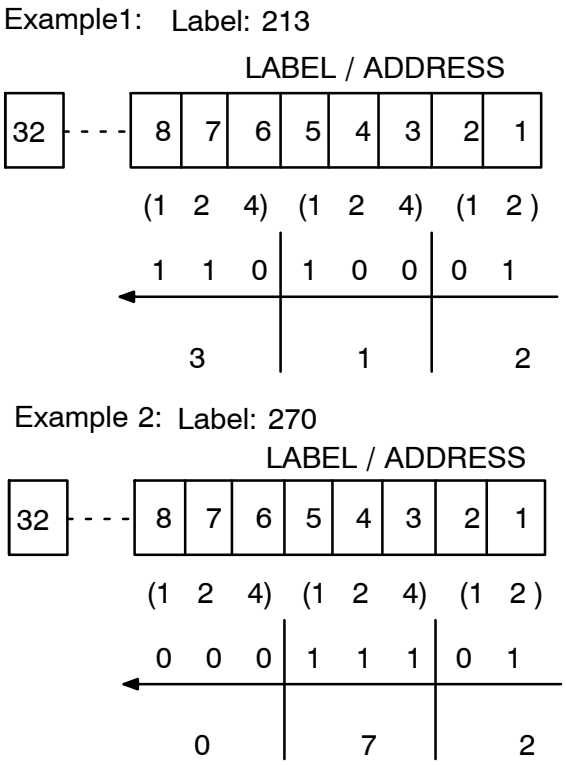

Figure 62 Label Evaluation Principle

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Guideline for Label Assignment

This guideline gives the assignment of the labels to certain types of information. In addition to that a list is available. From time to time there might be a change in that guideline.

The issue of that guideline can be read from the number of the ARINC:

e.g. ARINC 429–**14**.

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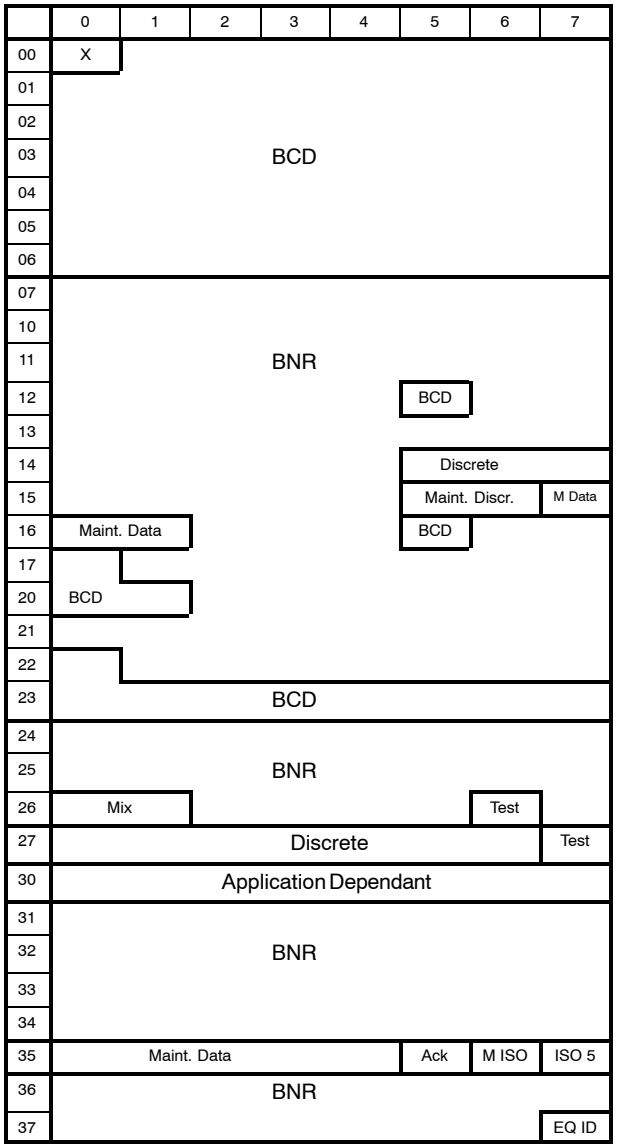

Figure 63 Guideline for Label Assignment

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BCD TABLE (EXCERPT)

Label	Eq. ID	Parameter Name	Units	Range	Sig. Dig.	Positive Sense	Resol
001	02	Distance to Go	N.M.	±3999.9	5		0.1
002	02	Time to Go	Min	0–399.9	4		0.1
004	01	Runway Distance to Go	Feet	0–79900	3		100.0
010	02	Present Position Lat.	Deg:Min	180N-180S	6	N	0.1
	04	Present Position Lat.	Deg:Min	180N-180S	6	N	0.1
011	02	Present Position Lon.	Deg:Min	180E-180W	6	E	0.1
	04	Present Position Lon.	Deg:Min	180E-180W	6	E	0.1
012	02	Ground Speed	Knots	0–7000	4		1.0
	04	Ground Speed	Knots	0–7000	4		1.0
	05	Ground Speed	Knots	0–7000	4		1.0
013	02	Track Angle (true)	Deg	0–359.9	4		0.1
	04	Track Angle (true)	Deg	0–359.9	4		0.1
014	04	Magnetic Heading	Deg	0–359.9	4		0.1
	05	Magnetic Heading	Deg	0–359.9	4		0.1
015	02	Wind Speed	Knots	0–799	3		1.0
	04	Wind Speed	Knots	0–799	3		1.0
	05	Wind Speed	Knots	0–799	3		1.0
016	04	Wind Direction-True	Deg	0–359	3		1.0
017	10	Selected Runway Heading	Deg	0–359.9	4		0.1
	A0	Selected Runway Heading	Deg	0–359.9	4		0.1
	B0	Selected Runway Heading	Deg	0–359.9	4		0.1
034	02	VOR/ILS Frequency		See Chapter 3			
	06	Baro Correction (mb) #3	mb	745–1050	5		0.1
	11	VOR/ILS Frequency		See Chapter 3			
	20	VOR/ILS Frequency		See Chapter 3			
	B0	VOR/ILS Frequency		See Chapter 3			

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BNR TABLE (EXCERPT)

Label	Eq. ID	Parameter Name	Units	Range	Sig. Bits (Not incl. Sign)	Positive Sense	Approx. Resol
070	29	AC Frequency (Engine)	Hz	512	11		.25
	- -	Hard Landing MAG #2	Lbs		12		-
071	29	AC Frequency (Alt. Source)	Hz	512	11		.25
	- -	Hard Landing MAG #2	Lbs		12		-
	33	VBV	Deg	64	12		.0016
103	01	Selected Airspeed	Knots	512	11		0.25
	02	Selected Airspeed	Knots	512	11		0.25
	03	Selected Airspeed	Knots	512	11		0.25
	20	Selected Airspeed	Knots	512	11		0.25
	29	DC Voltage (TRU)	Volts	128	9		0.25
	A1	Selected Airspeed	Knots	512	11		0.25
104	01	Selected Vertical Speed	FT/Min	16384	10	Upward	16
	02	Selected Vertical Speed	FT/Min	16384	10	Upward	16
	20	Selected Vertical Speed	FT/Min	16384	10	Upward	16
	29	DC Voltage (Batt)	Volts	128	9		0.25
	2B	Selected Vertical Speed	FT/Min	16384	10	Upward	16
	A1	Selected Vertical Speed	FT/Min	16384	10	Upward	16
110	01	Selected Course #2	Deg/180	± 180	12		0.05
	02	Selected Course #2	Deg/180	± 180	12		0.05
	10	Selected Course #2	Deg/180	± 180	12		0.05
	11	Selected Course #2	Deg/180	± 180	12		0.05
	20	Selected Course #2	Deg/180	± 180	12		0.05
	A1	Selected Course #2	Deg/180	± 180	12		0.05
	B1	Selected Course #2	Deg/180	± 180	12		0.05

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EQUIPMENT IDENTIFIER

Label 377

The “ARINC specification 429“ defines the label 377 to recognize the transmitting LRU on the bus by means of the so called EQUIPMENT IDENTIFIERS. This is an information like altitude, temperature, speed, ...

So this is not a part of every data word but only in that label 377 word.

They are defined by their code in the hexadecimal system.

Some systems don’t transmit the EQ ID.

Example

The example shows the label with the value 377 and the equipment identifier for the Inertial Reference System. This EQ ID is 04.

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EQ ID EXAMPLE

P	SSM		Data Field																			SDI		Label							
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0			1	1	1	1	1	1	1	1
			Pad Bits											(8)	(4)	(2)	(1)	(8)	(4)	(2)	(1)			(1)	(2)	(4)	(1)	(2)	(4)	(1)	(2)
														0				4						7			7			3	
														MSD				LSD						LSC						MSC	
														EQ ID 04										Label 377							
														IRS																	

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EQUIPMENT ID TABLE (EXCERPT)

Equipment ID (Hex)	Equipment Type
000	Not Used
001	Flight Control Computer (701)
002	Flight Management Computer (702)
003	Thrust Control Computer (703)
004	Inertial Reference System (704)
005	Attitude and Heading Ref. System (705)
006	Air Data System (706)
007	Radio Altimeter (707)
008	Airborne Weather Radar (708)
009	Airborne DME(709)
00A	FAC (A310)
00B	GPS
00C	
00D	AIDS Data Management Unit
00E	
00F	
010	Airborne ILS Receiver (710)
011	Airborne VOR Receiver (711)
012	Airborne ADF System (712)
04D	Fuel Qty Indicating System (757/767)
04E	Fuel Qty Indicating System (747)

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A340
AIRCRAFT MAINTENANCE MANUAL

C. Parameter List

(1) DMU Input Parameter List

NOTE : Each set of parameters is in the applicable chapter.

EQ	SYSTEM	CHAPTER
05C	CPC 1 & 2	21-31-00
05D	ZC	21-63-00
039	MCDU 2 & 3	22-82-00
15B	FCU (AFS M1 BUS)	22-81-00
F15	FCU (EIS CPL-BUS)	22-81-00
E15	FCU (EIS CPR-BUS)	22-81-00
002	FMGEC 1 & 2 (FMC-BUS)	22-83-00
001	FMGEC 1 & 2 (FGC-BUS)	22-83-00
00A	FMGEC 1 & 2 (E GEN-BUS)	22-83-00
024	ACARS	23-24-00
06C	FCDC 1 & 2	27-95-00
01B	SFCC 1 & 2	27-51-00
114	FCMC 1 & 2	28-51-00
F16	DMC (EFIS-BUS)	31-62-00
16B	DMC (ECAM-BUS)	31-62-00
026	FWC 1 & 2 (L1-BUS)	31-52-00
F26	FWC 1 & 2 (L2-BUS)	31-52-00
029	SDAC 1 & 2 (L1-BUS)	31-55-00
F29	SDAC 1 & 2 (L2-BUS)	31-55-00
037	WBS 1 & 2	31-44-00
06D	LGCIU 1 & 2	32-31-00
023	GPWS	34-48-00
006	ADIRU 1 & 2 (ADC-BUS)	34-12-00
004	ADIRU 1 & 2 (IRS-BUS)	34-14-00
06F	BMC 1 & 2 & 3 & 4	36-11-00
119	CMC	45-13-00
11A	MDDU	45-23-00
040	PRINTER	45-41-00
07A	ECB	49-61-00
116	EIVMU 1 & 2 & 3 & 4	73-25-00

Figure 64 Data Management Unit Input Parameter List

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SOURCE/DESTINATION IDENTIFIER

General

Bits 9 and 10 comprise the source/destination identifier, or SDI.

Purpose

The SDI function is used when it is necessary to indicate the source of information, or when the information is directed to a specific location (which has a minor function).

As an example, when specific words need to be directed to a specific system of a multi system installation, and when the source system of a multi system installation needs to be recognizable from the word content.

For example, if the ARINC word is to be sent to be recognized by system No 2 only, 10 is transmitted on bits 9 and 10. If 00 is transmitted on bits 9 and 10, the data is sent to be recognized by all receivers (ALL CALL). This is the most frequent case.

For another example: If there are several identical systems which transmit data, the transmitter sends its installed position on bit 9 and 10 (IRS No. 2 will transmit SDI−bits 10 on its output bus).

If 4 identical systems are installed, system 4 is identified by SDI code 00.

The same bit combination (00) is also used, if the receiver is not specified by its SDI (e.g. single system installed only).

Pin Programming

The respective system is mostly informed about its installed position by pin programming at the shelf receptacle or by an identification plug as it is used for example at the Electronic Engine Control (EEC). This is a computer which controls one engine.

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SDI

P	SSM		Data field																		SDI		Label							
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
																								Installation No.							
																						0	0	Not used / 4							
																						0	1	1							
																						1	0	2							
																						1	1	3							

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SIGN / STATUS MATRIX

General

The Sign / Status Matrix (SSM) gives validity status and the sign of the information carried by the word.

As far as validity information is concerned, there is no need for a separated wire carrying the discrete validity, failure / warning or flag signal to the various receivers.

BNR

BNR data have a SSM that consists of Bits 29, 30 and 31:

- bit 29 for sign
- bit 30 and bit 31 for status.

The meaning of the sign depends on the data word. The receiving computer reads the label and reads its own memory to find out what a 0 or a 1 in this position means.

The sign can be used to transmit the following information:

- Plus, North, East, Right, To, Above are transmitted as 0.
- Minus, South, West, Left, From, Below are transmitted as 1.

With the status a computer can transmit this information:

- Failure Warning
- No Computed Data
- Functional Test
- Normal Operation.

BCD

BCD data have a SSM that consists of Bits 30 and 31:

Discretes, AIM Data and File Transfer Data also have the SSM from Bit 30 and bit 31.

With the SSM for BCD data a computer can transmit this information:

- Plus, North, East, Right, To, Above
- No Computed Data
- Functional Test
- Minus, South, West, Left, From, Below.

In case of a failure the data word is suppressed (not transmitted any more).

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SSM

BNR

P	SSM		BNR Data Field																		SDI		Label							
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Sign Bit	
0	Plus, North, East, Right, To, Above
1	Minus, South, West, Left, From, Below

Status Matrix			Priority
0	0	Failure Warning (FW)	1
0	1	No Computed Data (NCD)	2
1	0	Functional Test (TEST)	3
1	1	Normal Operation (NO)	4

BCD

P	SSM		BCD Data Field																		SDI		Label							
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

		BCD Numeric Word	AIM	File Transfer
0	0	Plus, North, East, Right, To, Above	Intermediate Word	Intermediate Word Plus, North, etc.
0	1	No Computed Data	Initial Word	Initial Word
1	0	Functional Test	Final Word	Final Word
1	1	Minus, South, West, Left, From, Below	Control Word	Intermediate Word Minus, South, etc.

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PARITY BIT

Parity Check

To check transmission validity, the last bit (bit 32) of each word is used. It is called the parity bit. It is generated by the transmitter when the word is emitted and it is checked by the receiver upon arrival.

By means of this parity bit, the receiver can check that the different bits forming the word have all been integrally and correctly transmitted. It is used to increase transmission security.

The parity bit is defined, ”constructed”, in such a way that all ARINC words have an odd number of binary zeros (therefore an odd number of binary 1‘s).

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Exercise

The table below represents a data word with 4 data bit and one parity bit.
Fill in the table so that odd parity is achieved.

D	C	B	A	P odd
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

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DATA

General

The ARINC specification No 429 considers 6 type of transmissible data:

- Numeric Data BCD (Binary Coded Decimal)
- Numeric Data BNR (Binary Data)
- Discretes
- Maintenance data
- Alphanumeric data (AIM)
- Data file.

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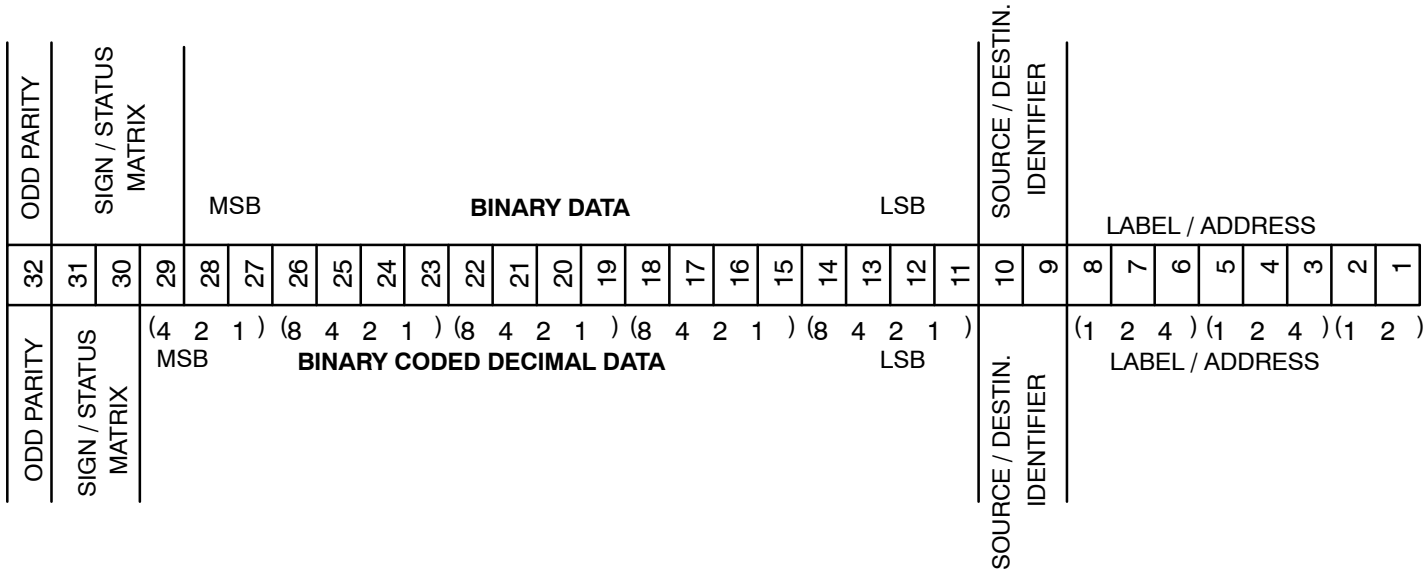

Figure 65 ARINC 429 Data Word

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BCD

General

BCD means Binary Coded Decimal.

A transmission of numeric data in BCD format consists of the Bits 11 to 29.

The Bits 29 to 27 form the MSC (Most significant Character) and has a range from 0 to 7.

The other digits are formed from four bit groups.

As not all the digits available are required for some specific information, ARINC gives the range and the resolution of the information contained in the data word.

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Label:	EQ-ID:	Parameter Name:	Units	Range	BNR Sig. Bits:	Pos Sense:	Resol:
015	002	Wind Speed	Kts	0-799	BCD Sig Digits:3		1.0

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0

Value: 069 kts

Figure 66 Data Example: BCD

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BCD EXEMPTIONS

VHF Frequency Selection

VHF means Very High Frequency.

VHF Comms Frequencies are from 118.000 MHz to 135.975 MHz. So there is no need to transmit the leading 1 which stands for 100 MHz.

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Label	Parameter Name	Number of significant Digits	Unit	Range	Resolution
030	VHF Comm Frequency	5	MHz	79.999	0.001

P	SSM		Data																			SDI		Label							
			4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1										
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
			2			8				5				3				0													

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BNR

General

BNR means Binary Number Representation. Sometimes it is just called Binary Data.

Numeric Data (e.g. Temperature, Speed ...), that is encoded as a binary uses the bits 11 to 28.

Bit 28 is always the MSB (most significant bit).

As not all the digits available are required for some specific information ARINC gives the range and the resolution of the information contained in the data word.

The RANGE is defined which gives the maximum value that can be represented (e.g., 1024 kts for a calibrated airspeed CAS).

The most significant bit (MSB) will therefore represent half of this maximum value.

- The following bit, a 1/4 th
- The following bit, an 1/8 th
- The following bit a 1/16 th etc...

The resolution is quite close to the LSB but not necessarily exact the same value.

Negative Values

Negative values are transmitted in the so called two's complement. To read the value this complement has to be reversed by inverting the binary word string and then add 1.

PAD-Bits

PAD-Bits are all the bits that are not a part of the information. They are filled with logic „0".

Sometimes they are used to transmit discrete data.

Example

The figure below gives an example of coding of numerical data.

For instance, here are the characteristics defined in ARINC Specification No 429 regarding Total Air Temperature (TAT).

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NUMERIC DATA (BNR), POSITIVE VALUE

Label	Parameter Name	Number of significant Bits	Unit	Range	Resolution
211	Total Air Temperature	11	°C	512	0.25 °C

P	SSM			Data											Pad-Bits							SDI		Label							
				2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}																
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	1	1	0	0	0	0	0	1	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1
			+	0	0	0	0	16	0	4	2	1	0	.25																	

16 + 4 + 2 + 1 + 0.25 = 23.25 °C

NUMERIC DATA (BNR), POSITIVE VALUE

P	SSM			Data											Pad-Bits							SDI		Label							
				2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}																
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1
			–	0	0	0	0	1	0	1	1	1	0	0																	
														+1																	
				0	0	0	0	1	0	1	1	1	0	1																	

16 + 4 + 2 + 1 + 0.25 = –23.25 °C

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DISCRETES

General

The ARINC specification No 429 defines two methods of transmitting discrete items of Information:

- Inside a word assigned to a specific data item, use of one or several bits not used for encoding such item.
- Use of words fully dedicated to transmission of discretes. The ARINC specification No 429 assigns 7 possible labels (octal 270 to 276) to those words. These words should be used in ascending label order.

The system receiving the data must be capable of identifying its source by reference to the port at which it arrives.

Groups

There are two groups of discretes.

General Purpose Discretes

General Purpose Discretes can be found in many (any) aircraft like TAT, A/S, Altitude, ...

Dedicated Discretes

Specific dedicated words with assigned labels are used when the data is intended for AIDS. They might also be used on aircraft with special (unique) equipment.

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EXAMPLE: DISCRETE FROM ADS

ADS Discrete Label 270:

Bit No	Function	Bit Status	
11	Icing Detector	1	0
12	Pitot Probe Heating	On	Off
13	ADS Computer Status	On	Off
14	Pitot/Static Probe Heating	Fail	Good
15	Static Source Heating	On	Off
16	TAT Probe Heating	On	Off
17	Left Side Angle of Attack Sensor Heating	On	Off
18	Right Side Angle of Attack Sensor Heating	On	Off
19	VMO/MMO Overspeed Warning	Warn	Not Warn
20	Spare		
21	Spare		
22	Spare		
23	Spare		
24	Spare		
25	Spare		
26	Spare		
27	Angle of Attack Alternate Correction	Yes	No
28	Baro Correction Port ”A”	Yes	No
29	Zero Mach SSEC	Yes	No

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MAINTENANCE DATA

General

The general purpose maintenance words are assigned 5 labels in sequential order (350 to 354) as are the labels for general purpose discrete words. General purpose maintenance words must contain only discrete or numeric data BNR or BCD coded.

Memory

They are used for maintenance purposes in shops.

Maintenance data is kept in a NVM. So the maintenance data is available even if power supply is shut off.

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EXAMPLE: MAINTENANCE DATA IRS

IRS Maintenance Data Definition Label 351:

Bit No	Function
11	RAM R/W - Nav Processor
12	RAM R/W I/O Processor
13	RAM R/W - Pre-Processor
14	OP Code - Nav Processor
15	OP Code - I/O Processor
16	OP Code - PreProcessor
17	Checksum - Nav Processor
18	Checksum - I/O Processor
19	Checksum - Pre-Processor
20	Checksum Cal ROM
21	Counter Compare Nav – I/O
22	Counter Compare I/O – P/P
23	Time-Out Counter P/P
24	Mounting Position Change
25	SDI Change
26	Discrete Wraparound
27	Mode Select
28	GND/AIR Invalid
29	

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AIM DATA

General

AIM data is used to transmit letters, words and even whole sentences via ARINC 429.

That specification uses the term AIM in referring to the three possible types of data:

- Label 355 – **A**cknowledgement: not applicable
- Label 357 – **I**SO alphabet No 5: Transmission of alphanumeric characters.
- Label 356 – **M**aintenance: Transmission of alphanumeric characters intended for maintenance

ISO Alphabet No 5

Alphanumeric data is encoded in ISO alphabet No 5 as called for in ARINC specification No 429.

The ISO alphabet No 5 is a **seven–bit code** set which implies that an ARINC specification No 429 word can include a maximum of three characters:

Bit No.9 to 15, 16 to 22, 23 to 29.

Several words must be used to transmit information which exceeds three characters. Therefore, ARINC specification No 429 lays down a procedure to cover this as outlined below.

The following words include the characters of the actual information. They are assigned the same label as the initial word and the SSM (status/sign Matrix): intermediate word, or final word whenever there are no more characters to be transmitted.

A control word may be in use following the initial word. It is used to set the character size, color and brightness as well as flashing of the text.

NOTE:

- The most significant character is the initial character transmitted (bits No. 9 to 15 of the first word containing information).
- As regards transmission of data known as Acknowledgement, the ARINC specification 429 does not lay down a format since an application does not yet exist.

Information for Pilots

In the future AIM Data will be used to transmit non-timecritical information e.g. communications frequencies in order to reduce traffic from Air Traffic Control (ATC) to the cockpit on voice communication channels.

An attention getter and a three-tone chime will come on in case a message arrives at the cockpit.

Bit No:		Usage
31	30	Alphanumeric
0	0	Intermediate Word
0	1	Initial Word
1	0	Last Word
1	1	Control Word

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Alphanumeric Signs from ISO Alphabet No 5

MSC								
0	1	2	3	4	5	6	7	LSC
NUL	DLE	SP	0	@	P	‘	p	0
SOH	DC1	!	1	A	Q	a	q	1
STX	DC2	„	2	B	R	b	r	2
ETX	DC3	#	3	C	S	c	s	3
EOT	DC4	$	4	D	T	d	t	4
ENQ	NAK	%	5	E	U	e	u	5
ACK	SYN	&	6	F	V	f	v	6
BEL	ETB	’	7	G	W	g	w	7
BS ←	CAN	(	8	H	X	h	x	8
HT	EM	)	9	I	Y	i	y	9
LF ↓	SUB	*	:	J	Z	j	z	A
VT ↑	ESC	+	;	K	[	k	{	B
FF →	FS	,	<	L	\	l	|	C
CR	GS	-	=	M	]	m	}	D
SO	RS	·	>	N	^	n	~	E
SI	US	/	?	O	_	o	DEL	F

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Figure 67 Alphanumeric List

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STRUCTURE OF AIM TRANSMISSION

Initial Word:

P	SSM		ISO Alphabet No 5							Spares						No of Words to transmit								Label							
			”STX”													Binary ”3”								7			5			3	
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	1

Control Word (Optional):

P	SSM		Spare							Flash	Char Size		Intensity		Colour			Line Count					Label							
										No					Green			3					7			5			3	
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	1	1	0	0	0	0	0	0	0	0	0					0	0	1	0	0	0	1	1	1	1	1	1	0	1	1	1

Intermediate Word:

P	SSM		Data Word 3							Data Word 2							Data Word 1								Label						
			P							L							A								7			5			3	
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	0	0	1	0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	0	1	1	1	1	1	0	1	1	1

Last Word:

P	SSM		Data Word 3							Data Word 2							Data Word 1								Label						
										A							H								7			5			3	
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	0	0	0	1	1	1	1	0	1	1	1

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Figure 68 AIM Data on Display

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DATA FILE

General

ARINC specification No 429 lays down certain characteristics for specific applications with file data transfer:

- file capacity: 1 to 127 records
- record capacity: 1 to 126 words of 32 bits
- data encoding: numeric data: BNR coded; characters: ISO Alphabet No 5 transmission protocol

All words in a file are assigned the same label as the file label. In this type of transmission, ARINC specification No 429 defines the words containing instructions permitting dialogue between the transmitter and receiver.

These words are always assigned a label associated with the file involved which is going to be transmitted or which has just been received and the SSM (Sign Status Matrix): initial word.

Normal protocol is as follow:

- Transmitter to receiver: Label ”Request to Send” – Initial word
- Receiver to transmitter : Label ”Clear to Send” – Initial word
- Transmitter to receiver : Label ”Data follows” – Initial word
  Label Information Intermediate word
  Label Check sum of all words in file – Final word
- Receiver to transmitter : (after check upon reception of final word)

ARINC specification No 429 furthermore defines use of the following instructions in initial words:

- Receiver to transmitter: ”Data Receiver Not OK”
- or ”Synchronization Lost” in the case of error or loss of synchronization detected by the receiver.
- Transmitter to Receiver: Header Information in the case of error or loss of synchronization detected by the receiver.
- Transmitter to Receiver: Header Information in the case where the transmitter informs the receiver of the file size, without awaiting the instruction to transmit.
- Bidirectional: Poll – This instruction denotes that the line is clear.

For other data regarding the radio–navigation systems:

ARINC specification No 429 furthermore defines other applications concerning ILS, DME, ADF, HF systems etc... which will be defined in the respective ATA specification No 100 chapters.

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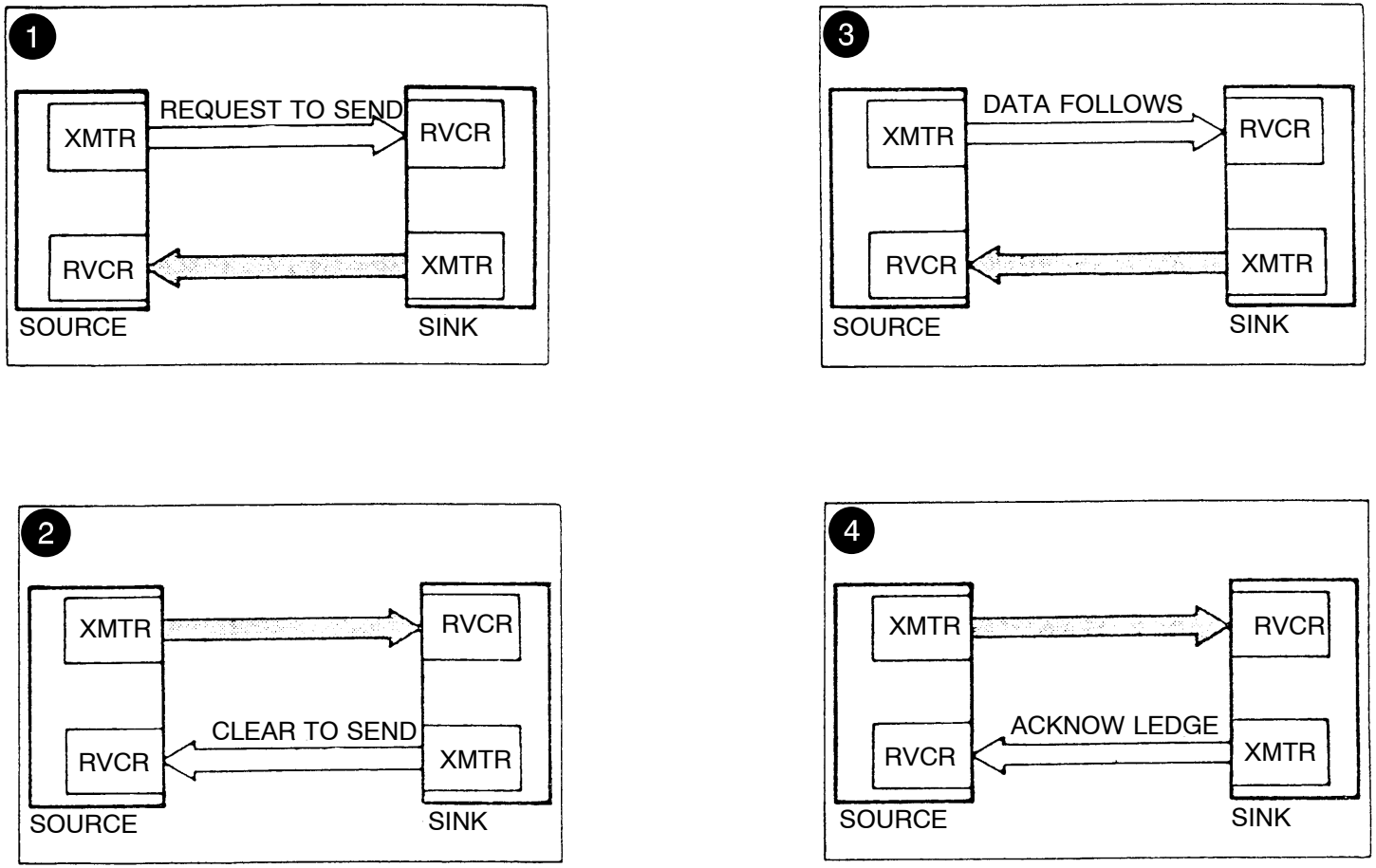

Figure 69 File Data Transfer Protocol

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TEST

Test Plugs

To check the data words which are transmitted by a computer, there are test plugs installed. So it is not necessary to send a computer to a shop.

An ARINC Tester can be connected to the test plug.

In many aircraft, the test plugs are in the compartment where the computers are installed.

Example

In the A 320, there are test plugs which are used to read the data of the Air Data Computers (ADC).

In the A 320 the Air Data Computers are a component of the Air Data Inertial Reference Unit (ADIRU).

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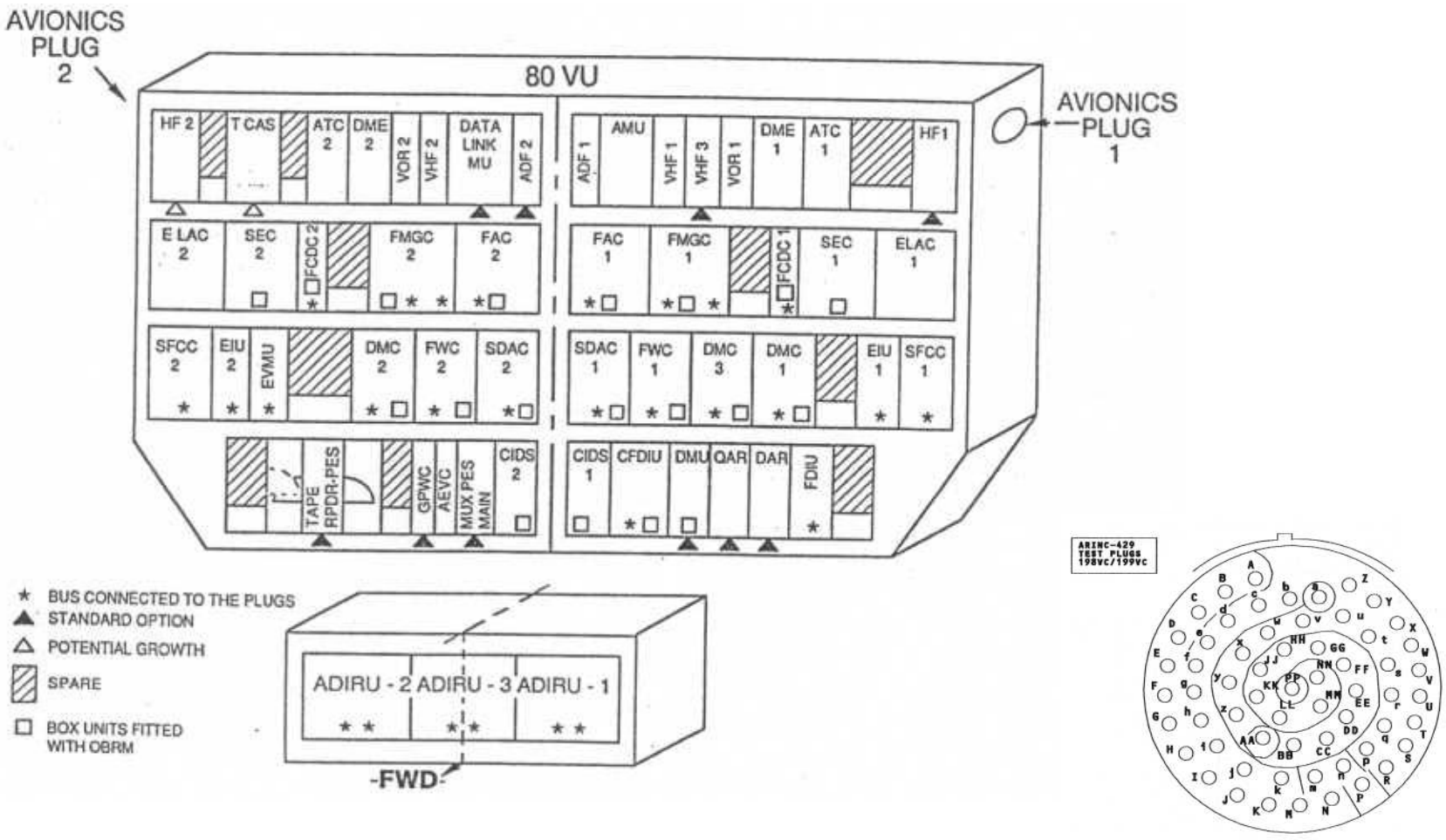

Figure 70 Test Plugs on A320

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Measurement Points

The table below shows which pin of the test connector can be used to read the data of the ADC.

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COMPUTER (ATA REF)	IDENT.	BUS			RACK CONNECTOR		TEST CONNECTOR		TERMINAL BLOCK			
		BIT RATE	FOR-MAT	LI-NE	PLUG	PI-NS	PLUG	PI-NS	LOCA-TION	IDENT.	NUM-BER	PINS
ADC 1	1FL1	LO SPEED	429	A B	AB AB	2A 2B	-	-	90 VU	84VT	9 9	E H
		LO SPEED	429	A B	AB AB	4A 4B	-	-	90 VU	84VT	7 7	E H
		LO SPEED	429	A B	AB AB	6A 6B	62FL1 62FL1	C B	90 VU	84VT	4 6	A A
		LO SPEED	429	A B	AB AB	8A 8B	-	-	90 VU	84VT	1 3	A A
ADC 2	1FL2	LO SPEED	429	A B	AB AB	2A 2B	-	-	80 VU	126VT	66 66	E H
		LO SPEED	429	A B	AB AB	4A 4B	-	-	80 VU	126VT	76 76	A F
		LO SPEED	429	A B	AB AB	6A 6B	62FL2 62FL2	C B	80 VU	126VT	71 73	H H
(34-11)		LO SPEED	429	A B	AB AB	8A 8B	-	-	80 VU	126VT	68 70	A A

Figure 71 Measurement Points

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ARINC 629

General

The new ARINC 629 communication system is a high-integrity, high-reliability, multi-user data bus, which was first deployed on the Boeing 777 aircraft. Boeing began working on a concept of a multi-transmitter data bus in 1977. The ARINC 629 specification was adopted by Airlines Electronic Engineering Committee (AEEC) in 1989.

It is derived from MIL Std 1553B.

ARINC Specifications 429 and 629 may both be applied on the same airplane in order to obtain the best technical and economic solution.

Features

ARINC 629 defines Half-Duplex-Operations as a standard.

ARINC 629 supports a multi-transmitter and bidirectional approach to digital data communications. The primary advantages of this multiple access data bus include the ability to move more data between LRUs at higher rates using fewer wires.

The data signalling rate is 2 MBit/s.

Another advantage of this concept is: it does not need a central bus controller, which could be a potential source of total data bus failure.

COMPONENTS

General

Physically the ARINC 629 system consists of the following components:

- Data Bus Cable,
- Couplers,
- Stub Cables.

Components which can be replaced in a short time period are called Line Replaceable Units (LRU).

The LRUs which communicate via ARINC 629 contain the following components:

- Serial Interface Module (SIM)
- Terminal Controllers.

Data Bus Cable

Three transmission modes and media are specified for the implementation of ARINC 629 networks:

- Current Mode Bus
- Fibre Optic Mode Bus
- Voltage Mode Bus.

Couplers

According to the Data Bus Cable there are associated Couplers implemented:

- Current Mode Couplers (CMC) or
- Fibre Optic Input/Output Ports.

(A Voltage Mode Coupler is as yet not specified.)

Stub Cables

The Stub Cable Assembly, consisting of four conductors, carries the differential voltage doublet from the Terminal to the Coupler and back.

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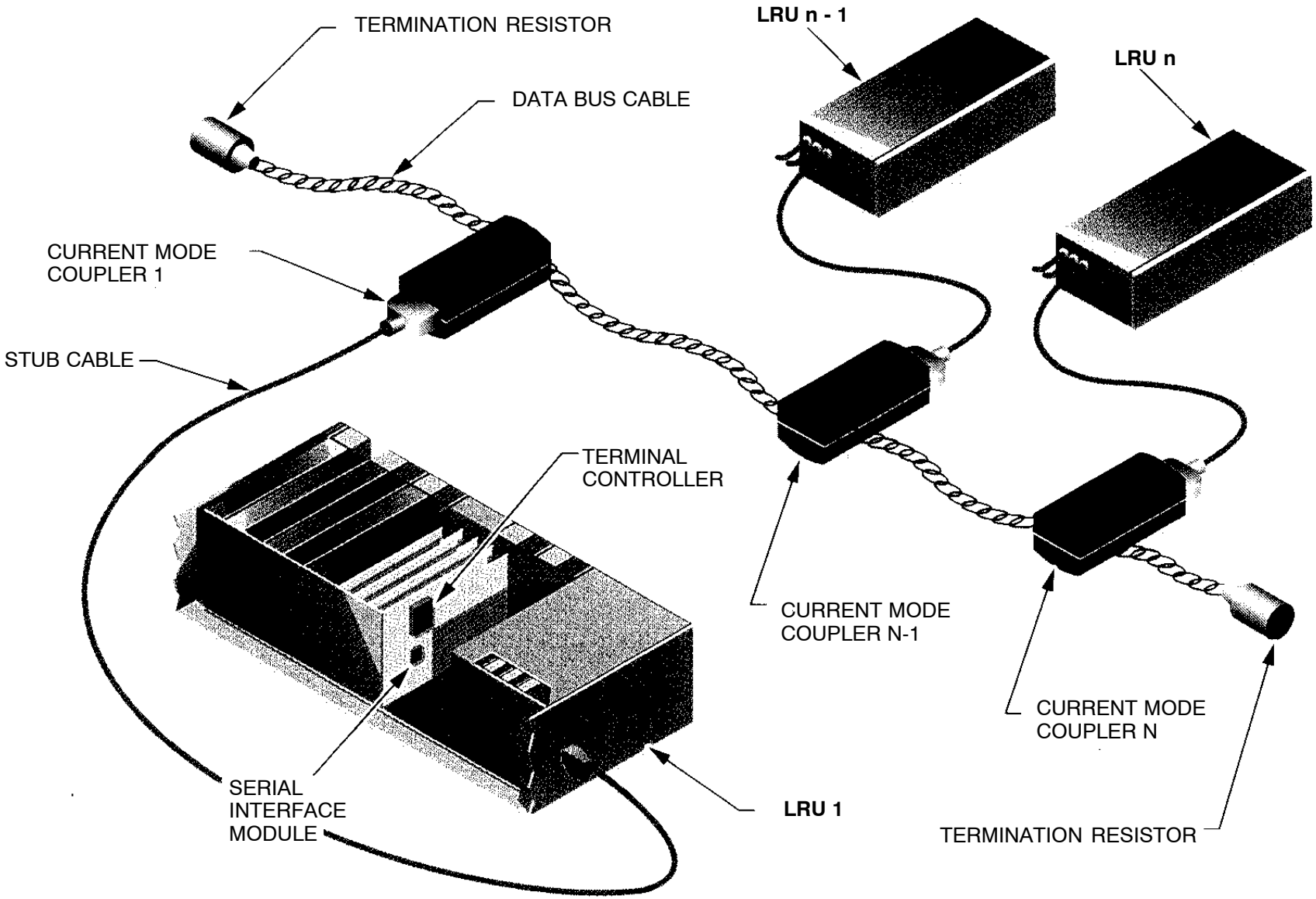

Figure 72 ARINC 629 Components

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LOCAL SIDE

General

The “Local Site“ of ARINC 629 is implemented in each computer unit.

