Aircraft Data Acquisition

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Abstract: The introduction of digital systems instead of analog ones has created a major separation in the aviation technology. Although the digital equipment made possible that the increasingly faster controllers take over, we should say that the real world remains essentially analogue [4]. Fly-by-wire designers attempting to control and measure the real feedback of an aircraft were forced to find a way to connect the analogue environment to their digital equipment. In order to manage the implications of this division in aviation, data optimization and comparison has been quite an important task. The interest in using data acquisition boards is being driven by the technology and design standards in the new generation of aircraft and the ongoing efforts of reducing weight and, in some cases addressing the safety risks. This paper presents a sum of technical report data from post processing and diversification of data acquisition from Arinc 429 interface on a research aircraft platform. Arinc 429 is by far the most common data bus in use on civil transport aircraft, regional jets and executive business jets today. Since its introduction on the Boeing 757/767 and Airbus aircraft in the early 1980s hardly any aircraft has been produced without the use of this data bus. It was used widely by the air transport industry and is even found in non-aviation applications such as commercial and military applications.

Key Words: ARINC 429, Data Acquisition, Digital data transmission, Aircraft Data bus, Data bus standards

1. INTRODUCTION

The advances of standard digital data buses in the civil aircraft have been matched by advancements in processor, memory and other microelectronic devices such as analogue-to digital and digital-to-analogue devices, logic devices etc. which made possible the application of digital technology to aircraft systems.

The greater single impact of standardized digital data buses is the improvement of the intercommunication between the aircraft systems.

In earlier analogue avionic systems the number of cables used to transfer the information between the various system components was considerably high.

As systems became more complex and integrated, this problem became a major issue. With these systems, at least one pair of wires has been required for each signal and so a typical installation requires several pairs of wires. With the equivalent digital systems, all the analogue signals are converted into their equivalent and are assigned unique address labels to ensure there are no conflicts. [1]. These signals are then transmitted down a single, twisted...
pair of wires, which makes up a data bus. Aircraft data bus systems allow a wide variety of avionics equipment to communicate with one another and exchange data. The type of language used on an aircraft data bus is known as the protocol.

Common types of digital data transmissions [5], include:
- Single source - Single Sink. This is the earliest application and comprises a dedicated link from a device to another. Single source - Multiple Sink. This describes a technique where one transmitting device may send data to a number of recipient device (sinks). Arinc 429 is an example.
- Multiple Source - Multiple Sink (full duplex). In this system multiple transmitting sources can transmit data to multiple receivers.

The use of data buses has experienced tremendous growth over the last few years especially with the introduction of COTS technology - adopting those buses designed for the computer and telecommunications industries [7]. This technology has been spread for reasons of cost, speed, component obsolescence and control, though a lot of attention is necessary to ensure that the proper variants are selected for the aerospace industry. Table 1 bellow lists most of the data buses used on aircraft today in ascending order of the data transmission. Statistics in Fig.1 show that fiber optic buses operate at a speed of 20 times higher than the speed through Ethernet and two times higher than the speed of the serial IEEE data buses, also referred as “FireWire”, thus providing a much faster alternative.

![Fig. 1 Digital Data rate buses used on aircraft in ascending order of the data transmission](image)

Table 1. Common digital data buses used on aircraft from 10kbp to 2 Gbps data transmission speed

<table>
<thead>
<tr>
<th>Number</th>
<th>Data rate (bps)</th>
<th>Type</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10000</td>
<td>Tornado Serial</td>
<td>Tornado &amp; Sea Harrier</td>
</tr>
<tr>
<td>2</td>
<td>64000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1000000</td>
<td>1553B</td>
<td>Very widely used in Military Community</td>
</tr>
<tr>
<td>5</td>
<td>100000000</td>
<td>Ethernet</td>
<td>B 787/Bus JETS</td>
</tr>
<tr>
<td>6</td>
<td>200000000</td>
<td>STANAG 3910</td>
<td>Typhoon Raphael</td>
</tr>
<tr>
<td>7</td>
<td>800000000</td>
<td>HSDB</td>
<td>JIAWG/F-22</td>
</tr>
<tr>
<td>8</td>
<td>1000000000</td>
<td>AFDX/A664</td>
<td>A 380/ B787</td>
</tr>
<tr>
<td>9</td>
<td>8000000000</td>
<td>IEEE 1394b</td>
<td>F-35</td>
</tr>
<tr>
<td>10</td>
<td>100000000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>200000000000</td>
<td>Fiber Channel FC-AE</td>
<td>F-35: F/A-18E/F F-16-E/F (Block 60)</td>
</tr>
</tbody>
</table>
2. DESIGN FUNDAMENTALS

