AVIATION DATA TRANSMISSION-MOVING FROM ELECTRONIC TO OPTICAL DOMAIN: REVIEW OF ARINC 429 & 629 STANDARDS

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ABSTRACT

In earlier airborne data networks, analog signals were transmitted from point to point with a copper wire pair for each signal. Hence, typical installations would require tens of wire pairs between ends to end. A large percentage of weight & volume of aircraft space was towards data cabling. Digital data transmission standards allowed for converting analog data to digital, multiplexing and labeling with unique destination addresses. Hence, with aviation data transmission protocols-like ARINC 429 & its successor ARINC 629, the weight and volume of on- board data cables and complexity of airborne networks has reduced and speed of data transmission & bandwidth has improved. This paper explains the ARINC 429 transmission standard, its specifications and word format. The need for high bandwidth moving from electrical to optical domain has been felt and high speed ARINC 629 was introduced. Key features, specifications and characteristics of ARINC 629 are compared with 429. In the end, a comparison between two transmission standards and relative advantages of 629 over 429 are brought out. This paper is part of studies on Avionics Optical Networks and Aircraft Maintenance at Dept of Aeronautical Engg., MIST, Dhaka, from Jun 2011 to Oct 2012.

FIELD OF RESEARCH

Advancement in Avionics Data Transmission Standards.

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1.0 INTRODUCTION

Data transmission is conveyance of information from source to destination. In analog avionics data transmission system, at least one pair of wire is required for each signal between the sources & destination. Hence, a typical point to point analog airborne network would require 10s of pairs of wires. In digital data bus, analog signals are converted into digital equivalents, assigned unique address labels, multiplexed and transmitted down a single pair of wire which makes up a data bus, which can either be serial or parallel. Integrated digital avionics data bus allows data multiplexing, transmission/reception and communication of on-board avionics data in modular avionics architecture. In vogue, data bus protocols are: ARINC 429, ARINC 629, MIL-STD 1553, MIL-STD 1773, Commercial Serial Digital Bus (CSDB) and Avionics Serial Communication Bus (ASCB).

2.0 ARINC 429

ARINC 429 or simply 429 is a Digital Information Transfer system (DITS) introduced in 1977 by Aeronautical Radio Incorporated (ARINC) [A]. It has been installed on most commercial transport aircraft including; Airbus A310, Boeing 727, 737, 747, 757, and 767; and McDonnell Douglas MD-11[B]. It defines both the hardware and data formats required for bus transmission. Hardware consists of a single transmitter or source connected up to 20 receivers or sinks on single shielded twisted wire pair[C]. Data can be transmitted in simplex mode; bi-directional transmission would require a parallel wire or a bus. The devices, line replaceable units (LRUs), are most commonly configured in a Star (Fig.1) or Bus-Drop (Fig.2) topology. This simple architecture, almost point-to-point wiring, provides highly reliable data transfer [D, E].