It contains

- Terminal Controller (TC)
- Serial Interface Module (SIM)
- associated hardware.

The Stub Cables, Bus Cables and Couplers (Global Side) are routed and installed within the airplane fuselage, primarily in the Main Equipment Centre.

Data Exchange

The operation of transferring data from one LRU to one or more other LRUs occurs as follows:

1. 16-bit parallel data is retrieved from the transmitting LRUs memory by the TC.
2. The TC determines when to transmit, converts the parallel data to serial data and sends it to the SIM.
3. The SIM converts the digital serial data into analog doublets and sends them to the Coupler via the stub.
4. The Coupler inductively couples doublets onto the bus. At this point the data is available to all other Couplers on the bus.

Receiving terminals perform the above operation in reverse, eventually writing 16 bit parallel data into their system memories and, thus, completing the transfer.

RPP

The Receive Personality Program (RPP) contains the set of all labels to be received by that terminal and the number of data words following each desired label to be stored in system memory.

Terminal Controller

The Terminal Controller (TC) contains the bus protocol access logic that determines when the terminal will transmit. The TC listens the bus and waits for a series of quiet periods before transmitting.

Only one terminal is allowed to transmit at a time and, once a terminal has transmitted, it must wait for all other terminals on the bus to transmit before it transmits again.

Three internal protocol timers are utilized to ensure that this orderly bus access occurs. For redundancy the access protocol circuitry is duplicated and utilizes two independent Oscillators (clock sources of 32 MHz square wave) to prevent a single failure from interfering with bus access for other terminals.

The TC takes 16–bit parallel data words from system memory, converts them into serial bit stream messages and transmits them via the SIM and CMC onto the bus. The TC also receives everything it transmits and monitors the data for proper format and length. The labels are checked to ensure that they are allowed for transmission by this terminal.

XPP

The Transmit Personality Table (XPP) contains all the essential information needed to formulate a terminals transmission.

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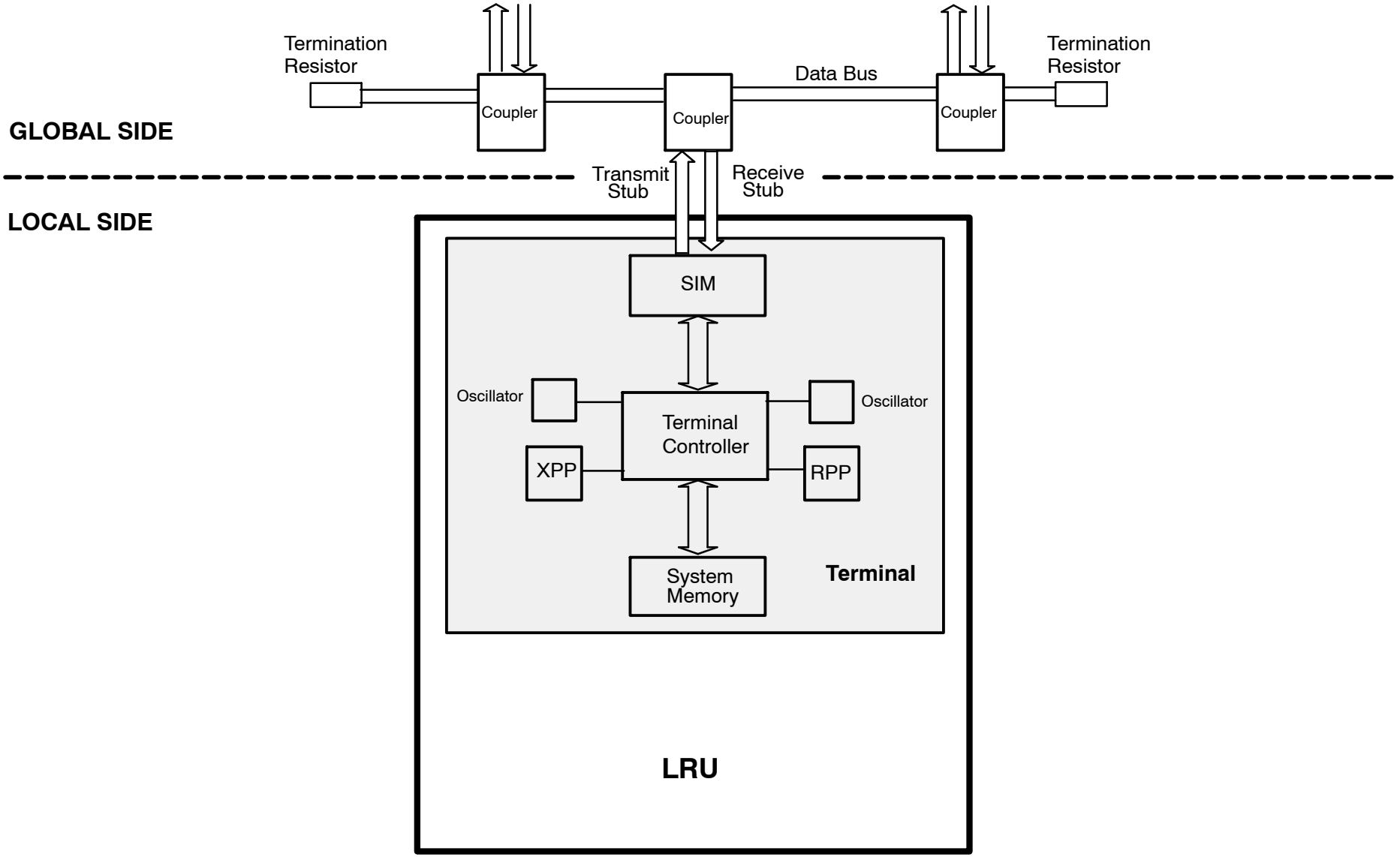

Figure 73 Local Side

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GLOBAL SIDE

General

The Global Side is used to establish the interface between the LRUs.

Coupler

The Current Mode Coupler (CMC) takes the differential voltage mode doublets produced by the SIM and inductively couples them onto the data bus.

The doublet propagate along the data bus, where they are detected and read by all connected terminal CMC's. All doublets on the bus are coupled back onto the stub cable as a differential voltage mode signal.

Every terminal on the bus will receive all information, only data following labels pre-programmed into receiving terminals RTP will be transferred to system memory.

The coupler contains two redundant transmit and receive channels to provide fault tolerance.

Up to 60 components can be connected to the bus through inductive bus couplers.

Stub Cable

Each component is connected to its coupler by a stub cable.

The stub cable assembly, consisting of four conductors, carries the differential voltage mode doublet from the SIM to the CMC and back.

Two types of stub cables are used:

- The first consists of two twisted, shielded pairs.
- The second consists of a shielded quad-twist configuration.
  These quad-twist stub cable can be up to 75 feet in length (depending on the aircraft type).

Bus Cable

The Current Mode Bus cable assemblies are twisted pair of wires, terminated at each end with a Terminal Resistor (characteristic impedance of the bus cable), which is 130 Ohms.

Most of the used buses are unshielded. However, the two longest are shielded to reduce radiated emission.

A bus cable can be up to 300 feet in length. On the 777, the longest bus is approximately 180 feet.

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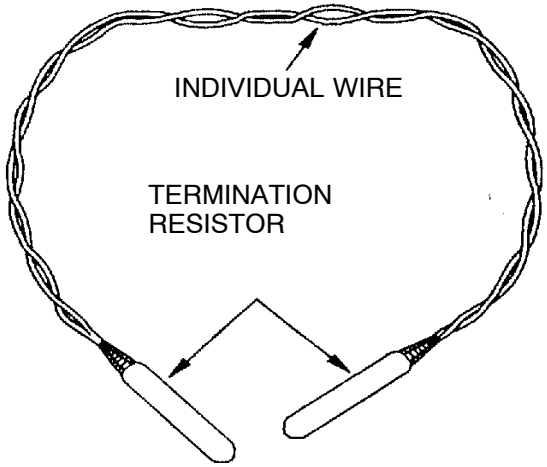

Data Bus Cable

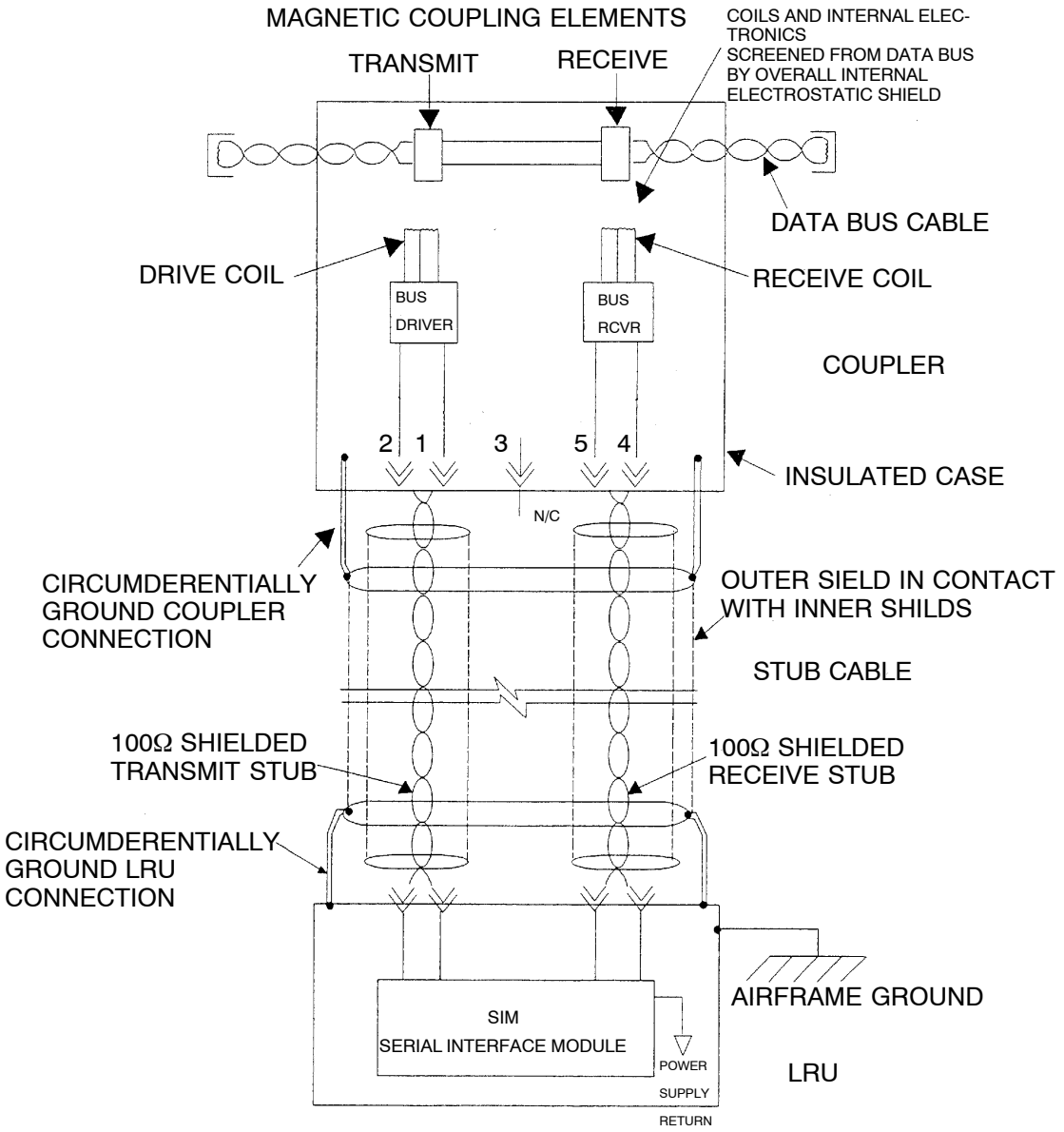

Figure 74 Global Side

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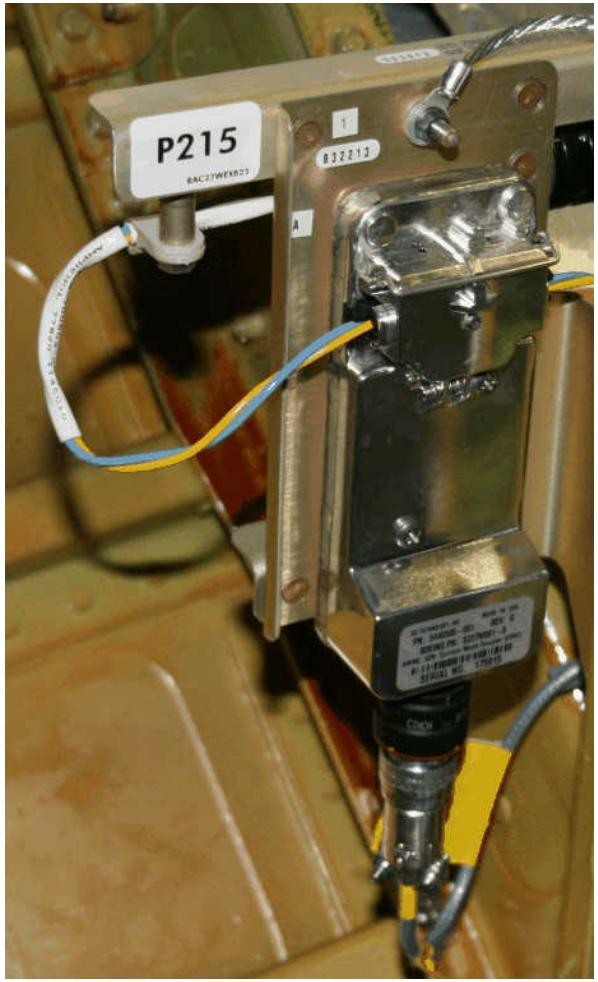

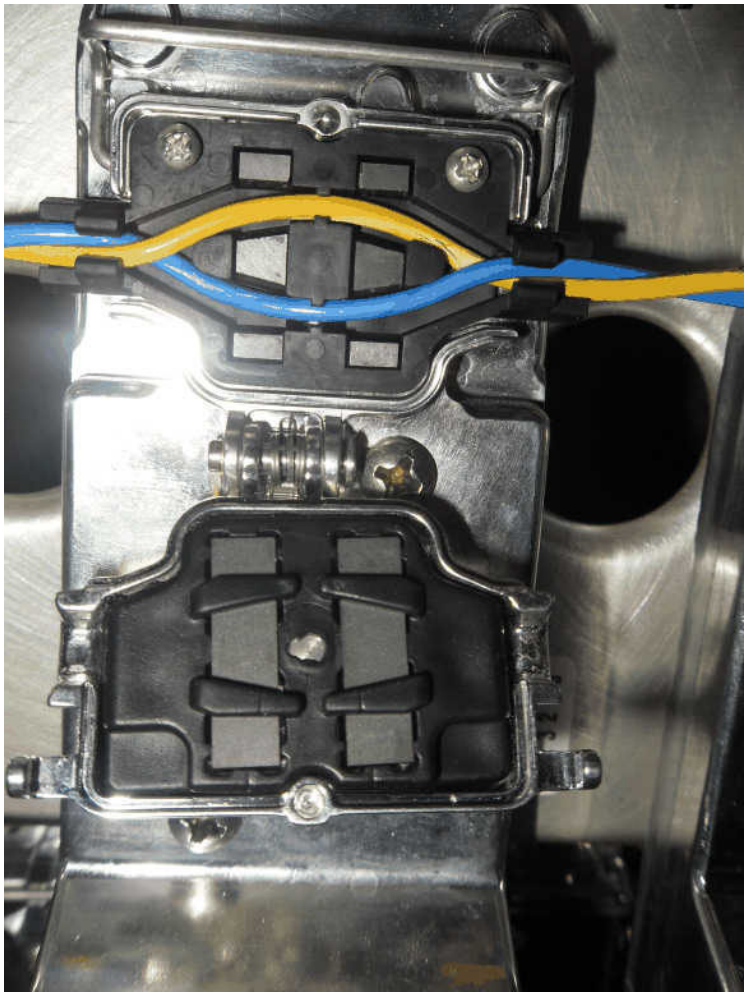

Figure 75 Current Coupler

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Figure 76 Patch Field

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SIGNAL MESSAGE

General

A message is made up of a series of word strings. Each consisting of a 16-bit label word (incl. 4 extension bits), followed by up to 256 16–bit data words. The transmission rate is two Mega bits per second, which allows 100,000 20 bit words to be transmitted each second.

Each component can send a **message** that contains up to 31 **word strings** and each word string contains a **label word** and a maximum of 256 **data words**. Where a message contains more than one wordstring. A gap of four bit should be inserted between wordstrings.

Each word uses an additional bit-time for parity and three bit-times for word synchronization, adding to a total of 20 bit-times per word.

ARINC 629 identifies and specifies the format for many data types:

- binary data
- alphanumeric data (ISO #5)
- discrete data
- real numbers
- extended binary data
- byte data
- graphic data.

Data can be organized in single words, multiple word messages and multiple message bulk data formats. The data format used in ARINC 629 was inherited from Mil-Std-1553.

Only one ARINC 629 terminal may transmit on the data bus at a time. To avoid data collisions, terminals ''listen'' to traffic and wait for a ''quiet'' bus to transmit data

Upon starting the transmission of its own data , each terminal activates interval timers that are programmed to hold off additional transmission until all other terminals on the data bus have had an opportunity to transmit their data

Labels and data present on the bus, but not desired by the receiver, will be ignored by the Terminal Controller.

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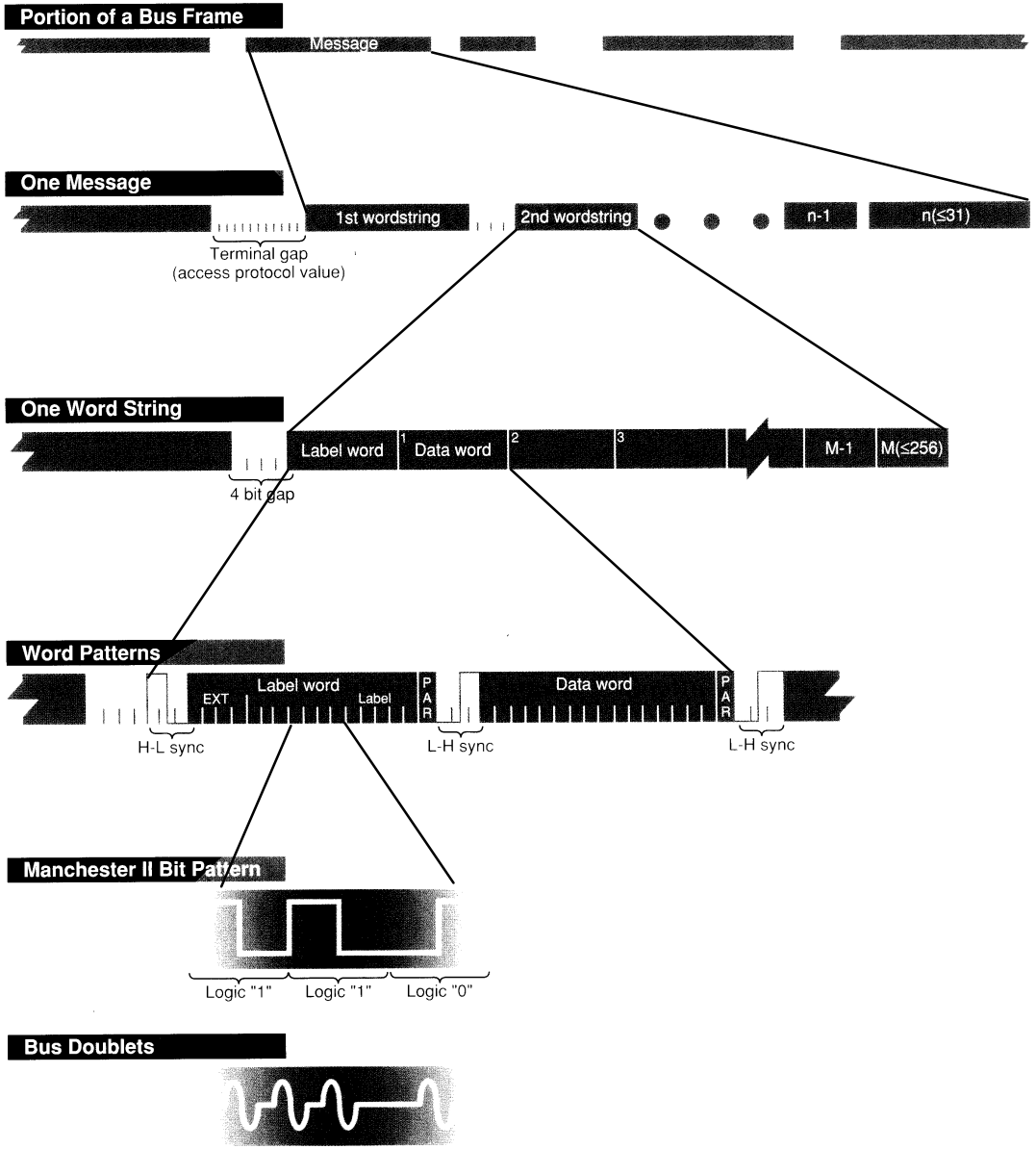

Figure 77 Signal Message

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INTERFACE EXAMPLE

General

The ARINC 629 System supports data communication between many terminals over a common bus.

B 777

Boeing uses in the B 777 up to eleven Current Mode Buses for different systems and only few Fibre Optic Mode Buses for test purposes:

- 3 dedicated ARINC 629 Flight Control Buses for Flight Control Systems connected with 24 LRUs.
- 4 ARINC 629 System Buses for the main Communication Systems connected with 39 LRUs of the following systems
  - Avionics
  - Electrical
  - Electro-mechanical
  - Environmental Control
  - Propulsion.
- 4 ARINC 629 Inter-Cabin Buses.

Redundancy

For redundancy reasons, most LRUs are supplied by two separated buses.

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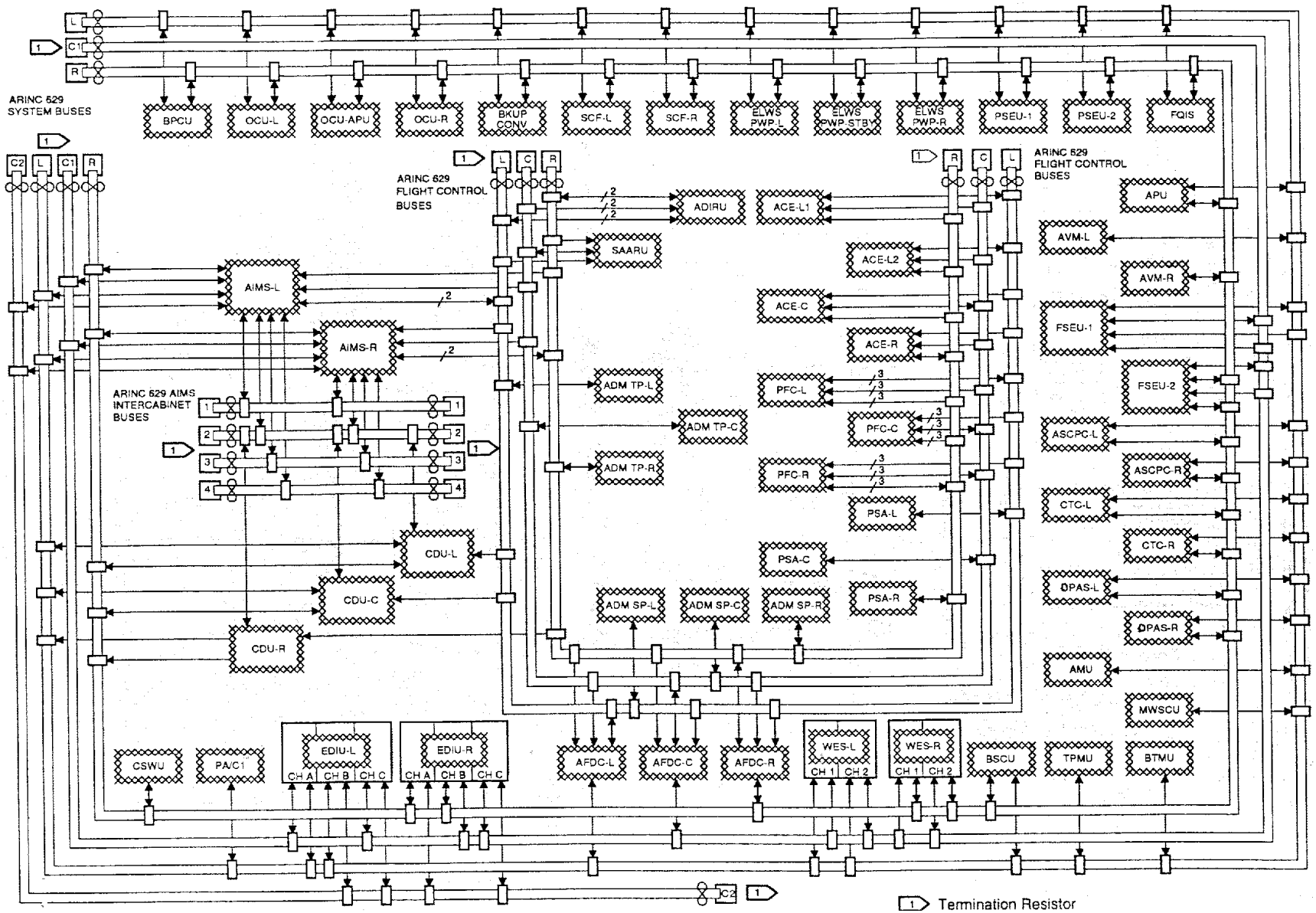

Figure 78 Interface Diagram

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ARINC 664

Ethernet

In the past, the aircraft avionics systems used primarily the ARINC 429 data buses to transfer information.

It uses a data transport rate of up to 100.000 bit per second or 100 kilo bps in short and allows a data exchange only in one direction.

Each individual avionics component needs a wired connection to all other computers that need the data, which is called a “point−to−point interconnection“.

If for example a new LRU has to be added because of a modification you have to install new wires to all other involved computers.

The classic Ethernet−based data communication needs just a connection of each unit to the common Ethernet bus, used for both transmission and reception, and the data speed is increased up to 10 million bits per second or 10 Mega bps in short.

If a new LRU has to be added the hardware modification just needs a new connection to the Ethernet bus.

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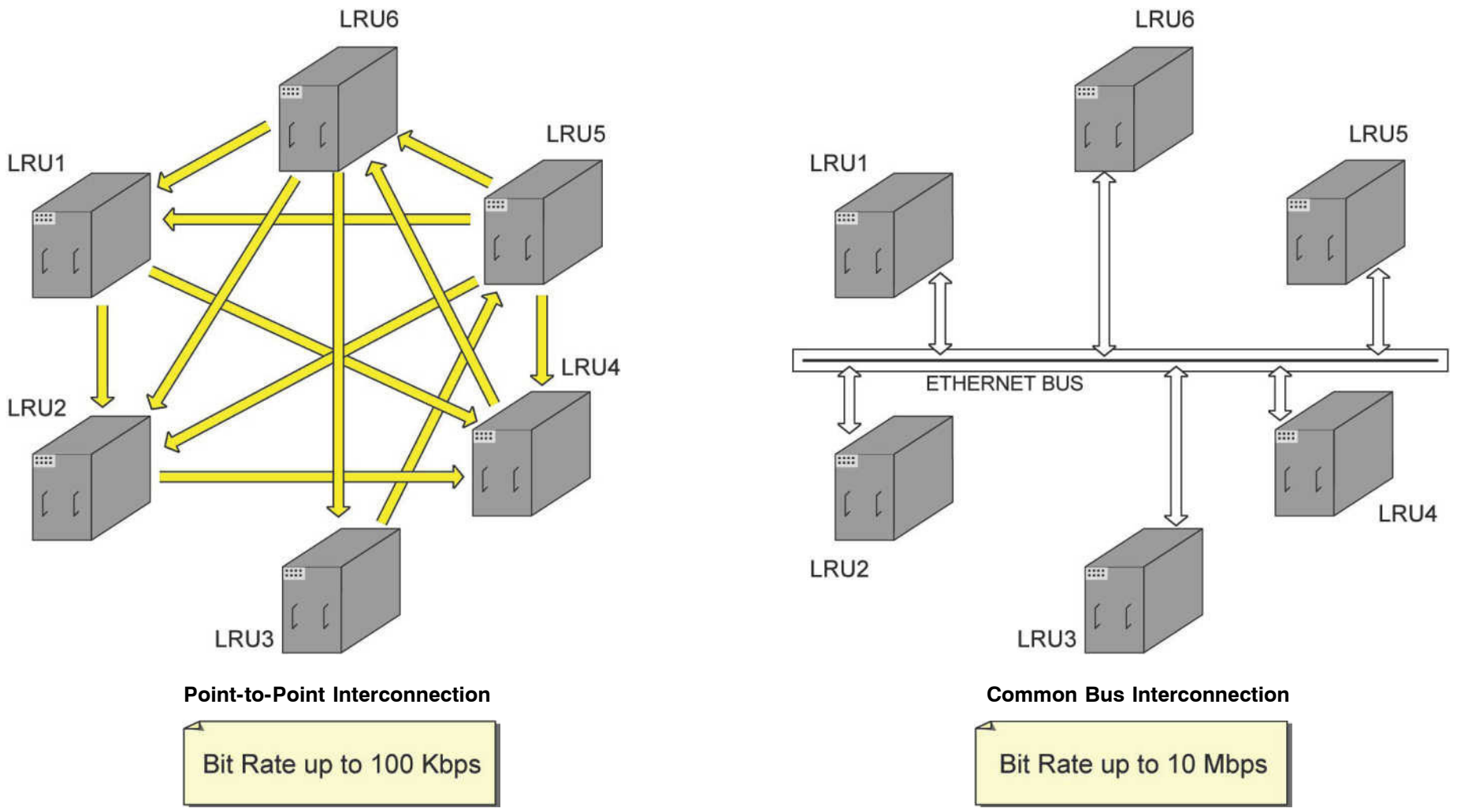

Figure 79 Ethernet Basics

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Classic Ethernet

The classic Ethernet−based communication is based on the so called CSMA / CD principle.

CSMA stands for carrier sense multiple access and CD for collision detection.

These communication rules are comparable to those which polite people use during a meeting.

Multiple access means that anybody can talk to all people at the table and all can listen to the speaker at the same time.

For the computer this also means that all have access to the Ethernet bus at the same time.

Carrier sense means that all people have to listen first and only start to speak if the medium is silent.

Also the computer have to listen first and are only allowed to transmit data if the bus is at idle.

In a few cases it may happen that two transmitters, or people, start talking at the same time.

In this case both detect this collision and stop the conversation immediately, this is called “collision detection“.

After a few micro−seconds of listening the first computer starts to transmit again and the normal conversation continues.

The waiting time is random so that never the same computers start the conversation again at the same time.

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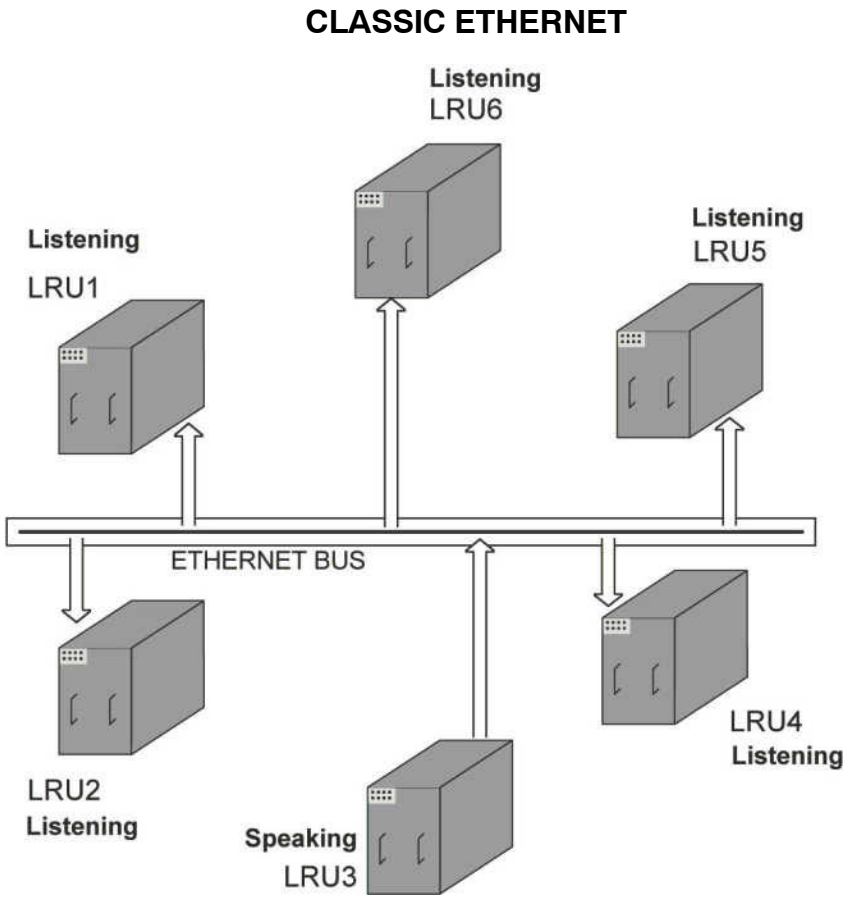
Collision detected:

- all stop transmission
- after few micro-seconds one computer starts again
- random waiting time prevents that same computers start again at same time



CSMA / CD

- **CSMA** : Carrier Sense Multiple Access
- **CD** : Collision Detection

Figure 80 Classic Ethernet

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Switched Ethernet

A problem with the classic Ethernet is that if you have many computers you may get long waiting times to detect a silent medium that allows you to transmit the information.

Therefore if you have time critical data transmissions like in the avionics system, you need to divide the network with intermediate devices to control the traffic.

On the A380, these intermediate devices are routers or switches, which have a dedicated segment for each computer.

Now all computers can transmit data at any time and the router/switch transfers the data only to the receiver who needs the information.

Here for example from computer 1 to computer 3. At the same time computer 5 could send data to computer 6. A collision is not possible, because the router/switch always buffers the data until the specific line is free.

If for example computer 1 and computer 4 want to send data at the same time to computer 3, then the router/ switch buffers both data and transmit the data after each other.

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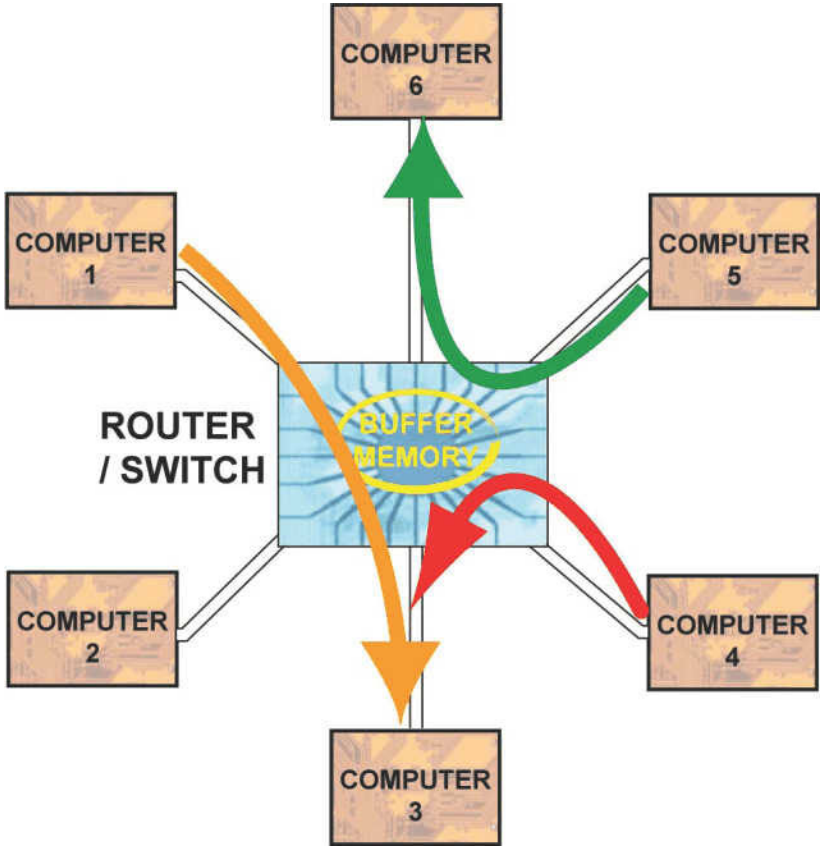

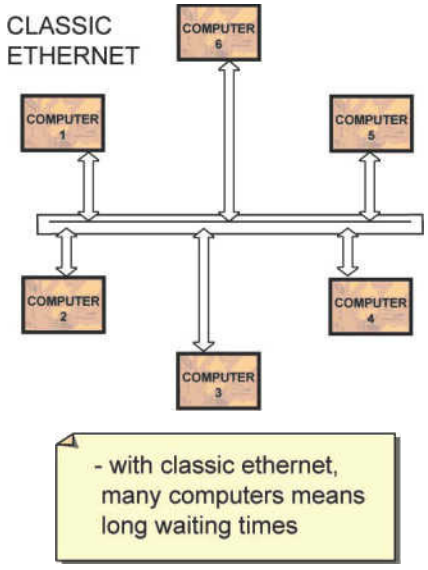

Figure 81 Switched Ethernet

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Full Duplex Ethernet

Full duplex operation mode can only be used when all of the following statements are fulfilled:

- The physical medium is capable of supporting simultaneous transmission and reception without interference.
- There are exactly two stations connected with a full duplex point−to−point link.
- Both stations are capable of use, and have been configured to use full duplex operation.

Since there is no use of a shared medium, the CSMA/CD principle is unnecessary.

But if one of these conditions is not fulfilled the Ethernet−based data communication works in half duplex operation, taking into account the CSMA/CD principle.

The most common configuration for full duplex operation has a central intermediate device with a full duplex point−to−point link to each computer or other intermediate device.

On the A380, the central intermediate devices are AFDX switches for the avionics world and routers for the open world.

Both worlds use quad cables as full duplex point−to−point links.

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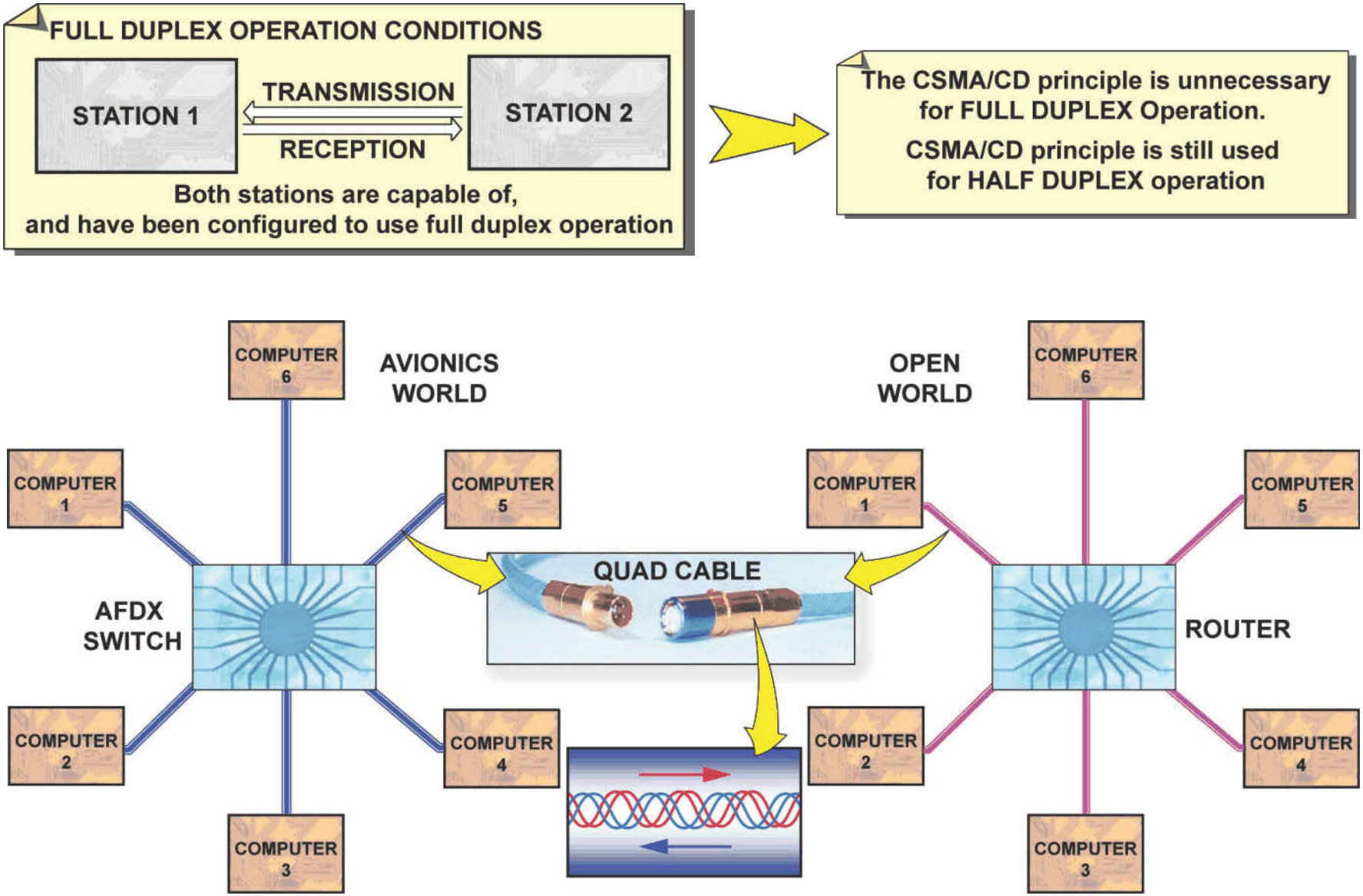

Figure 82 Full Duplex Ethernet

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Aircraft Data Communication Network (ADCN) Architecture

All ADCN subscribers communicate to each other through the ADCN via AFDX switches and AFDX harnesses.

Highlight that AFDX harnesses are made of Quad cables.

For availability reasons, the ADCN has two redundant networks, Network A and Network B.

So all ADCN subscribers are connected to both networks.

Each subscriber sends a sequence of data through both networks and the destination subscriber will use a policy of first valid data wins.

On the A 380, there are 80 subscribers interconnected through the ADCN via 16 AFDX switches and AFDX harnesses.

