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New Age Aircraft Cabin Systems & Technologies

Redefining Passenger Experience

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Table of contents

Introduction

Commercial aircraft passenger cabins have undergone a significant change over the past few decades in terms of features, functions and equipment. Airlines use passenger cabins as a representation of their brand image and gain patronage by providing competitive features, comforts and ambience.

Aircraft cabin electronics include the monitoring & control of a large number of interconnected and electrically powered equipment and subsystems of the cabin. These include cabin illumination, air conditioning equipment, window shades, smoke detection and fire extinguishing systems, cabin overhead audio, water and waste systems, flight crew interface to various cabin functions and support for in-flight entertainment systems. Being a significant component of the overall cost of an aircraft, the airlines and the OEMs are looking to manage the cost of cabin electronics and service life of aircrafts.

In order to stay competitive, OEMs are adopting the latest technologies and investing in the evolution of next generation aircraft cabins. This requires a substantial amount of engineering services and the support from a large network of supplier organizations. This paper describes the transformations in the cabin features & functions and highlights key technologies being adopted.

Technology Brief and Trend

Cabin Applications: Cabin illumination control

Aircraft cabin illumination is the single most important piece of equipment that creates the ambience passengers look for during their journey. Cabin illumination comprises of ceiling wash lights, dome lights, seat lights, window lights and stairways. Today's cabin illumination systems especially on long haul flights emphasize on ambience created by dazzling display of colors, hues, transitions and are aptly termed "mood lighting". They not only create artificial night & day (known to reduce jet lag) but also influence passenger moods e.g. warm lights during dining. However, most low cost airlines operating on regional routes continue to prefer low cost installations that are plain white light with just a warm hue.

Cabin lighting has seen a revolution in the last few decades from incandescent lamps through fluorescent tubes to all-LED lights. LED lamps not only provide the cost advantage due to their long life, lower weight, low power consumption and ultra low switching times but can also be completely controlled electronically to obtain the right color and intensity to create any kind of lighting effect. Mood lighting sequences can be conveniently programmed using simple screen based selections that define the color, intensity and duration of each transition.

Cabin illumination can be a complex system to develop, install and maintain, yet very simple to operate. The flight crew is provided with a touch screen from where they can simply select any cabin zone to monitor and operate the lights. For a large aircraft, there can potentially be thousands of controllable lighting end points all along the length of the cabin and hence need a distributed hierarchical data network and controllers with digital addressing capability. The light intensity and color is controlled by PWM controllers that are embedded in the cabin panels and connected via data links to a central control system. Using digital control, it is possible to obtain an accurate color mix and intensity resolutions as per standards and specifications.

However, LED lights are very sensitive to ambient temperature and device current. They also have problems of degradation due to ageing, resulting in chromatic inconsistencies and color temperature shifts. Diagnostic monitoring, adaptive controls and predictive analysis can assist in managing these issues. Light color and intensity transitions should appear uniform across zones along the length of the cabin. This demands special considerations to manage time synchronization of the electronic components and adapt to data path latencies. LED lamps of different makes or from different manufacturing batches show variations in light output and have to be considered during implementation. Planning for correct placement of lamps in the cabin also demands a great deal of engineering expertise and tools, to create the right ambience and uniform illumination in all areas of the cabin.

In addition to new aircraft programs, there is a large market opportunity for cabin illumination upgrades in retrofit business offering various solutions - from fluorescent tube to LED replacements to complete refurbishments of the entire cabin lighting system.

Cabin Surveillance: Securing the cabin

Post 9/11 terrorist attack, there has been a significant increase in security and surveillance initiative, especially in commercial aircrafts and airports. Cockpit door and passenger cabins are being equipped with cameras and the pilots and the cabin crew will be able to monitor all areas of the aircraft using display devices. The videos can also be transmitted to equipment outside the aircraft when the aircraft is on the ground, to analyze and archive the video footage.

Finger print recognition as a technology in the cockpit has also been considered to ensure that no one other than the pilot takes control of the aircraft. With face recognition and tracking systems maturing, continuous monitoring of the pilot position is possible to sound an alert if anyone else occupies the pilot seat during flight.

Highly sophisticated systems such as for tracking passenger movement, passenger authentication and identity protection are also being designed. However, it will need a higher level of systems maturity to implement such systems.

