COMPLEX SYSTEMS FOR ELECTRONIC INDICATION AND SIGNALLING OF AIRCRAFTS

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This article concerns about analysis of complex systems for indication, signalling and displaying of individual informations on the dashboard of the latest aircrafts. Specifically it deals with the EFIS, ECAM and EICAS systems. The introduction starts with a brief description of EFIS, ECAM and EICAS systems, enclosed with flow diagrams. The EFIS chapter describes in detail the symbol generator and its functions. The next part of the article contains the description and layout of display unit types. The same part explains in detail the layout of Head Down Displays, description of CRT displays, LED displays and LCD displays. The last chapter outlines the prospective indicators (the latest trends of displays), the touch-screen displays.

Key words: complex systems, display units, EFIS, ECAM, symbol generators, touch-screen display

1 INTRODUCTION

The development of on-board aircraft equipment was directly bonded with the advancement of the aircrafts. The demands for flight control rose in flights in higher altitudes or in worse visibility, therefore there was a need for equipments, which would ensure the flight.

In the first part of this article are described the systems for electronic indication and signalling on-board of the aircraft, specifically the EFIS, ECAM and EICAS systems. The main part of the article concerns about brief decsription of EFIS, ECAM and EICAS systems. In the EFIS subhead is described in detail the symbol generator and its functions. The end of this article outlines the prospective indicators.

All the informations were gathered from web sites, which were available in english language or from technical books published in english or russian language.

2 SYSTEMS FOR ELECTRONIC INDICATION AND SIGNALLING ON-BOARD OF THE AIRCRAFTS

The present airliners are equipped with fourth-generation display unit equipments and systems. All the measured and displayed parameters are generally evaluated and displayed on CRT displays on the aircraft dashboard. The gadgets consist of several interacting systems. Aerometrical computer, inertial navigation system and wireless technology altogether with navigation equipment are in most of the present aircrafts the main source of flight navigation informations. Their visible output is the primary flight display and navigation display. Jointly are processed the engine parameters which are visualised on the engine system display. The airframe checkup of the aircraft is performed by the computer system and this is shown on the central multifunctional display [7].

The CDS system contains :
- Two primary displays and twonavigation displays, belonging to EFIS system – Electronic Flight Instrument System.
- E/WD Engine/ Warning Display and SD System Display, belonging to ECAM system – Electronic Centralized Aircraft Monitoring.
- Two MFD - Multi–Function Displays

Fig. 1 Dashboard of A380 aircraft

1.1 Electronic Flight Instruments System

EFIS is a fully integrated system with a digital computer base. In this system, the digital electronic instruments with CRT, LED, LCD AMLCD and plasma displays are replacing the conventional electromechanical board instruments. These displays are enabling to show the flight informations in electronic version. This way, it is possible to show a lot of informations in a transparent way. EFIS falls into the group of flight and navigation systems. It is a complicated system regarding its construction. EFIS displays to the flight crew flight and navigation informations in one unit. Depends on the aircraft type, how many display units are allocated on the dash-borad. There are minimum indicators on the fourth-generation display units. These units are multifunctional. Pilot can chose on each display individual parameters needed for the specific flight stage. Figure 2 shows the main flow diagram of EFIS, jointly with input data, which are the informations from VOR, DME, ILS systems, informations from altimeter, informations from meteorological radar [11].
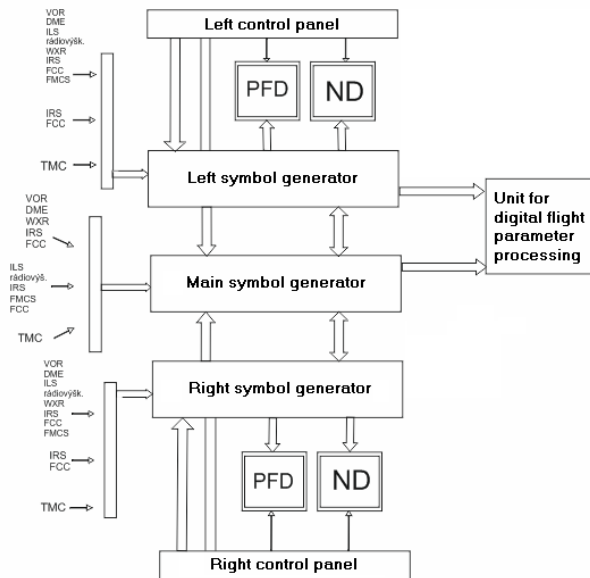
Fig. 2 EFIS flow diagram with description of input data