ARINC, abbreviation for Aeronautical Radio, Inc. [2] was established in 1929 and is a private company who copywrites and publishes a series of standards produced by AEEC (Airlines Electronic Engineering Committee) which were divided into three types of documents:

1. ARINC characteristics or definitions of forms and functions that describe the operating equipment.
2. ARINC specifications that define the physical location and installation of equipment, communication standards and advanced programming languages.
3. ARINC reports that provide general information, guidance referring to maintenance and support procedures for aviation companies.

Arinc 429 defines the standard for digital data transfer between aircraft systems in commercial aircraft, known as the Mark 33 DITS specification. Signal levels, timing and protocol features are defined to facilitate the design and implementation of data communications bus.

![Fig. 2 Arinc 429 Topology [2]]

Arinc 429 is a specification developed and written separately to provide interoperability between interchangeable type units LRU (Line Replaceable Units) on commercial aircraft which purpose is not only to indicate to prospective manufacturers of equipment the considered opinion concerning requisition but also to channel new equipment designs in a direction which permits a maximum standardization of the majority of the characteristics [6]. There is no legal obligation for manufacturers of avionics equipment to meet the specifications required by this standard, but the design of equipment systems respecting a standard line enables interoperability between functional units regardless of manufacturer.

Data can be transmitted in one direction - simplex communication - two-way transmission requiring two channels or buses. Devices or LRU (Line Replaceable Units) are
the most commonly configured in a star topology (Star) or Bus type (Bus) as represented in Figure 2. As systems on aircraft became progressively more digital in nature, it became apparent to avionics designers that a multiplexed bus system was required to make a connection by only one set of wires possible [9]. Each LRU may contain multiple transmitters and receivers for communications on different buses. This simple architecture provides a common environment for transmission and a highly reliable data transfer.

A transmitter can broadcast on a single bus, grouped within 20 receptors and may require a notification from each for receiving data (Handshaking is a particular type of message). LRU power transmission element consists of packets of 32 bits that contain actual data portion of 24 bits and a label of 8 bits describing the data itself. A LRU has no actual address assigned by Arinc 429, however, it has the equipment identification number, which allows grouping them in systems to facilitate the system management and data transfer. Message sequences are separated by at least 4 bits of 0 volts, this null gap eliminating the need for a clock signal.

Data bus uses a shielded cable and twisted 78Ω, the two barbs and secured at each node along the network as represented in Figure 3 below.

![Figure 3: Cable features for Arinc 429](image)

Transport speed may be small, set at 12-14kBytes per second or higher of 100 Kbits per second; the higher rate is by far the most commonly used. Data are transmitted in a format with bipolar return to zero point as a modular between states HIGH, LOW and NULL. Transport Tensions are measured at the output terminals of the source.

Tensions presented at the receiver input signal will depend on the length of the line, the node configuration and the number of connected receivers. The following voltage levels indicate the three allowable states:

<table>
<thead>
<tr>
<th>TRANSMIT</th>
<th>RECEIVE</th>
<th>STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>+10.0 V ± 1.0 V</td>
<td>HIGH</td>
<td>+ 6.5-13 V</td>
</tr>
<tr>
<td>0 V ± 0.5 V</td>
<td>NULL</td>
<td>+ 2.5-2.5 V</td>
</tr>
<tr>
<td>-10.0 ± 1.0 V</td>
<td>LOW</td>
<td>- 6.5-13 V</td>
</tr>
</tbody>
</table>

The modulation technique is bipolar Return to Zero (RTZ) as shown in the table above and the actual format of the return to zero point HIGH (or 1) is performed when the signal goes from the NULL transmission to +10 V for the first half of the cycle bit and then returning. A point of low (or 0) is produced by the fall of the signal from NULL to -10 V for...
the first half of the bit cycle, and then back to zero. In terms of wave parameters, the rise and fall signals are controlled by simple RC circuits built inside the system. Permissible values vary depending on the transmission speed.

**Messages format**

The standard embraces many fixed labels and formats so that a particular type of equipment always transmits data in a particular way. This standardization has the advantage that all manufacturers of particular equipment know what data to expect despite differences. In other words all data messages are transmitted in 32 bit packages.