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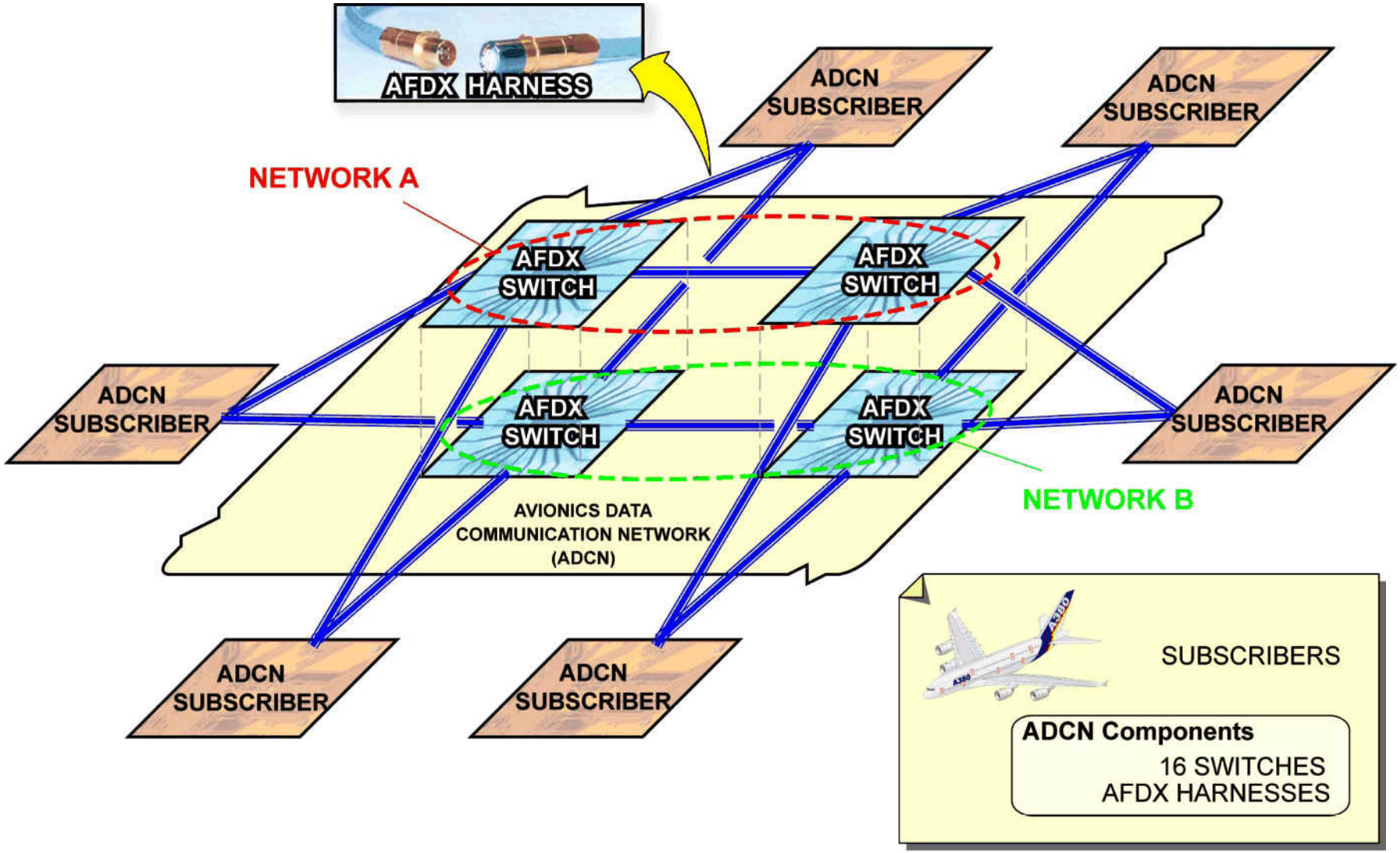

Figure 83 ADCN Architecture

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AFDX Benefits

The AFDX technology has the following main benefits:

It provides bi−directional communication with a high speed of up to 100 MBit/s, so a very high data throughput is available.

It works in a Virtual−Link concept, which means that one transmitter can communicate with any of the theoretically high number of receivers .

It has the flexibility to manage any evolution in the system with a few wiring modifications.

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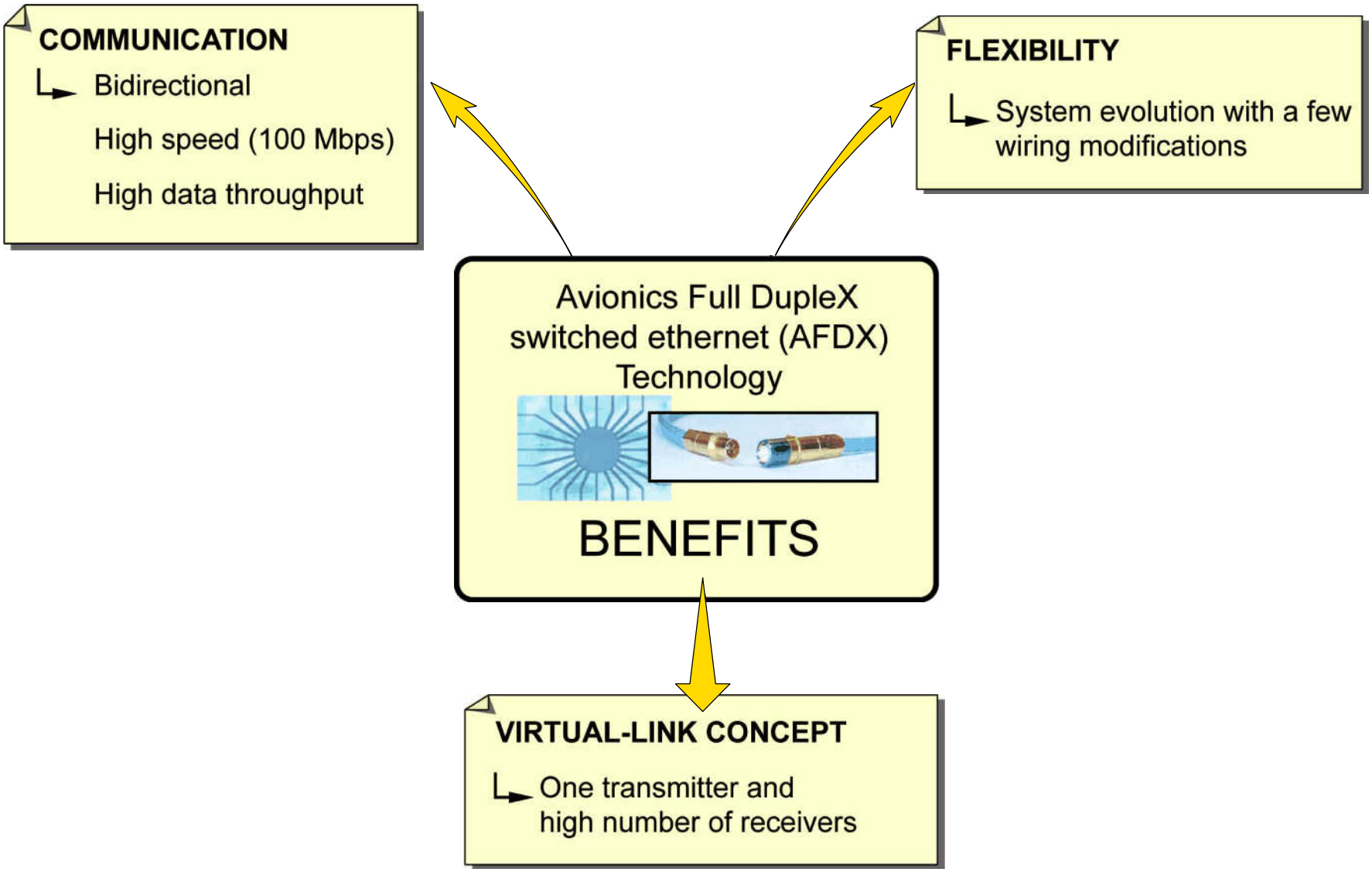

Figure 84 AFDX Benefits

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ARINC 717

General

ARINC 717 deals with the data transmission between DFDAU (Digital Flight Data Aquisition Unit) and DFDR (Digital Flight Data Recorder).

Its aim is to store critical data in a (Solid State) Memory to enable evaluation of the data in case of an incident.

COMPONENTS

DFDAU (Digital Flight Data Aquisition Unit)

The DFDAU receives information from various avionics units via several buses e.g. ARINC 429 Data Bus. Information is evaluated and converted into a specific format. Data then is forwarded to the DFDR.

Usually the DFDAU (or FDIU, Flight Data Interface Unit) is located in the avionics compartment.

DFDR (Digital Flight Data Recorder)

The DFDR is a memory storing information from the DFDAU. Its capacity is 25 hours. In older systems a magnetic endless tape is used. As this tape has to be tested once a year the DFDR will be to the shop for 3 days (1 x recording, 1 x reading and comparing). Modern DFDR use electronic memory (Solid State), which can be written and read out within seconds or minutes. No moving parts are contained so no wear has to be expected like from the friction of the magnetic tape reel layers.

The housing is very substantial, it can withstand massive shocks and has a thermal insulation to withstand fire. In addition an Underwater Locator Beacon (ULB) is attached providing acoustic signals to be picked up by sonar. The ULB activates if it comes in contact with water.

The DFDR usually is located on the aft section of the aircraft. It becomes active as soon as one of the engines is powered up.

For maintenance purposes it can be activated manually via the Ground Control Pushbutton.

Data Bus

The data bus is a shielded twisted pair.

Data transmission is simplex operations only. Data is only transferred to the DFDR.

Some aircraft have an option to access the DFDR via the CMC system. In this case an additional data bus is required transferring data from the DFDAU to the DFDAU.

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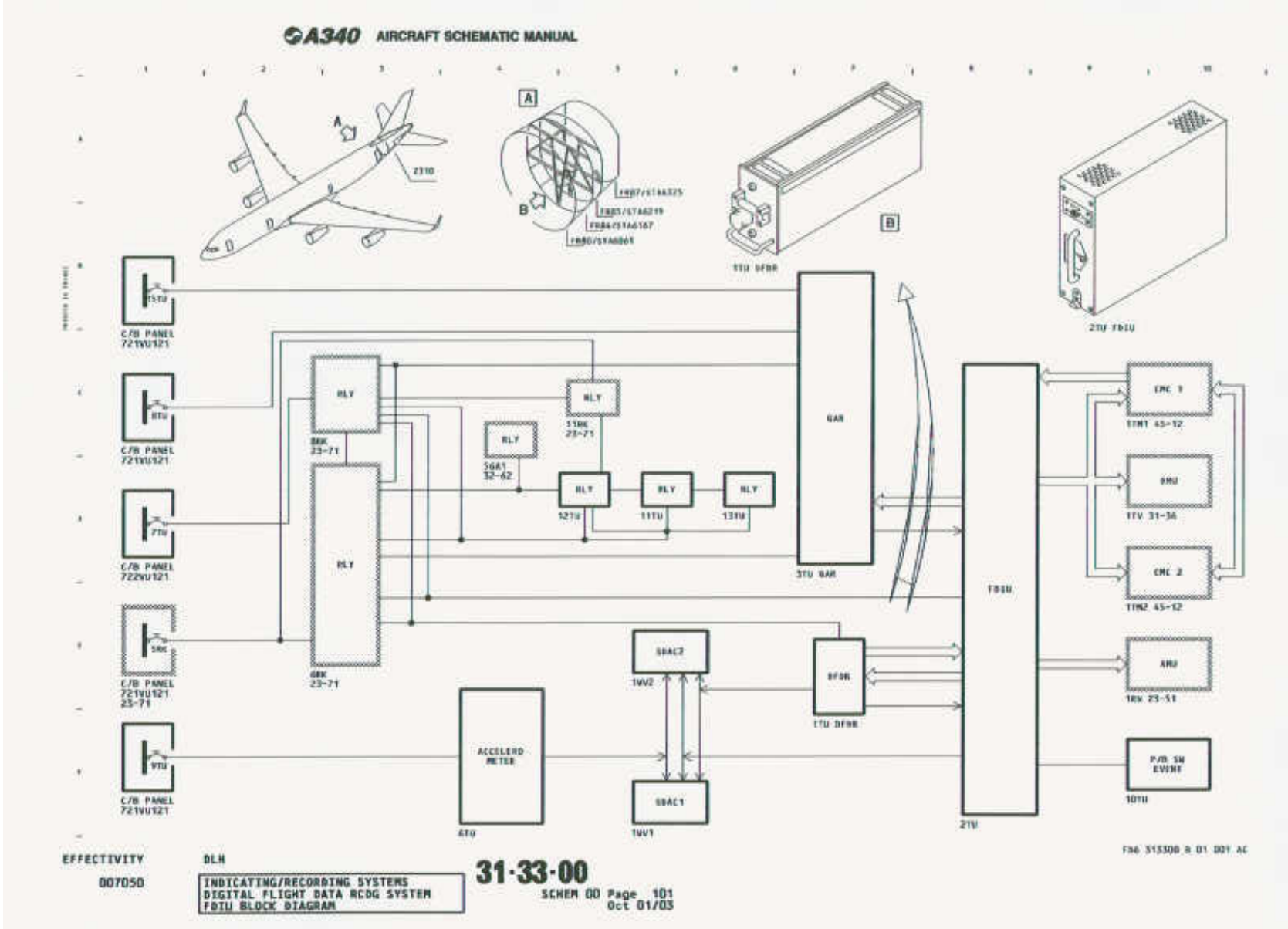

Figure 85 Flight Data Recording System Layout A340

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DATA TRANSMISSION

General

ARINC 717 uses a DC-free Bi-Phase-Signal. Bits are transmitted using Havard Bi-Phase layout.

This layout provides high transmission security.

Bus Protocol

A Bi-Phase signal is in use. It uses positive and negative voltages of 10 Volts.

Transmission speed is 768 Bit per second (at 64 Data words).

Composition of the Signal

Information is transferred in packages, the so-called **frames**. Frame and transmission speed together allow the evaluation of the information transmitted. Each parameter has a fixed position within a frame. By using a table the parameter becomes readable.

The Frame

Transmission time for each frame is 4 seconds. It contains 4 Sub-Frames.

The Sub-Frame

The Sub-Frame is a set of several parameters called words. Depending on legal requirements a Sub-Frame may contain 64 parameters at least.

Example Airbus A320:

- 128 Parameters EASA/JAA
- 256 Parameters FAA (US)

On the A380 1024 parameters are stored.

Transmission of a complete sub-frame takes one second.

Some parameters are transmitted once per frame, other more important parameters may be transmitted with every sub-frame.

The Data Word

Any information (parameter) is transmitted as a 12–bit data-word. With 64 parameters the data rate will be:

12 x 64 = 768 Bit/second.

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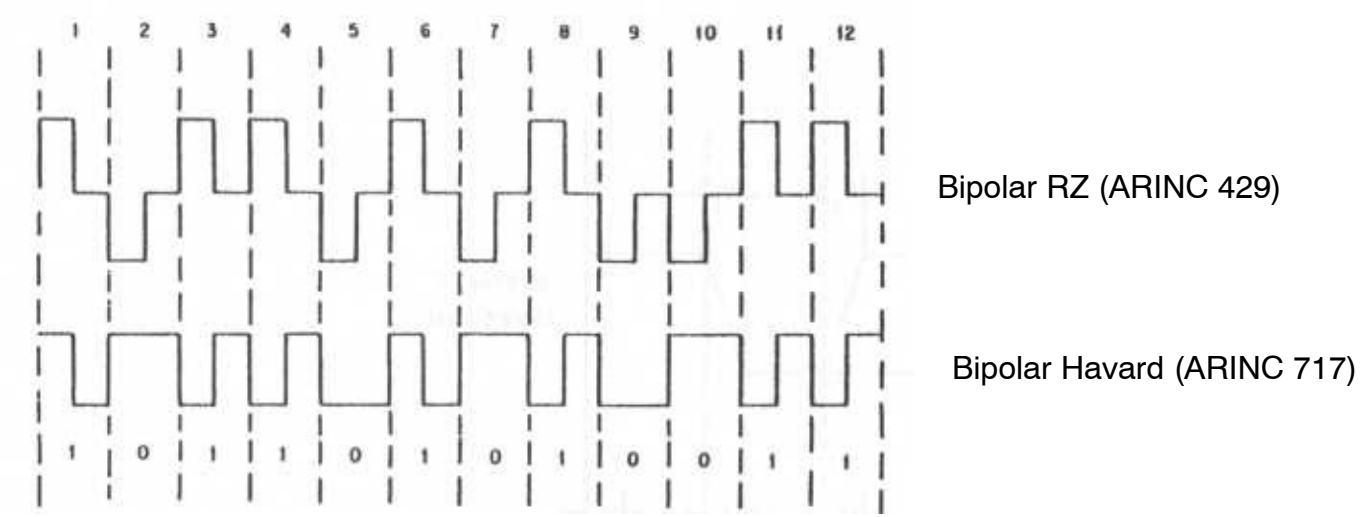

Figure 86 Signal Form Havard Bi-Phase

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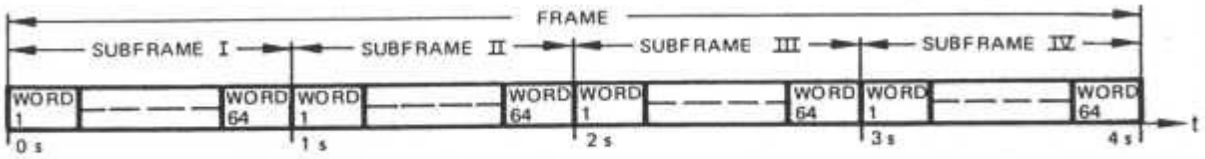
Diagram :



Frameformat:

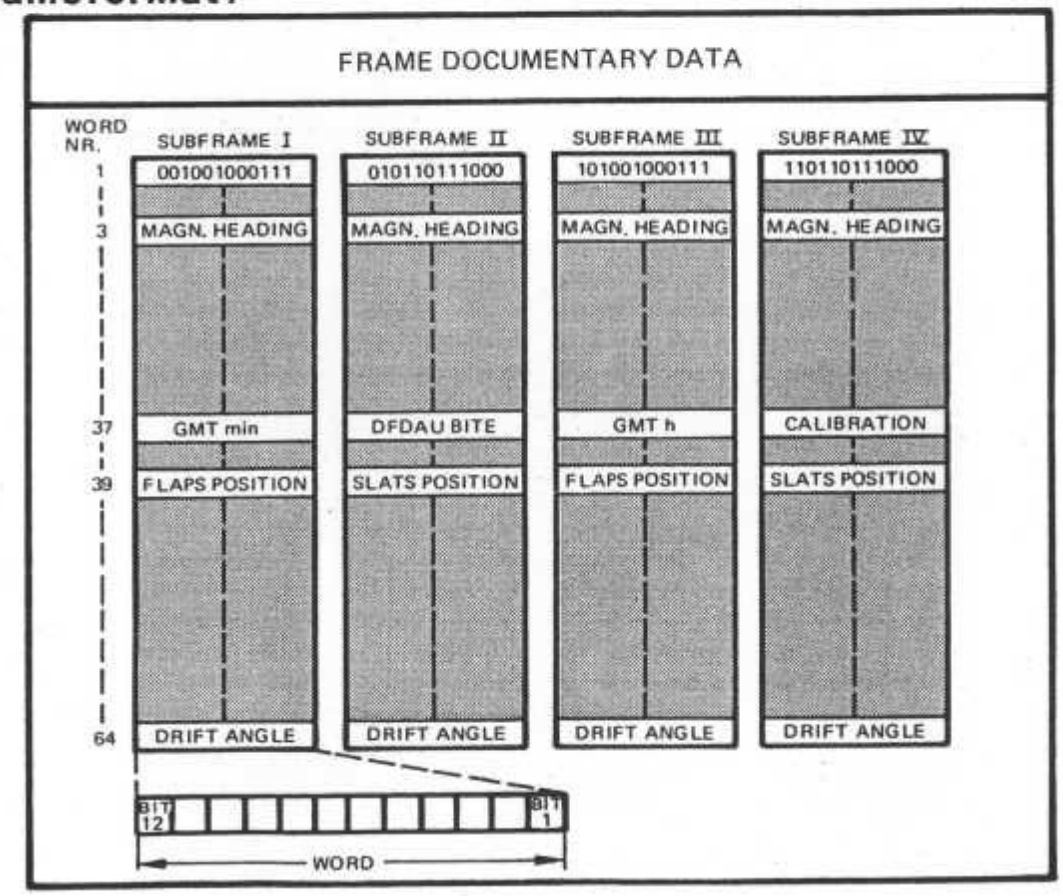


Figure 87 Composition of an ARINC 717 Frame

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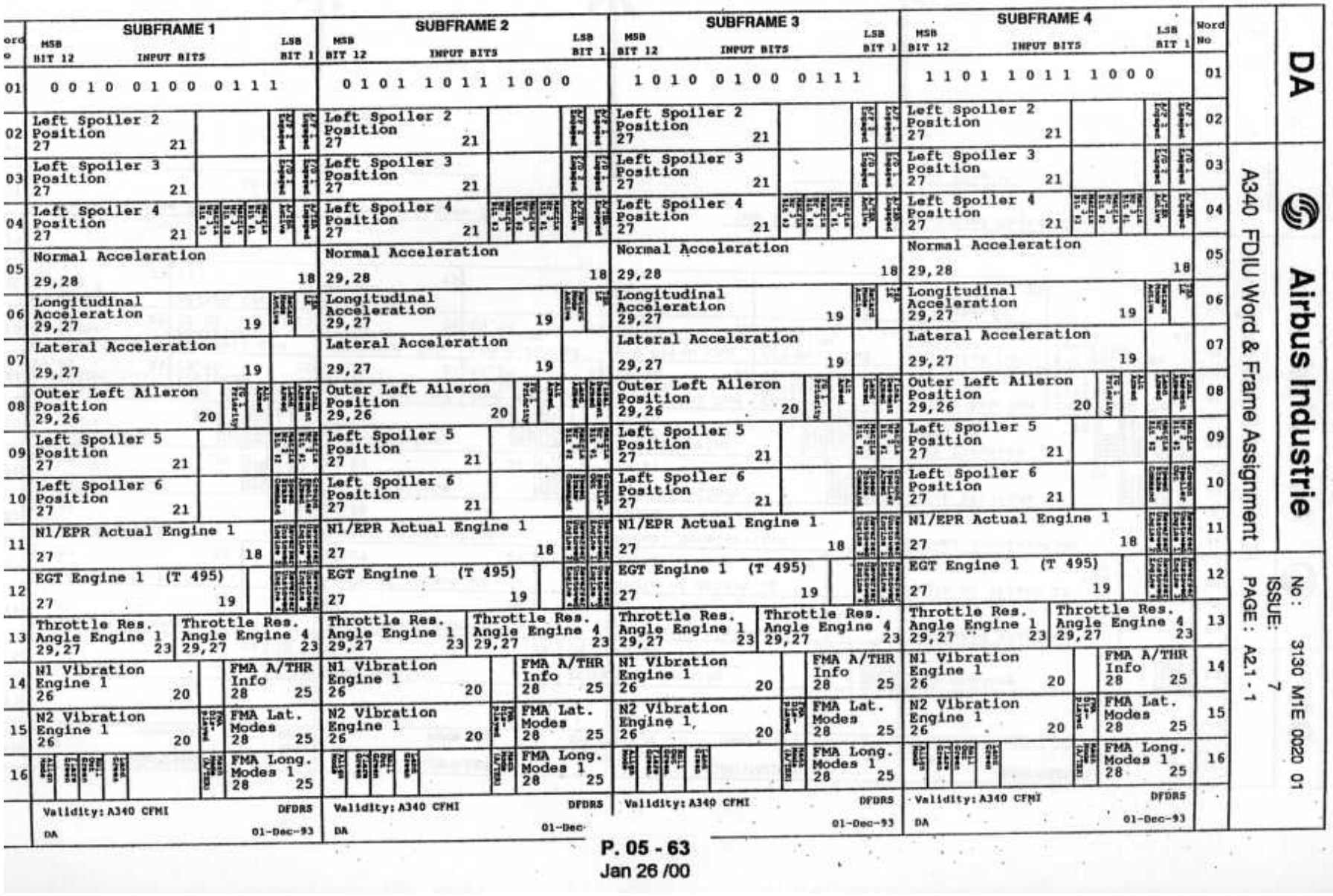

Word No	SUBFRAME 1 (MSB BIT 12 … LSB BIT 1)	SUBFRAME 2	SUBFRAME 3	SUBFRAME 4
01	0 0 1 0 0 1 0 0 0 0 1 1 1	0 1 0 1 1 0 1 1 1 0 0 0	1 0 1 0 0 1 0 0 0 1 1 1	1 1 0 1 1 0 1 1 1 0 0 0
02	Left Spoiler 2 Position 27 21	Left Spoiler 2 Position 27 21	Left Spoiler 2 Position 27 21	Left Spoiler 2 Position 27 21
03	Left Spoiler 3 Position 27 21	Left Spoiler 3 Position 27 21	Left Spoiler 3 Position 27 21	Left Spoiler 3 Position 27 21
04	Left Spoiler 4 Position 27 21	Left Spoiler 4 Position 27 21	Left Spoiler 4 Position 27 21	Left Spoiler 4 Position 27 21
05	Normal Acceleration 29,28 18	Normal Acceleration 29,28 18	Normal Acceleration 29,28 18	Normal Acceleration 29,28 18
06	Longitudinal Acceleration 29,27 19	Longitudinal Acceleration 29,27 19	Longitudinal Acceleration 29,27 19	Longitudinal Acceleration 29,27 19
07	Lateral Acceleration 29,27 19	Lateral Acceleration 29,27 19	Lateral Acceleration 29,27 19	Lateral Acceleration 29,27 19
08	Outer Left Aileron Position 29,26 20	Outer Left Aileron Position 29,26 20	Outer Left Aileron Position 29,26 20	Outer Left Aileron Position 29,26 20
09	Left Spoiler 5 Position 27 21	Left Spoiler 5 Position 27 21	Left Spoiler 5 Position 27 21	Left Spoiler 5 Position 27 21
10	Left Spoiler 6 Position 27 21	Left Spoiler 6 Position 27 21	Left Spoiler 6 Position 27 21	Left Spoiler 6 Position 27 21
11	N1/EPR Actual Engine 1 27 18	N1/EPR Actual Engine 1 27 18	N1/EPR Actual Engine 1 27 18	N1/EPR Actual Engine 1 27 18
12	EGT Engine 1 (T 495) 27 19	EGT Engine 1 (T 495) 27 19	EGT Engine 1 (T 495) 27 19	EGT Engine 1 (T 495) 27 19
13	Throttle Res. Angle Engine 1 29,27 23 / Throttle Res. Angle Engine 4 29,27 23	Throttle Res. Angle Engine 1 29,27 23 / Throttle Res. Angle Engine 4 29,27 23	Throttle Res. Angle Engine 1 29,27 23 / Throttle Res. Angle Engine 4 29,27 23	Throttle Res. Angle Engine 1 29,27 23 / Throttle Res. Angle Engine 4 29,27 23
14	N1 Vibration Engine 1 26 20 / FMA A/THR Info 28 25	N1 Vibration Engine 1 26 20 / FMA A/THR Info 28 25	N1 Vibration Engine 1 26 20 / FMA A/THR Info 28 25	N1 Vibration Engine 1 26 20 / FMA A/THR Info 28 25
15	N2 Vibration Engine 1 26 20 / FMA Lat. Modes 28 25	N2 Vibration Engine 1 26 20 / FMA Lat. Modes 28 25	N2 Vibration Engine 1 26 20 / FMA Lat. Modes 28 25	N2 Vibration Engine 1 26 20 / FMA Lat. Modes 28 25
16	FMA Long. Modes 1 28 25	FMA Long. Modes 1 28 25	FMA Long. Modes 1 28 25	FMA Long. Modes 1 28 25
	Validity: A340 CFMI DA — DFDRS 01-Dec-93	Validity: A340 CFMI DA — DFDRS 01-Dec	Validity: A340 CFMI — DFDRS 01-Dec-93	Validity: A340 CFMI DA — DFDRS 01-Dec-93

DA — Airbus Industrie

A340 FDIU Word & Frame Assignment

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Figure 88 Frame of an A340

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RS 485

General

The RS-485 (or EIA-485) data bus is a standard bus for digital data transmission that is used in aircraft to control the ballast units (cabin lighting system).

The RS-485 only describes the electrical properties. The protocol and connector layout are not specified and is system-dependant.

Layout

RS-485 usually consists of a twisted pair of wires. The voltage difference between the 2 wires determines the signal on the bus with voltage levels between -7V and +12V.

The minimum differential voltage is +/- 200mV.

Logic „1“ is represented by a negative voltage, logic „0“ by a positive voltage.

Even though the data is transmitted over a 2−wire twisted pair bus, all EIA−485 transceivers interpret the voltage levels of the differential signals with respect to a third common voltage. Without this common reference, a set of transceivers may interpret the differential signals incorrectly. In a typical setup, this third voltage is incorporated in the power supply common/ground connection.

With one twisted pair only half-duplex transmission is possible.

In some cases 2 pairs of wires may be used allowing full duplex transmission.

Usually the bus has to be terminated on both ends by a 120 Ohms resistor, at least when the bus is long.

The maximum length of such a bus is 1200m.

The maximum bit rate is 100 kBit/s − 10 MBit/s depending on the bus length. The longer the bus the lower the bit rate has to be. In case the bus has a length of 10 m maximum a data rate of 35 MBit/s can be achieved.

It can be used for point-to-point transmissions as well as multi-point transmissions with a maximum of 32 devices on one bus.

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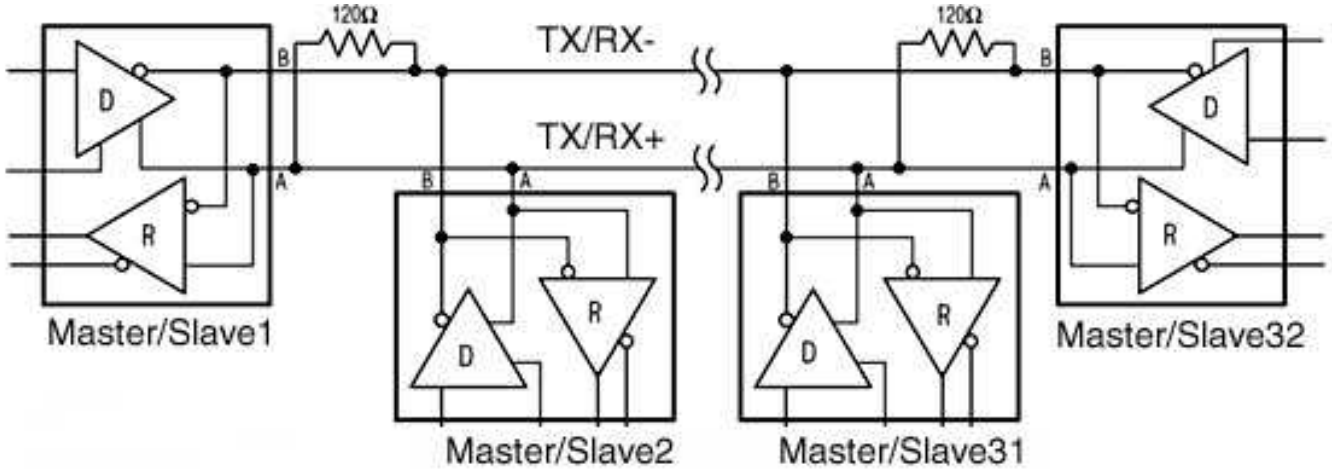

Figure 89 RS 485 Architecture

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RS 422

General

The RS-422 (or EIA-422) data bus has the same major properties of the RS-485 bus. Again, only the electrical properties are described, the protocol and connector layout are not specified and is system-dependant.

Airbus uses this data bus to transmit data to the displays.

Layout

RS-422 usually consists of a twisted pair of wires. The voltage difference between the two wires determines the signal on the bus with voltage levels between -6V and +6V.

The minimum differential voltage is +/- 200 mV.

Logic „1“ is represented by a negative voltage, logic „0“ by a positive voltage.

RS-422 is a simplex mode bus with up to 10 receivers per bus.

The maximum length of such a bus is 1200 m.

The maximum bit rate is 10Mbit/s depending on the bus length.

RS-485 hardware can also be used on this bus but RS-422 hardware can not be used on RS-485 buses.

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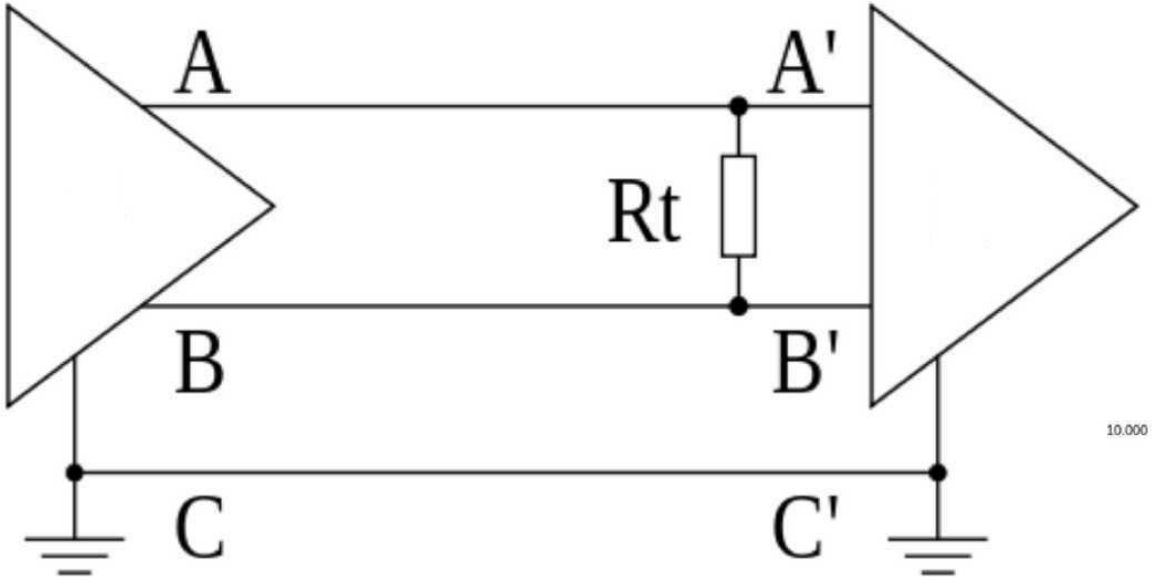

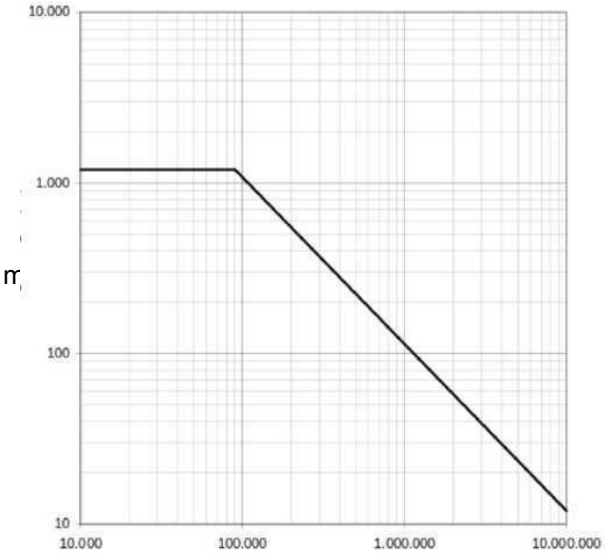

Figure 90 RS 422 Connection

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CAN BUS

INTRODUCTION

General

The CAN Bus (Controller Area Network) is an asynchronous serial bus that had been developed by Bosch in 1983 for automotive applications. The objective was to reduce wiring. It was used in the Mercedes S class (in 1990) for the first time.

Many components, such as lights, switches, rpm-, temperature- and pressure sensors as well as motors and switches are connected via CAN.

Due to its low price and high interference tolerance CAN is also used in automated textile and agricultural machines as well as in medical appliances and even space travel.

Today Airbus (A380) and Boeing (747−8F) use the CAN bus in their aircraft according to ARINC 825 specification.

Overview CAN ISO Standards

In November 1993 CAN was normed as ISO Standard 11898. This standard describes the architecture of CAN with regard to the ISO/OSI 7 Layer Model. It specifies parts of the physical layer (ISO/OSI Layer 1) and parts of the data link layer (ISO/OSI Layer 2).

- ISO/OSI Layer 1 (Physical Layer)

  This layer defines the electrical and mechanical characteristics of the communication system as well as type and form of the connectors and cables. In addition, the electronic properties of the signals are specified, such as the bit coding and bit synchronisation.

- ISO/OSI Layer 2 (Data Link Layer)

  The data link layer controls and protects communication. Each data packet is provided with appropriate additional information, such as a parity bit and a CRC, which enables errors in data transfer to be detected.

Over the years various ISO 11898 norms have been developed.

The first published version of the CAN protocol was CAN 1.1. This was developed further into CAN 1.2, then CAN 2.0A and finally CAN 2.0B.

The versions differ, among other things, with regard to the oscillator frequency and changes in the identifier fields.

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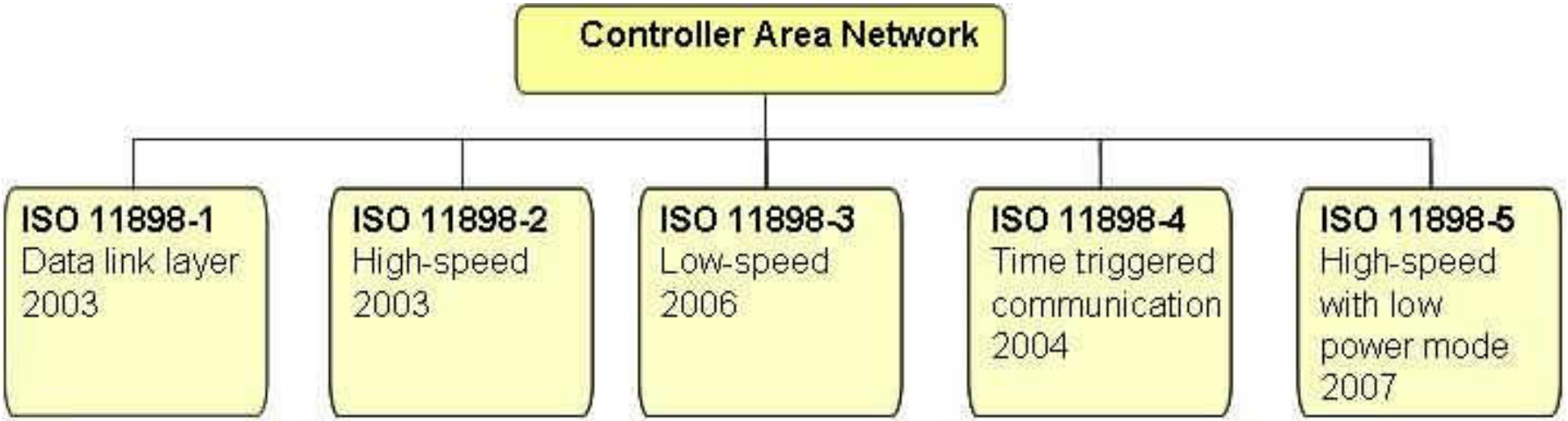

Figure 91 ISO 11898

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Bus Interconnection

Mainly copper wires are used, especially for longer buses twisted pair is used including a shielding if possible.

The minimum amount of wires is three. Connectors usually have 4, 5 or 10 terminals.

Every subscriber is a transceiver that can transmit and receive.

On higher data rates a termination resistor of 120 Ohms should be attached on both ends.

Although the buses are designated as high speed and low speed bus the effective data rate depends on the length of the bus (see table below).

Fiber optics technology is also possible.

Basic Principle of Data Exchange on the CAN Network

When data is transmitted in a CAN bus system, the messages are not addressed directly to a node, but the content of a message (e.g. oil pressure or engine temperature) is first marked with a unique identifier.

The messages are then sent to all nodes connected to the bus.

Measured values which are needed as information by several nodes are distributed over the CAN network in such a way that not every control unit requires its own sensor. The data from a sensor is made available to all devices connected to the system.

When the message is received correctly, the nodes decide by using the identifier if the data received is relevant for them or not. Apart from content identification, the identifier determines the priority of the message. For example, an ABS signal has priority over engine temperature.

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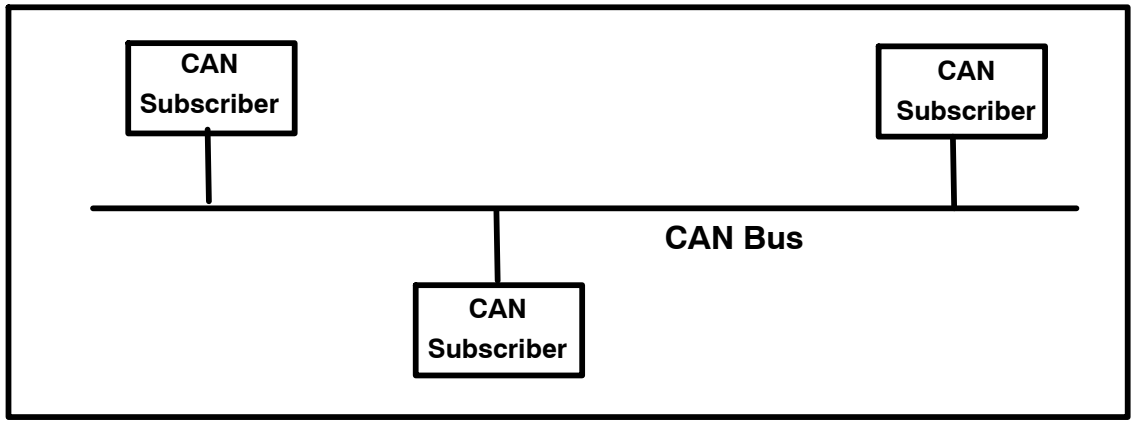
Bus principle



Bit rate

Bit rate	Bus length
10 kBit/s	6,7 km
20 kBit/s	3,3 km
50 kBit/s	1,3 km
125 kBit/s	530 m
250 kBit/s	270 m
500 kBit/s	130 m
1 MBit/s	40 m

Figure 92 CAN-Bus Interconnection

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DETAILS

Interfaces

The bus consists of two wires: CAN H and CAN L. A differential transmission is used.

Interferences affecting both the wires do not affect the bus as they cancel each other out (common mode rejection).

Due to the open collector arrangement on both wires several subscribers can be connected to the bus without creating short circuits.

If the npn transistor (the lower one) is conductive and the PNP transistor (the upper one) is blocking a logic 0 is created. This condition is dominant.

If the npn transistor is blocking and the PNP transistor is conductive a logic 1 is created. This condition is recessive.

If several subscribers transmit at the same time the logic 0 is dominant thus subscribers trying to transmit logic 1 can sense the dominant 0 and abort their transmission. They will retry transmitting at a later time.

This principle is called **CSMA/CA** (Carrier Sense Multiple Access with Collision Avoidance).