System enables to show on displays basic flight parameters, as the horizontal and vertical situations are. For these are used the EADI display – Electronic Attitude Director Indicator, for vertical situation and EHSI display – Electronic Horizontal Situation Indicator, for horizontal situation. Both these displays are CRT or LCD types. The EFIS system consits of two independent subsystems, whilst each is intended to one pilot. EFIS is fully inegrated and interconnected with the digital navigation computer.
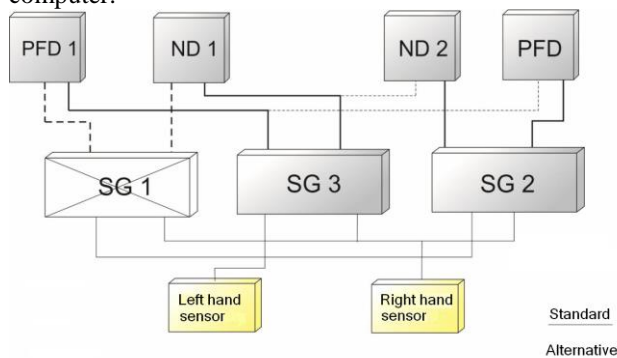

Fig.3 SG Failure 1[9]

As it is clearly visible from figure 3, the EFIS system display units are gathering informations from three SG – symbol generators. The third generator, so called HOT SPARE, is under standard mode used as a spare.

Each of the generators are able to produce informations also in format needed for PFD displays and ND displays. Each of the display unit has to show the informations from standard source but also from alternative source (SG). To both symbol generators are leading infomations from both sensors, that means from right hand and also from left hand sensor. All the display units can decide, wheather they are going to display the informations from standard or alternative source.

In case, that one symbol generator fails, as it is shown on figure 10, the related display units are receiving informations from the alternative source and that is in our case the SG 3. The visual formats on PFD 1 and ND 1 are remaining independent from the other ones on the other side of the dash-board.

If there is a failure of display unit, than the SG 1 changes the output in order to combine the ND 1 to PFD/ND display with all the necessary primary flight data including compass.

EADI display traditionally shows the flight attitude to the earth, that means the gradient and tilt of the aircraft. Inertial system ensures the informations about the location. It is also possible to display the instructions for control and regulation of flight, assigned speed, offsets from glide path, altitude, speed to earth, decision height and chosen option of engine thrust control automated system.
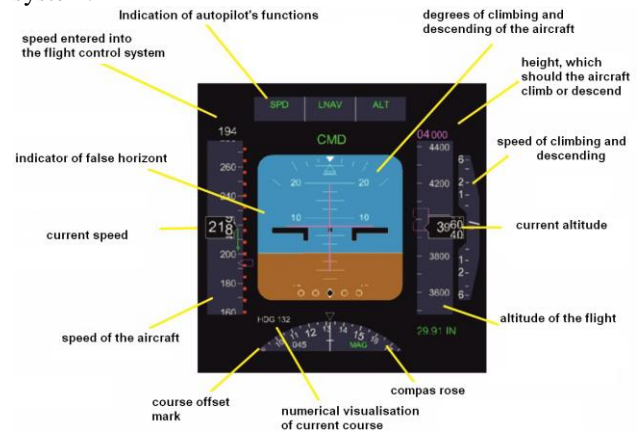

Fig. 4 PFD

The EHSI display enables dynamic displaying of flight course (adjustable) and appropriate location of aircraft on the chosen flight path. It works in 4 basic modes: MAP - the relevant inertial system ensures the information about course, PLAN – shows the static map of background with active data about path pointed to true north, ILS/VOR – these show the compas rose, whilst it also shows the data about chosen scale of distances, wind data.