ARINC 429 data packages of 32 bits consist of five main areas:

- Parity - 1 bit,
- SSM matrix (Sign / Status Matrix) - 2 bits,
- The data - 19 bit,
- SDI index (Source / Destination Identifier) - 2 bits,
- Label (Label) - 8 bits.

ARINC 429 Protocol uses a point-to-point format, and most ARINC messages contain only one package consisting of either a binary code (BNR), binary decimal (BCD called Binary Coded Decimal) or alphanumeric data.

The only mandatory fields are labeled by definition and parity bit, leaving up to 23 bits available for the presentation of data at a resolution better. Many non-standard formats have been adopted by various manufacturers of avionics equipment. Any unused bits are allocated with zeros. The most significant bit (MSB Most Significant Bit or) is defined as the parity. Arinc used as an indication of even number error detection to ensure a clear reception of the data without a proper correction.

**3. TECHNICAL REQUIREMENTS AND SPECIFICATIONS**

Embedded systems on the aircraft Be C90Gtx aim to achieve research missions weather, topographical surveying, communications applications using Data-Link and aerial photogrammetry and thermography.

The aircraft was modified as an airborne laboratory and imposes certain requirements in terms of maintenance and operation, dictated by the manufacturer's documentation for each subsystem. The aircraft is fitted with a data acquisition device type Arinc429.

The transfer of digital information DITS type (Digital Information Transfer System) is the technical standard used predominantly to data busses of transport aircraft in operation in decades. Capturing packets of digital data has applications in multiple domains; the data can be used to:

- Supports all type applications Lidar, CAPS, Hawkeye, Data Link,
- Data extraction speed, altitude and angle of flight, engine power required for a simplified calculation of the airplane dynamics,
- After analyzing the flight envelope that influences the operation of the sensors attached to the tail assemblies,
- Operator awareness regarding flight parameters.

**I. Technical Requirements**

In order to operate the system, a laptop must be connected to the USB port (using a cable of this type which is permanently on board). Data bus is active only when the airplane is in operation, powered with external power or battery plane.
Before operating the system, use an application called DDC Card Manager and check whether the device was detected.

II. Acquisition system

During system operation, the interface with all the options, control and representations is available to users as in Fig 4. The Data acquisition system consists of two parts:

1. Hardware
A four-channel data interface reception Arinc429 is located inside the central pedestal and a USB port cabin is placed in a special support in Internet High-hand operation. The recording is done by setting AVIONICS on.

2. Data acquisition software
DataSIMS is a tool for designing, testing and graphical analysis of ARINC 429 data. The software can facilitate multiple operations such as: defining technical units, connecting communication flows, online and real-time analysis, generating reports, creating own gadget panels.

![DataSIMS interface](image)

The software operates in four different modes with menus, tools and display panels that provide control capabilities.

Each operating mode is selected from the list that appears by clicking on the "Mode" menu bar in the left corner.

a. Setup Mode
To work with data the card configuration and calibration are required before starting the data acquisition.
Setup mode allows the inspection of the work area without communicating and it is used to configure and open a project workspace.

After enabling the data connection to the bus by card DataSIMS allows monitoring or simulating the traffic on communication channels [3]. From this point DataSIMS can switch in a way that allows viewing of raw Arinc429 transmitted over the data bus, including order status, names and particular communication errors.

While working with DataSIMS the physical aspects of communication (transfer of messages, names of the raw data, communication errors) or logical significance of data traffic (values in units of measurement used in engineering, modes etc.) can be tracked.

To analyze the physical aspects of such communications data, there are specific types of display for these purposes, which can be used instantly, but the definition of the minimum elements of a database is useful for finding the messages by name.

b. Simulation Module

Simulation mode is an active mode in which data can be monitored, simulated and recorded in real time.

c. Monitoring Module

This mode is used to view data passively, without acting on the channels of communication. It is used in flight to watch the data and crosscheck with the pilots.

d. Replay Mode

This mode is of two distinct types: Off-Line with a simple readout data on a screen, and On-Line directly on the data bus as can be seen in Figure 4.

It is also a passive way simple to use on ground to generate reports and analyze the recorded data.

4. RECORDING OF FLIGHT PARAMETERS

Most mobile devices use routinely, such as tablets, smartphones or GPS handheld have a variety of sensors, such as position receiver, accelerometers, gyroscopes or magnetometers that can be used to purchase and view data movement along a flight path.

The advantage of systems acquisition and analysis of data on aircraft is that it provides the ability to compare and test digital data with results from analog sensors.

Focus capture system parameter data transmitted via bus standard avionic databus meeting ARINC 429.