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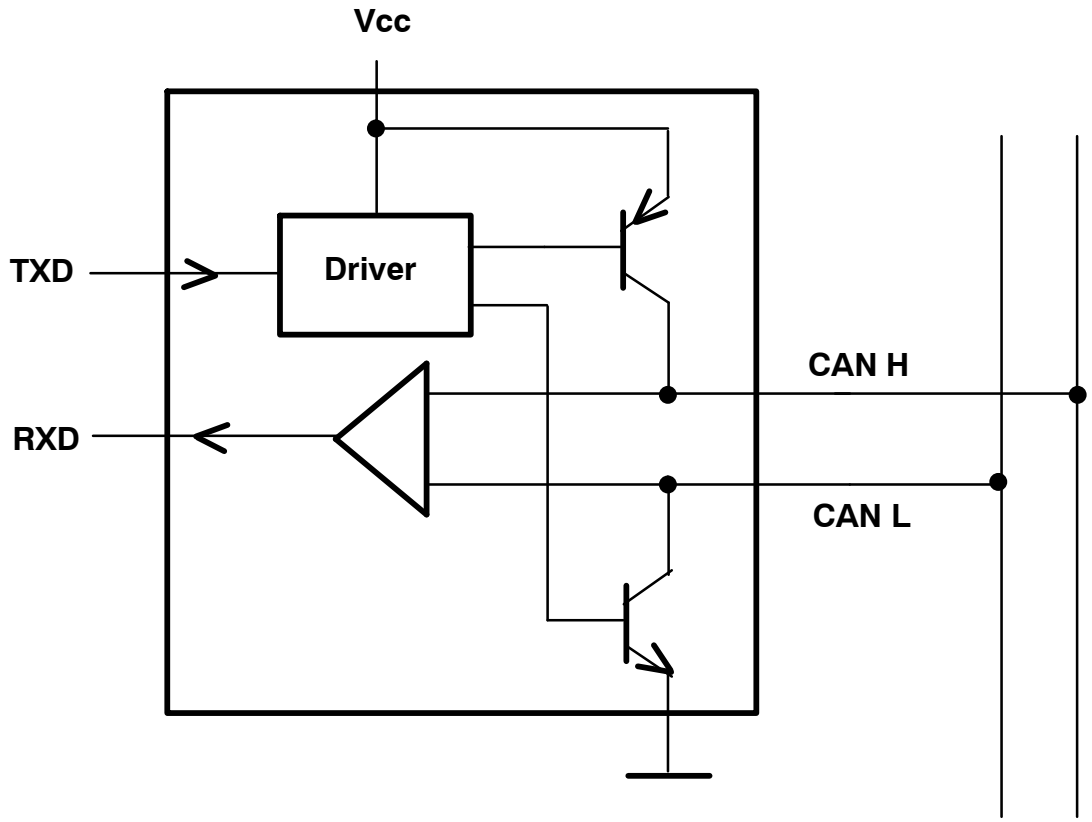

Figure 93 CAN Subscriber

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Error Detection

For error detection 3 functions are implemented:

- **CRC** (Cyclic Redundancy Check), the transmitter adds check bits to the transmission. On the receiver side the CRC is recalculated and compared to the CRC received.
- **Frame check**, the structure of the frame is checked. If the result is negative a formatting error has occurred.
- **ACK fault**, the receiver reports that data received is not OK.

Frame composition Standard Frame

A frame consists of 7 items:

- Start condition
- Message identifier
- Control bits
- Data
- Check bits
- Acknowledge bit
- Stop condition

The segments within the frame are used as follows:

- Start: dominant, for synchronization purposes
- Identifer: states the contents and the priority of the transmission
- RTR: Remote Transmission Request in order to derive between data transmission and data request
- IDE: Identifier Extension, indicates that with the extended format 18 more identifier bits will follow
- r=: reserved
- DLC: Data Length, the amount of byte in the data field
- CRC: Cyclic Redundancy Check, for integrity check purposes
- ACK: Acknowledge, feedback from a receiver to indicate correct reception of the transmission
- EOF: End Of Frame, end of transmission (7 recessive bits)

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Start	Identifier	RTR	IDE	r0	DLC	Data	CRC	ACK	EOF
1 Bit	11 Bits	1 BIT	1 Bit	1 Bit	4 Bits	0 - 8 Bytes	15 Bits	2 Bits	10 Bits

Figure 94 Frame Composition Standard Frame

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MAXIMUM BIT TRANSFER NUMBER

The maximum number of bits to be transmitted in a frame is different in the standard and the extended formats.

To calculate the maximum number of bits, a maximum data length of 64 bits and a maximum possible number of 19 stuff bits in the standard format and 23 in the extended format are used.

Standard Format

Maximum Number of Bits	Contents
1	Start Bit
+11	Identifier Bits
+1	RTR Bit
+1	IDE Bit
+1	r1 Bit
+1	r0 Bit
+4	DLC Bit
+64	Data Bits max
+15	CRC Bits
+1	CRC Delimeter Bit
+1	ACK Slot Bit
+1	ACK Delimeter Bit
+7	EOF Bits
+3	IFS
+19	Stuff Bits (max.)
=130	Bits

Extended Format

Maximum Number of Bits	Contents
1	Start Bit
+11	Identifier Bits
+1	SSR Bit
+1	IDE Bit
+18	Ext. Identifier Bits
+1	RTR Bit
+1	r1 Bit
+1	r0 Bit
+4	DLC Bit
+64	Data Bits max
+15	CRC Bits
+1	CRC Delimeter Bit
+1	ACK Slot Bit
+1	ACK Delimeter Bit
+7	EOF Bits
+3	IFS
+23	Stuff Bits (max.)
=154	Bits

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USE OF THE CAN BUS IN AN AIRCRAFT

CAN in the Boeing 747–8F Cargo Loading System

The CAN bus is used in the B747–8F Cargo Loading System. It connects the cargo control box with the power drive units (PDU's) and the maintenance display unit.

The cargo control panel sends analogue data to the cargo control box.

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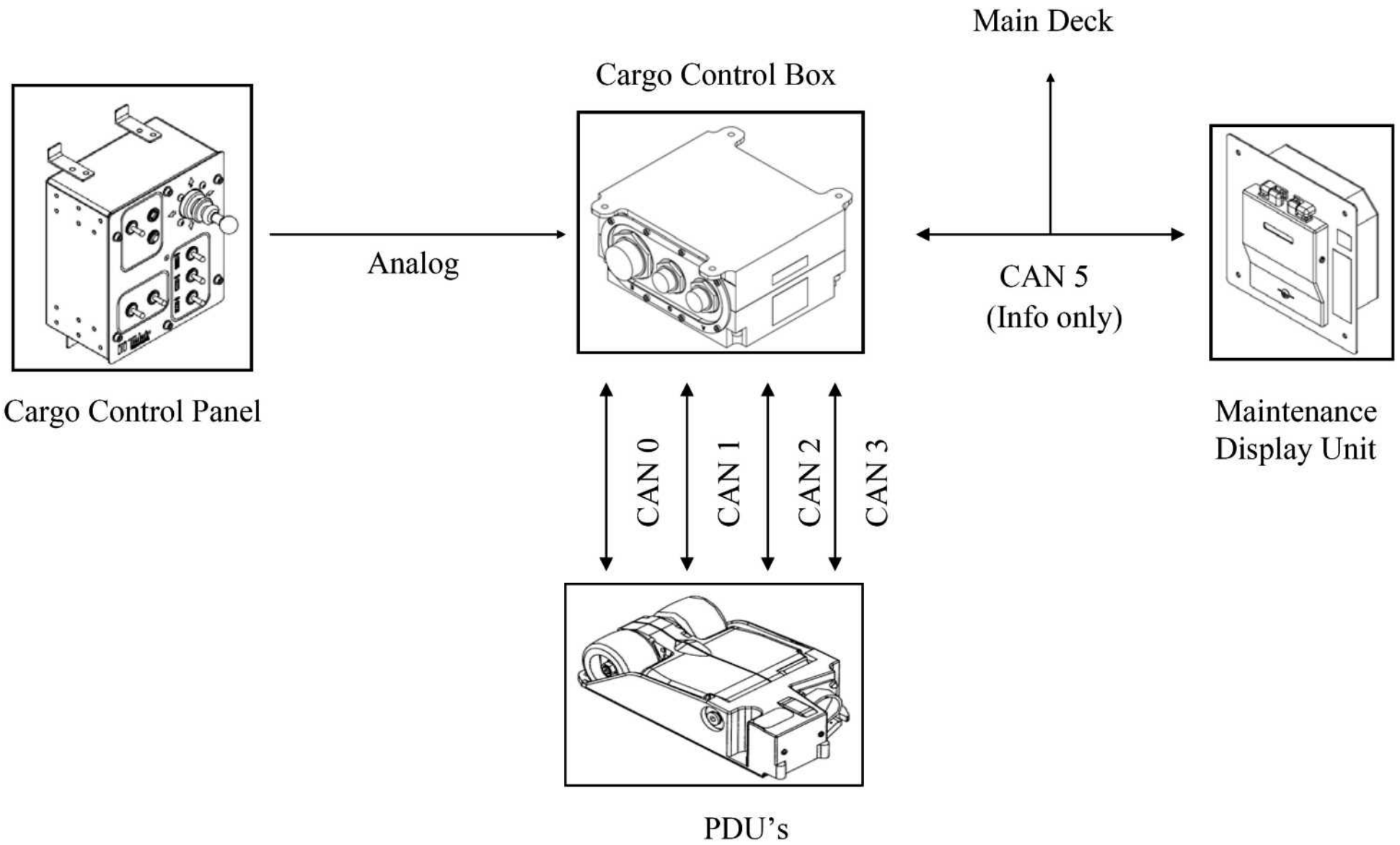

Figure 95 CAN BUS at B747–8F Cargo Loading System

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Use of the CAN Bus in the Enhanced CIDS

Because of its high reliability, the CAN bus is used to transfer data from the optical smoke detectors in the cargo compartments and the lavatories to the CIDS directors.

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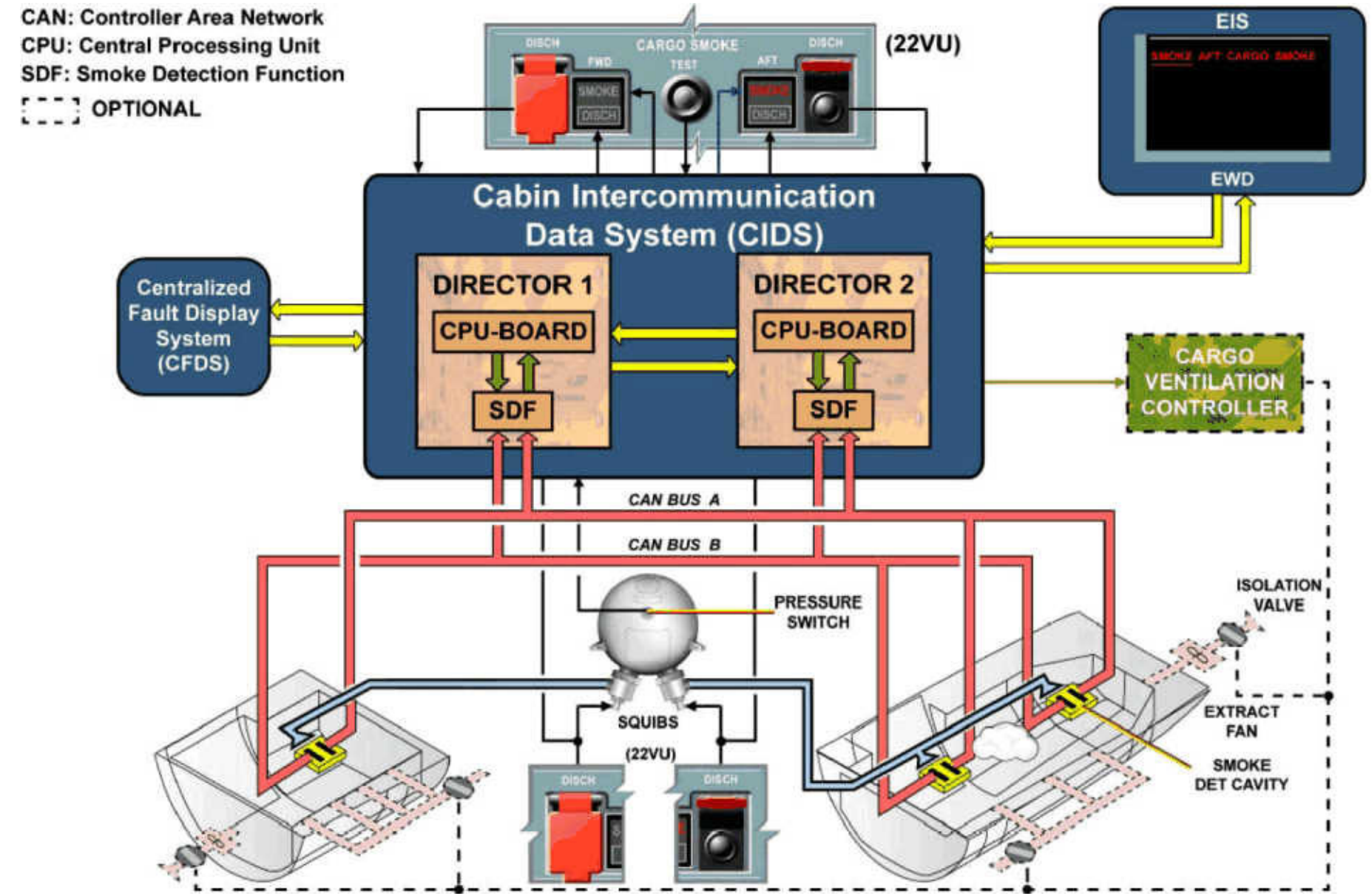

Figure 96 Cargo Smoke Detection Single Aisle

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Use of the CAN bus in the Integrated Control Panels (ICP's) in the A380

In the cockpit of the A380 many control panels have been converted from standard technology with discrete cables between the switches and push−buttons and the relevant system computers to CAN bus technology. These control panels are called ICP's (integrated control panels).

The ICP's receive information and give commands to the aircraft systems, such as the LRUs and the LRMs.

Conventional control panels are referred to as (VU) and the ICP's as (VM).

The ICP's (VM) are found in the A380 mainly in the overhead panel and in parts of the pedestal.

ICP's can be divided into two groups.

- Digital ICP's, which are also called ICP CAN. These use discrete, analogue and CAN signals to transfer data. The discrete and analogue signals form the backup.
- ICP's no CAN, which use only discrete and analogue signals.

CAN 2.0B (29 bit identifier) is used in the ICP's and works at low speed with 125 kBit/s.

In order not to lose the function of the panel following a CAN bus failure, the bus systems have up to fourfold redundancy.

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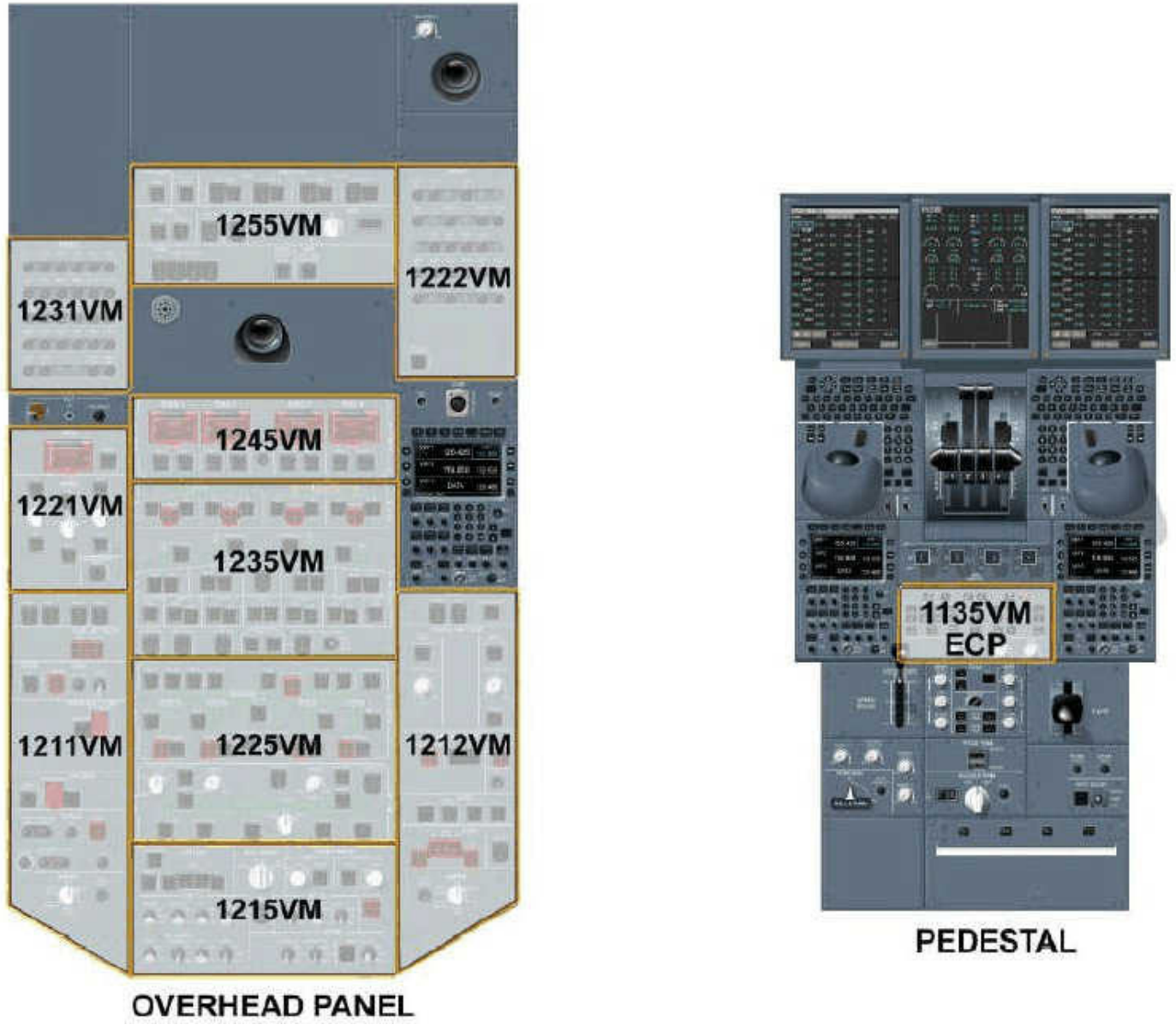

Figure 97 Integrated Control Panel A380

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CAN Bus in the A380 Control and Display System (CDS)

The CDS has eight identical display units and two keyboard and cursor control units (KCCU's). Data between the KCCU's and the DU's is transmitted via a CAN bus. The CAN network enables the DU's to be controlled by the KCCU's.

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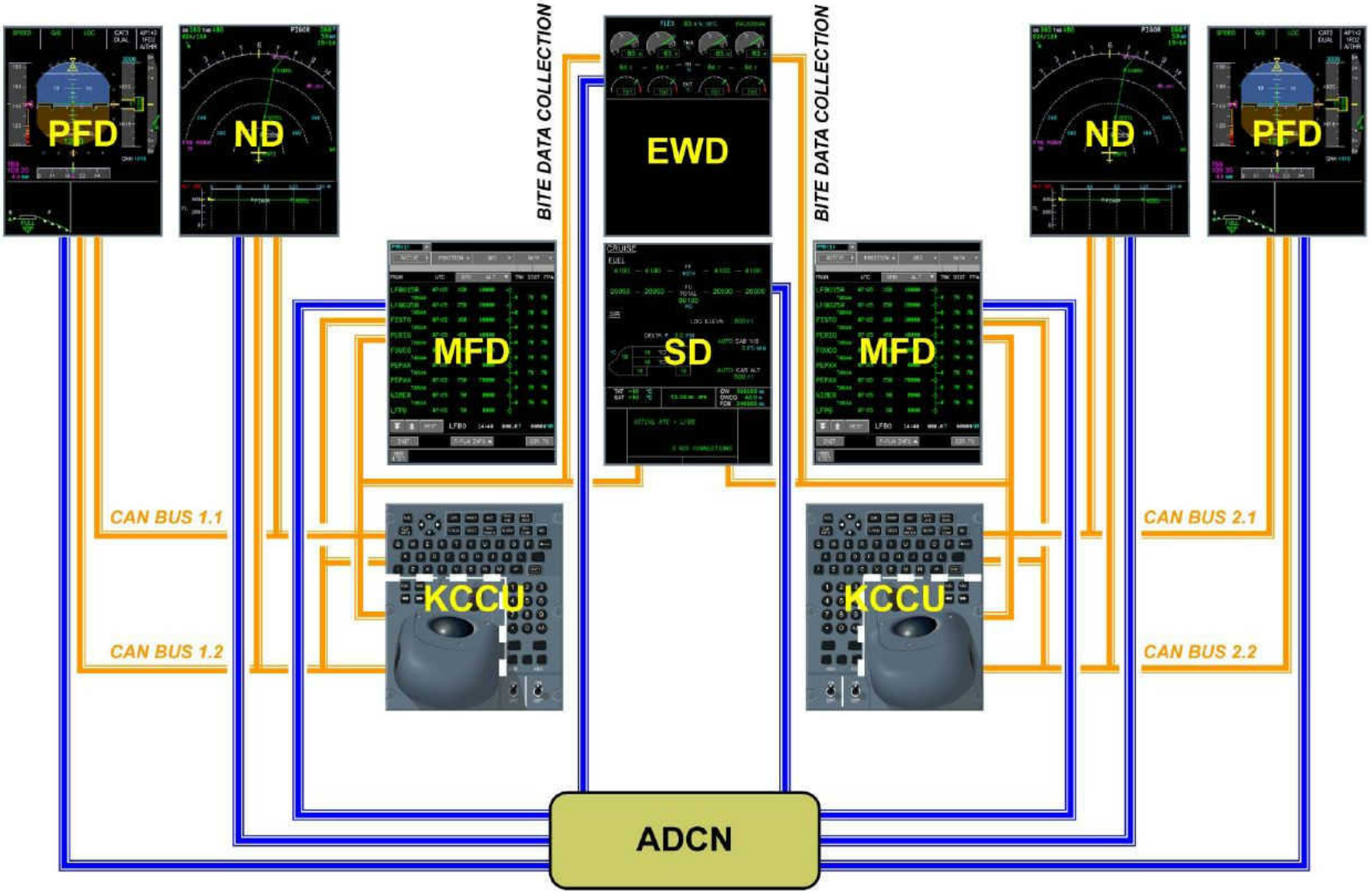

Figure 98 Control & Display System Architecture A380

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M5.10 FIBRE OPTICS

INTRODUCTION

General

In recent years fibre optics systems have found increased application in the transmission of digital data. Its most prolific use has been in the area of ground-based communications. Because of its many benefits, however, fibre optics are being seriously considered as a medium for the transfer of digital data between systems on aircraft.

In fibre optics cables data is transmitted in the form of light. Consequently, large electric and magnetic fields do not affect the transmission. Any light leakage from the fibres is eliminated by surrounding the fibre with an opaque jacket. As such, fibres cannot interfere with each other. In most communication applications the power levels used are safe to personnel and electrically dangerous environments. In addition, jacketed fibre optics cables are significantly smaller and lighter and can tolerate more mechanical abuse than comparable electrical cable.

Limitations of fibre optics arise mainly from the need for optical/electrical conversion and the implementation and maintenance of the physical connections. At each terminal point an optical/electrical converter is required for each fibre being utilized by a system. This could result in a multiplicity of these converters being required by a system.

At present, multiple connections on a fibre optics cable are economically impractical. In addition, the special methods required for repair of these cables are more involved than that for wire cables. Terminations also require special care to prevent damage to the fibre end.

Advantages and Disadvantages

In comparison to copper cables the following advantages and disadvantages are obvious.

The advantages are:

- Optical signals unaffected by EMI/EMP.
- No cross talk between fibres.
- Less weight than comparable electrical cable.
- Very high transmission data rate (Giga–Bit range).

The disadvantages are:

- Requires optical/electrical converters.
- Multiple connections are economically impractical.
- Repair requires special methods.
- Terminations require special care.
- Larger bending radius

Fibre Optic Structure

A typical fibre optics cable structure is shown.

The core is the light carrying component of the cable. It is through this core that the digital data is transmitted. The surface of this core is coated with a cladding that acts to reflect the light rays which would otherwise pass out of the core and be lost. The silicone coating prevents scuffing of the thin cladding layer with the buffer jacket providing additional protection. Fibreous tensile strength members running the length of the cable allow it to be pulled through a long conduit. The outer jacket provides protection from crushing and impact damage.

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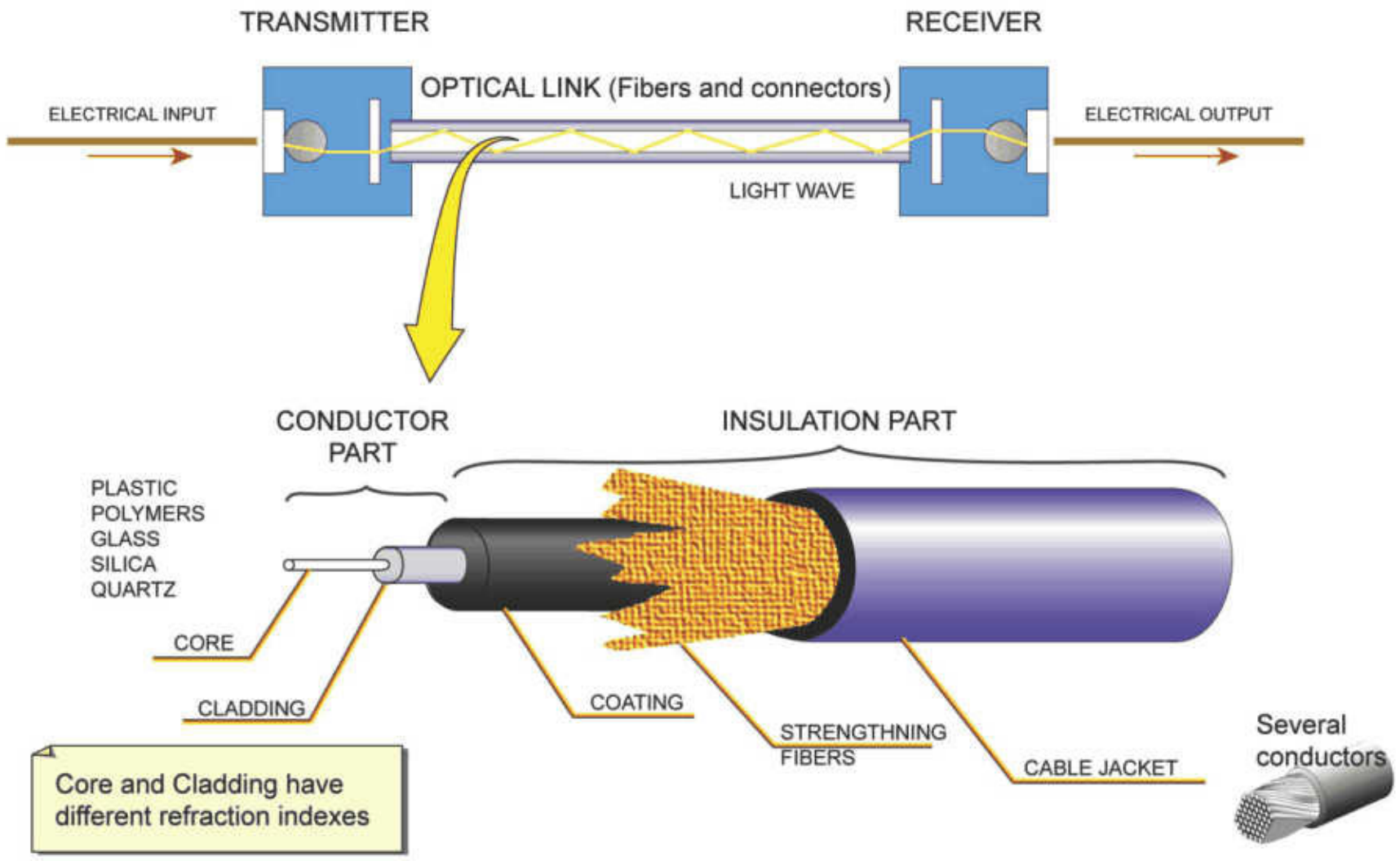

Figure 99 Fibre Optics

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Wave Length

Several wave lengths have proofed to be most useful for transmission because of the low damping / signal losses.

The wave lengths suitable for transmission are called optical windows.

Usually the light is infrared and therefore invisible.

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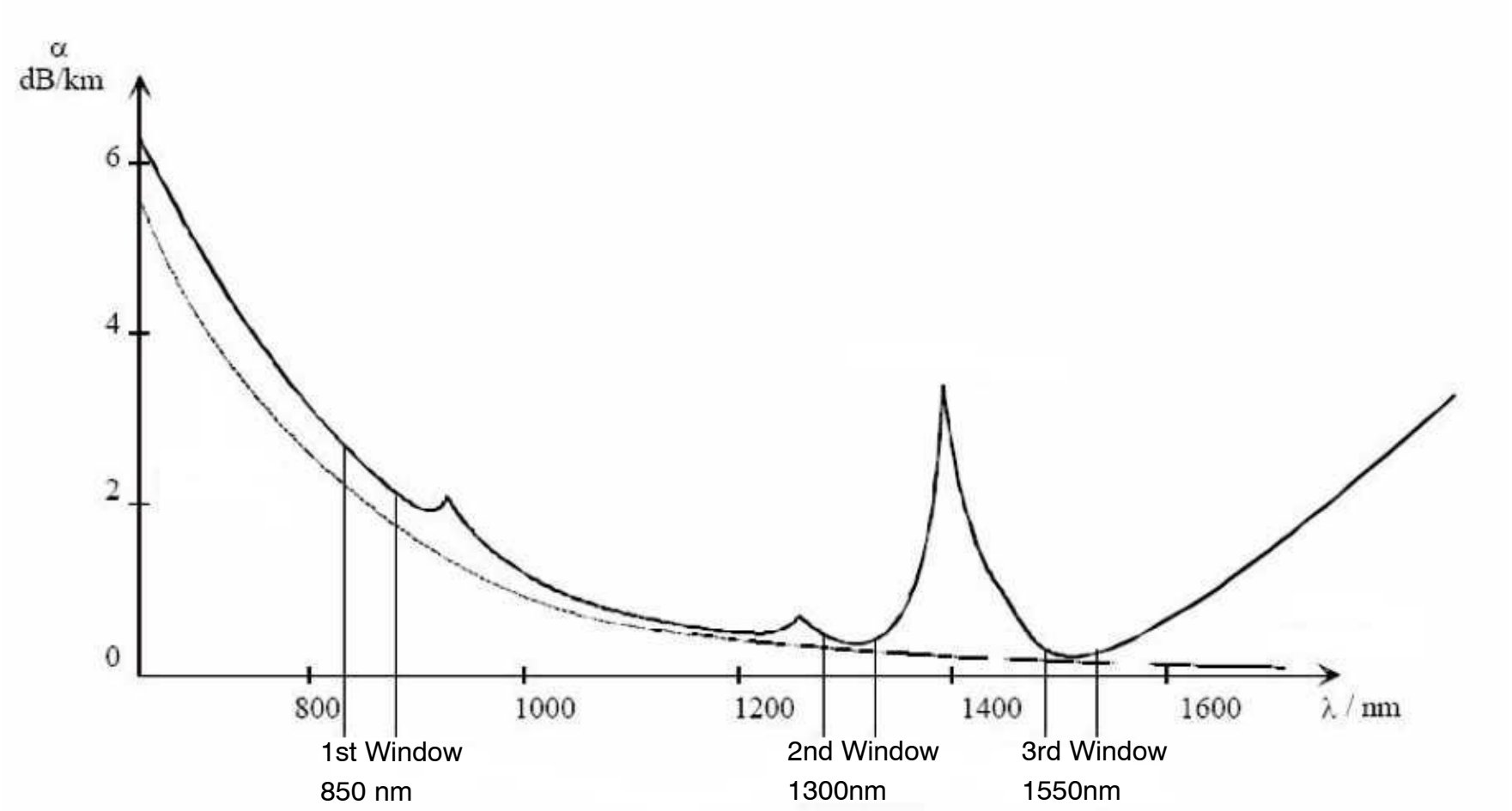

Figure 100 Optical Windows

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OPTICAL/ELECTRICAL CONVERTERS

Transmitter

Conversion of electrical signals into light signals is accomplished by an optical transmitter. This transmitter is electrically connected to the transmitting system. Digital signals applied to the transmitter cause the internal light source (usually an LED or similar device) to operate between two distinct output levels. This light output is then applied to the end of the fibre optics cable.

Receiver

At the receiving side an optical receiver converts the light signals back into electrical signals. A photosensitive device responds to the light at the end of the fibre optics cable by providing a signal level input to a receiving amplifier. This amplifier then provides the driving levels required by the output transistor.

Couplers

It is possible, by using optical couplers, to attach more than one set of transmit and receive terminals to a single fibre rather than run a separate fibre or cable for each transmit–receive pair.

The most common application for this technology is with Local Area Networking, (LAN), whereby a common fibre carries the multiplexed signals from multiple terminals placed at various locations served by the LAN. Access to the LAN is made through optical couplers that divert part of the signal power on the LAN fibre to each receiver and couple power from each terminal transmitter onto the fibre.

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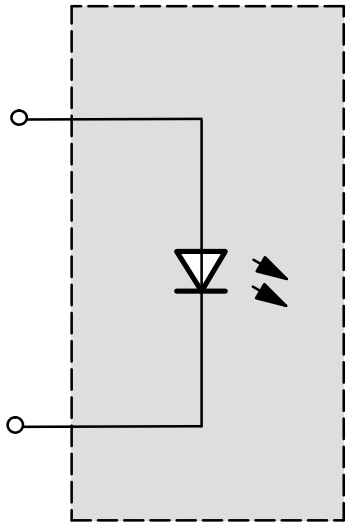
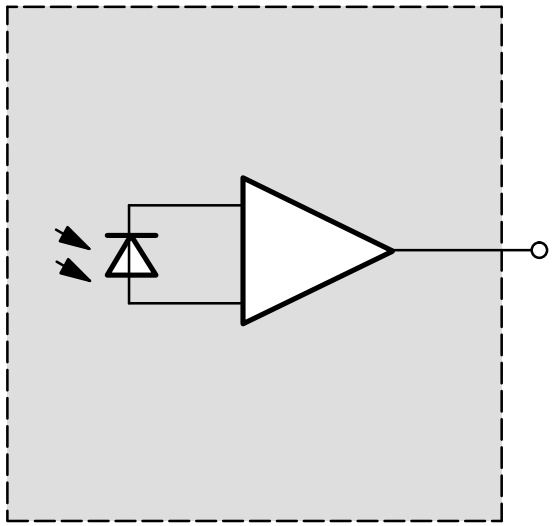


OPTICAL TRANSMITTER



OPTICAL RECEIVER

Figure 101 Optical/Electrical Converters

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TERMINALS

Remote Terminals

Remote terminal units collect data automatically and connect directly to sensors, meters, loggers or process equipment. They serve as slave units to supervisory controllers or supervisory control and data acquisition masters.

Remote terminal units are located near the monitored process and transfer data to the controller unit on command.

They often include integral software, data logging capabilities, a real−time clock (RTC) or totalisator, and a battery backup.

Control Terminals

Control Terminals provide features including advanced reporting and control, instant status and alarm reporting, and easy interfaces to Internet, intranet, and local area networks.

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Figure 102 Fibre Optic Terminal

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ACTUAL APPLICATION

General

After the invention of fibre optics, many engineers dreamt of a quick application of this new technology in aircraft. The fist commercial aircraft with this technology was the B777 with the ARINC 629 data bus for some aircraft systems. But soon the disadvantages of this technology became obvious, and the new Airbus A 380 uses it for the entertainment system only.

Problems

The radius for fibre optics leads is relatively large. If installed, the leads are not stiff so they have a tendency for sagging and, if this happens, for braking. Additionally, connections and repairs are not easy to execute correctly.

The shielded twisted pair will be used for data transfer between units.

Actual Application

Fibre optics is mainly used for entertainment systems. The B 777 uses it for the interface of the Maintenance Access terminal to the avionics racks.

Large aeroplanes like the A340−600 or the A 380 use fibre optics to lead video signals from the camera in the vertical stabilizer or the lower fuselage to the flight deck.

The B 787 uses fibre optics for the avionics for a Avionics Full−Duplex Switched Ethernet (AFDX). Remote Data Concentrators will reduce the wiring and ease upgrading. Additionally, they are said to be highly reliable.

The A 350 probably will also use fibre optics.

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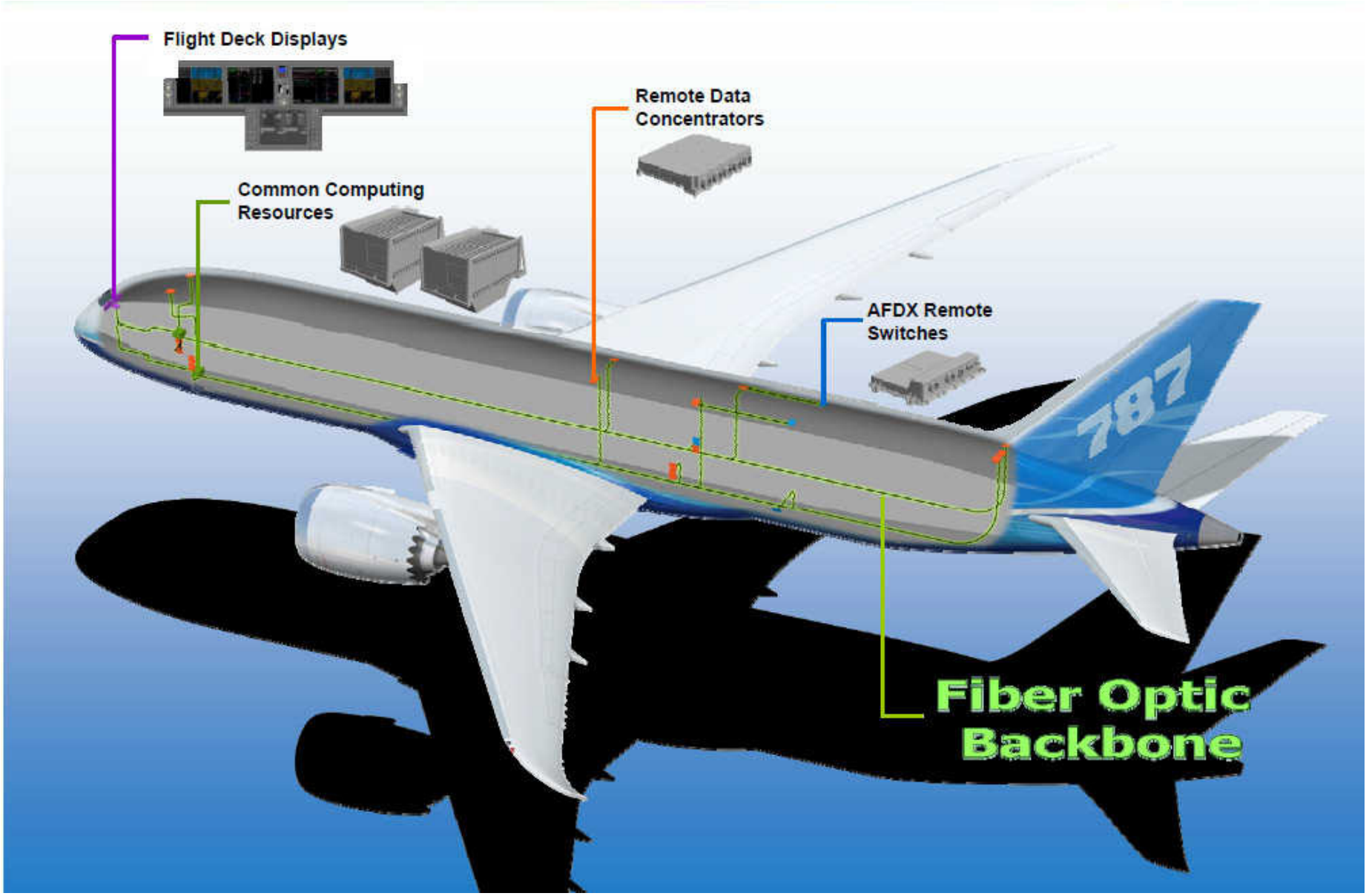

Figure 103 Fibre Optics in B787

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M5.11 ELECTRONIC DISPLAYS

INTRODUCTION

General

Electronic Displays in modern aircraft are realized in the following technologies:

- LED (Light Emitting Diode),
- LCD (Liquid Crystal Display),
- CRT (Cathode Ray Tube),
- OLED (Organic LED).

Digital Displays

Displays may be constructed in several ways.

Incandescent displays use thin filaments for each segment, similar to lamps.

Another type of display uses the gas-discharge tube. This older type of unit operates at high voltages and emits an orange glow.

LIGHT-EMITTING DIODE (LED)

General

A display produces light output to show information in visual form. Displays can be divided into two categories. Character displays give visual indications of numbers and letters. Graphic displays are more complex and can give pictorial as well as alphanumeric information.

Advantages

The advantages are:

- small dimensions
- robust
- long lifetime

Disadvantages

The disadvantages are:

- high current consumption (compared with LCD)
- limited flexibility

Formats

Two types of character display formats are common:

- the 7 segment LED
- dot matrix displays.

Typical fonts for both a 7–segment and a dot matrix display are shown in the figure.

The 7-segment display is used where numbers and a limited amount of other symbols are required.

7–Segment

Typical packages for character displays is shown. The 7-segment display fits a standard 14-pin DIP socket.

A multi-digit display is common in digital clocks and other equipment.

5x7 dot matrix

The 5 x 7 dot matrix display can represent most alphanumeric characters.

Note the five columns of seven dots in the matrix for each character.

The 5 x 7 dot matrix display also can be inserted in a 14-pin DIP socket.