1.1.1 Symbol generator

Symbol generator is a specialised processor, ensuring immediate visualisation on the indicator based on formerly created program. Symbol generator (SG) ensures the interconnection with all the systems and sensors, collection and processing of its informations. The exception is the information from the aircraft sensors – radar, camera. It is not necessary to process these informations in SG, but it is layed on them the prepared visualisation. The function of SG consists of given sensors' measurement, in switch of visualisation of data transfer from circle system coordinators to rectangular.

They are creating analog, individual, definitive and digital signals which are creating the interface between flight systems, display unit and control panel. At the same

time, they are generating symbols, monitoring the system, verification of power supply level and basic check functions of EFIS.

SG may be allocated in the same electronic unit as the indication panel, than are leading to this unit also the connections from on-board systems and sensors, those informations are indicated with the specific indicator. SG may be allocated also in an individual unit, than the SG is transfering its prepared visualisation to indicator. Analog signals were used for this in the past, the present SG are transfering their data to a high-speed numeric channel - Gigabit Ethernet, Fibre Channel etc. It is possible to calculate the data throughout with the following scheme:

$$N = I \cdot 3.\log_3(G) \cdot f \cdot k_{sl} \qquad (1)$$

1.1.2 Functions of present symbol generator

The basic functions of present symbol generator are the following:
- Symbol plotting – vectors, curves, macrosymbols, numbers, letters etc.

- Indication of video displaying – sensors in graphic window, change of windows' size and layout, storage of graphic symbols' visualisation on the screen.

- Transfer of layout data, operating in a circle system of coordinates (i.e. weather radar ARINC-708, enhanced ground proximity warning system EGPWS), operating in a direct system of indicator coordinators, display of azimuth and distance markers, connection of visualization to the screen.

- Storage to the memory and indication of radio navigation, tactical and topographic map, recall of visualization from archive, interconnection of map with the coordinators, turn at the change of the course, audio signal related to visualization chosen by the pilot.
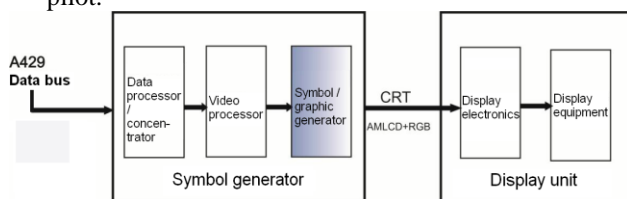
Fig. 5 Symbol generator structure [9]

The videoprocessor is collecting the visualization from sensors and unpacks the numerical information from the data processor. Ensures the synchronizing of data from different sources, ensures transfer, turn and measurement of these data to display them in standard format on the display. Symbol generator is a microprocessor which is generating symbols for the following finalization of visualization. The 3D transporter is generating three-dimensional perspective visualisation, where it is using the symbols obtained from the symbol generator. These symbols are at first prepared (they get shortened, prepared their illumination, ensured their connection towards the coordinators), than is performed

the finalization of the visualization formating. The final visualization which consits of processed markers are transfered to 2D-channel. 2D-channel is a graphical processor, which is generating traditional 2D symbols and unites them with visualizations, which obtains from other parts of symbol generator. The needed features of these accessories are listed in the table 1. [14].

Tab. 1 Needed accessories for operation of perspective symbol generator [14]

Accessories	Features
Data processor	**125 MIPS, 30 MFLOPS**
Video processor	**48-120 MPIPS, 240 MIPS**
2D-channel	**1 MVEPS, 10 MIPS, 100 MPIPS**
3D-transformer	**0,5M – 2M marks/sec, 200 MFLOPS, 1,5 MPIPS**

2 ELECTRONIC CENTRALIZED AIRCRAFT MONITORING

Electronic Centralized Aircraft Monitoring – ECAM, uses CRT or LCD display types, which became standard accessories of many aircraft types. Parameters, shown on these displays are connected with engine functions and other systems on the aircraft.