This system, electrical interfaces, signal format, and addresses can be specified discrete data with protocol for exchanging data between different devices.

Using a data acquisition card Arinc 429 is via a digital communication protocol and enables the implementation of a user interface for viewing in real time or retrospectively.

Reader actual operation is done by providing a USB interface for storing and recording any external peripheral unit (laptop, notebook hard drive etc.).

The data acquisition is ongoing aircraft while the plane is in operation, but depends upon the communication channel architecture having a fixed number of labels that correspond to a standard name or address manually. Each has a parameter that can be assigned via software acquisition record DataSIMS.

To obtain the file of orders registration required parameters associated control surfaces of the airplane: elevators, ailerons, steering, four communication channels Arinc 429 [Fig. 5] are insufficient.
The technical solution to extend the range of recorded data involves the installation of an additional USB port and the use of the acquisition plate already fitted on the airplane Gtx Beechcraft C90. [Fig. 5].

Change can be done by an organization specializing in aircraft maintenance Part 145 Be type C90, but also requires certification Part 21J.

The main advantage in using an already installed system is keeping a standardized interface to the operator's point by maintaining a level of information that can be processed by the crew. The collected data is uploaded to a computer or server after the flight, in order to perform statistical analyses. Registration files containing generated data such as speed, acceleration, angles, altitude, position in space, attitude, and information from the propulsion system and beyond.

Of particular interest to flight dynamics is the use of the system for the control of the surfaces: flap, aileron and rudder. They are controlled by an automatic system to exempt subordinate tasks and pilot flight guidance and serve to increase awareness of the situation. The basic tasks with a high potential for fatigue are automated, but still require continuous monitoring and processing of information. This way the human error is not removed, but channeled in other directions. Obtaining of high precision parameters is vital for designing a flight test model for the real environment. A flight control system, as part of an aircraft contains a number of safety critical functions and requires absolute honesty. Augmenting the acquisition system keeps the viewing functions and flight guidance in the plan and provides additional information necessary for a high situational integrity in extreme situations.

5. RESULTS

Data SIMS is designed to record different aircraft parameters including: Altitude (also Baro-Corrected), Static Pressure, Present Position Latitude, Present Position Longitude, Ground Speed, True Airspeed, Baro-Correction (hPa), Baro-Correction (Hg), Static Air Temperature, Airspeed, Pitch Angle, Roll Angle, GMT (FMS), UTC (GPS), Total Air Temperature, Date (FMS, GPS). The reports can be generated in table format to list and process the recorded data. In order to process the trajectory that has been flown the .xml file should be rearranged and converted to a .kml file that can be visualized on a map.

Example: Trajectory processing for Lidar research mission with Be C90 aircraft on 29.06.2014. The source of the data is the Arinc 429 data acquisition board. The variables recorded are: altitude, longitude and altitude. In Figure 6a the low altitude flight profile of the lidar scanning is represented while in Figure 6b a section of the return flight can also be observed.
The recording consists of 54 points from 1 min intervals. The data covered in the report provide the necessary information to create a trajectory using google earth or any other similar application.

### 6. CONCLUSIONS

To extend the range of applications and missions a combined research will use a special software to convert the recorded data, processing and post-processing.

At this study, after examining the position data acquired using a simple GPS file from a Garmin AERA 795 with the actual data recorded using an acquisition board, it is obvious that the second method has quite a lot of advantages such as:
- more recording points,
- special software to correct position errors,
- better time stamp,
- the trajectories can be easily identified and saved,
- a way of recording long flights with no battery limitations,
- easy to connect trajectory with other aircraft data.

Data acquisition and transmission in general from avionic systems and their usage on aircrafts are explained and ARINC 429 data bus standard is examined in detail.

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APPENDIX A: ACRONYMS

A 429 – ARINC 429 Data Bus
AEEC – Airlines Electronic Engineering Committee
AFDX – Avionics Full Duplex Switched Ethernet
ARINC – Aeronautical Radio Inc.
BCD – Binary Coded Decimal
BNR – Binary
COTS – Commercial off the Shelf
DDC – Data Device Corporation
DITS – Digital Information Transfer System
GPS – Global Position System
HSDB – High Speed Data Bus
LRU – Line Replaceable Unit
MSB – Most Significant Bit
RC – Resistor-capacitor circuit
RTZ – Return To Zero
Rx – Receive
SDI – Source / Destination Identifier
SSM – Sign / Status Matrix
STANAG – Standardization Agreement
Tx – Transmit

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