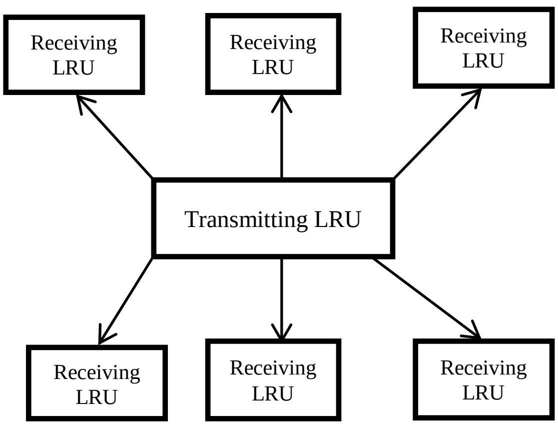

Figure.1: Star Topology

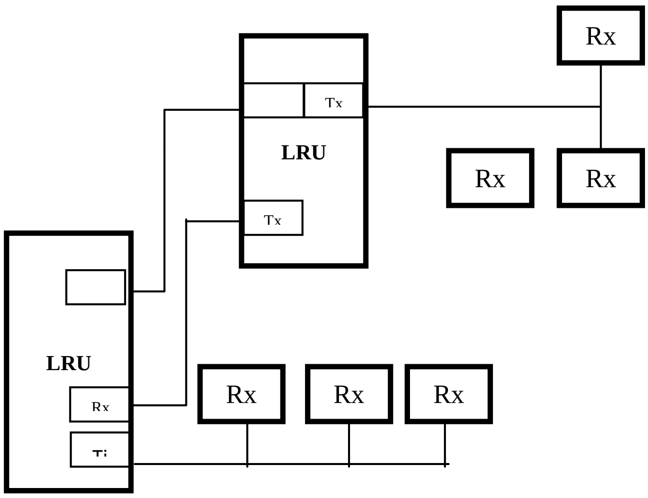

Figure.2: Bus-drop Topology

2.1 ARINC 429 CHARACTERISTICS

ARINC 429 is a self-clocking, asynchronizing data bus; hence messages can start at any moment of the time line. And if there are no messages, the transmission line is in null state and there is no voltage, which is a power saving advantage. A set of bits or bytes comprising the smallest unit of addressable memory is called word. 429 transmitters might supply more than one data word at a time and in such a case the receiver has to be given the information about order of reading the words. 429 has two variants; a high speed variant operating at 100 kbps and low speed variant at 13 kbps. There are three logic states in the 429 system: logic-0, logic-1 and null. Logic-1 state is between +6.5 V and 13.0 V, while logic-0 state is the same except for negative voltage and when no pulse is transmitted, the bus is in the null state. If any of the two lines of the twisted pair shorts to ground, transmitter voltage is cut in half which is an unacceptable range for the receiver [D, E, F].

2.2 ARINC 429 WORD FORMAT AND DATA ENCODING

ARINC 429 transmitters are always transmitting, either data words or NULL state [G]. Most ARINC 429 messages contain only one data word consisting of Binary (BNR), Binary Coded Decimal (BCD) or alphanumeric data. 429 data words are 32 bit long made up of five primary fields which are shown in Fig.3.

MSB LSB

32	31	30	29 ---------- 11	10	9	8--------1
P	SSM		MSB Data LSB	SDI		Label

Figure.3: ARINC 429 32 bit word

The MSB is always the parity bit for ARINC 429 which is normally set to odd except for certain tests. It means that there must be an odd number of “1” bits in the 32-bit word and that are insured by either setting or clearing the parity bit. Bits 31 and 30 contain the Sign/Status Matrix (SSM) which contains hardware equipment condition, operational mode, or validity of data content. Bits 29 through 11 contain the data, which may be in a number of different formats while bits 10 and 9 provide a Source/Destination Identifier (SDI). This is used for multiple receivers to identify the receiver for which the data is destined. Bits 8 through 1 contain a label identifying the data type and the parameters associated with it [B]. ARINC 429's data encoding uses a Complementary Differential Bipolar Return-to-Zero (BPRZ) transmission waveform, Fig. 4 refers. Pulse rise and fall times are controlled by RC circuits built into ARINC 429 transmitters [G]. This circuitry minimizes overshoot ringing common with short rise times. Allowable rise and fall times and other parameters for both high & low speed ARINC 429 are shown in Table-1. It can be clearly seen that it’s not merely the data speed that distinguishes between high & low speed 429 standards, but also the rise & fall time.The Bit rise & fall time for low speed 429 are approximately 9 times slower than high speed 429. Approximately the same is the rate to bit rate between the two catagories of ARINC 429.

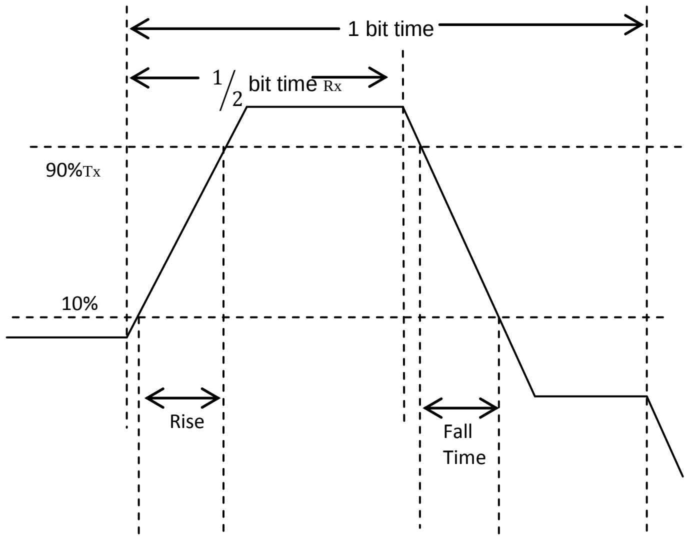

Figure.4: ARINC 429 Waveform Parameters

Bit Timing	**High Speed 429**	**Low Speed 429**
Bit Rate	100 kbps ± 1%	12 – 14.5 kbps ± 1%
1 bit time	10 µ sec ± 2.5%	(1/Bit rate) µ sec ± 2.5%
½ bit time	5 µ sec ± 5%	(1 bit time/2) ± 5%
Rise Time	1.5 µ sec ± 0.5 µ sec	10 µ sec ± 5 µ sec
Fall Time	1.5 µ sec ± 0.5 µ sec	10 µ sec ± 5 µ sec

Table.1: ARINC 429 waveform parameters

Every LRU transmitter has interface chips providing line drivers, receivers and logic translation from three-level signals to logic zeros and ones. Most sophisticated chips include registers and interface circuits for direct application to a microprocessor bus. Introduction of 429 reduced the bulk & volume of wires in the aircraft. Tuning of various LRU required only keying or programming the parameters from one source to multiple receivers thus number of control panels is reduced.