ECAM system was developed by Airbus company. System is basically displaying the primary flight system data, by the check list and also in diagram. In the second case is the acces chosen in a way to show the data from the work of the engine continuously during the whole flight. The block layout of ECAM system is shown on fig. 19 [9].
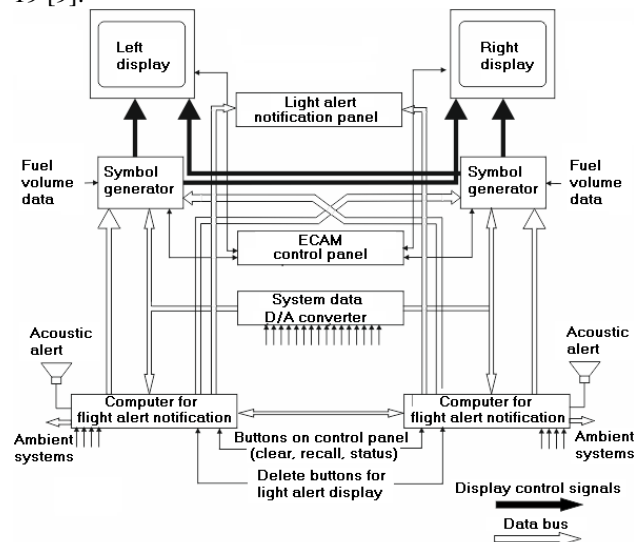
Fig. 6 Block layout of ECAM system

2.1 Display units

Units are situated in the center of the dash-board. The lower one is displaying the informations of the status of individual systems, warnings and performed corrective steps, all by means of check list. The upper one is

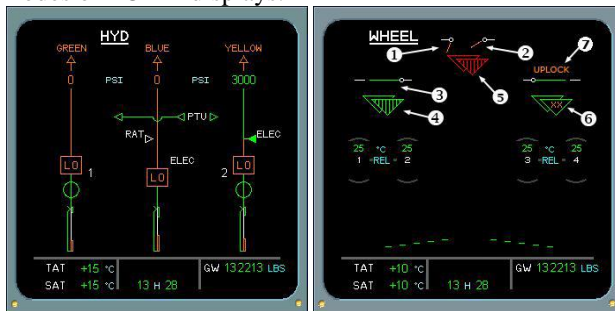displaying these data schematically. Fig. 7 shows two modes of ECAM displays.

Fig. 7 ECAM display units

3 ENGINE INDICATING AND CREW ALERTING SYSTEM

Engine Indicating and Crew Alerting System – EICAS is a system, which collects and processes informations about engine status, which are consequently displayed on the individual CRT or LCD display, which eliminates the need of use of traditional indicators. Data, just as in other systems, doesn't necessarilly need to be shown on the display during the whole flight time, only when it comes to anomalies. In these cases the crew is alerted automatically by generated messages with individual colors, which are depending from the type of the message, and moreover the acoustic and light warning signalization is activated [9].

Basic layout of EICAS consist of two display units, flight control panel and two computer units, where are leading analog and secret signals from engine parts and their sensors. Schematical layout is shown on fig. 8.
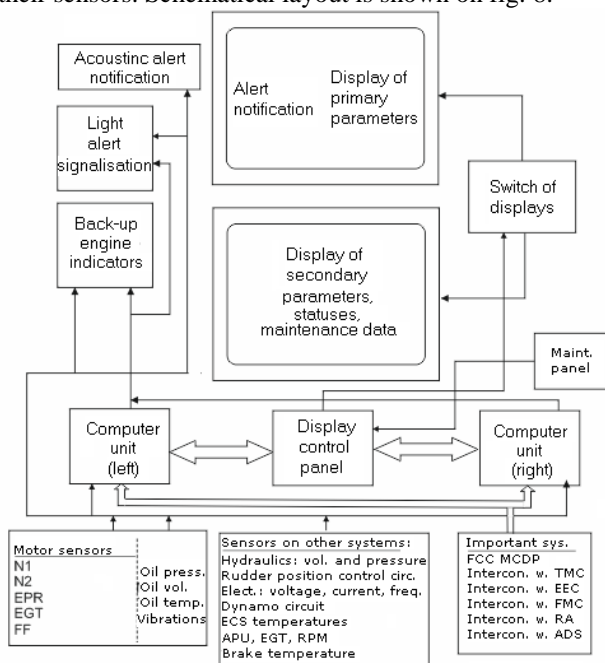

Fig. 8 Schematical layout of EICAS

The unit notifies the crew about main, primary engine parameters during the whole operating time, as well as about secondary parameters, which is possible to switch with the other informations of automated systems.