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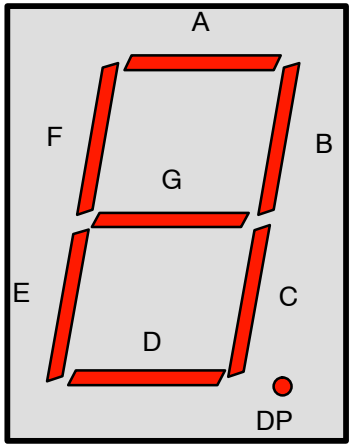

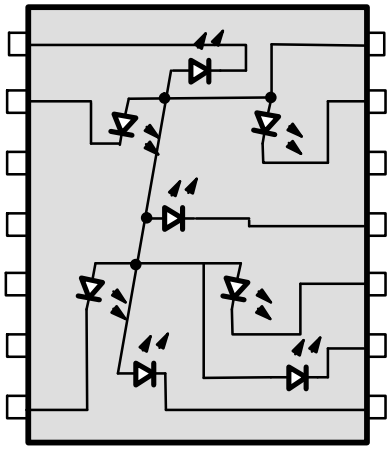

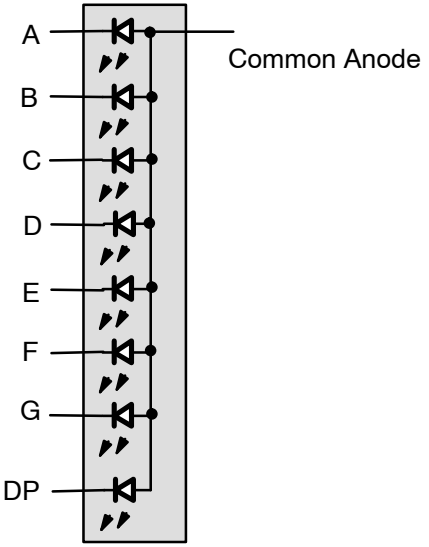

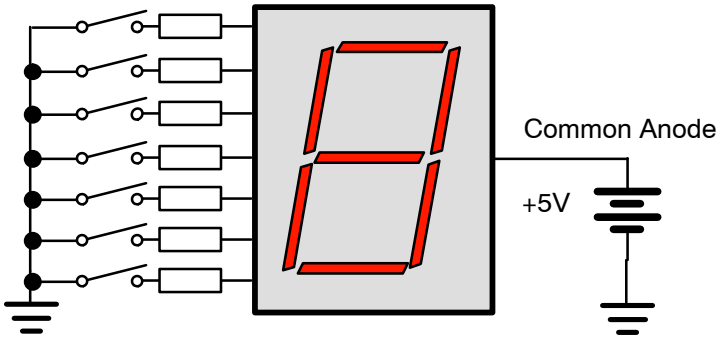

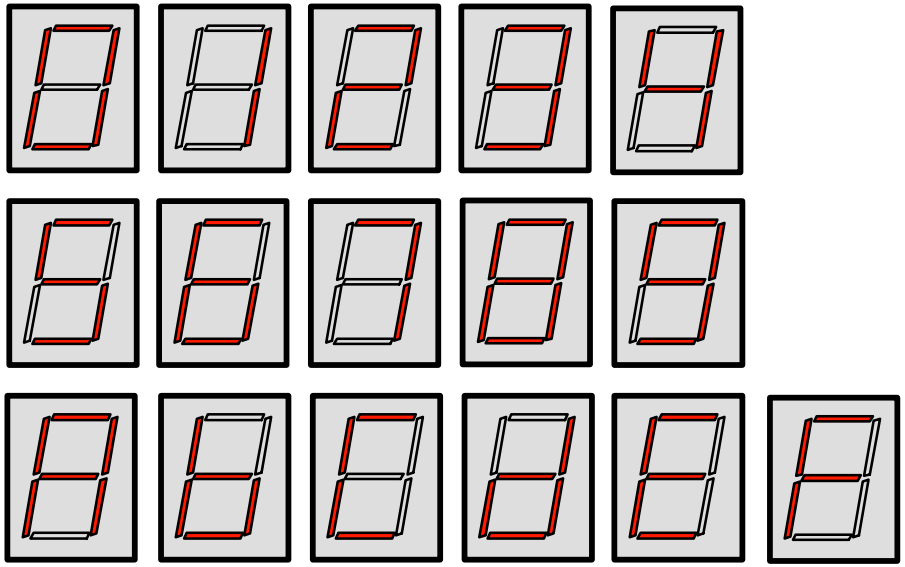

Figure 104 LED 7 Segment

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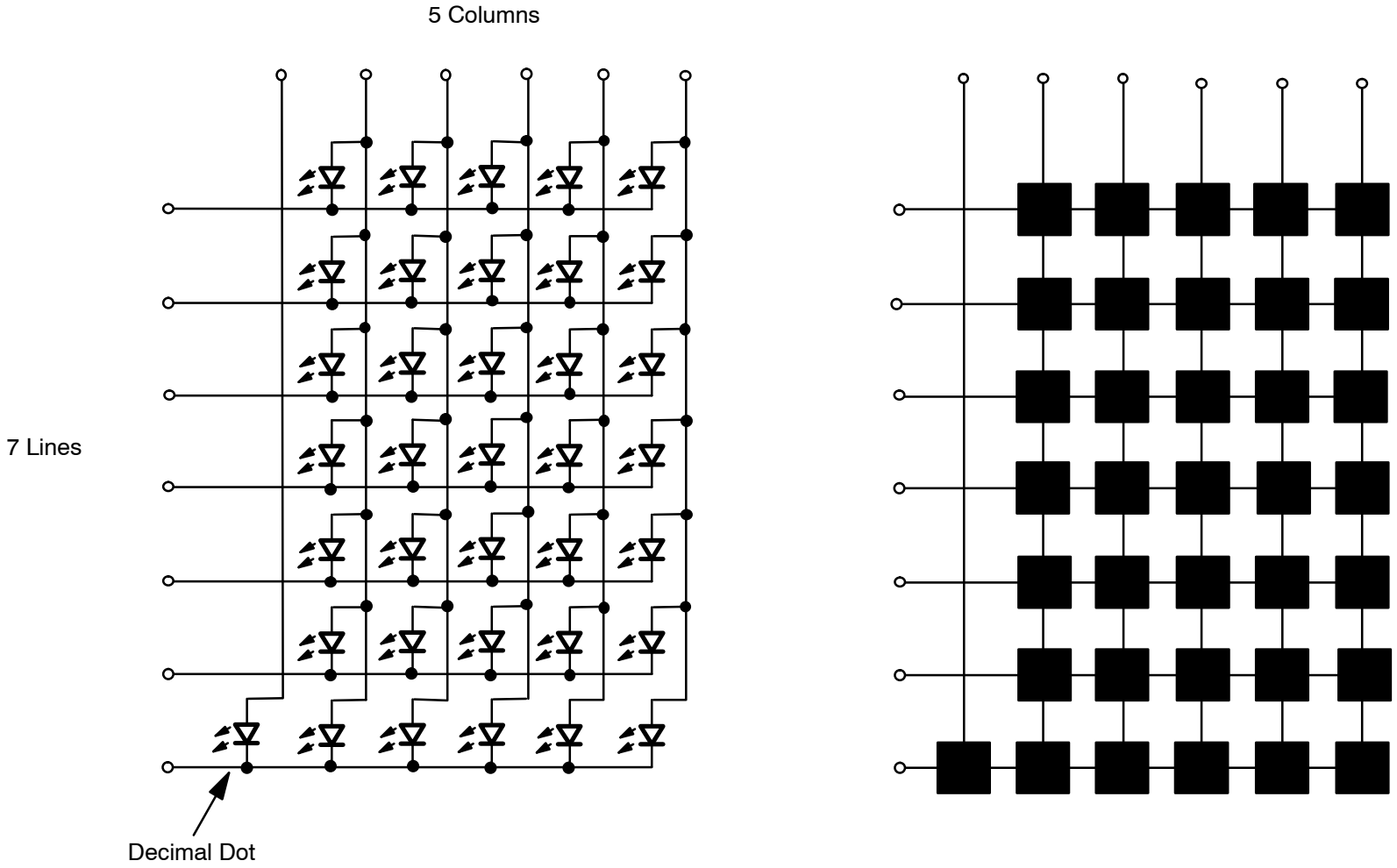

Figure 105 LED Dot Matrix

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CRJ100 VHF Panel



B737–300 N_1 RPM Indication

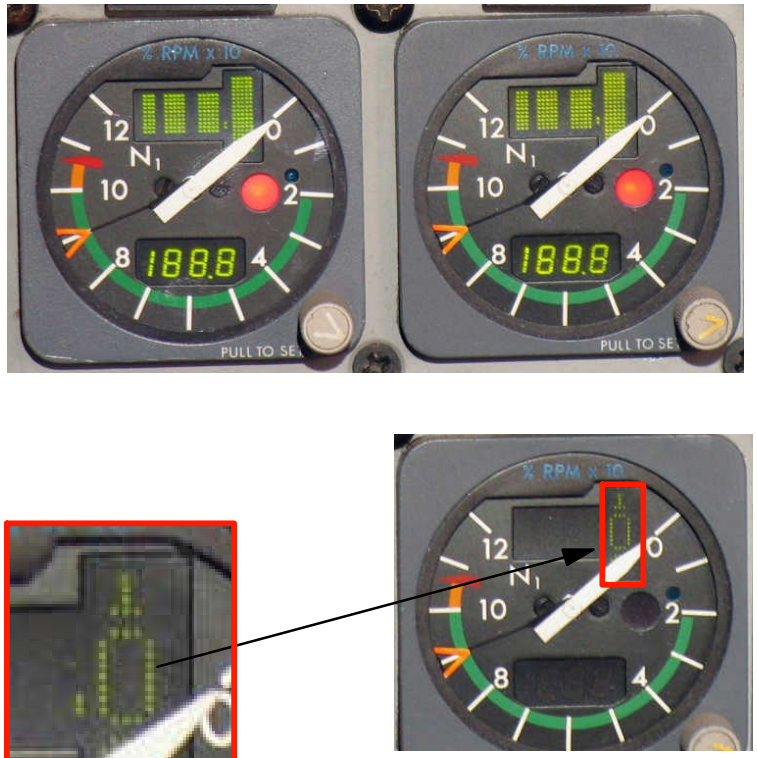

Figure 106 LED Cockpit Display

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CATHODE RAY TUBES

General

The old but widely used Cathode Ray Tube (CRT) still is standard in many aircraft.

It is the same principle as used in Oscilloscopes: in order to prevent magnetic fields the deflection is done by electrostatic means. As the force applied to the electrons is lower then the deflection angle is lower too. This is the cause to that longer shape in comparison with TV-Tubes.

Burn-In is prevented by slowly shifting the picture.

Usage

CRTs are used in:

- Control and Display Units (CDU)
- EIS or IDS
- Weather-Radar Displays.

Advantage

The advantage against electro-mechanical indicators is that coloured multifunctional displays are possible. The desired indication can be selected.

Disadvantages

The disadvantages are:

long shape, requires lots of space
heavy weight,
warming up required (approx. 10 sec.),
limited lifespan,
high power consumption,
thermal sensitive,
tends to burn-in.

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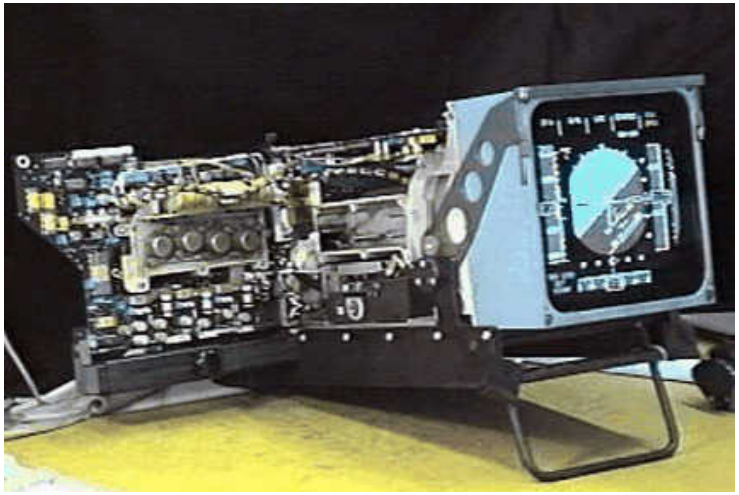
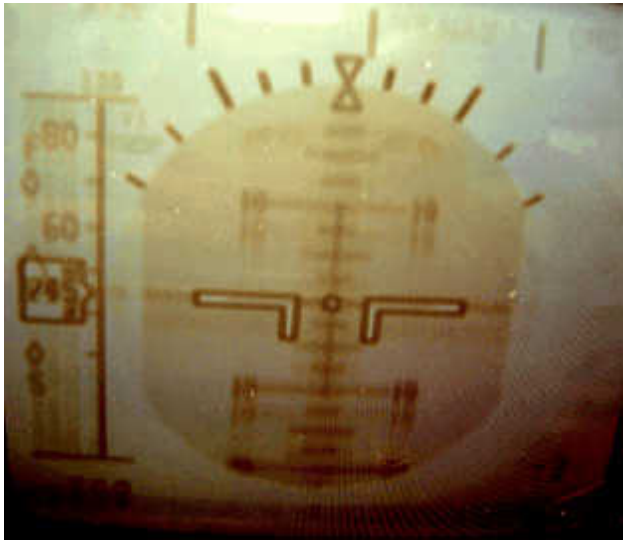


CRT Construction



CRT as Primary Flight Display



CRT with Burn-In

Figure 107 Cathode Ray Tube

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Construction

The electron beams are sucked towards the screen (Anode) by a high voltage (up to 40.000 V) and produces a blur spot in the centre of the screen. So the beam has to be focussed with an electrical lens. Now there is a sharp bright spot right in the centre of the screen.

As we expect a picture on the whole screen, the electron beam has to be deflected. This can be done by electromagnets like in TV-Sets or electrostatic as in Oscilloscopes and Cockpit-Displays.

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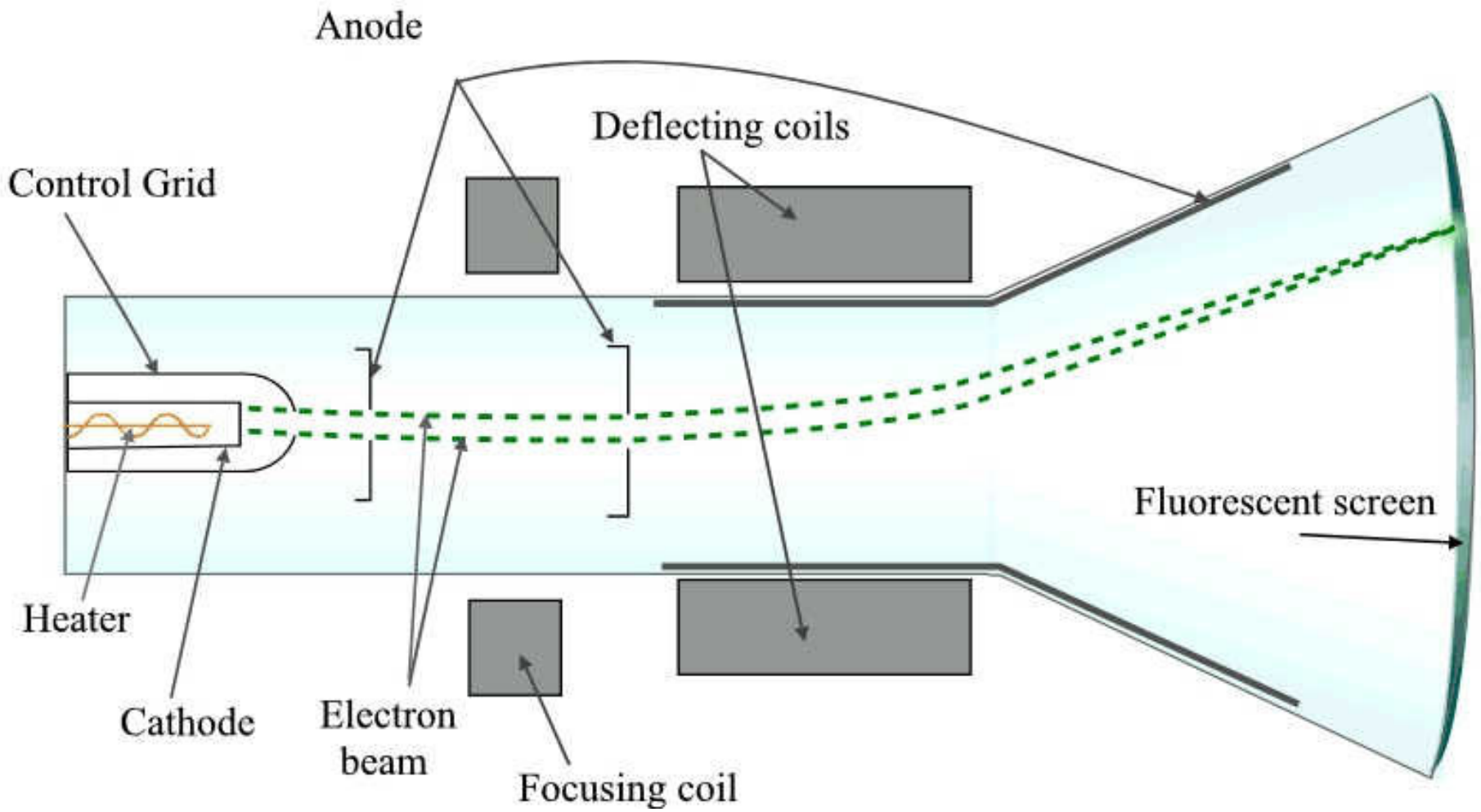

Figure 108 Construction of a CRT

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Colour

A Colour-CRT contains three cathodes. Each cathode is used for one of the colours. On the screen there are small dots of fluorescent paint. If the dots are hit by the electron beam they start to glow. To make sure that the beam only hits „its“ colour an iron mask is fitted between cathode and screen. This mask has many small holes through which the electron beam may pass.

On computer monitors you can sometimes find a statement of the distance between the dots (which also is a statement about the size of the dots), e.g. 0.27 inch. This means that every 0.27 inch there is another dot. This gives the resolution of the screen.

A picture is composed of three different colours:

- red
- green
- blue

All these colours together give a white dot. By mixing the three colours in given ratios every colour can be displayed.

- Yellow: Red and Green
- Cyan: Green and Blue
- Magenta: Red and Blue

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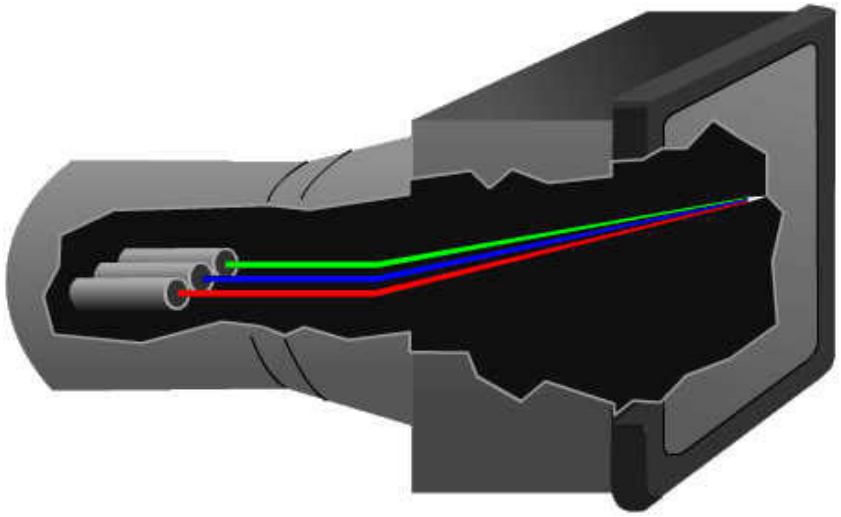

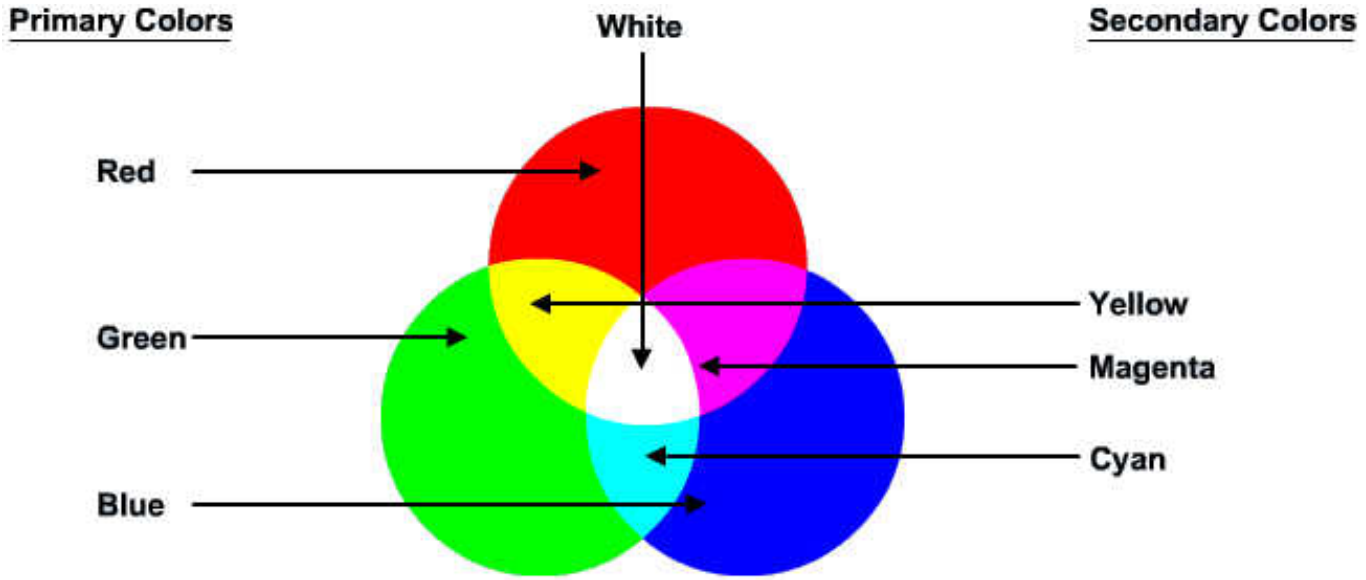

Figure 109 CRT Colours

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Display Scan Modes

The indication on the screen is created from two different scan options:

- Raster Scan
- Stroke Scan

The raster scan mode deflects the electron beam in lines across the screen. This mode is used for background indications like the blue/brown picture from the artificial horizon.

The stroke scan mode deflects the electron beam along the shape of the symbols to be displayed. This mode is far more power efficient that the raster scan but can not be used for backgrounds/areas.

The display in normal operation keeps on toggling between both the modes all the times.

The alternation between raster and stroke appears as one picture only.

Failure Mode

In case one of the colours fails a white picture is no longer displayable. Example: if blue fails the picture will look yellow.

In case of overheat some systems shut down parts of the display.

Example: if the temperature of the tube exceeds 70°C the raster is shut down, only the symbols remain as stroke scan is still performed. Further heating up beyond 90°C will cause a complete shut-down of that monitor.

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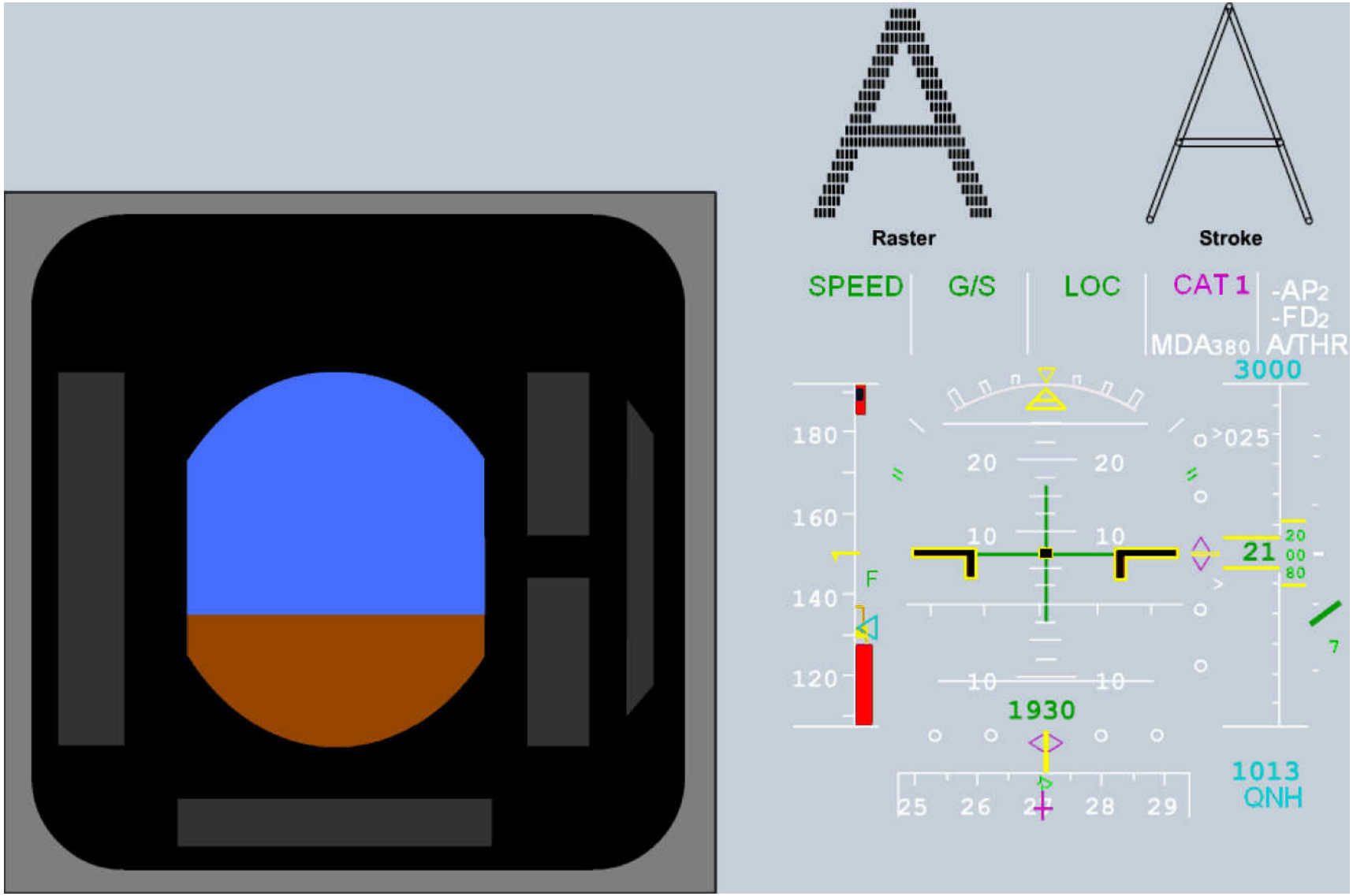

Figure 110 Raster / Stroke

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LIQUID-CRYSTAL DISPLAY (LCD)

General

While LEDs give off light, liquid-crystal displays (LCDs) are not light sources but control light.

Liquid-crystal is an organic (carbon based) compound that may influence light. It forms twisted strings which the light will follow.

First light is applied to a polarizer. This filter allows only light with a selected polarization to pass. All the remaining will be blocked. The light that passed the polarizer will then pass the liquid crystal while following the crystals twist. Depending on the state of the crystal the polarization of the light may be altered.

A secondary polarizer in a 90° arrangement to the first one allows light to pass if the polarization matches.

If a voltage is applied to the liquid crystal it adjusts in a straight line, no twist of light is performed. If no voltage is applied the crystal twists and the light will follow this twist.

Since LCDs radiate no light, they must be used in lighted areas with a mirror installed on the back side, or they must use an active back–light.

The figure on the next page show how the light passes the

- Polarizer
- Liquid Crystal Cell
- Colour Filters and
- Second Polarizer.

Usage

The application of LCD depends on the complexity of the arrangement itself:

- Watches
- Meters
- CDUs
- EIS or IDS, flat screens within the cockpit
- TV screens (entertainment) for the passengers

Advantages

The advantages are:

- flat,
- high-quality picture,
- good illuminated,
- multifunctional displays
- low energy consumption,
- long lifespan,
- virtually no maintenance required.

Disadvantage

The disadvantage is that it is temperature sensitive, the fluid might freeze.

If used for EFIS-, ECAM- or EICAS-Displays they must be operated in a certain temperature range in order to ensure high-quality pictures and fast reaction.

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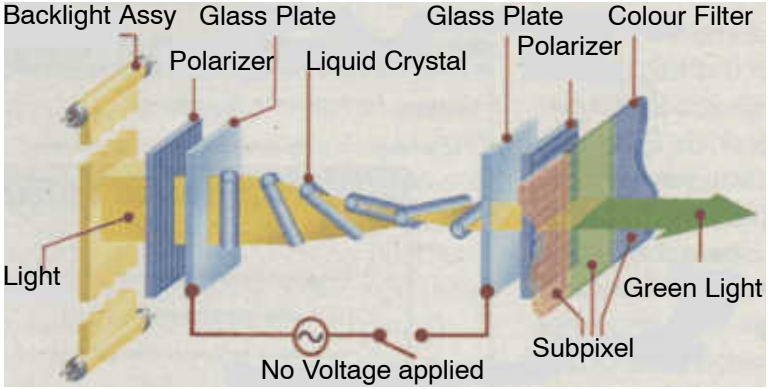

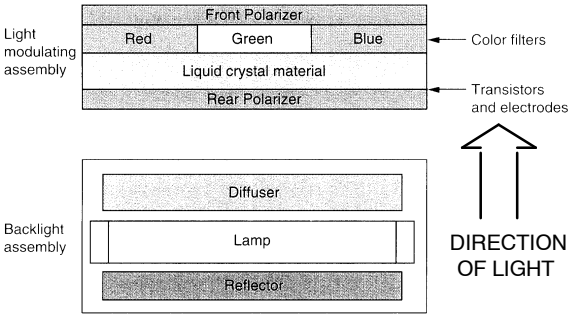

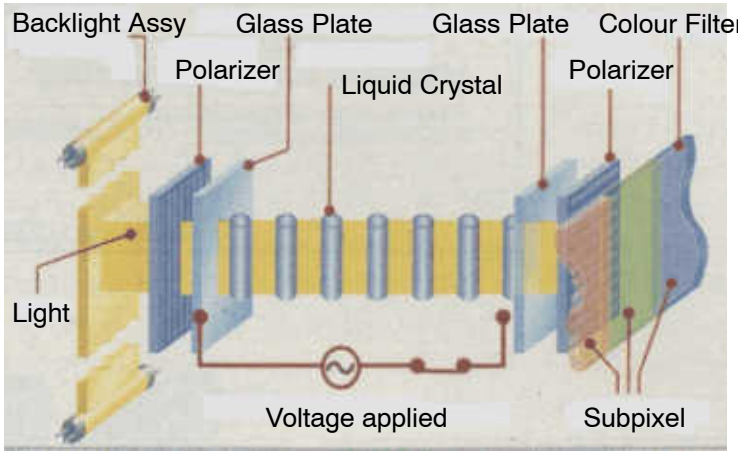

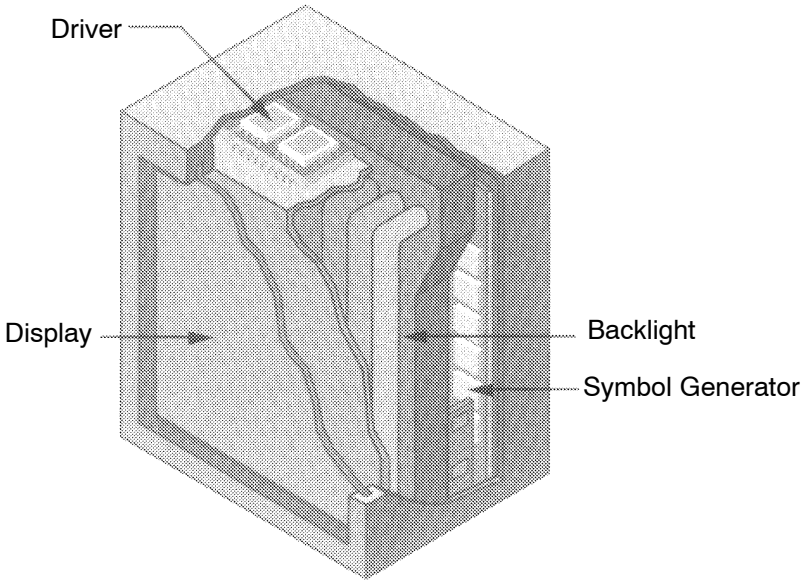

Figure 111 Liquid Crystal Display

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Technology

Liquid crystal displays are either the dynamic-scattering or the field effect type.

- The older dynamic-scattering type of LCD produces frosty white letters on a dark background.
- The field-effect LCD produces black letters on a silvery background. As an example, the display used on a Digital Multi Meter is normally a field-effect type of LCD.

The display consists of two glass plates with a special liquid crystal or nematic fluid filling the space between. The under surface of the top plate has nearly invisible metallized shapes where the segments and symbols are to appear. The glass back plate is also metallized. A polarizer forms the top and bottom of the sandwich. Contacts are attached to the back plate and to each segment of the display.

Direct current must not be used to drive LCDs, as it will damage them.

LCDs are widely used in battery power applications such as calculators because of their extremely low power consumption. They are easy to read in sunlight and other areas of high light intensity. For this reason, they are widely used on service station pumps.

The field- effect LCD is the most widely used because it consumes the least power and is easy to read. A steady back-light can be used for the LCD in applications where the light level is too low.

Colour Liquid Crystal Display

Colour is added to an LCD by the incorporation of filters under the liquid crystal layer. Segmenting of the lower electrode allows selection of the colour desired. Further segmenting of the upper electrode 90° with relation to the lower electrode produces a display in which individual picture elements, or pixels, can be addressed. The activation of one X electrode along with selected Y electrodes results in a column of colour elements. By continuously activating successive X electrodes with corresponding Y electrodes pictures and graphics can be formed on the display.

TFT-Displays

TFT-Displays are active displays, they contain the control circuitry but still are dependant on back–lights or other illumination. As it is virtually impossible to produce millions of dots without any faulty dot they are classified depending on the kind and amount of faulty dots based on 1M pixels:

	Type I	Type II	Type III
Class I	0	0	0
Class II	2	2	5
Class III	5	15	50
Class IV	50	150	500

Type I means Pixel are always lit
Type II means Pixel never shine
Type III means Pixel might always be on or always off.

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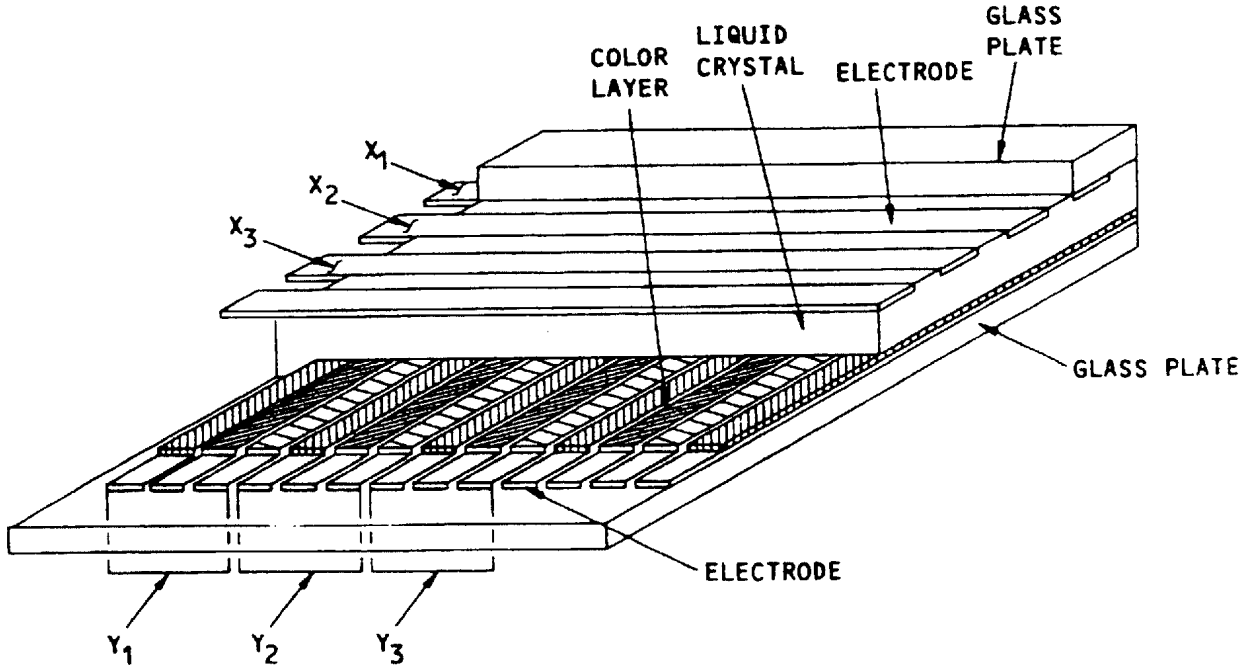
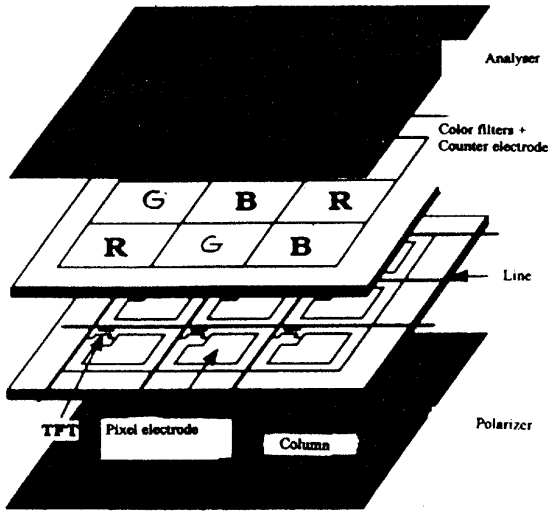


Colour Liquid Crystal Display



Colour Filters

Figure 112 LCD Technology

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Colour Generation

Each pixel consist of 3 liquid crystal molecules with a following colour filter in blue, green and, red because this display type also generates a colour picture by combining the 3 basic colours.

The switch in fact is a transistor which is on a foil.

This is why we call it a TFT display which stands for thin film transistor.

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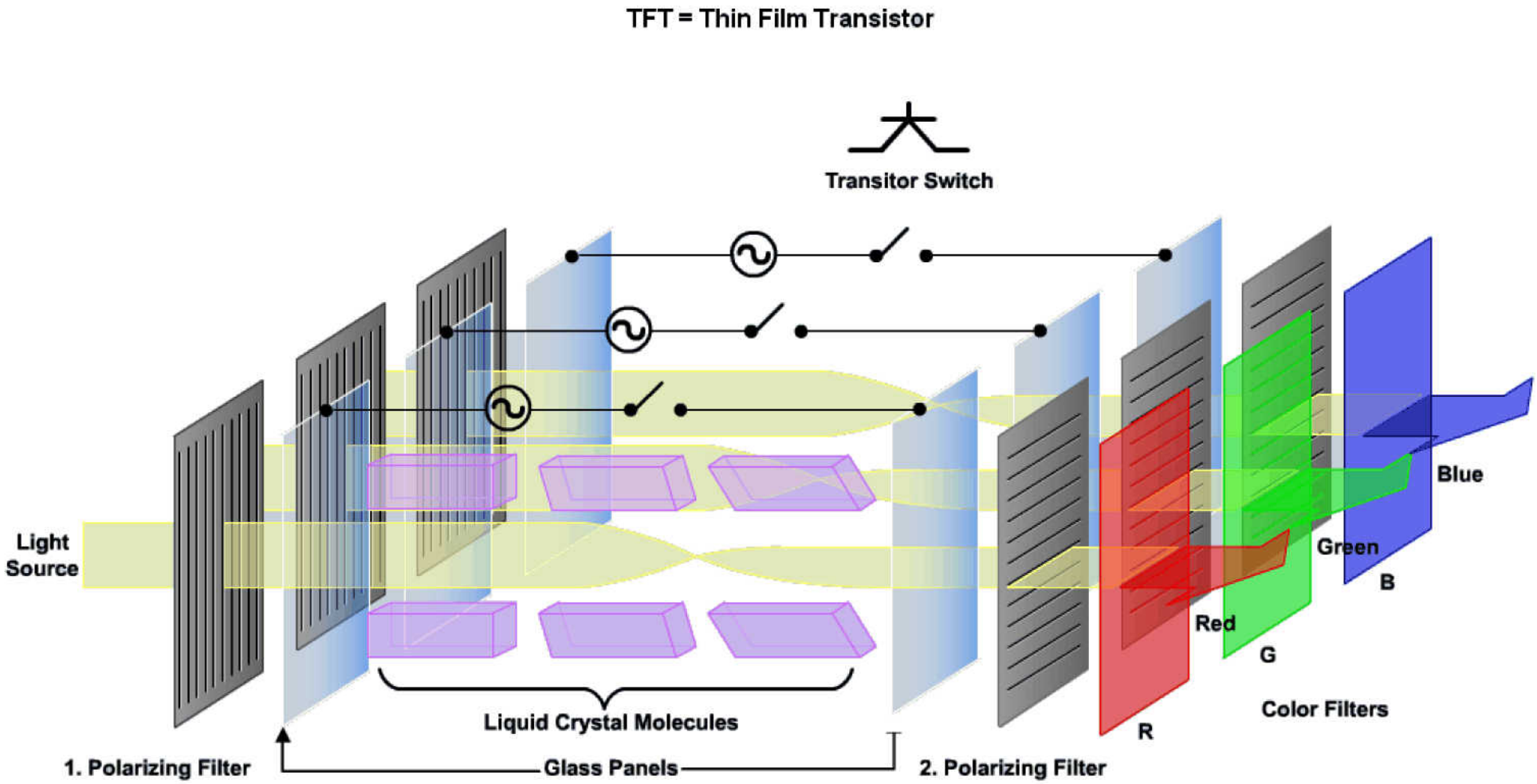

Figure 113 LCD with Thin Film Transistor (TFT)

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Cockpit Display

The picture shows a LCD display for engine parameters.

As you can see, each digit has seven segments. Additionally, there are dots.
Also dot matrix displays are available.

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B737–300 VHF Comms Control Panel



A320 Flight Control Unit



Figure 114 LCD Displays

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Airbus begins flight tests of A340 digital head–up display

Manufacturer aims for parallel certification of new technology on all types next year. Airbus has started flight testing the Thales–developed liquid–crystal–based digital head–up display (HUD) in a bid to gain certification by the second half of next year. Thales has installed the system, known as D–HUDS, on board an Airbus A340–600 widebody. It will also fit the display to an Airbus narrowbody and the ultra–large A380 to achieve parallel certification across the manufacturer's entire family. This follows Airbus¿s selection of Thales two years ago to design and produce the equipment. Head–up displays have previously been based on cathode–ray tube technology. Rival HUD firm Rockwell Collins Flight Dynamics, which was beaten to the Airbus contract by Thales, performed the first test flights of its own liquid–crystal head–up display with an Embraer 170 on 7 April - six days ahead of the first A340–600 flight with the Thales system.

Thales says that, in comparison with cathode–ray tubes, the liquid–crystal display provides greater reliability and increased luminosity. The HUD provides a $35^\circ \times 26^\circ$ field of view and the equipment weighs 23kg (51lb). The display shipset comprises three line–replaceable units: the head–up display computer, which receives and processes the data and generates the graphics; the projector unit; and the fold–down optical combiner, which aligns the graphic overlay and the real–world view.

Airbus will be able to offer the digital head–up display as a single or dual installation. Carriers including Air France and FedEx have already opted for the system on the A380 and it will also be fitted in the cockpit of the Airbus Military A400M transport aircraft.

From Flight International, 05 - 11. July 2005

Usage of HUD in Aircraft

HUD are successively installed in many aircraft to improve landing abilities under bad weather conditions. Freighters and VIP Jets already use this technology and it will become quite common in the future.

The picture below shows a HUD installed in an Embraer 190 where it was fitted in for (succsessful) Cat III Certification.

Picture from Flight International, 29. Aug - 04 Sep 2006

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Figure 115 Usage of HUD in Aircraft

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OLED

General

Organic LED (OLED) is available since 2003 and on the way to replace old LCD displays.

OLED–Technology has several advantages over LCD–Technology. The colours are brighter, the screen can also be read from a side view and is thinner and even flexible. Its power consumption is also much lower as no backlight is required.

Nowadays only very small displays with low resolution can be assembled as there are still some difficulties in producing the driver-matrix.

Production of OLED can be done with inkjet printers as the polymer ink is just printed on a transparent slide.

The lifespan is limited but will hopefully be extended within the next few years.

Major problems arise from operating temperature and sealing of the displays as the OLED must be protected from humidity and oxygen.

Under ideal conditions red OLED may last up to 1M hours while blue is limited to 150.000 h only.