Maintenance & Diagnostics

From push button test functions on each Line Replaceable Unit (LRU) to centralized fault monitoring and reporting systems, the maintenance capability in aircrafts have come a long way. Cabin equipment diagnostic systems have a hierarchical structure in which all equipment are connected to a central maintenance system. Equipment faults, data link and interface faults, failover events are logged at the central maintenance system. Considering the fact that there are a number of electronic equipment and

devices in the cabin and the airlines cannot afford to ground the aircraft for unscheduled maintenance, locating the root cause of the problem rapidly and replacing the faulty component is vital. Equally important is the proper operation of diagnostics system to avoid false alarms and event notifications. Intelligent diagnostics with a core analytics engine can filter diagnostic events, sift through equipment state and historical data and identify root cause especially in case of multiple and cascaded faults. Predictive diagnostics is a next generation concept being considered which helps in identifying faults before they occur. Transient errors, slow degradation of a signal or output of a unit are used to deduce an incipient problem and corrective action is planned in advance.

Context based maintenance procedures and illustrations for a particular fault greatly helps the field technician in removing the component, installing a replacement, power up and perform a validation check. Augmented reality based maintenance tools are also evolving to assist the technician in carrying out repairs.

Innovations

Many technological innovations and technology demonstrators are in progress today, some of which are likely to get adopted in the near future.

Energy harvesting: In line with the impetus towards greater energy efficiency such as better aerodynamic design, fuel efficient engines & reduction of aircraft wiring and weight, there are several approaches to harvest energy from the aircraft cabin, in a natural way. At cruising altitudes above the clouds, there is an abundance of sunlight. Solar radiations can be tapped from the window shades to harness useful energy. Aircraft cabin shell and structural assemblies are usually subjected to mild vibrations during flight that can potentially serve as an energy source to power sensors and sensor networks to obtain strain measurements for structural health monitoring. Water flow in the water and waste system of the aircraft cabin can be used to derive small quantity of energy that is enough to drive the sensors installed in the plumbing, to acquire and transmit flow and temperature measurements over wireless networks, especially in inaccessible areas. Body heat from the passenger seats can also be a potential source of energy to power small cabin devices such as LED indications.

Pilot Fatigue monitoring: Statistics show that a majority of the air crashes have occurred due to pilot error[1]. Of these, most have been attributed to pilot fatigue, especially during long duration flights. Using a combination of image& seat pressure sensors, algorithms that analyze the posture and visual appearance of the pilot's face and eye blinking rate, it is possible to detect if he is under a medical stress or fatigue and alert him / co-pilot and the ground control appropriately.

[1] http://www.lewisandtompkins.com/library/plane-accident-statistics.cfm

Next Generation Avionics Platforms

Integrated modular avionics (IMA) systems have brought about a significant transformation in the area of avionics platform technologies. These technologies have been adopted in Airbus A380, Boeing 787 and some military aircrafts and will be the standard on all aircraft programs in future. Evolving out of traditional federated architecture of older generation avionic systems, IMA continues development to the next generation, known as the Distributed Modular Electronics (DME).

Federated architectures split the implementation of the avionic functions into separate LRUs. This not only carried a burden of a large number of LRUs including redundant hardware for each subsystem but also increased the number of data interconnects and wiring, power & space consumption, heat dissipation and weight. Maintenance of these equipment and stocking spares are also a financial and operational burden to the airlines.
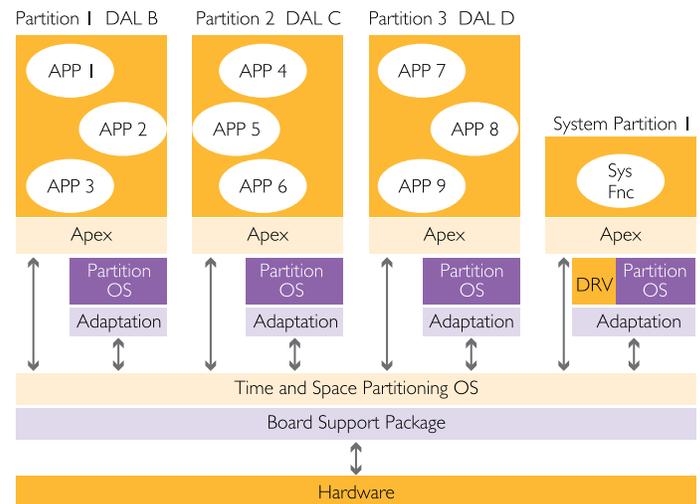
The Avionics specification ARINC 653, defines the standard for the IMA concept. This technology promotes sharing of compute and IO resources with an architecture that is optimal since several avionic functions can now be integrated into the same hardware. It features a system with memory partitions where avionics application processes are installed and a message based transport (via ARINC 664 network) provides the communication interfaces between processes within a partition and also across partitions and hardware modules. Since spatial isolation is provided by a partitioned memory space, the avionics functions are isolated from each other preventing fault propagation. Spatial separation also supports applications of different DAL criticality levels to be co-hosted in the same hardware module and simplifies certification effort. Cabin functions can be categorized into three different safety critical levels which can all be hosted

on the same hardware module but in separate partitions and hence can be separately certified. An example is listed below.