It displays, as it was said earlier, also the alerting messages jointly with the recommendations, how to solve the individual situation. For visualisation is used a CRT (LCD) color display, which is interconnected with functional blocks, where these functions are identical with with the specific blocks in EFIS. Displays are situated one under each other. The upper display shows the primary engine parameters, such as the operating speed of low pressure compressor (N1), temperature of exhaust gasses (EGT) and alerting messages. In some cases is this unit able to show also the data from engine power, or engine pressure ratio - EPR (ratio behind the low pressure turbine and before the low pressure compressor), which are depending on the engine type, data processing methods and Turn-out Management Control – TMC. The lower display shows the secondary engine parameters, those are operating speed of high pressure compressor (N2), fuel consumption, oil level and its temperature and pressure and also the vibrations of the engine. It is possible to show the status of non-engine sysytems such as hydraulic systems, APU system, etc. These data can be displayed mutually with the configuration of the aircraft and with maintenance data [9].

In case of failure of the lower display during displaying of secondary parameters, a warning message „EICAS DISPLAY" is shown in amber color in the top left corner of the display.

Fig. 9 EICAS display unit

4 DISPLAY UNIT TYPES

Display units on board of the modern aircrafts are divided to three basic groups based on the method of displaying the informations (in which viewing field of the pilot are they situated):

- **HDD – H**ead **D**own **D**isplay
- **HUD – H**ead **U**p **D**isplay
- **HMD – H**elmed **M**ounted **D**isplay

4.1 Head-Down Display units

Multifunctional Head-Down display units, called also MFD, MHDD, MPD multi-purpose display and MPCD multi-purpose color display, offer some kind of on-board designer with adaptable display media, where are presented the data in different ways according to the needs of the flight crew in individual phases of the flight. These are display units, where pilot has to incline his head down from following the surroundings [11].

4.1.1 Cathod Ray Tube display unit

First display technology was displaying on Cathod Ray Tube (CRT) displays. CRT was the first fully adaptable display unit, used for primary flight displaying on-board. Except mechanical indicators, lamps and sensors with moving coils, is the cathode tube the oldest displaying technology used in present aircrafts. Despite its age, CRT offers a lot of important advantages, including the ability to display in extremely bright colours, which can be read in wide angle. These are the two reasons, why are the CRT displays still present on-board of the modern aircrafts even though, they are being relpaced by Amoled Crystal Displays, plasma nad also touch-screen displays [11].

4.1.2   Light-Emitting Diode Displays

Light-Emitting Diodes can be used for universal indicators. They are working with markedly lower voltages and currents in comparison with ususal lamps. LEDs are a lot more reliable than the lamps. Most of the LEDs offer accurate intensity of light output by using a forward current between 5 mA and 20 mA . Light diods are available in different formats, whilst the most favourite ones are the round ones. Round LEDs are easily available in plastic cases with a 3 mm diameter and 5 mm (0.2 inches), as well as in rectangular format 5 x 2mm. The emitting angle of round LEDs are between 20° and 40°, whilst at rectangular ones it is increased to app. 100°. Spectral light response of different colours can be achieved by means of different semiconductor materials in LEDs' construction.

Fig. 10 Example of LED display

Different LED colours differ in terms of efficiency and light output. This is why are the red displays with 650nm peak output the most used ones, this is getting near the visible spectrum. The 7-segmented LED displays are used for displaying the numerical data. Base of these displays is the 7-segmented indicator, which is frequently used in groups from three to five digits, by which it creates a display. Segments differ by letters from a till g. Just because each segment consist of individual LEDs, it is necessary to use a logic to decode the binary data (or binary coded decimal data), to light up the correct combination of segments to display the individual number.