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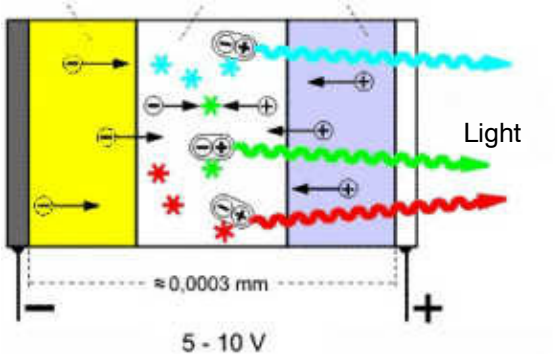
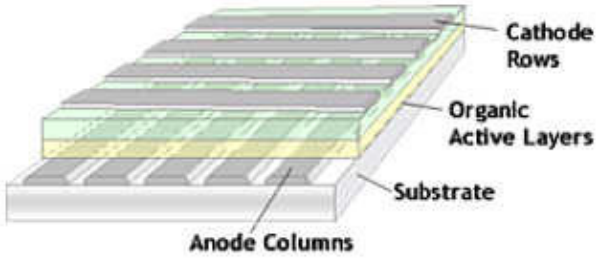
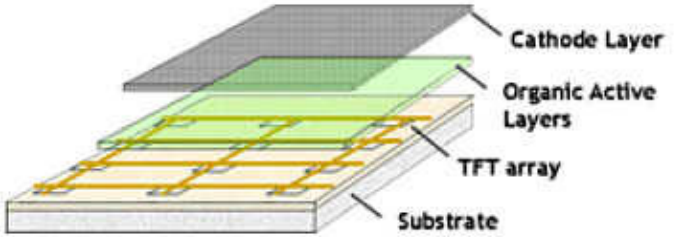




Passive Matrix OLED



Active Matrix OLED

Figure 116 OLED

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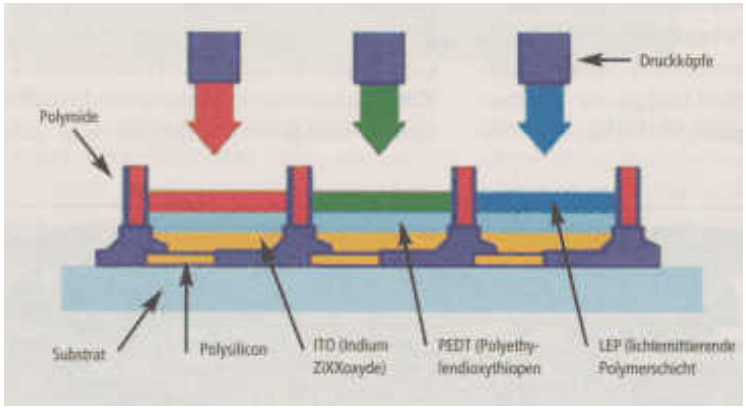

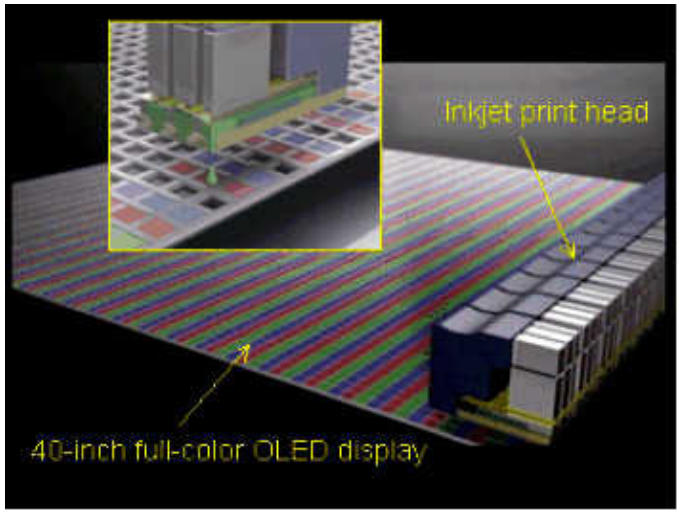

Production with Inkjet-Technology

Figure 117 OLED Production

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Figure 118 Displays with Organic LED

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M5.12 ELECTROSTATIC SENSITIVE DEVICES

INTRODUCTION

History

With the advent of a new generation of devices replacing the former digital AVIONIC devices round about 1979 it became apparent that there were problems with ESD (Electrostatic Sensitive Devices). Because many of these devices were identical to the old ones it was possible to compare the failure statistics objectively.

An increase in the number of minor errors and data differences ranging up to 3 or 4 fold were observed. Further fault analysis revealed that more than 1/3 of these minor errors were attributed to ESD -related changes in the specification of the components.

In addition, it was also noticed that 80–90% of these failures were not total-failures but only changes in their properties. These wounded components were able to pass quality tests without showing any faults. However, further analysis revealed that when compared to fully functioning components they had an increased amount of leakage current and also a change in the switching behavior.

There was also the additional problem in practice that, depending on the working temperature a gliding shifting of the defective parameters occurred. Device-internal ”CHECK SUM”- and ’’BITE”-Tests often were not capable of detecting these errors.

A BITE-Test (Built In Test Equipment) is a test that runs when the equipment is switched on and checks the hardware (Power-Up Test).

Die Check Sum is the sum of digits retrieved via the software and which can detect faults in the memory.

What is ESD?

Electrostatic discharge is always present in our environment, consequently also at our place of work. An example is when we walk over a carpet to open a door we get a slight shock shortly before touching the door handle and perhaps even see a spark or hear crackling.

These are typical forms of appearance of static discharge.

Static electricity is created as soon as two materials are rubbed together, are separated or are in moving in some kind of fluid or gaseous form.

The static charge is then stored in those material which are non-conductive and tend to look for the nearest way to discharge. This discharge can be extremely fast and full of energy. It can also be very destructive.

ESD-Effects

If there are semiconductors, thick film- or integrated circuits along the discharge path of the static electricity then the charges will flow through the components in an uncontrolled fashion or will even be completely penetrated.

Local overheating, gasifications, distortions, separation or reduction of strip conductors as well as pitting can be the result of ESD in the micro structure of a component.

Short–circuiting between tow strip conductors is seldom the case.

The damage is always irreparable!

As a result of the progress in technology the integration density has increased which causes the ESD problems also to increase rapidly!

Voltages from well below 100 volts can be absolutely fatal for components!

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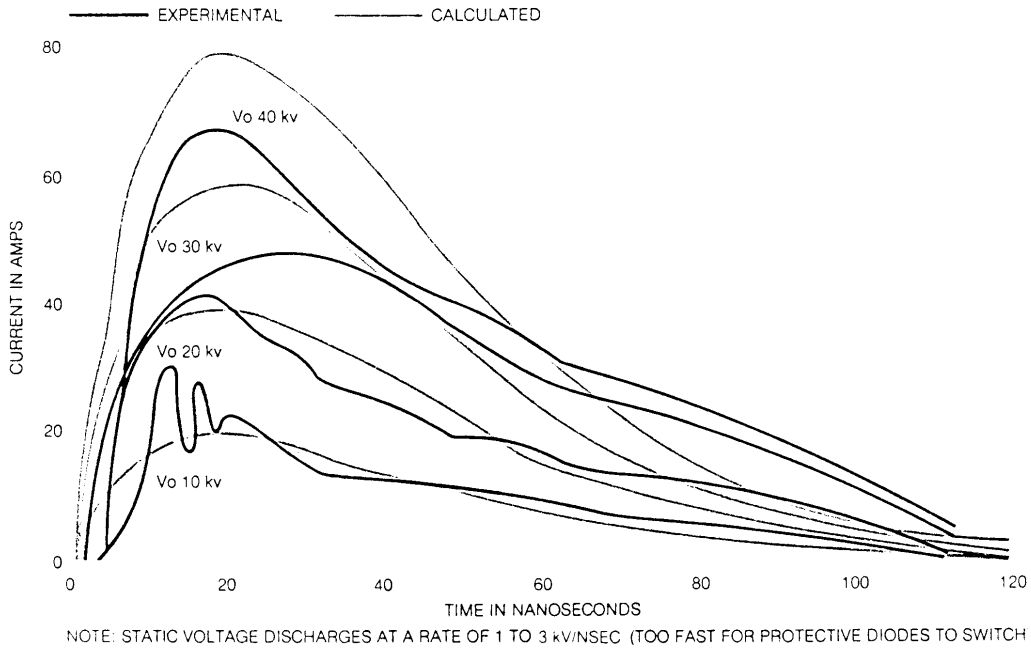
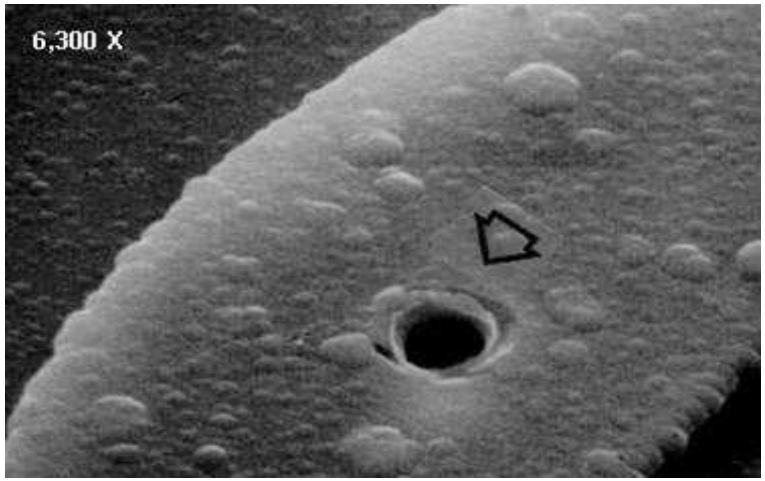


NOTE: STATIC VOLTAGE DISCHARGES AT A RATE OF 1 TO 3 kV/NSEC (TOO FAST FOR PROTECTIVE DIODES TO SWITCH

ESD Damages



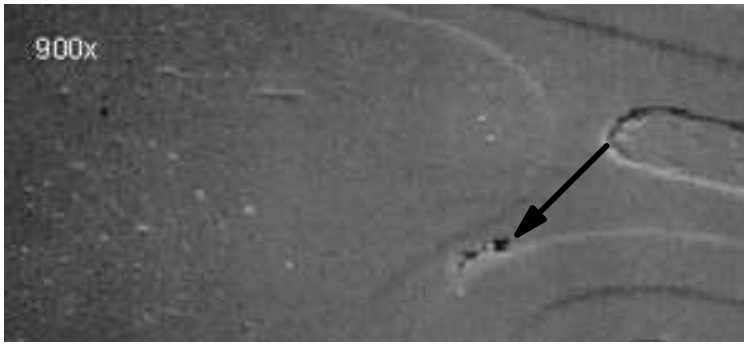


Figure 119 ESD

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ESD GUIDE–LINES

General

Personnel performing work on ESD components and devices must have a good knowledge of the procedural guide–lines pertaining to ESD.

These include:

- identifying components sensitive to ESD. These are usually labelled as such.
- assuring that suitable grounding techniques are applied to set both personnel and the device with the same potential.
- application of static neutralizers, to prevent any charging of personnel, tools and workbench.
- opening an LRU or removal of an SRU (Shop Replaceable Unit) only on a work area prepared for such a purpose.
- fitting protective caps on the electrical terminals of LRUs as soon as they are no longer installed.
  Conductive protective caps are preferred.
- handling defective equipment as carefully as if handling new equipment. Otherwise this would make it difficult to find the actual cause of the fault.
- using conductive material for transport and dispatch
- storing parts away from sources of high energy like radar, x-rays and laser beams.

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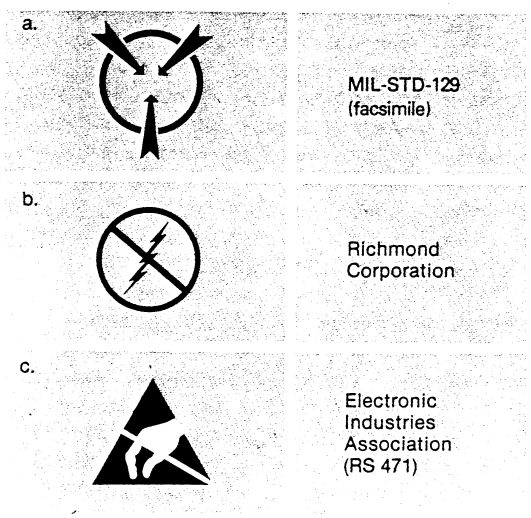

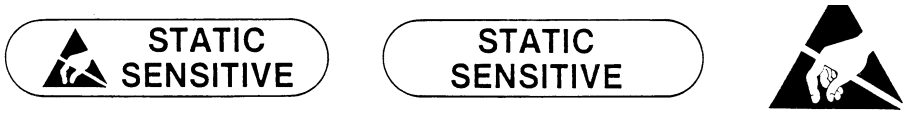

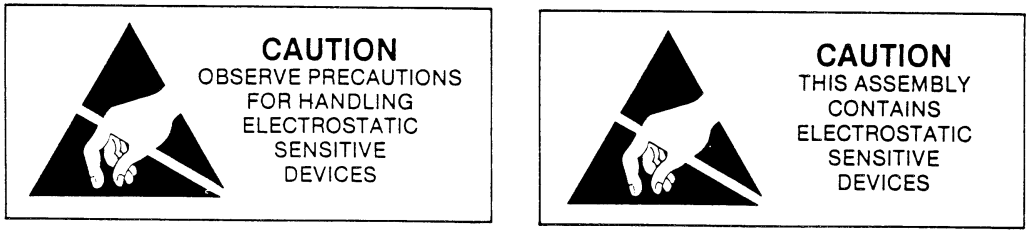

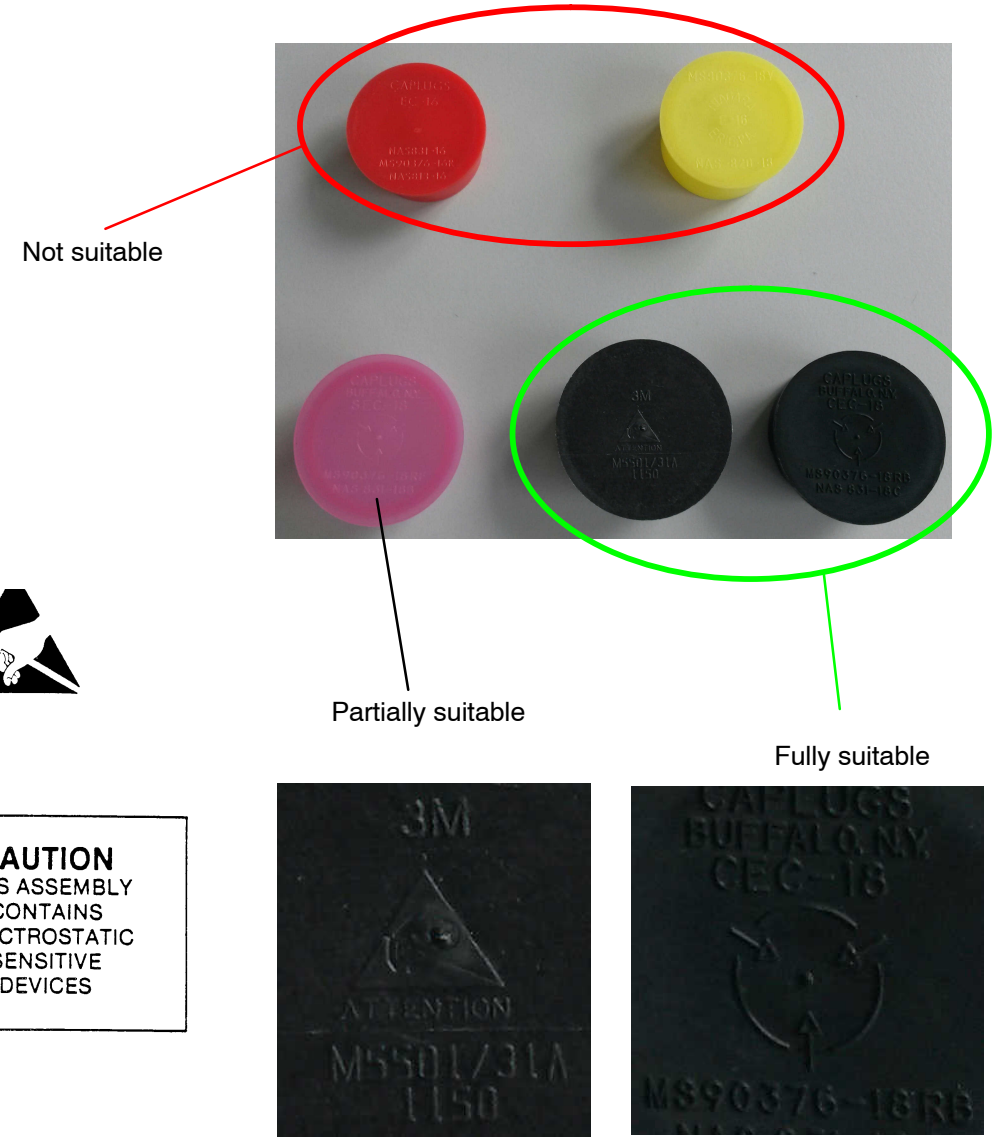

Figure 120 ESD Symbols

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M5.14 ELECTROMAGNETIC ENVIRONMENT

INTRODUCTION

General

All electric/electronic equipments influence the environment by electromagnetic radiation.

Radio communication and navigation systems operate by transmitting controlled EM radiation.

All other electronic devices radiate to some degree, but this radiation should be reduced as far as possible.

Also electronic devices should be able to operate normally in the presence of EM radiation.

We distinguish between units that are:

- permanent installations within the aircraft and
- transportable units like mobile phones, electronic note books, CD-Players etc.

Various terms are used for Electromagnetic Environment.

EMC

EMC, electromagnetic compatibility, meaning units will not adversely affect one another.

Good grounding techniques are required to avoid EMC as two metal surfaces or a metal surface and a shielding may act as antennas.

So grounds must be clean and free of oxidation.

EMI

EMI, electromagnetic interference is the maximum interference allowable for a particular transmission on a bus or wire.

Good grounding techniques must be provided for the shielding of screened wires as the shielding may act as an antenna.

To keep within limits it can be necessary to install so called EMI-filter on the receiver and transmitter side of the unit.

Also portable devices like mobiles or walkie talkies can influence components brought into E&E in case maintenance personnel carries them during maintenance.

HIRF

HIRF, high intensity radiated field is the zone of high radiation which is caused by equipment such as ground radar or strong radio or TV stations.

Lightning / Lightning Protection

High voltage electric discharges can produce high currents. The nature of these currents can produce intense bursts of EM radiation. Both the radio transmitter/receivers and non radio equipment can be influenced by this disturbance.

On wires and cables overbraids made of copper are used to avoid malicious effects.

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AIRCRAFT COMPONENTS

General

The components installed in aircraft are subject to build regulations. In the identification sheet for the aircraft, the status of the build regulations is fixed (under licence).

The specification of the appliance describes its Technical Standard Order (TSO) for the American area, or Joint TSO for the European area. The TSO, or the JTSO, are the authorized industrial standards of the authorities (FAA or EASA). As a rule, they describe the fulfilling functionality of a component (MOPS = Minimum Operating and Performance Standards) and define the environmental conditions under which the components are operated (Environmental Conditions).

By the testing of components, it ensures that they do not exceed their fixed tolerance values.

These test procedures and the limitations are fixed in RTCA Document DO−160C, or in EUROCAE document ED−14C.

As well as the specification for a component, the integration of it into the aircraft is important. The chance of disturbing neighbouring components must also be taken into account, as well as the chance of the unit being influenced by other units.

The ”Advisory Circular 25−10” details regulations on this subject.

Herein is described, amongst other matters, the procedures for checking the ”electromagnetic compatibility”. In carrying out an EMI−survey in an aircraft, all electrically operated systems in the aircraft are checked for disturbances which could originate from newly installed components.

If the new component is critical to flight safety, the examination is repeated in reverse.

Radio Frequency Transmitters

Radio frequency transmitters are a separate case, because they are designed to radiate electro-magnetic waves. Because of this, the national rules for the issue of a certificate of airworthiness are specifically detailed:

- **UK CAA:**
  The approval of an aircraft radio installation is based on a survey by the CAA followed by such ground and flight tests as are required in respect of a particular installation, to prove the satisfactory functioning of the installation. (BCAR Sect A Chapter A3 -11).
- **German LBA**:
  A ruling by the German Aviation Authorities (7/91) states that ”Before the sampling inspection, there is a test for freedom from interference ....”

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PORTABLE COMPONENTS

General

Taking into account the electromagnetic environment is simple regarding the aircraft components despite the complexity of regulations which is a designer problem.

The devices passengers carry on board is create far more problems when in use.

The authorities usually simply forbid the use of any portable radio, mobile and remote control on board. The situation is about to change as far as cell phones are concerned as the EU allows the use in cruise flight as long as they are operated in flight mode since November 2013.

Authorities have little influence on such devices if they are not intended to transmit radiation like handheld game consoles.

The airlines share their experiences in order to decide if the use of such devices can be permitted.

Now it's just up to the cabin crew to make sure these rules are obeyed.

Tests by airlines have shown, that some devices do not have an impact on flight safety, so passengers may be permitted to use them at the discretion of the operator. This may include laptops with wifi where a connection to the Internet is established via satellite.

The integration of mobiles into such satellite connections is already available with some airlines where the national legislation allows the use of such.

The connection to ground is itself established via INMARSAT satellites.

Rules at Lufthansa

Here are the rules governing usage of electronic devices on Lufthansa aircraft:

May be permitted to be operated during certain phases of flight:

- Mobile phones in flight mode,
- Laptops / note books (including those with CD ROM drives),
- Cassette players (Walkman),
- CD players, Minidisk players,
- Computer games (game boy),
- Video cameras,
- Video recorders,
- Displays with liquid crystal technology (LCD).

Prohibited from use on aircraft at anytime :

- Walkie talkies,
- Remote controlled devices,
- Cordless computer mice,
- Computer printers,
- CD ROM writers,
- CD ROM recorders,
- Mini disk recorders,
- Displays using cathode ray tube technology (CRT).

Use of Mobile Phones during Flight

On Sep 30 2006 Ryanair announced the installation of OnAir mobile phone equipment on the Boeing 737 fleet starting in the 2nd half of 2007 (subject to relevant regulatory approval).

Passengers then may use their mobiles during flight at rates with „mirror" international roaming charges.

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Figure 121 Portable Components

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M5.15 TYPICAL ELECTRONIC/DIGITAL AIRCRAFT SYSTEMS

EFIS

General

The EFIS (Electronic Flight Instrument System) displays the situation outside the aircraft. This comprises the attitude of the aircraft in relation to the ground as well as traffic navigation stations on the ground and air traffic.

The displays used are the PFD (Primary Flight Display) and the ND (Navigation Display).

The first Electronic Flight Instrument Systems used Cathode Ray Tubes for the indication.

Later systems use LCD displays.

Basic T

The main indicators in the cockpit are arranged as a so called BASIC T.

Classic Layout

With the classic layout four different indicators form the BASIC T.

Central indicator is the artificial horizon (ADI, Attitude Director Indicator). It indicates the vertical situation of the aircraft.

This comprises:

- Pitch (Nose up/down)
- Roll (Bank angle)

On the left the airspeed indicator is found. It displays the speed in Knots. Limitations of the aircraft due to flaps as an example could be indicated by markings that have to be set by hand.

On the right the altimeter is found. It doesn't always indicate the altitude over ground but the flight level which is based on the air pressure (ambient pressure) of the airport or on standard atmosphere.

Below the ADI the HSI is found (Horizontal Situation Indicator).

Besides indicating the heading also some information from radio navigation systems can be found.

Glass Cockpit Layout

In the glass cockpit the PFD (Primary Flight Display) displays all the BASIC T. The arrangement of the four analogue indicators is reproduced by computers making it look very similar on an electronic display.

Additional information is incorporated in the PFD as well. As an example right besides the altimeter the VSI (Vertical Speed Indicator) is located indicating the change in altitude in feet/minute.

Limitations from the configuration of the aircraft are no longer displayed by markers but are a part of the indication itself.

On the speed indication patterns will be displayed from the top/bottom indication unsafe speeds. Safe flying is only possible between these markings.

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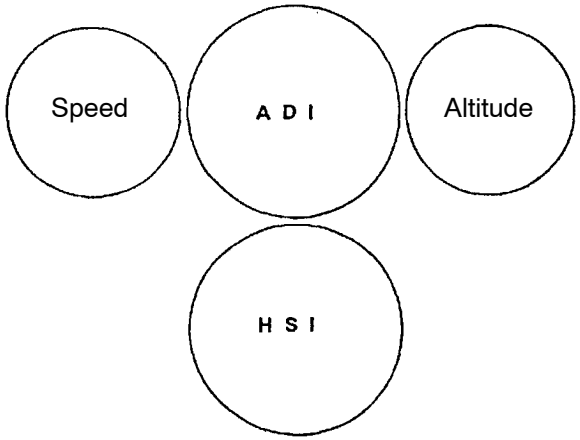

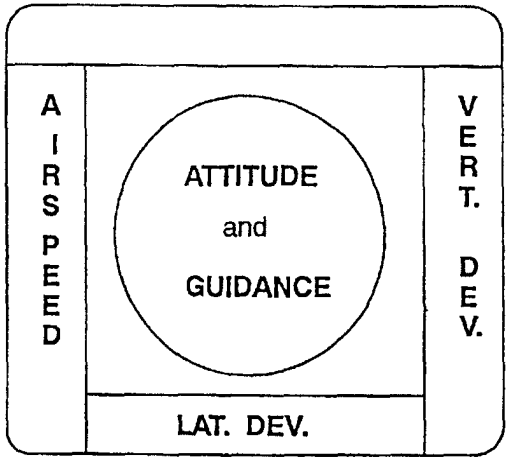



Classic Layout



Glass Cockpit Layout

Figure 122 Basic T Layout

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Navigation Displays

With the classic layout navigation data was indicated on the HSI, but also on other instruments.

With the glass cockpit all that information is displayed on a common screen which is called Navigation Display. In addition weather data could also be displayed.

The pilot can read information about the routing, aircraft traffic as well as weather- or ground proximity information.

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Figure 123 Navigation Display

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System Arrangement

A typical Electronic Flight Instrument System has the following components:

- Display Computers
- 4 Display Units
- 2 EFIS Control Panels.

Display Computers

Display computers receive various inputs from many aircraft systems and send these data to the Displays.

The inputs are:

- Navigation data (digital)
- Auto Flight System data (digital)

There are at least two display computers. Large aircraft have a third display computer for redundancy.

The arrangement which computer supplies which display unit depends on the type specific engineering.

The name of the computer is also different.

Many navigation computers and some auto flight computers are installed in an aircraft. Each of them sends its data via a data bus to the display computers. So each display computer has many data bus inputs.

Generations

In the first generation of EFIS, the display computers contain a symbol generator. They send video signals to a display.

The second generation of EFIS has displays with an integrated symbol generator, so they are called “display units“. The display computers send data to the display units.

EFIS Control Panels

Since there are many data from the navigation systems each pilot can select on a related EFIS Control Panel what he wants to see on his navigation display (ND).

BITE

The Display Computers are equipped with a Built-In Test Equipment (BITE). This includes a memory for faults which have been detected during operation.

In Aircraft with an CMS (Central Maintenance System), the EFIS computers are tested via the CMS.

On aircraft without CMS, an interactive BITE can be performed using the controls for the indication system.

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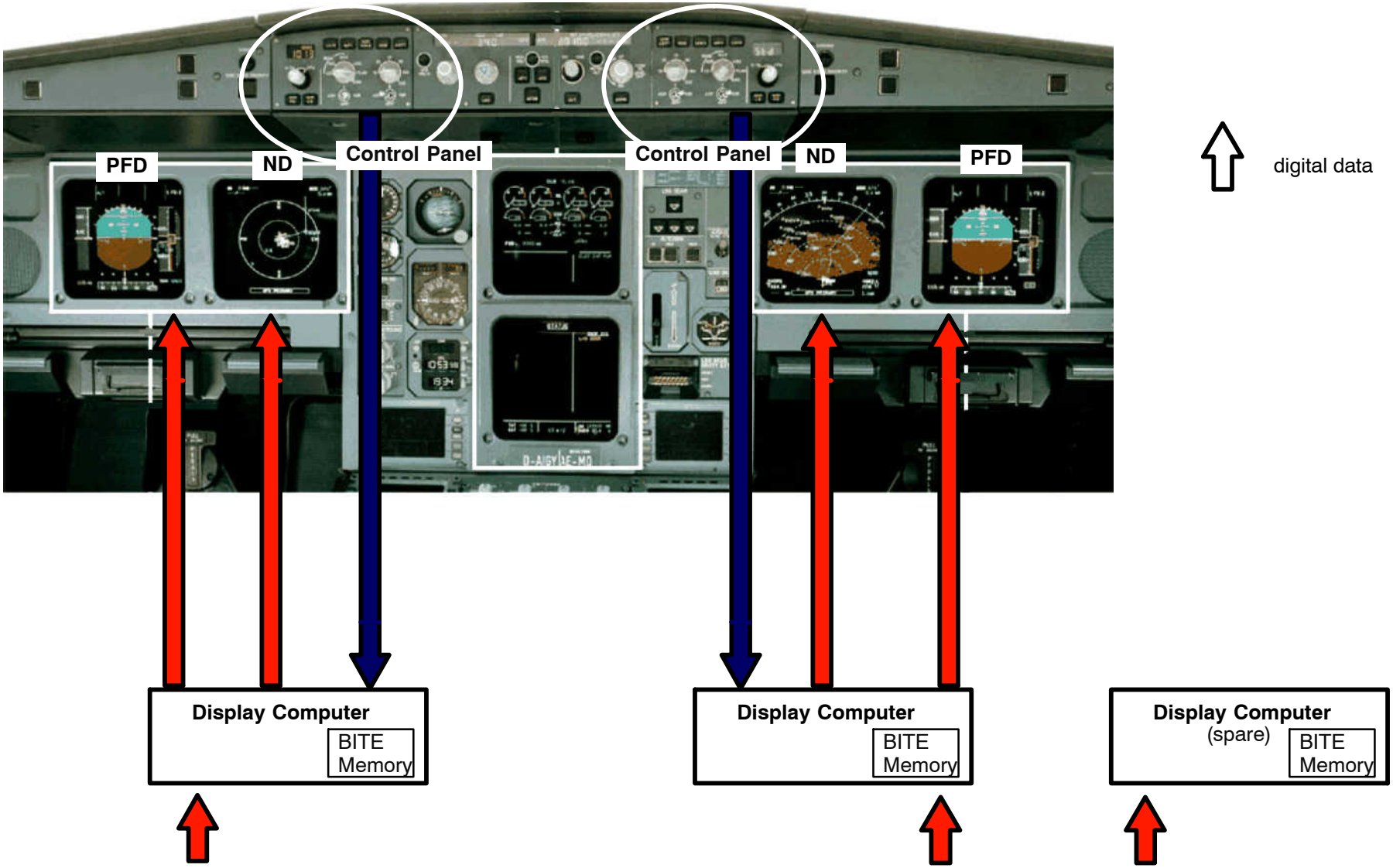

LTT

Figure 124 Electronic Flight Instrument System Arrangement

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ECAM/EICAS

General

The Central Warning System consists of an upper and a lower display located in the middle of the instrument panel.

Its application is:

- displaying information from the Central Warning Computers
- displaying systems synoptic
- permanent display of some additional aircraft parameter

Upper Display

The upper display is called „Engine and Warning Display“ on Airbus aircraft, „Primary EICAS Display“ on Boeing aircraft.

Below two examples of such a display can be found indicating the similarity of Airbus and Boeing layout.

The Boeing 747 Primary EICAS Display is on the left as the Airbus 320 Engine and Warning Display is on the right.

Every screen has an area for the Central Warning System messages and aircraft information to be displayed permanently.

These information comprise:

- main engine parameter
- Fuel on Board (FoB)
- Flap Position

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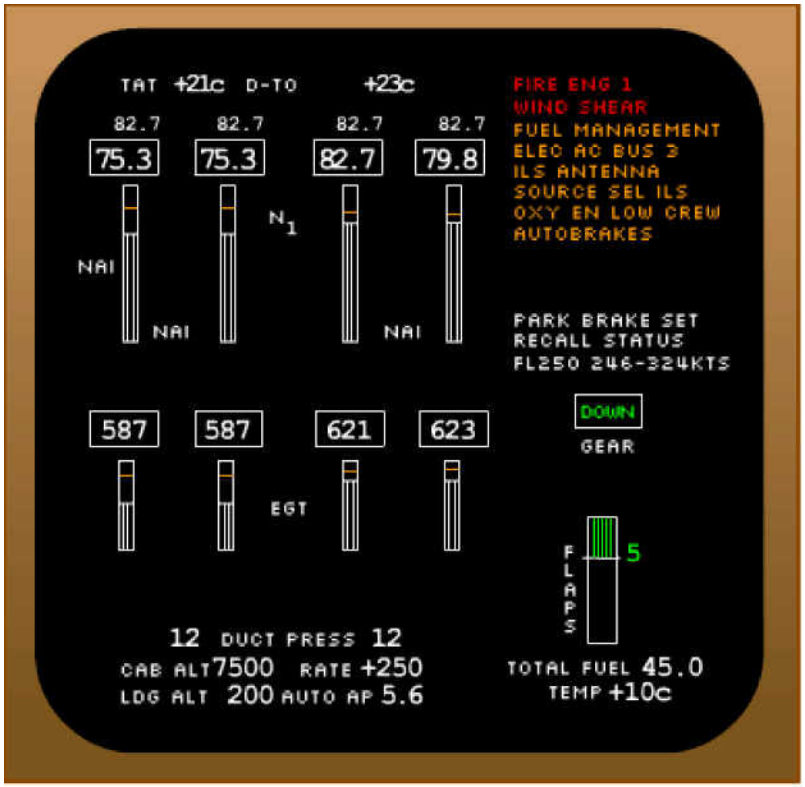

Primary EICAS Display



Engine and Warnig Display

Figure 125 Upper Display

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Lower Display

The lower display of the CWS indicates the status of the aircraft systems.

Airbus calls it „System Display“ while Boeing calls it „Secondary or Auxiliary Display“.

A wide amount of different parameters may be displayed on the lower EICAS/ECAM screen.

They are called Pages or Display Formats.

Also permanent data like temperature and weight are displayed here.

Control Panel

For the centre displays there is a control panel. It is used to select the system which is appropriate to be monitored.

Additionally, there are features to handle the alerts.

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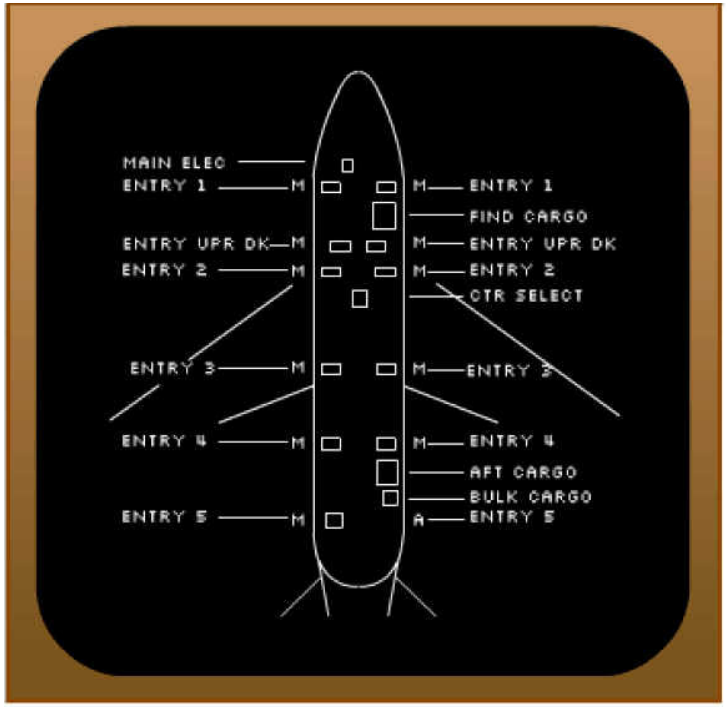

Secondary or Auxiliary Display



System Display



Control Panel



Control Panel

Figure 126 Lower Display

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System Arrangement

A typical Central Warning has the following components:

- Display Computers
- 2 Display Units
- Control Panel.

Display Computers

Display computers receive various inputs from many aircraft systems and send these data to the Displays.

The inputs are:

- Engine data (digital)
- Data from various aircraft systems (digital and analogue)

On some aircraft types the computers are the same as the computers for the EFIS.

The arrangement which computer supplies which display unit depends on the type specific engineering.

Alerts

On the upper display, the Central Warning System can display messages if any malfunction of an aircraft system is detected.

Additionally, aural warnings can be generated. Loudspeakers in the flight deck will generate the sound.

BITE

The Computers of the system are equipped with a Built-In Test Equipment (BITE). This includes a memory for faults which have been detected during operation.

In Aircraft with EICAS and a Central Maintenance System (CMS), the EICAS Computers are tested via the CMS. On aircraft without CMS, an interactive BITE can be performed using the EICAS controls.

In Aircraft with an ECAM, the DMCs (computers for ECAM) are connected to the Central Maintenance System (CMS).

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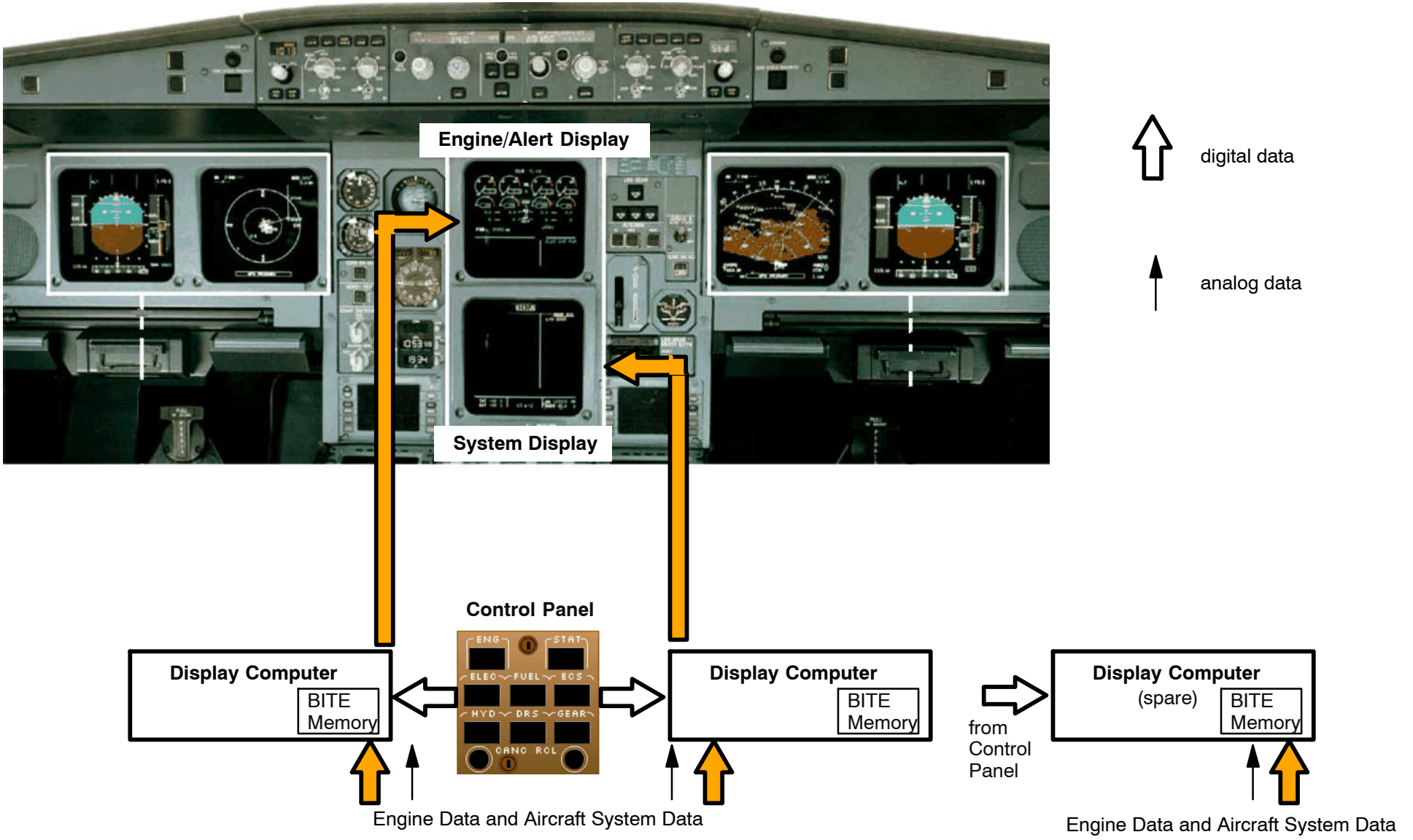

Figure 127 Central Warning System Arrangement

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FLY BY WIRE

General

The Airbus 320 and Boeing 777 are examples of commercial aircraft which have full Flight Guidance Systems. These differ from other modern aircraft such as Airbus 310, Boeing 757 and 747, because the manual control of the control surfaces is exclusively by a fly by wire system.

A fly by wire system will provide electrical signals from the computers to control surface actuators. The actuators will then move the control surfaces under hydraulic power.

Older aircraft like B737−100 have a system which works like a primitive fly by wire system, but they had no protection for limits and a full mechanical linkage to control the flight controls.

One advantage of a modern fly by wire is the reduction in mechanical connections between the cockpit and control surfaces. This simplifies aircraft construction and reduces weight. Another advantage is the protection of the limits for attitude, this is called “flight envelope protection“. A pilot can not command the aircraft beyond critical limits because the computer will know the relevant limits.

Basic Principles (Airbus 320)

The fly by wire system has been designed and certified to make the new generation of aircraft more cost effective, safer and nicer to fly or ride in than earlier generation aircraft.

The flight control surfaces are all:

- Electrically Controlled.
- Hydraulically Activated.

The stabilizer and rudder can be controlled mechanically.

Side sticks which replace the more conventional handwheels are used to fly the aircraft in pitch and roll. The pilot inputs are interpreted by computers and move the flying controls as necessary to achieve the desired flight path.

However, regardless of the pilot’s input the computers will prevent excessive manoeuvres or exceedance of the safe flight envelope.

BITE

The fly by wire system is checked with the BITE of the Flight Control System. The related computers are connected to the Central Maintenance System (CMS).