a.   Low criticality (level E) — passenger entertainment related

b.   Medium criticality (level C, D) — Such as crew interface system

c.   High critically (level B) — Emergency systems such as smoke detection and fire extinguishing systems

The IMA platform software also implements scheduling mechanisms that provide temporal separation. An Application Executive (APEX) API (as per ARINC 653) enables portability and reduces the impact of obsolescence in the face of rapidly evolving hardware.

In view of the new avionics platform architecture, the industry is divided into three interdependent roles as mentioned below:-

1.   Platform suppliers who build the hardware modules and the IMA platform software

2.   Application developers who build applications for specific subsystems

3.   System integrators who put these together and control the system configuration

Though ARINC APIs describe the platform interface details, application developers will need platform development and debug tools for the partitioned environment. They also are dependent on the system integrator for application timing constraints and memory requirements. A platform simulator for functional testing and verification will be of great use to the developer community. With model based development, code generation and code re-use across the application developer community, better product quality can be achieved at a lower cost and schedule.

Next Gen IMA: IMA concept is continuing to evolve but there are several issues to address before new features and enhancements are adopted.

Dynamic re-configuration – The current IMA platforms have static pre-set configurations – e.g. the partition data, application data, scheduling data, interface port definitions etc. Dynamic re-configuration during flight can achieve fault tolerance and system availability.

Multi-core CPUs – The current IMA systems have been designed to work with single core processors. With the emergence of multi-core processors, single core processors will become obsolete in the near future. For current IMA systems to work on multi-core processors, several issues related to timing and CPU cache have to be addressed in the platform software.

Porting legacy applications to IMA: Migrating applications from the legacy federated architectures to IMA will need to consider merging all the individual applications running on separate hardware and implement the ARINC 653 APEX interface. The migration should also consider effects of a partitioned environment and IO architecture on application latency and IO performance.

Cabin Network Architecture

Aircraft cabin comprises of several different network technologies – Ethernet, ARINC 429, ARINC 664/AFDX, CAN and even MIL 1553. Different subsystems have different needs from the network infrastructure. While in-flight entertainment systems can work with best effort delivery to transmit media content, other systems such as smoke detection systems will need more determinism and reliability. Time triggered protocols are desirable for equipment such as cabin audio that usually are high fidelity systems carrying uncompressed audio data.

Proprietary interfaces and protocols lock in the hardware and make technology insertions and upgrades difficult to achieve in all the connected equipment. There is also a growing trend towards adopting COTS hardware and moving all features and functions into software. To keep abreast with technology and manage obsolescence, it is important to adopt COTS hardware and standard interfaces. Deployment of IMA is a step in this direction.

Towards a wireless cabin: In-flight entertainment systems are gearing up to wireless content distribution and many airlines have already begun to deploy them, eliminating a myriad of data cabling, network switches and wiring. Aircrafts of the future are likely to sport a wireless network infrastructure for various cabin functions such as the passenger service unit functions, cabin lighting etc. In addition to the advantages of savings in wiring and maintenance costs and overall weight reductions resulting in fuel savings, cabin re-configurations will become simpler.

Conclusion

Air travel volume is increasing exponentially and so is the demand for more aircrafts. With increasing fuel costs, aircraft manufacturers and airlines are equipping their cabins with new and better features for safety, comfort and ambience and are also adopting modern technologies to remain competitive at an affordable cost.

This paper has described cabin equipment and features that have evolved over time and a perspective of what is the future. Transformational avionic technologies are also discussed, providing an insight into next generation architectures.

With several new aircraft programs being launched and a growing fleet of ageing aircrafts requiring retrofits, there is a huge demand for engineering services in the area of cabin electronics. OEMs and supplier organizations are gearing up to face this demand, backed by engineering service providers who are not only providing the time and cost advantage but also generating innovative solutions.

About the Author:

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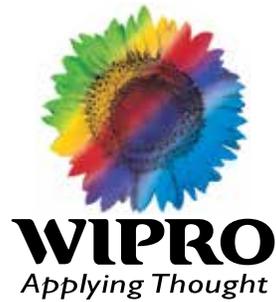
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