4.1.3 Liquid Crystal Displays - LCD

The specific property of liquid crystals, which makes them attractive for use as a base of electronic displays, is the possibility to adjust with electric field the orientation of molecules and consequently the transition of light through the crystal [11].
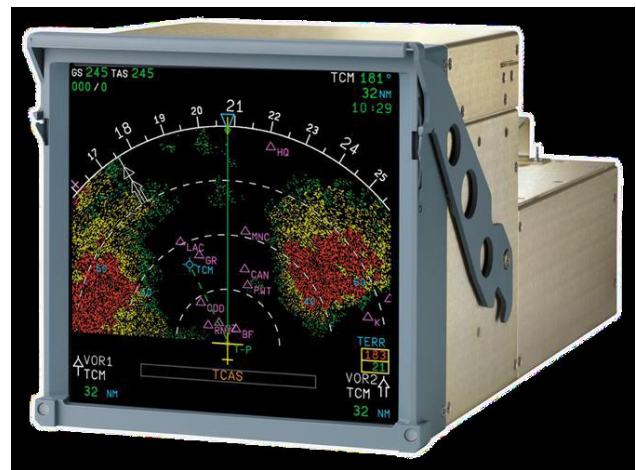

Fig. 11 LCD displey of A340 aircraft in [5]

LCDs can be reflex or illuminated, whether it is using incident light or it contains its own source of light. In contrast with LED displays, the LCDs are not emitting their own light, therefore they need some source of light. It is easy to build larger displays, which accompany some numbers into one display. Thanks to this, we can have integrated displays, where on common displaying unit can be displayed several groups of informations. Each LCD replaces several 7-segmented LED displays. This kind of display is ideal for displaying short text messages.

5 PERSPECTIVE INDICATORS

The touch-screen display controls belong to the most perspective indicators. In present, the companies Rockwell Collins and Garmin belong to the main manufacturers of touch-screen displays for aircrafts. Because the aircraft touch-screen displays have to meet difficult requirements, they have to take a complicated certification. Touch-screen displays for aviation industry have to meet several difficult criteria. The most important one is a good response of the touch-screen display, that means it has to respond to each touch of pilot, with naked hand or with gloves. In case that it comes to a failure of

some pixels, the functionality of the display unit has to be preserved. The next requirement is to offer as wide viewing angle as possible, what is the main insufficiency of regular touch-screen displays.

Fig. 12 Dash-board with touch-screen displays

Separation according to control:

Direct control: Touch-screen display is controlled directly by a touch to some point of the display or symbol. Pilot can input the change parameters and informations directly on the screen, that means, he doesn't need any other equipment to input the data.

Pro Line Fusion from Colins company belong to systems, which are controlled directly.

Base of the system is the 15 inch display. Usually there are 2 to 4 touch-screen displays used on board.

Fig. 13 Touch-screen display with direct control,[5]

Indirect control: Pilot uses for indirect control other auxiliary input equipment, which might be used also an another touch-screen display, that serves for information input. Main displaying unit serves only for data display, or there might be a version, where on the main displaying unit is displayed only a few touch buttons and the rest of the screen is passive, it is not possible to input the informations by a touch.

Fig. 14 G3000 System of touch-screen displays with indirect control

Garmin G3000 from company Garmin belongs to indirect touch-screen displays.

The base of the system are main displaying units which are represented by GDU 1400 displays, 14,1 inch wide and with a resolution of WXGA 1280/768. Displays are serving only for displaying the data. In the lower part of the display is allocated a line with touch buttons, by which pilot can change simple functions of the display and displayed information. For extensive displaying of informations and their change are used the control displays.

Control displays are represented usually with two GTC 570 displays, 5.7inch wide and with a resolution of 480x320 pixels. These are used for information input and for control of main displaying units.

Fig. 15 GTC 570 control displays of G3000 system

6   CONCLUSION

Tis article is describing the complex systems for electronic indication and signalling in the aircrafts. It deals with analysis of modern independent indication and signalling systems on-board of the aircrafts, such as the Electronic Flight Indication System - EFIS, Electronic Centralized Aircraft Monitoring – ECAM, Engine Indicating and Crew Allerting System – EICAS. Consequently are described in the article the displaying unit types on-board of the aircrafts, with a description of used display types, such as CRTdisplays, LED displays and LCD displays.

The last chapter of the article is outlining the latest indicators , which are the touch-screen displays, with a basic separation.

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