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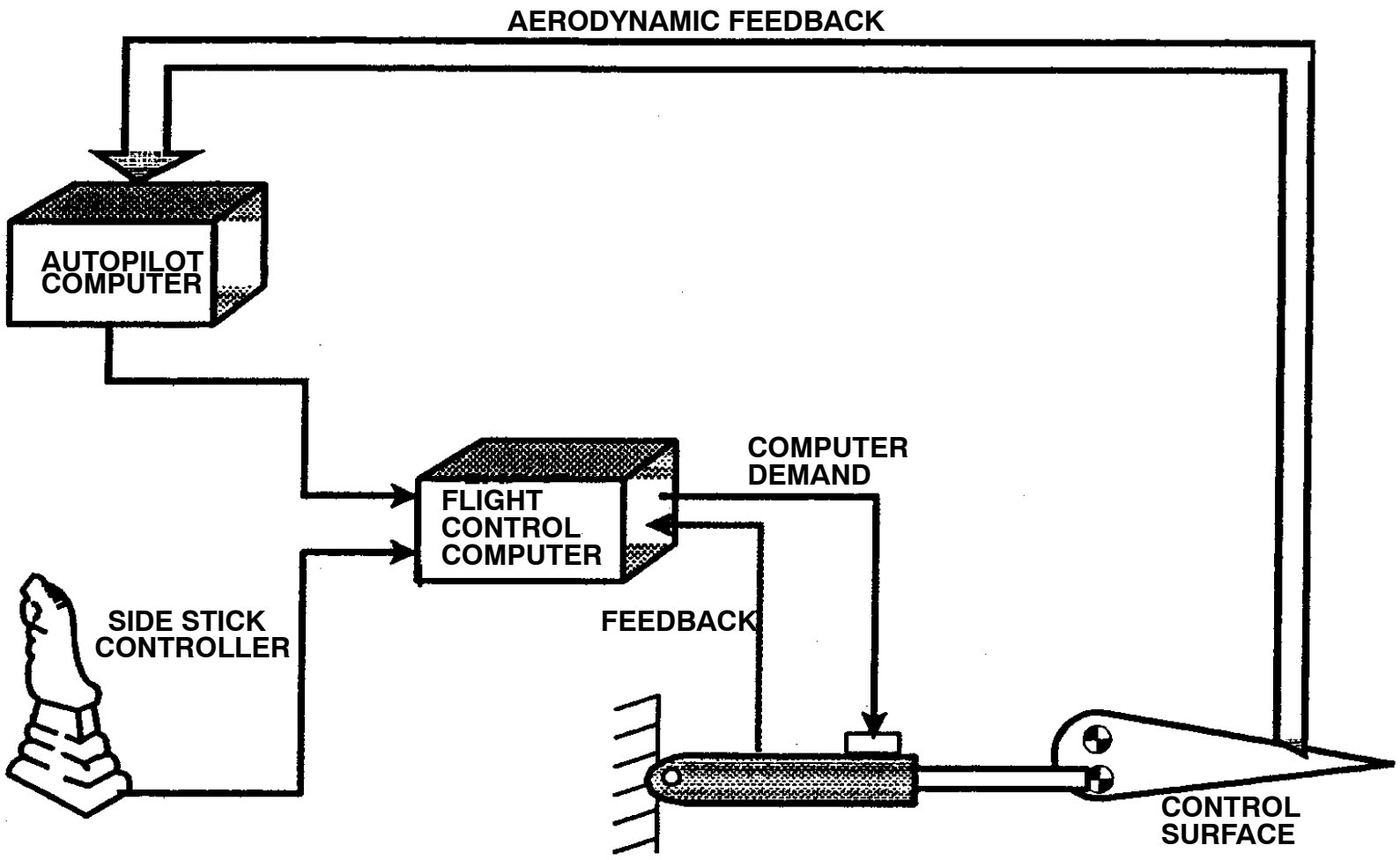

Figure 128 Simplified Fly By Wire Schematic

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Airbus 320 Flight Control Surfaces

The Airbus 320 flight controls are electrically or mechanically controlled as follows:

Pitch Axis:

Elevator control = Electrical

Stabilizer control = Electrical for normal or alternate control.
Mechanical for manual trim control.

Roll Axis:

Ailerons control = Electrical

Spoilers control = Electrical

Yaw Axis:

Rudder Control = Mechanical, however control for yaw damping, turn coordination and trim is electrical.

All surfaces are hydraulically actuated. Two side stick controllers are used for pitch and roll manual control, one on the captains left hand side and the other on the F/O right hand side. The two side sticks are not mechanically coupled. Each controller sends independent electrical signals to the Flight Control Computers. Two pairs of pedals which are rigidly 'interconnected' ensure mechanical control to the rudder.

A speed brake control lever is provided on the centre pedestal. Two hand wheels on the centre pedestal are used to mechanically control the trim of the horizontal stabilizer.

A switch installed on the centre pedestal operates the rudder trim control.

Computers

Seven Flight Control Computers process pilot and autopilot inputs according to normal, alternate or direct flight control laws. All surfaces are electrically controlled through a computer arrangement which includes:

2 ELACs – Elevator Aileron Computer.

These provide normal elevator, aileron and stabilizer control.

3SECs – Spoilers Elevator Computer.

These provide normal spoiler control and standby elevator and stabilizer control.

2 FACs – Flight Augmentation Computers

These provide normal electrical rudder control.

In addition two Flight Control Concentrators acquire data from the Elevator Aileron Computer and the Spoiler Elevator Computer to send to the Electronic Instrument System.

The ADIRU is a navigation computer which gives attitude information to the fly by wire system via a data bus.

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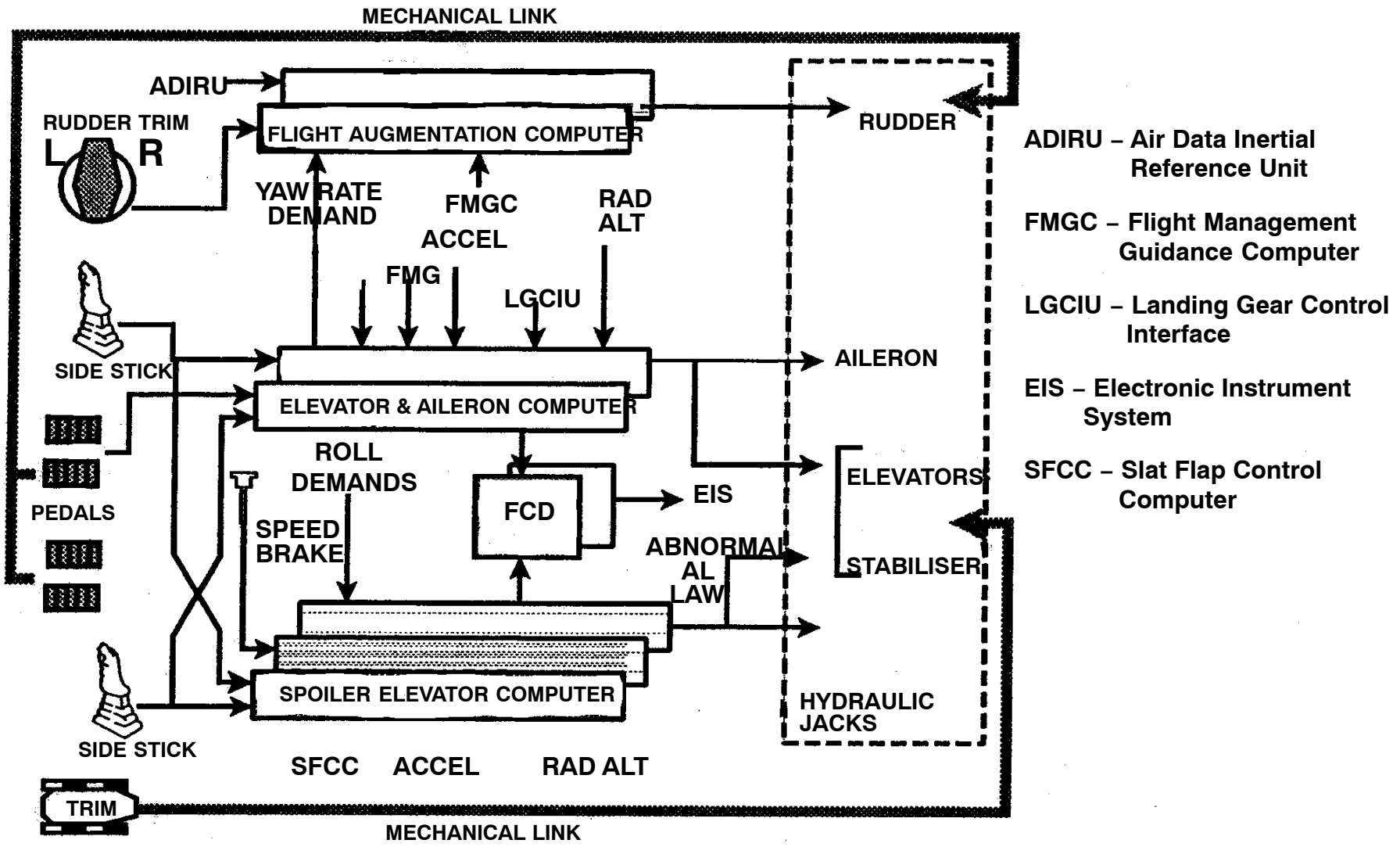

ADIRU – Air Data Inertial Reference Unit

FMGC – Flight Management Guidance Computer

LGCIU – Landing Gear Control Interface

EIS – Electronic Instrument System

SFCC – Slat Flap Control Computer

Figure 129 Schematic of a Flight Control System

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FLIGHT MANAGEMENT SYSTEM (FMS)

General

The Flight Management System is used for automatic control of the aircraft, navigation and performance management.

It comprises the following components

- Flight Management Computer
- MCDU
- Sensors

System Layout

Prior to flight the FMS receives the Present Position that has to be entered manually into the MCDU.

This information will be forwarded to the IRS system which also needs the Present Position prior to flight. The IRS compares the entered Present Position with its calculated latitude and reports discrepancies.

The FMC contains a NAV data base from which it calculates the route by using start point an aim. Also waypoints are found in the NAV data base.

The NAV data base has to be updated every 28 days.

Modern FMC are also capable of controlling the NAV receivers, setting them to the frequencies required.

Communication with data sources and receivers usually is done by using ARINC 429 data buses.

FMS Data Sources

The following digital data sources are connected to the FMC:

- IRS
- GPS (if installed)
- NAV radios
- Fuel Quantity System
- MCDU.

These data sources are used for lateral and vertical navigation. Also it will be calculated if the Fuel On Board is sufficient for the remaining flight.

FMC Data Receivers

Besides MCDU data is also transmitted to:

- Nav Display (via SGU or DMC)
- Autopilot in LNav Mode (Lateral Navigation)
- Autopilot in VNav Mode (Vertical Navigation)
- Auto Throttle System.

BITE

The Flight Management Computer is directly connected to a MCDU. The BITE can be done using the FMS menu. Additionally, on some aircraft there is a connection to the Central Maintenance System (CMS).

On some FMC types a BITE on the front face of the FMC unit is possible.

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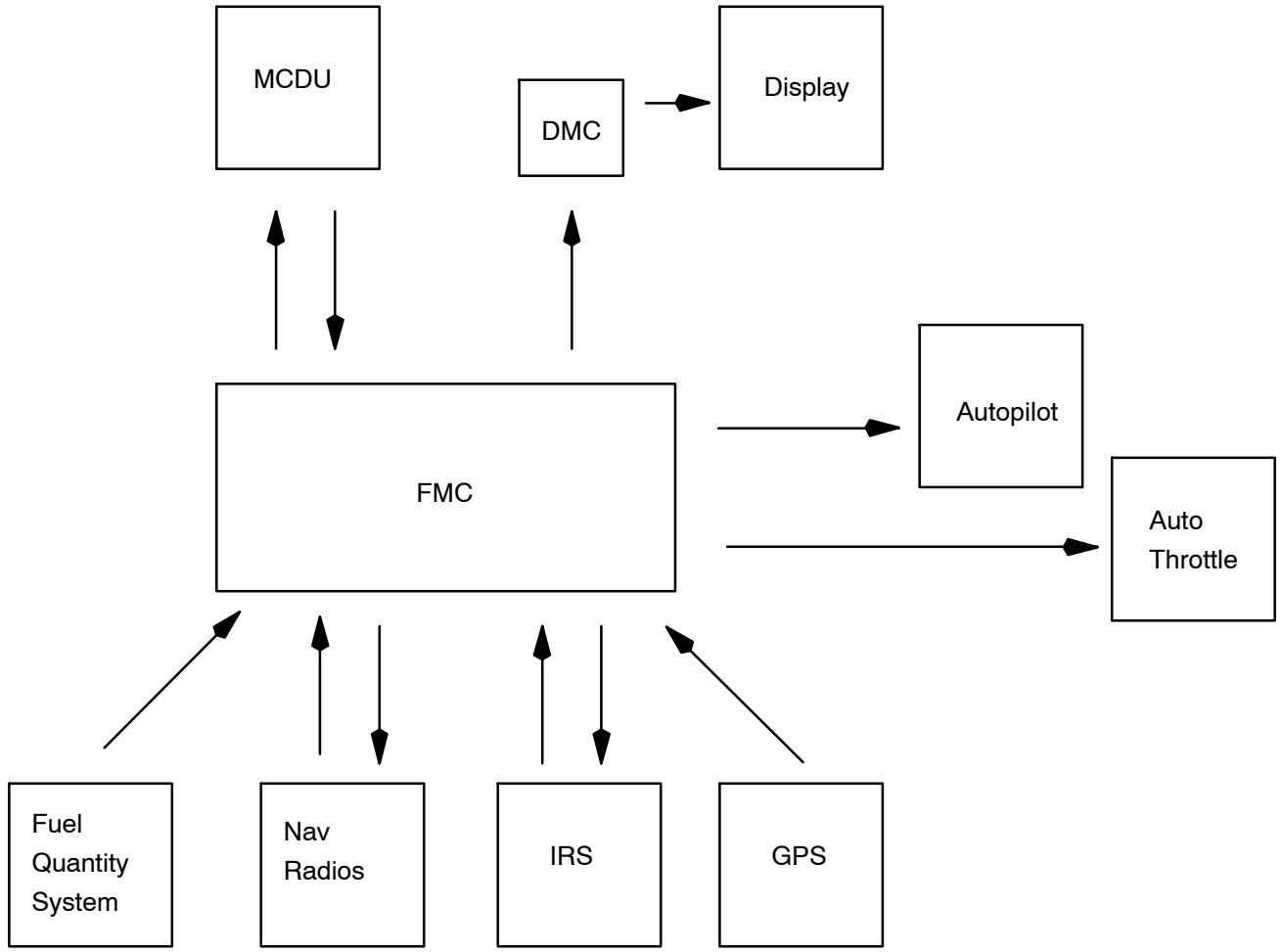

Figure 130 Overview Flight Management System

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INERTIAL REFERENCE SYSTEM (IRS)

General

The inertial reference system is the standard system in today's generation of aircraft.

Usually either 2 or 3 independent systems are installed in an aircraft.

A system consists of an Inertial Reference Unit (IRU) which contains all the necessary system components.

The gyros used are normally laser gyros.

The IRS system has a mode select unit, MSU in short. On this unit can be found the ON – Off switches.

Some systems also need an inertial sensor display unit (ISDU) in short for data entry and monitoring. Modern systems don't have an ISDU because all functions are controlled from the MCDU.

The IRU primarily provides output signals for attitude, heading, ground speed, wind and inertial vertical speed.

It also receives inputs from the Air Data Computer (ADC).

Present Position

The IRU has a very powerful computer which is able to calculate the present position of the aircraft. For this calculation it needs a 10 minute align phase on the ground. During that time the aircraft may not be moved.

The present position calculation is updated during the whole flight using the acceleration signals, so it can be used by the lateral navigation of the Flight Management System.

These calculations must never be interrupted during flight, therefore the IRS requires a backup electrical supply directly from the aircraft battery or from an own battery unit.

The IRU needs the present position for the alignment before it can output navigation data. For the alignment, it receives this data from the Flight Management Computer or from the ISDU.

Heading

The computer knows the magnetic variation. This is stored in its memory for all positions on earth. Therefore, it does not require a flux valve to calculate the magnetic heading. The system calculates true heading and adds the appropriate magnetic variation. On the data bus, it can transmit both the true heading and the magnetic heading. The receiving systems can distinguish that by the label.

BITE

On aircraft with an Central Maintenance System (CMS), the IRU is connected to it.

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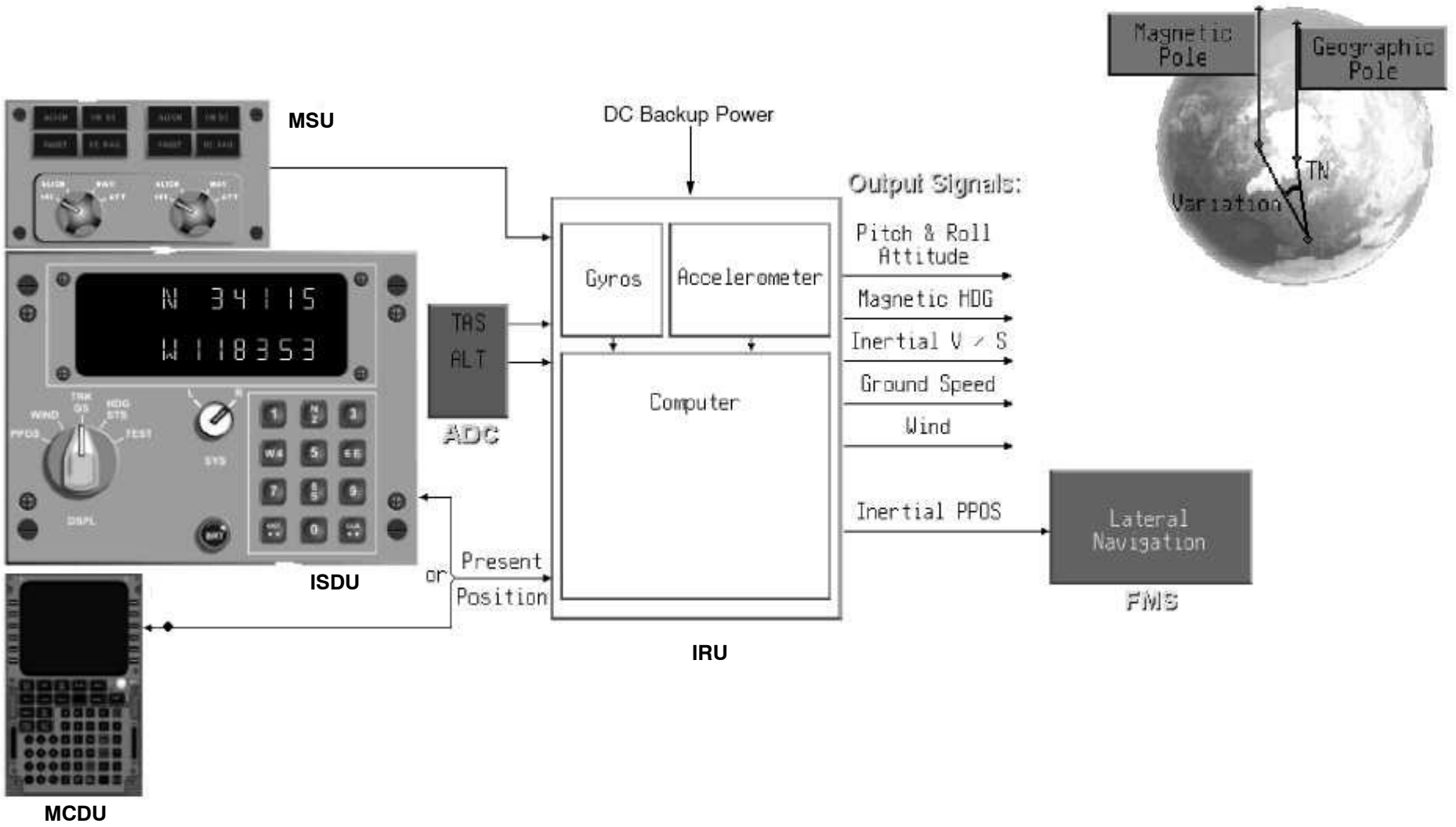

Figure 131 IRS Arrangement

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ACARS

General

The Aircraft Communication Addressing and Reporting system or ACARS, is a datalink communication system which can transfer messages and data between the aircraft and the ground via radio systems.

Data Transfer

Normally, it uses the VHF Communication system number 3.

It is also possible to use the Satellite Communication System. This is done when there is no ground station in range for the VHF System.

Nowadays airlines also have an option for HF data transfer. For voice communication HF had the major disadvantage of poor quality but for data transmission it is sufficient.

The major advantage for the airlines is that HF is free of charge while SatCom produces costs for the data transmission service from the providers.

Network

The data sent by ACARS is received by the ground station of a network provider which transports the data via its network to the users. The data transfer in this direction is called the downlink. Consequently the data transfer from the ground to the aircraft is called the uplink.

Link means, that data is sent by one station and a confirmation from the other station is received.

Reports

ACARS transmits and receives either automatic reports from the Aircraft Condition Monitoring System (ACMS), which usually depend on the flight profile, and manual reports which are independent of the flight profile.

System Arrangement

The system has one central unit, the ACARS Management Unit (ACARS MU).

The ACARS MU receives data via one data bus from the ACMS and data via one data bus from the Central Maintenance Computer (CMC).

Analogue discretes give additional status information. For example “door open“.

Data buses establish digital data transfer from and to the communication systems.

MCDU

The Multipurpose Control and Display Unit (MCDU) is used for manual control of the ACARS. The figure shows a menu of the ACARS which can be used by the pilots before flight.

The menu depends on the type of ACARS MU and on its software which was selected by the airline.

BITE

In most aircraft, the ACARS MU is directly connected to the MCDUs. Then the BITE can be done using the ACARS menu.

Additionally, a BITE test on the front side of the ACARS unit is possible.

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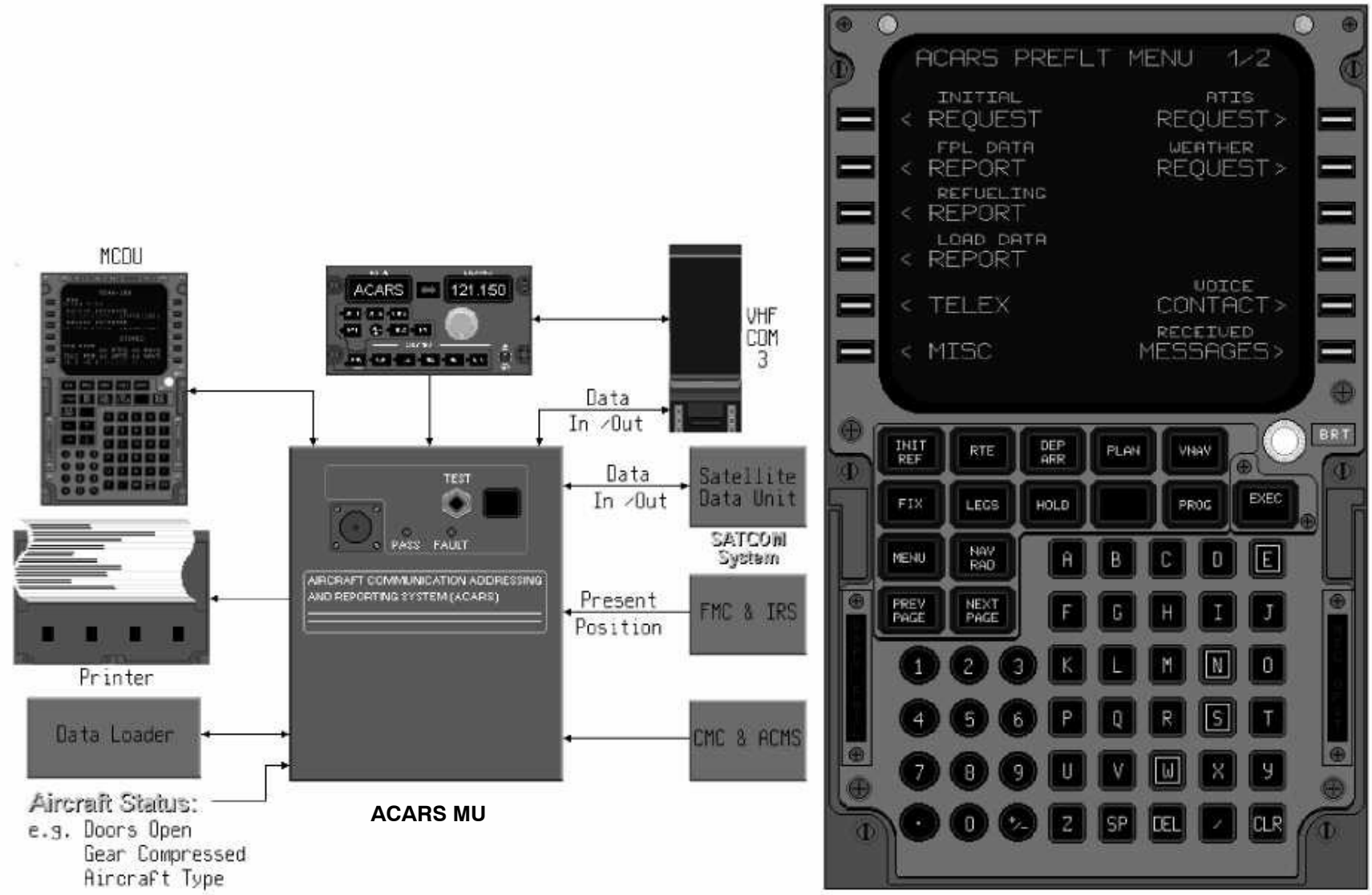

Figure 132 ACARS Arrangement

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GLOBAL POSITIONING SYSTEM (GPS)

General

The Global Positioning System, or GPS in short, is a satellite−based navigation system that calculates aircraft position with high accuracy.

The initial set−up used 21 primary and 3 spare satellites which orbit about 10900 Nm above the earth. Now it is 36 satellites in total.

Each satellite completes an orbit once every 12 hours and permanently sends signals which include the time of the transmission.

The GPS unit in the aircraft calculates the travel time of the signal by comparing the time of the signal reception with the transmission time. The travel time gives the distance to the satellite, because radio signals travel at the speed of light.

GPS can calculate the aircraft latitude, longitude and altitude, when the distance to at least four satellites is available.

Usually two GPS are installed.

The GPS unit processes the signals and sends them primarily to the flight management system for position calculation.

Antenna

Each GPS has one top−mounted antenna which receives the satellite signals. The satellite signals are routed to a GPS unit which is, for example, in a dedicated component near the antennas or inside the multimode receiver.

BITE

In aircraft with a Central Maintenance System (CMS), the GPS Receiver is connected to the CMS.

On aircraft without CMS, there are specific BITE features.

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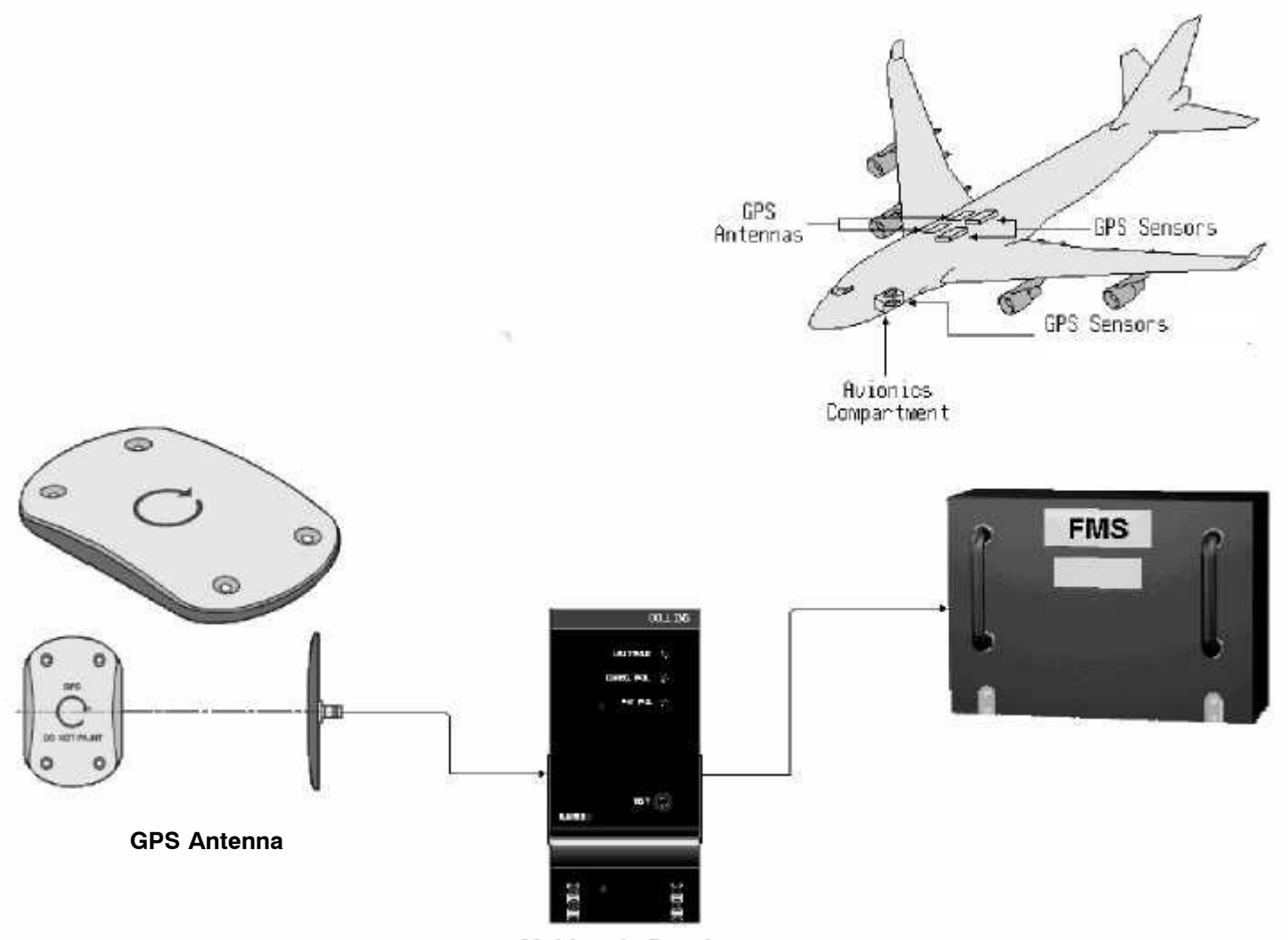

Figure 133 GPS Arrangement

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TRAFFIC ALERT COLLISION AVOIDANCE SYSTEM (TCAS)

General

A typical TCAS system has the following main components:

- A TCAS Computer which is located in the Avionics compartment
- Two antennas which are used for transmission and reception, one at the top and one at the bottom of the aircraft.
- Finally a combined ATC and TCAS control panel.

The TCAS computer communicates via the antennas with the ATC transponder of other aircraft, therefore it uses the same two frequencies as the ATC transponder.

It transmits interrogations on one frequency (1030 MHz) and receives the replies on another frequency (1090 MHz).

Antennas

The two TCAS antennas consist of four electronically controlled elements. This gives the antenna a directional characteristic so that the computer can calculate the direction to an intruder.

BITE

In aircraft with a Central Maintenance System (CMS), the TCAS Computer is connected to the CMS.

A test can also be initiated on the ATC/TCAS Control Panel. This will simulate foreign aircraft on the TCAS indication.

Additionally, a BITE from the front plate of the TCAS unit is possible.

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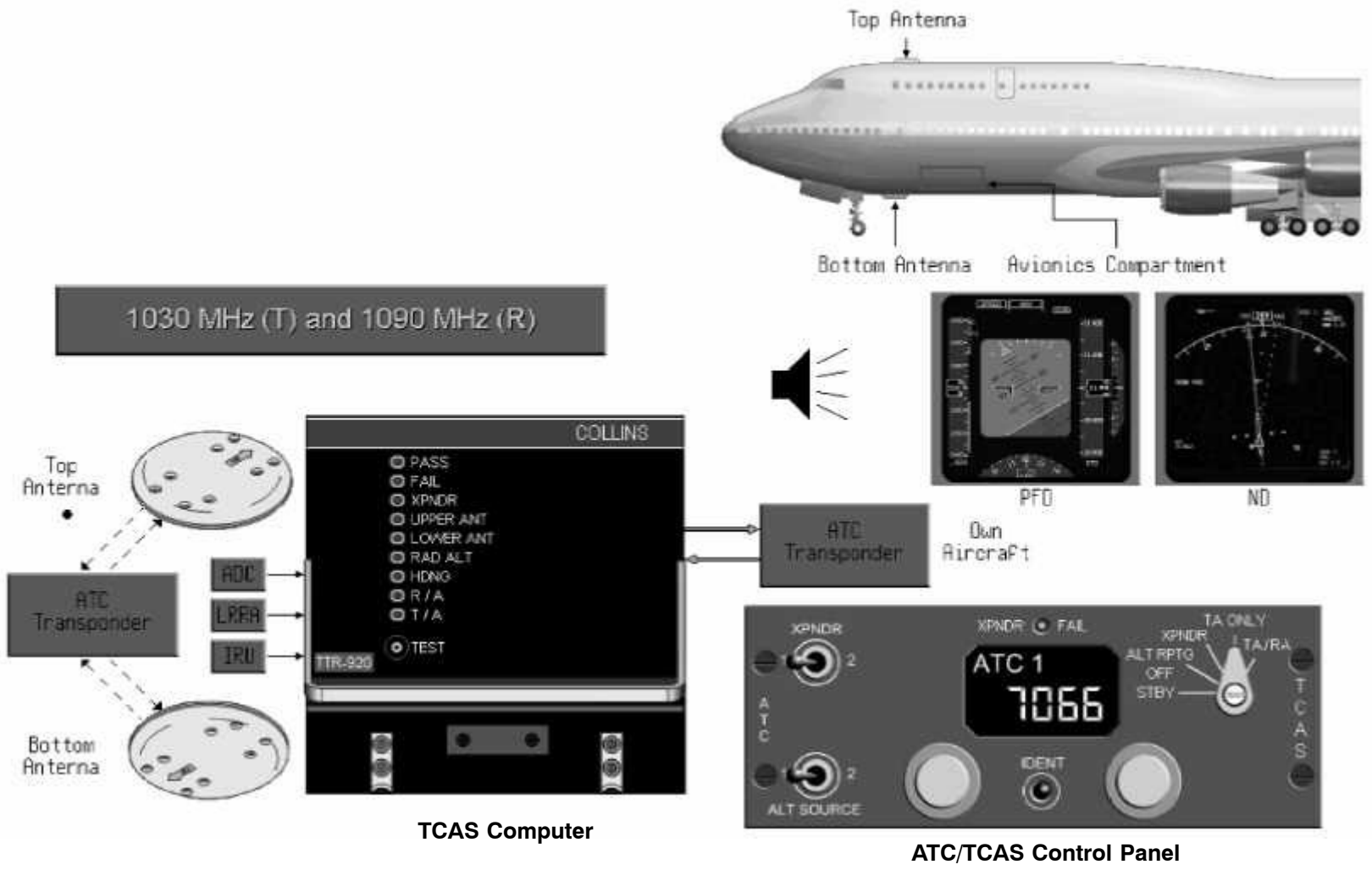

TCAS Computer

ATC/TCAS Control Panel

Figure 134 TCAS Arrangement

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INTEGRATED MODULAR AVIONICS (IMA)

General

In today's aircraft each system has its own line replaceable unit, LRU in short.

Thanks to the new avionics concept Integrated Modular Avionics (IMA), most of the conventional LRU functions now become avionics applications.

These independent applications are hosted in shared IMA modules, called Core Processing Input/Output Modules or CPIOMs in short.

The general purpose of these CPIOMs is to provide centralized computing, memory space and data communication capability between aircraft systems and conventional LRUs with no AFDX interface.

IMA

Moreover, in order to satisfy the high demand of conventional LRUs, this service of data communication capability has been increased thanks to additional IMA modules called Input/Output Modules (IOMs).

CPIOMs and IOMs are Line Replaceable Modules (LRMs).

Advantages

The main benefits of the Integrated Modular Avionics, IMA in short are:

- IMA modules are Commercial Off The Shelf (COTS) components. This means there is no difference to commercial electronic boards.
- The same type of LRMs are interchangeable, what will reduce the part number and maintenance cost.
- and each LRM can be configured to provide services for one or more system applications.

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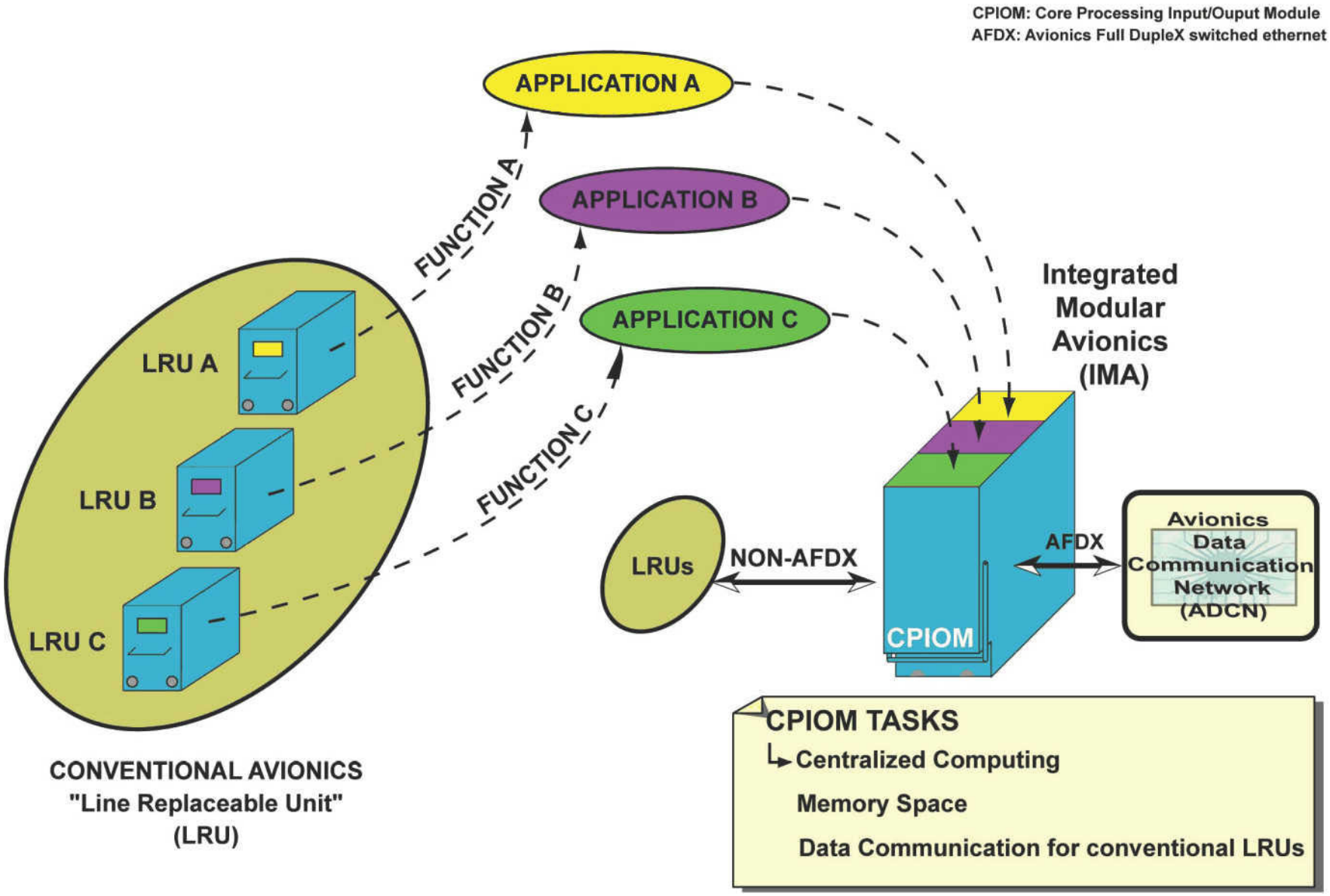

Figure 135 Integrated Modular Avionics (IMA)

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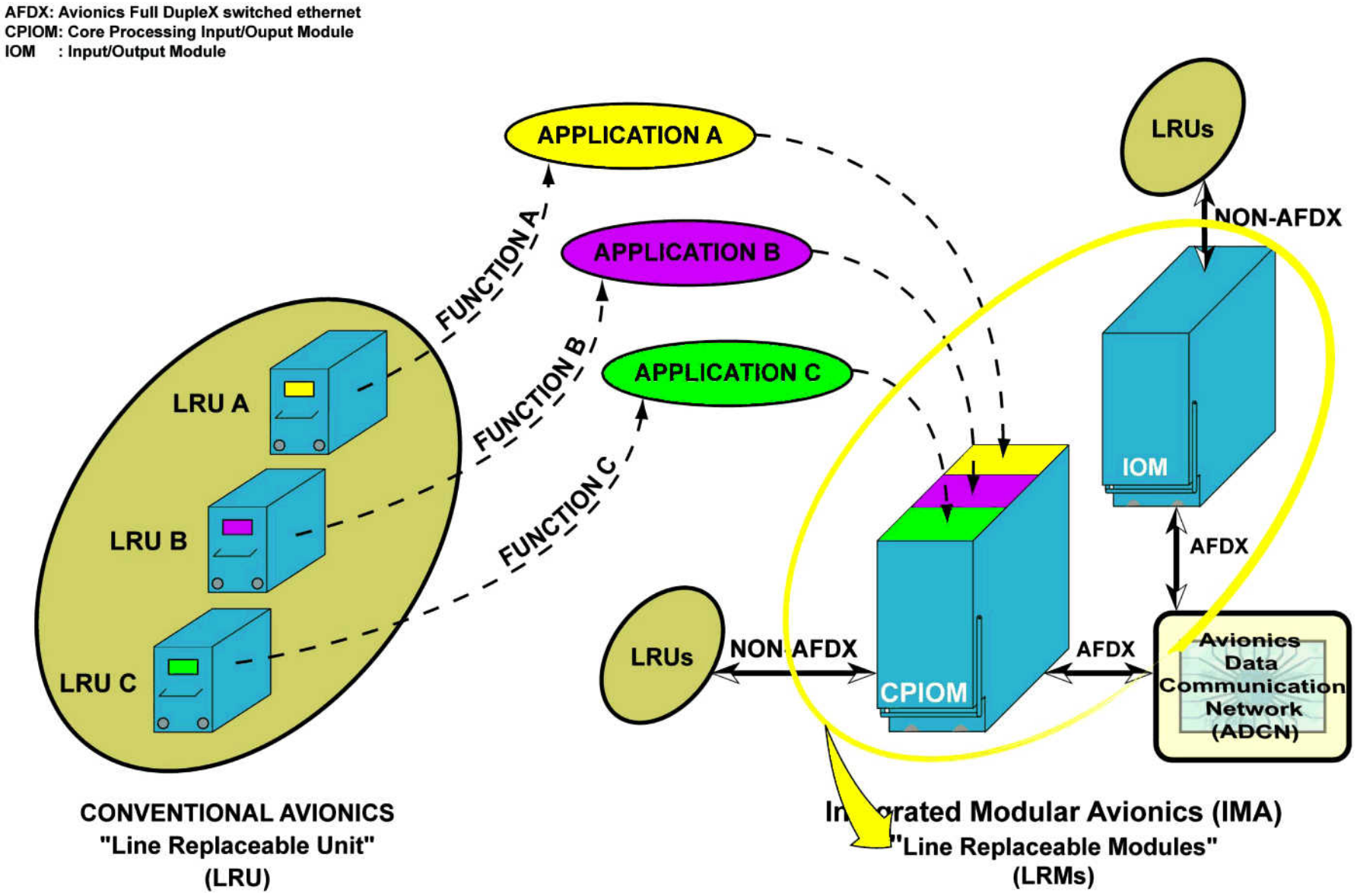

Figure 136 Integrated Modular Avionics (IMA)

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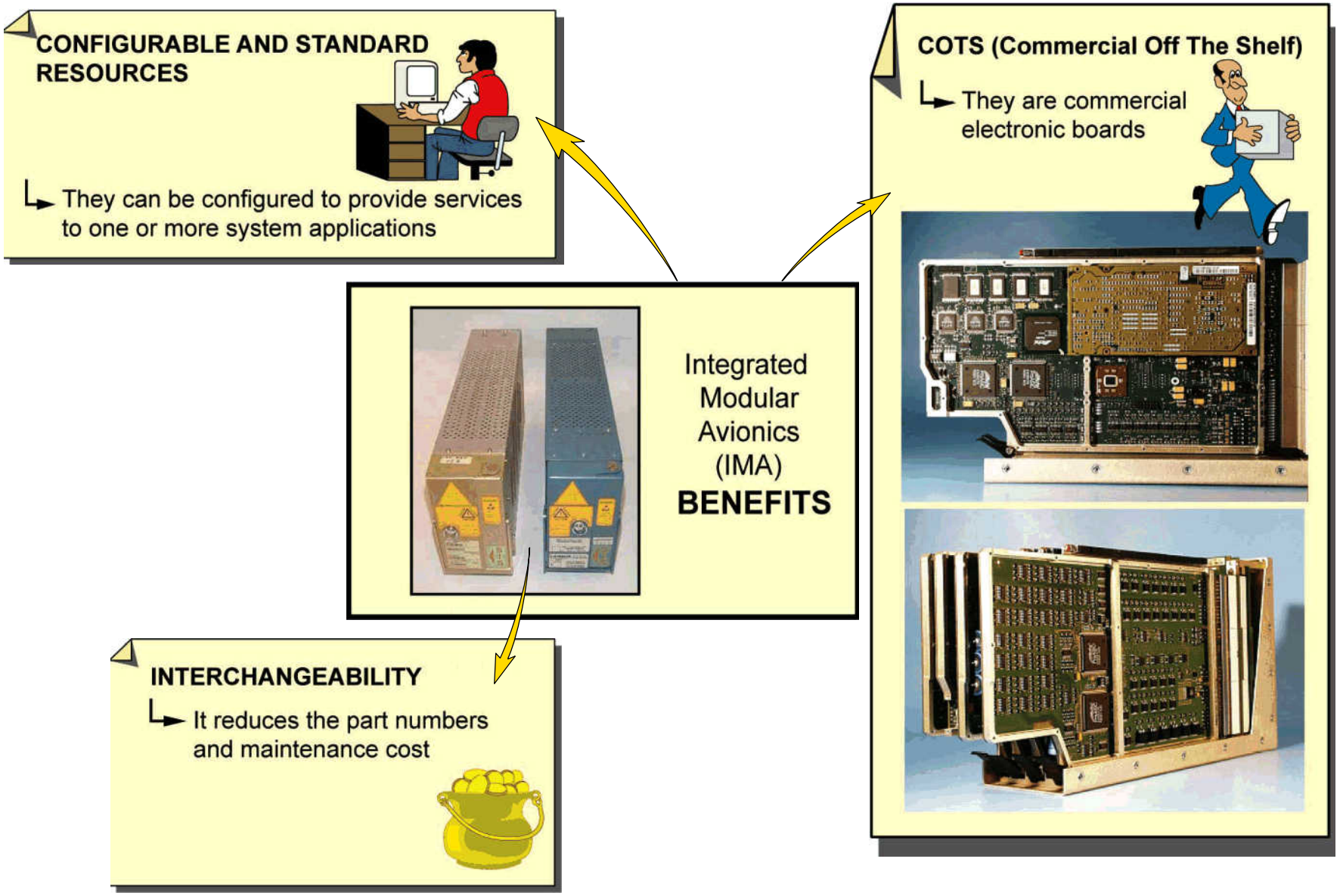

Figure 137 Integrated Modular Avionics (IMA)

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CABIN SYSTEMS

General

Cabin Systems provide functions like communication within the aircraft, e.g intercom, and passenger entertainment. This comprises voice, music and video.

