Application of distributed integrated modular avionics concept for perspective aircraft equipment control systems

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Abstract. The paper considers the possibility of distributed integrated modular avionics concept application for control systems of aircraft equipment. This approach allows reducing the cable network weight and size, reducing the noise of transmitted data, increasing the system reliability, shortening the time of the development and further modernization. As a result, the design of system and component part is proposed.

1. Introduction

Avionics of many modern aircraft is developed using the integrated modular avionics (IMA) concept. In this case, the functions of aircraft systems are performed by functional software. It is located in one or several physical units or modules (unified in terms of design), which are set in a common housing – a crate. As a result, the transition from concept “one system – one function” to concept “many functions in single computer” is provided. Avionics based on the IMA concept was realized on a number of aircraft (for example, the Boeing 787, Airbus A380, MC-21).

A prospective trend in avionics development is the distributed IMA (DIMA) concept. In this case, it is possible to dispose the modules in separate blocks outside the crate installed all over the aircraft near the sensors and actuators. This approach allows reducing the cable network weight and size, reducing the noise of transmitted data, increasing the system reliability, shortening the time of the development and further modernization.

Some avionics projects contain aircraft equipment control system (AECS), which allows implementing the computing functions of many aircraft systems in a single unit. Data acquisition from the sensors and actuators are carried out by using of information input-output devices distributed across the plane. The usage of the AECS provides a reduction of time and material expenses at every stage of the aircraft life cycle due to the increasing of the system software functions and decreasing the number of processor units.

AECS architectures of Airbus A-380, Boeing 787, Sukhoi Superjet 100 and MC-21 were considered. These systems developed with similar design and contains of central processing and data transmitting units. ARINC 825, ARINC 664, ARINC 429 interfaces are used for data communication between them. Further modernization of such systems is limited because of low flexibility without distributed network topology implementation. DIMA concept allows eliminating this problem [1, 2].

This paper presents the research about the possibility of DIMA concept application for AECS development. These systems perform functions with assigned function development assurance level
(FDAL) “A” (failure of the function could cause a catastrophic effect on aircraft) in accordance with the recommended practice ARP4754A [3].

2. Proposed AECS design
The proposed AECS design contains aircraft equipment control module (AECM) placed in central avionics computers and peripheral units – information transformation modules (ITM). ITM receive data from sensors and control actuators. ITM are single units located in places with high concentration of sensors and actuators (in the aircraft nose, tail and center section). The systems list controlled by AECS could be different and determined by the aircraft designers.

The proposed AECS design is shown in figure 1.

**Figure 1.** AECS design

AECS performs functions with assigned FDAL “A”, so redundancy is required in accordance with DO-178C and DO-254 [4, 5]. The proposed redundancy is achieved by implementing the AECM on four avionics computers. It makes it possible to achieve required fault safety level. Consequently, the central elements of the proposed AECS design are four control modules controlling the onboard equipment in accordance with the specified algorithms and providing the informational communication with other systems.
Since the avionics computers provide a significant number of functions, there is a huge data exchange between onboard systems. Thus, it is necessary to ensure high network bandwidth. In the proposed design the aircraft has two networks organized in accordance with ARINC 664. The first one is external: it carries out data exchange between the aircraft systems. The second one is internal: it connects all DIMA platform modules. In order to reduce the weight of the cable network, it is necessary to connect the ITM with modules via switches, which are installed in the central part of the aircraft.

AECS operates as follows. Each AECM receives data from ITM through ARINC 664 interface and from aircraft systems via ARINC 429, ARINC 825 and ARINC 664 interfaces. AECM process the received information in accordance with defined algorithms and transmits required information to aircraft systems through ARINC 429, ARINC 825 and ARINC 664 interfaces, as well as to ITM by ARINC 664 interface. In addition, manual control of actuators from overhead control panel is provided.

As an example, aircraft equipment can include elements of such systems as hydraulic, fire protection, anti-icing, fuel, electrical power generation, landing-gear, brake control, emergency lighting and doors.

The design of central avionics computers in accordance with DIMA concept is shown in figure 2.

![Figure 2. Central avionics computers design](image)

The design of central computer based on DIMA concept consists of processing platform and modules, which provide system functions. Real time operating system ensures the DIMA modules operation (including AECS modules) on a single platform. The resource sharing is strictly determined. Modules are independent. Applications use shared resources of platforms (for instance, memory). If necessary, using of special hardware or software is provided [6–8].

The proposed architecture of ITM is shown in figure 3.

The ITM design consists of two dissimilarity channels. The data from sensors of systems providing functions with FDAL “A” and “B”, is received by channels A and B. Digitalized data is compared in channel A. If difference more than specific value depending on signal type, invalidity status is set. If systems FDAL is “C” or below data can be received by channel A or B only.

Each channel receives the commands from avionics central computer about the need of generating the discrete signals for the actuators. Generated discrete signals by ITM is divided into two groups. False generating of signals from the first group can cause a catastrophic or hazardous situation. False generating of signals from the second group should not cause such situations. First group discrete signals are prepared by each channel and are compared in channel A. A signal is not generated in case of mismatch. The comparison for second group signals does not perform. In addition, ITM performs echo check of output control discrete signals.
Hardware dissimilarity is provided by implementing channels based on devices with different operation principles: information processing in channel A is based on a microcontroller and in channel B by means of a field programmable gate array. Software for each channel is developed by different groups of programmers.

Channel A consist of input and processing module №1 (IPM-1), discrete signals generating module (DSGM) and power module (PM).

IPM-1 provides the following functions:
- digital data exchange with central computers;
- receiving of discrete signals from sensors and actuators;
- receiving of analog signals from sensors;
- data processing by microcontroller;
- data comparison calculated by channels A and B.

DSGM generates control discrete signals to actuators.

PM provides the following functions:
• power providing of channel A;
• power providing for aircraft sensors;
• high-intensity radiated fields protection.

Channel B consist of input and processing module №2 (IPM-2), DSTM and PM. IPM-2 provides the following functions:
• digital data exchange with central computers;
• receiving of discrete signals from sensors and actuators;
• receiving of analog signals from sensors;
• data processing by field programmable gate array;
• data transmitting to channel A for comparison.

DSGM generates second group control discrete signals to actuators.

PM provides the following functions:
• power providing of channel B;
• power providing for aircraft sensors;
• high-intensity radiated fields protection.

The proposed design of ITM satisfies the software and hardware requirements for FDAL “A” in accordance with DO-178C и DO-254 [4, 5].

3. Conclusion
The design of the perspective AECS based on the DIMA concept is proposed. This approach provides more flexibility relative to analyzed systems. The system performs functions with assigned function development assurance level “A” (failure of the function could cause a catastrophic effect on aircraft) in accordance with the ARP4754A standard [3]. The proposed architecture satisfies the regulations requirements of aviation authorities of Russia, Europe and USA.

The proposed design allows reducing the weight and size of the cable network, reducing the noise of transmitted data and increases the system reliability.

References
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