CIDS System

The CIDS (Cabin Intercommunication Data System) is used on all Airbus aircraft (except the A300/310) providing passenger related functions and cabin crew related functions.

Also functions like smoke detection and water/waste functions are integrated.

Core Components of the CIDS System

The CIDS System core consists of:

- 2 CIDS Directors (A380: 3)
- DEU A (Decoder Encoder Unit)
- DEU B
- FAP (Flight Attendant Panel)
- Data Buses

Some of these components interface with other Aircraft components and systems.

CIDS Functions

Passenger related functions are:

- Control of the cabin lighting/reading lights
- Passenger address
- Passenger call lights
- Passenger signs (No smoking / fasten seat belt / ...)

Cabin Crew related functions are:

- Cabin Crew interphone
- Service interphone
- Emergency evacuation signals

Cabin System functions are:

- Boarding music
- Pre-recorded announcements
- Lavatory smoke warning
- Temperature-controlled drain mast system

Programming, monitoring and test functions are:

- CIDS programming and system tests
- Reading and work lights test
- Door and escape slide bottle pressure monitoring
- Emergency light test

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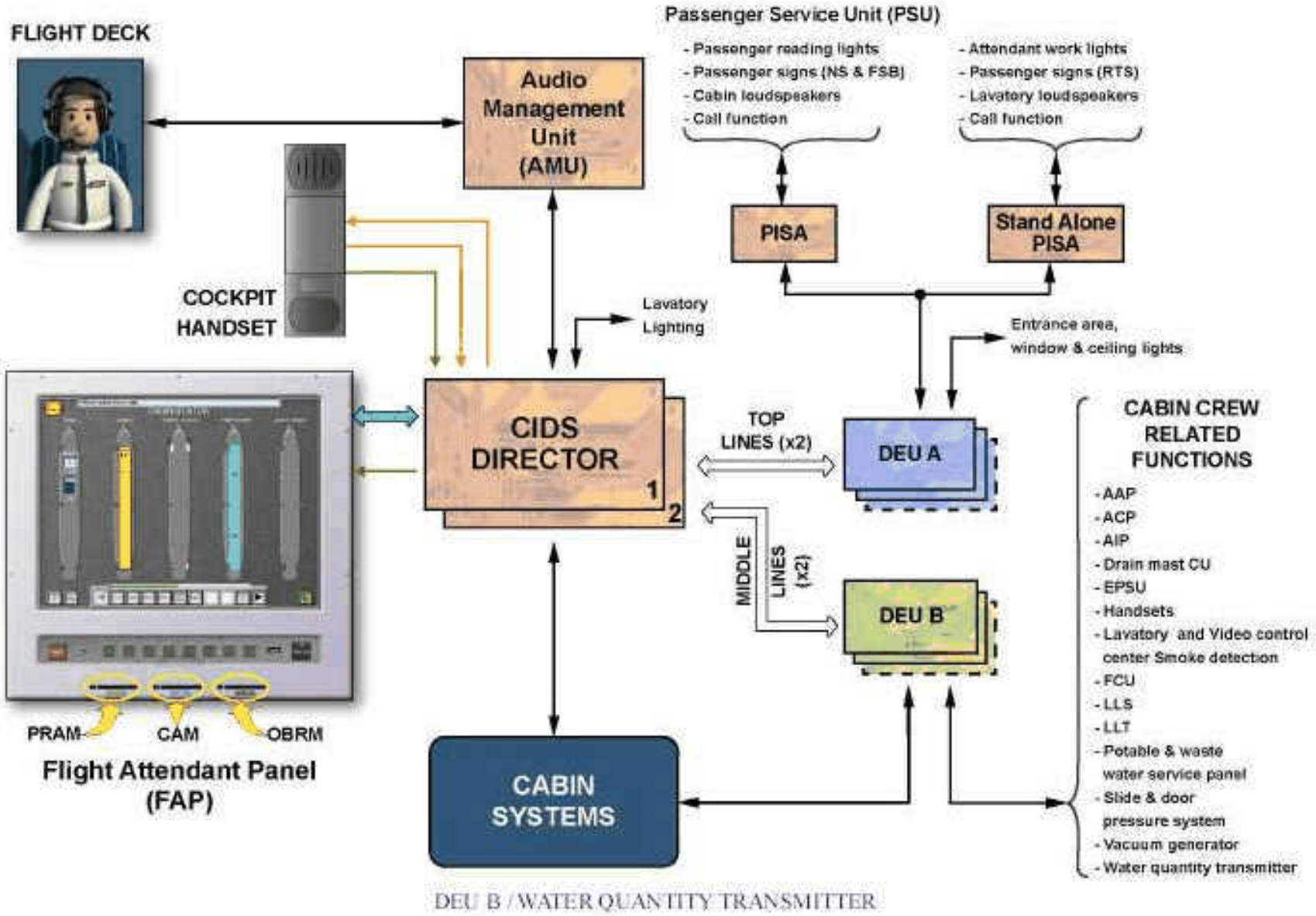

Figure 138 CIDS Components

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Location of the CIDS Components

The CIDS Directors are located in the Avionics Compartment. One is the active one, the second a hot spare (A380: 2 hot spare).

They control all the cabin functions.

In the classic CIDS the CIDS directors have an OBRM attached to the front panel containing the cabin layout.

The enhanced CIDS gets the layout from the FAP where the Cabin Assignment Module (CAM), a Compact Flash card, contains the layout.

The DEU are located at the passenger seat rows (DEU A) or the flight attendant stations (DEU B).

CIDS Data Buses

The CIDS system uses 2 different data buses:

- The Top Line Buses
- The Middle Line Buses

Both buses are bi-directional, in half-duplex mode.

In the classic CIDS the transmission speed was 5 MBit/s, with the enhanced it is 4 MBit/s.

On the A380 the speed is 10 MBit/s.

Top Line Bus

The Top Line Bus is used for passenger related functions. Here the CIDS Director transmits a sync signal followed by 6 time-compressed audio channels and discrete data (control information for call lights, reading lights, ...). With every transmission only one DEU A receives the discretes, one after the other.

After that transmission the DEU A actually addressed repeats transmitting its discretes.

One Transmission (incl. DEU answer) takes 38,5 µs.

The passengers interact with the DEU A via PSU (Passenger Service Unit). It contains a PISA (Passenger Interface Supply Adapter) that connects to the DEU A via LVDS Bus (Low Voltage Differential Signalling).

In addition so-called stand-alone PISA are used where Attendant lights and stand-alone No Smoking / Fasten Seat Belt signs have to be controlled.

Middle Line Bus

The Middle Line Bus is related to cabin crew functions.

The CIDS Director transmits a sync signal followed by discretes to a dedicated DEU B, then the DEU B answers.

After that the CIDS Director transmits 16 time-compressed audio channels.

One Transmission (incl. DEU answer) takes 77 µs.

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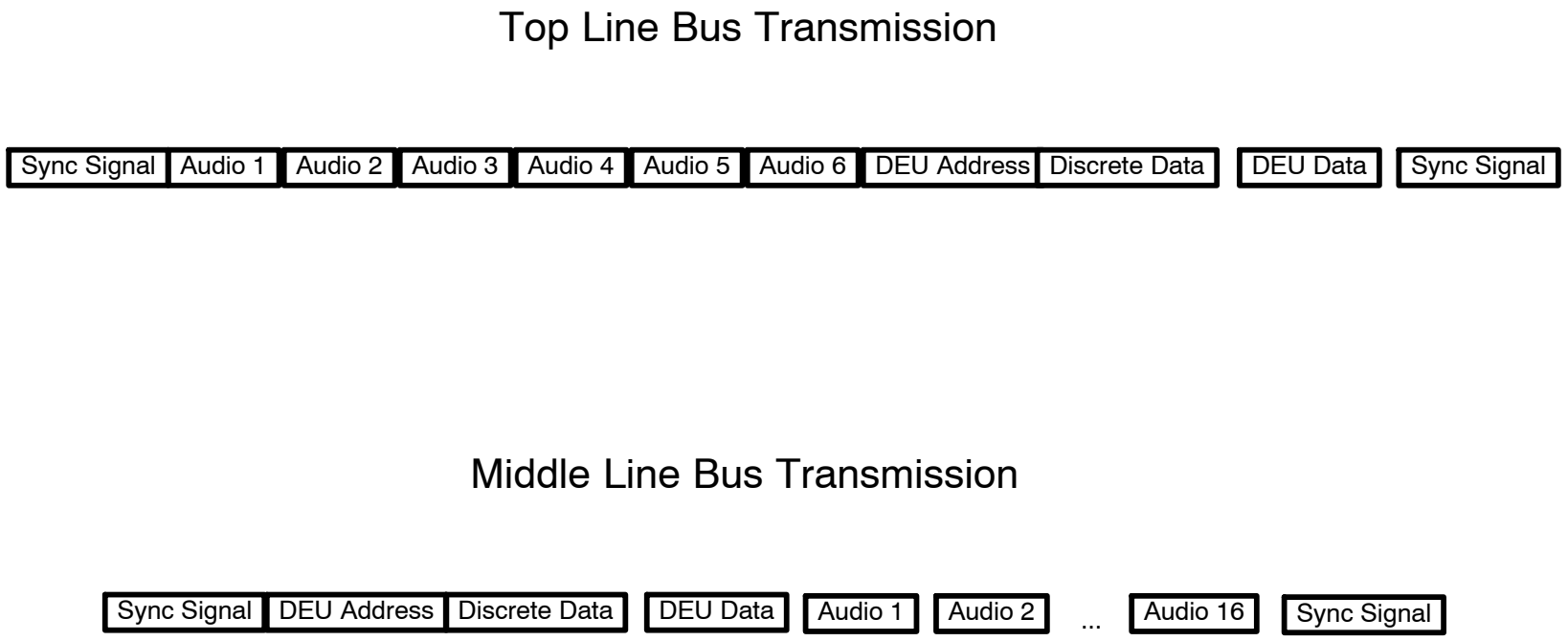

Figure 139 CIDS Bus Transmission Structure

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NETWORK SERVER SYSTEM

General

The Network Server System (NSS) is one of the Information Systems.

New technologies are used for data communication.

Inside the aircraft two so called onboard worlds are defined:

- the avionics world and
- the open world.

In the avionics world you can find all avionics systems necessary to fly the aircraft.

In the A380 open world you can find electronic documentation and non−critical applications for aircraft safety called Onboard Information System (OIS), which is hosted by an on−board hardware platform called Network Server System (NSS).

The OIS is shared out between three NSS domains, each one related to one NSS sub−network:

- the avionics domain,
- the flight−operations domain and
- the communication and cabin domain.

The avionics and the open worlds communicate to each other via so called firewalls, to make sure that only safe data can be exchanged.

Also the communication with the worldwide network uses firewalls for safety reasons.

The communication with the worldwide network is done by using the VHF or HF communication systems or SatCom.

In the worldwide network the data are transferred to all users like Air Traffic Control Centres and the Airline Operational Control Centres.

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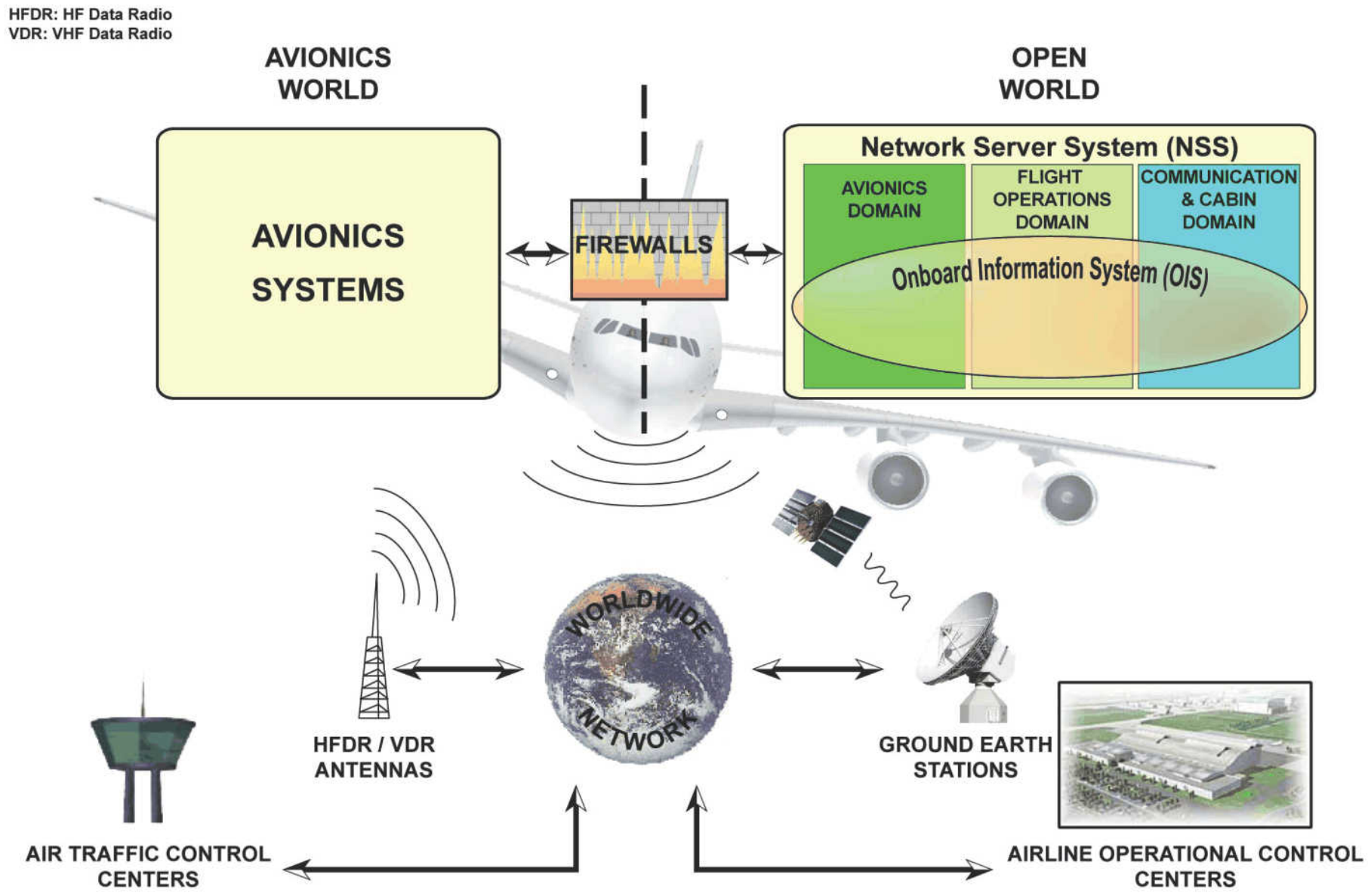

Figure 140 New Data Communication

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Architecture

We will now have a closer look at the Network Server System.

You can identify again the avionics domain, the flight operations domain and the communication and cabin domain.

The Open World Diode (OWD) allows a unidirectional data flow coming from the Avionics Domain and going to other NSS domains and some cabin systems.

Note that the OWD is an electrical device that gives a single way of communication from its left to its right.

It prevents malicious data coming from its right going to the avionics domain and to the avionics world.

The NSS also supplies external data communication capability for all domains.

The avionics domain has to guarantee a high safety level because it communicates with the avionics world, thus integrated firewalls are installed.

The avionics domain also connects with the NSS human machine interfaces related to its hosted applications.

Highlight that the flight operations domain has captain and F/O laptops stored in their respective docking station to supply computing and memory resources to their hosted OIS applications and documentation.

This domain communicates with NSS human machine interfaces related to its hosted applications.

Passengers benefit from the communication and cabin domain through the Cabin Wireless Unit and the In−Flight Entertainment System.

This domain communicates with NSS human machine interfaces related to its hosted applications.

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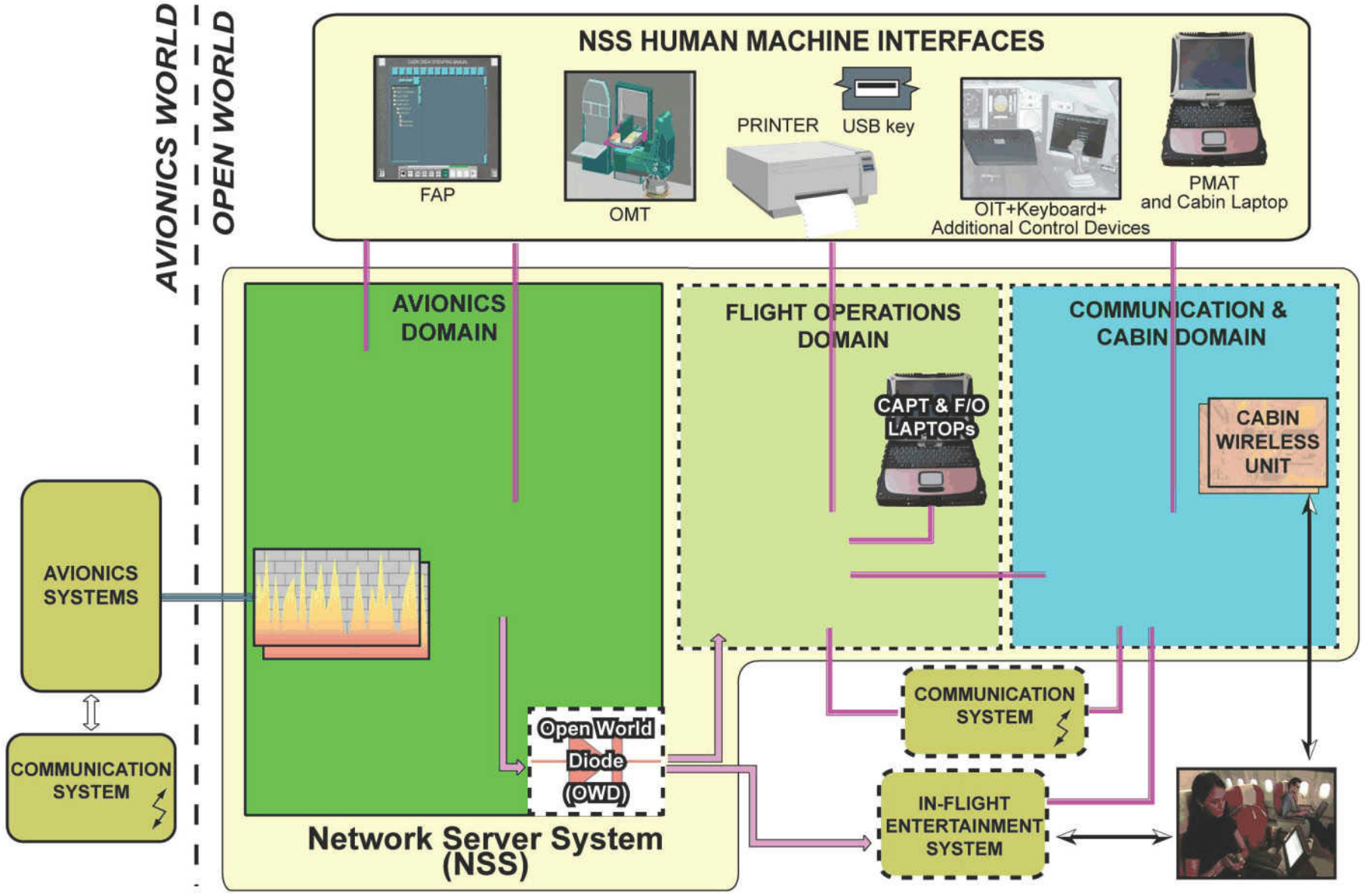

Figure 141 A380 Open World / NSS Architecture

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Components

The first type of main components of the network server system is the firewall, which prevents unauthorized access to or from a network.

On the A380, the Secured Communication Interface or SCI in short allows to safely exchange data with the avionics system.

Firewalls also protect the data communication to and from the ground.

The second type of main components of the network server system is the router unit, which primarily controls and route the exchange of data with the avionics world, NSS HMIs, the communication systems or between the different domains.

Some of them include firewall functions to avoid unauthorized data exchange or safely connect some NSS HMIs.

The last one is the server unit, which primarily works as the database for all electronic documentations, computing resources, manage different services, and host software applications.

For example passengers can get e−mail service on their wireless laptop and maintenance staff can access all maintenance documentations from the Onboard Maintenance Terminal (OMT).

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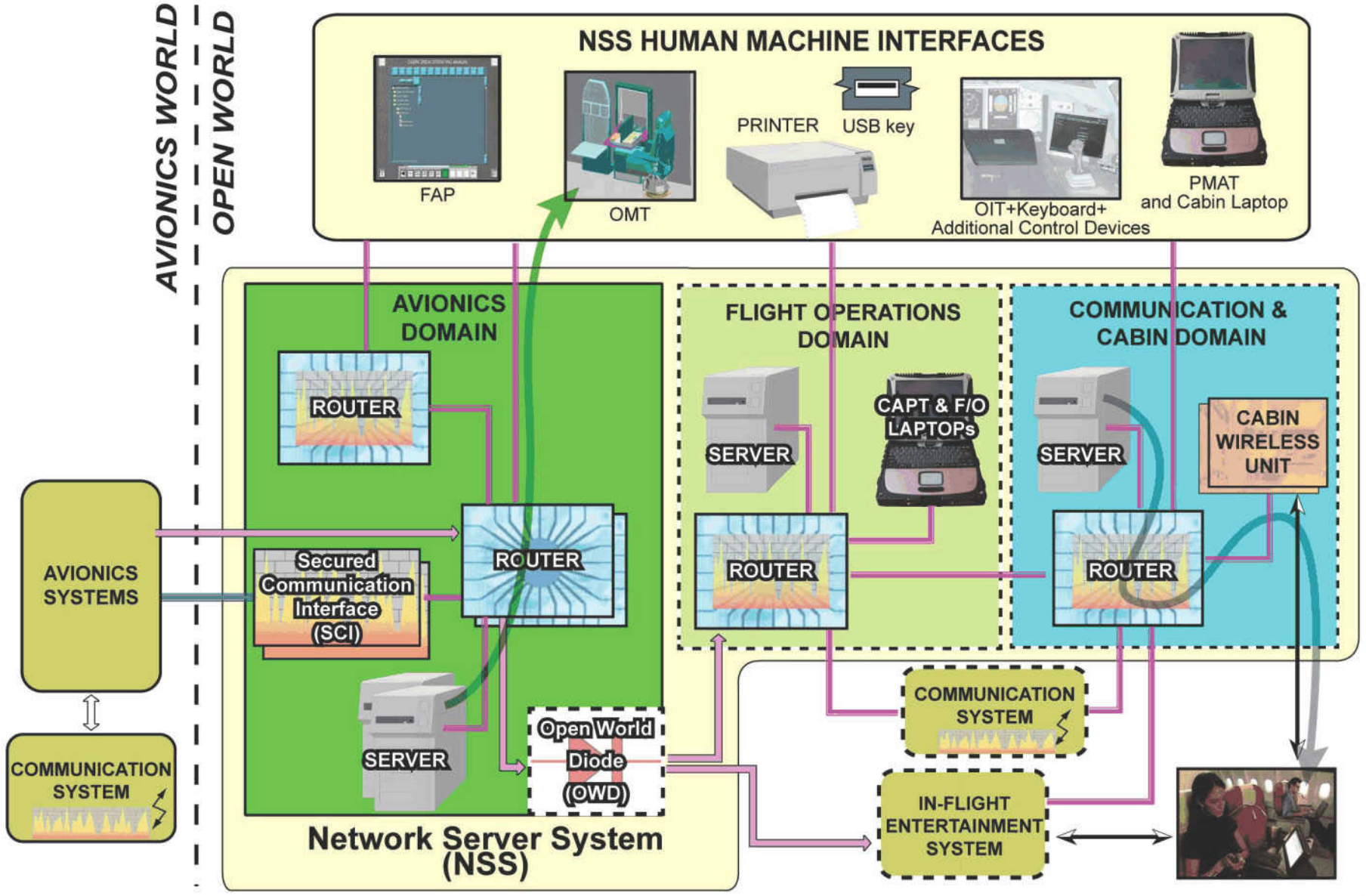

Figure 142 A380 Open World / NSS Components

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NSS & OIS Benefits

The network server system, hosting the On−Board Information System, drastically reduces the paper volume needed in the cockpit, because many papers are replaced by electronic documents.

The components of the server system are commercial off the shelf components, COTS in short, which provide high flexibility and low costs.

The NSS also centralizes information for the users as it supplies hardware platform to host different applications, documentations and database.

The NSS domains improve the security, the administration and the communication.

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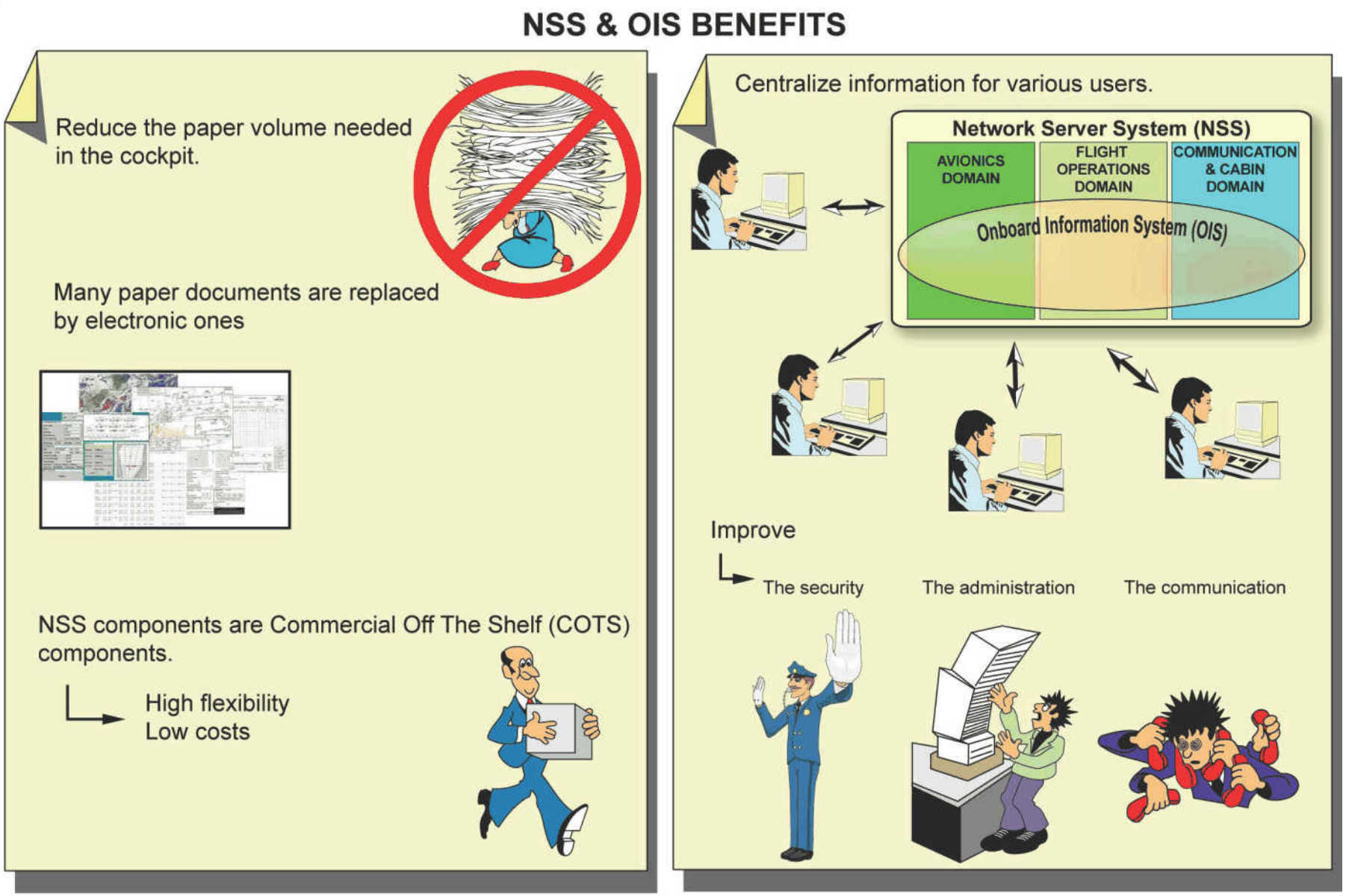

Figure 143 A380 Open World / NSS & OIS Benefits

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ATIMS

Cockpit Information Systems

The Cockpit Information Systems are:

- Air Traffic and Information Management System (ATIMS), ATA 46–21.
- Air Traffic Services (ATS), ATA 46–22.
- Airline Information Services (AIS) ATA 46–23.
- ATSU Router, ATA 46–24.

Air Traffic and Information Management System (ATIMS)

The Air Traffic and Information Management System (ATIMS) enables data link communications and the exchange of complex data or specific reports between the aircraft and the ground centres:

- controller–pilot datalink communications (VHF/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.

Air Traffic Services (ATS)

The Air Traffic Services are in charge of

- the ATC FANS A applications:
  - ATS Facilities Notification (AFN) for connection with an ATC ground centre,
  - Controller–Pilot Data Link Communications (CPDLC),
  - Automatic Dependent Surveillance (ADS) for aircraft path surveillance
- the ATC ARINC 623 applications:
  - Departure Clearance (DC) application,
  - Oceanic Clearance (OC) application,
  - Automatic Terminal Information Service (ATIS) application.

Airline Information Services (AIS)

The Standard Airline Operational Control (AOC) applications are datalink applications used by the airline for maintenance, flight operations and administrative purposes.

ATSU Router

The ATSU router provides:

- data link services to remote AOC applications hosted in on–board peripherals,
- data link services to the ATC/AOC applications hosted in the ATSU,
- management of the datalink media: VHF, SatCom (optional), HF (optional).

ATIMS General

The Air Traffic Information Management System (ATIMS) complies with the future developments of the Communication, Navigation, Surveillance and Air Traffic Management (ATM) also known as Future Air Navigation System (FANS). It covers the evolution of the way the airspace will be used in the years to come. It will be used in different operational environments and is designed to be easily configured to the airlines needs.

ATIMS enables data–link communication: VHF Data Radio (VDR), HF Data Radio (HFDR) and SatCom (if installed) and the exchange of complex data or specific reports.

Standard AOC functionality is basically provided but airlines can customize these functions and the way they are accessed by the crew. On the ground, the different existing networks dispatch the messages. These networks are operated by private companies such as ARINC, SITA and others, which are known as service providers.

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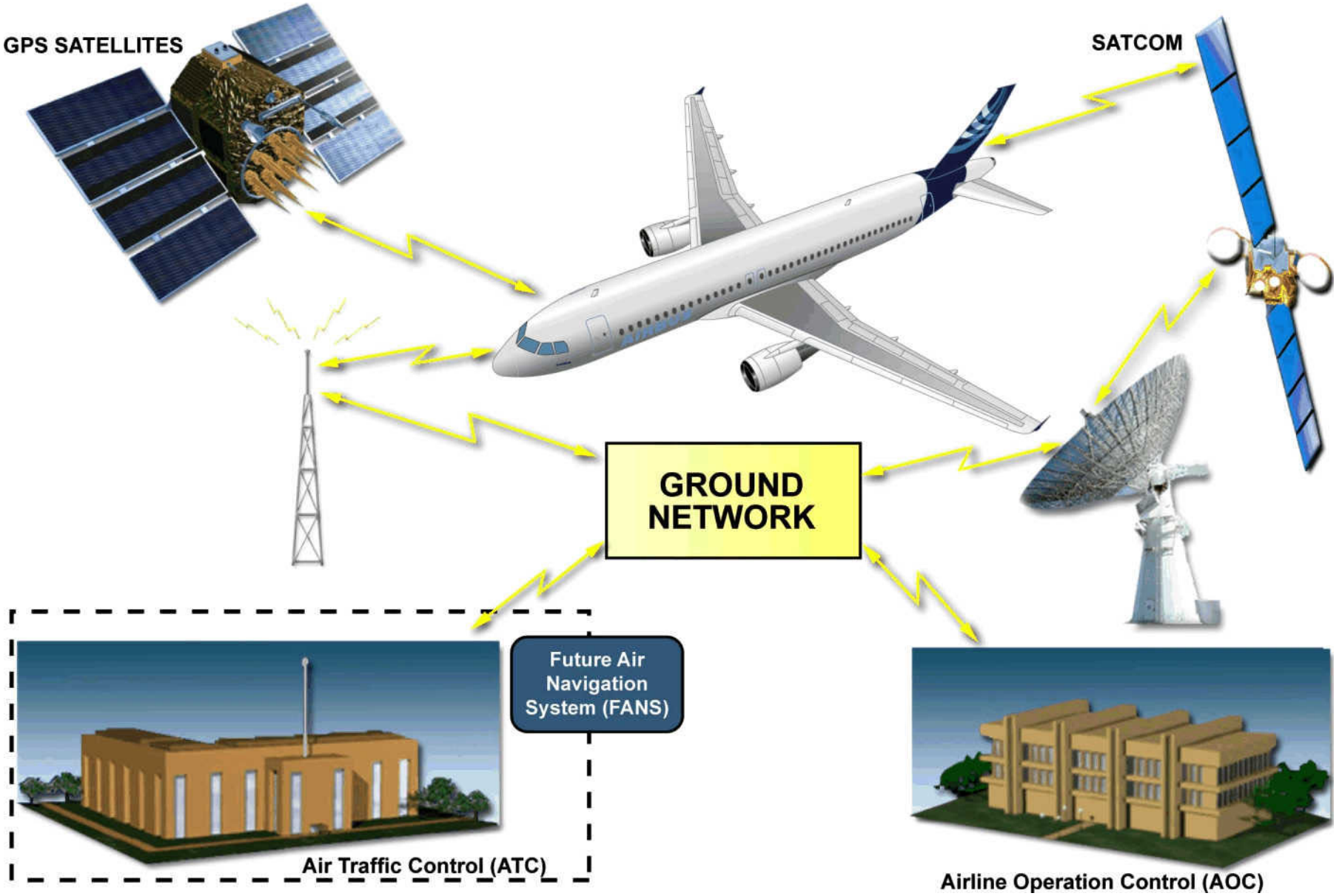

Figure 144 ATIMS Principle

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FANS

FANS is an abbreviation and is for Future Air Navigation System.

Up to now, flight crew have communicated with air traffic controllers using HF and VHF radio communications which are subject to atmospheric disturbances and so, often difficult to understand.

Furthermore, the transmission networks become saturated due to the air traffic increase, and to the limited capability to exchange complex data (routes, weather information...).

Consequently, the Air Traffic and Information Management System (ATIMS) has been developed to enable datalink communications and the exchange of complex data or specific reports between the aircraft and the ground centres:

- controller−pilot datalink communications (HF voice in backup) for air traffic management,
- specific airline−aircraft communications (operational control) to improve airline operational costs and flexibility.

PRE−FANS, FANS

There are three stages of FANS development.

5. Pre−FANS (Communications (COM) and AOC functions),
6. FANS A (pre−FANS + ATC functions) and
7. FANS B (FANS A + improved ground network + Traffic Alert and Collision Avoidance System (TCAS)).

Today, the pre−FANS allow the AOC function.

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 aloft requests,
- free text message exchanges,
- diversion, delay, refuelling, flight reports,
- aircraft data from Central Maintenance System (CMS), Aircraft Condition Monitoring System (ACMS), cabin terminal...etc.

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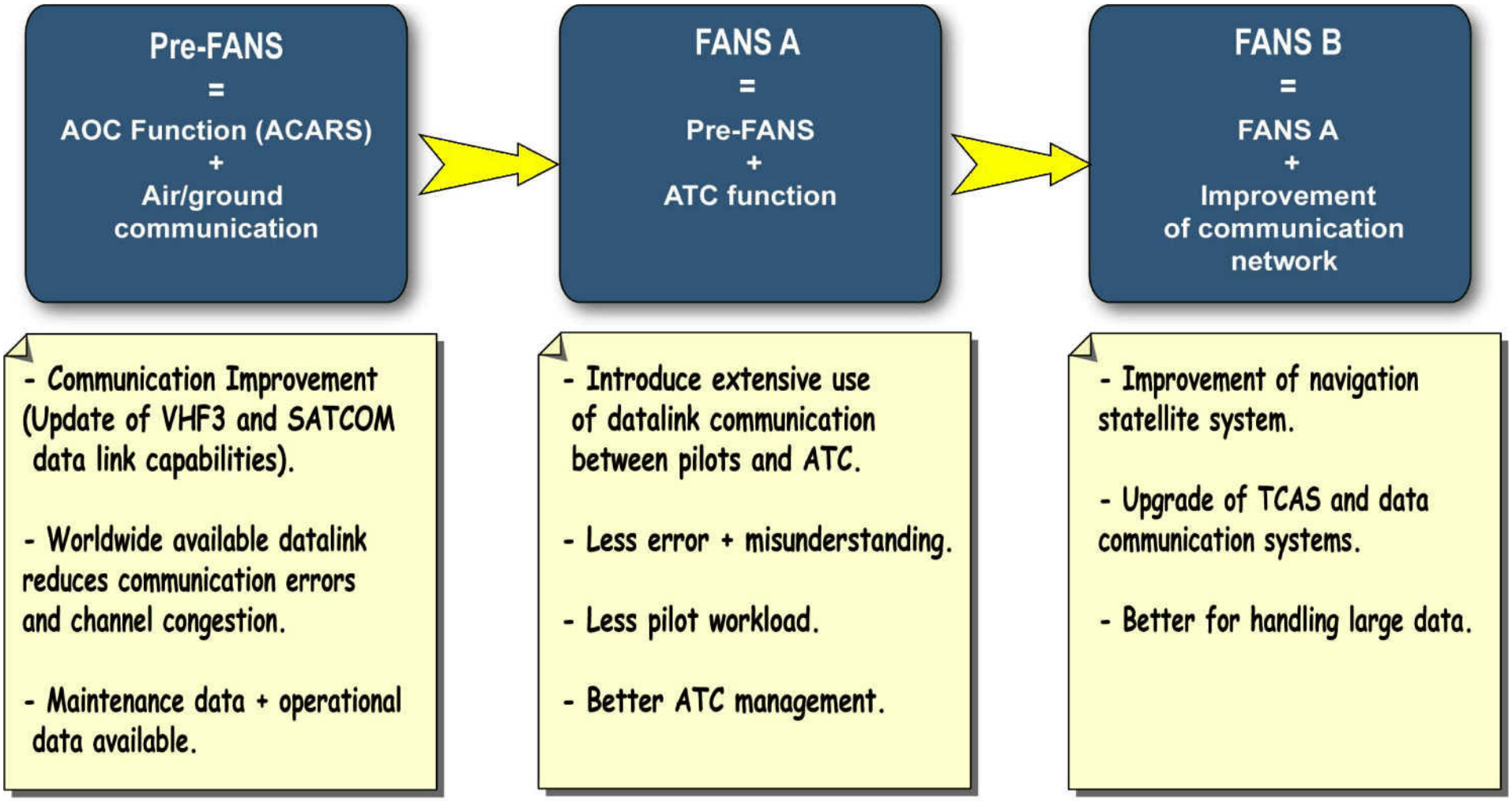

ACARS: Aircraft Communication Adressing and Reporting System
AOC: Airline Operation Center
ATC: Air Traffic Control
FANS: Future Air Navigation System

Figure 145 FANS Overview

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