3.0 ARINC 629

The need for high-bandwidth airborne avionics data links that are lightweight, immune to electromagnetic interference and highly reliable are always felt. So, the next stage of development is optical fiber data communication. Modern digital avionics systems require a system capable of transporting microwave and millimeter-wave RF signals that carry digital data on board an aircraft [H]. The high bandwidth-to-weight ratio, performance and routing flexibility offered by the combination of single mode optical fiber and wavelength division multiplexing (WDM) are among the prime attractions justifying the optical network approach to on-board avionics communications systems [I]. The ARINC 629 is a new standard for aviation industry for the transformation of digital data between avionics system elements. It was first introduced in May 1995 and is currently used on the Boeing 777, Airbus A330 and A340 aircraft [J]. The ARINC 629 civil aircraft data bus standard has been developed as a successor to ARINC 429. It is used in the MAC layer protocol [O]. By the concept of bus cycle, this protocol manages periodic and aperiodic traffic exchanges. Its unique feature is that there is no need for a bus controller and bus access is determined by each terminal independently [D].

3.1 ARINC 629- SPECIFICATIONS AND CHARACTERISTICS

ARINC 629 source transmits either broadcast or address specific message to all or specific receiver or sinks. If the sinks equipment needs to reply, each will need to be fitted with own transmitter and a specific physical bus for the same. The single pair of wire connecting LRUs works in full duplex mode. In 629 LRU may transmit and receive digital data using a standard protocol.. The protocol is described as Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) [K, N]. 629 is a dual redundant data bus architecture where two buses are hot standby to each other in a linear bus topology, Fig. 5. Each terminal can transmit 629 data to and receive data from every other terminal on the data bus, which allows much more freedom in the exchanging of data between units in the avionics system. The 629 data bus cable has an unshielded twisted pair of wires and can be up to 100 meters long. Remote terminals are autonomous and for timing synchronization each RT has independent transmitter and receiver PROM for sequencing the time.

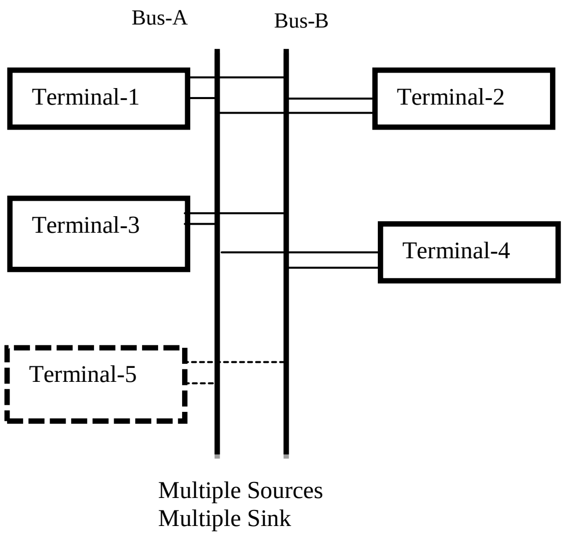

Figure.5: ARINC 629 Dual Redundant Data Bus

To identify the labels of messages, PROM is available in each RT. This feature is not available in 429, where all these activities are done by master controller (MC). 629 have unique label word and each message has a source channel identification code (CID) which identifies the source of messages.

3.2 WORD FORMAT

ARINC 629 20 bit data word format is shown in Fig. 6, [A, J]. The first three bits are related to word time synchronization. The next 16 bits are the data contents, and the final bit is a parity bit. Data groups transmitted by ARINC 629 are called messages. Messages are comprised of word strings, up to 31 word strings can be in a message. So, maximum 620 bits are possible in a word string.

Sync	Data (depending upon word type)	Parity
1 2 3	4 5 6 ………………………………………………………19	20

Figure.6: ARINC 629 Word Format

The ARINC 629 standard defines a multi-level protocol for inter LRU communications across a common, multiple access data bus [L]. In 429 stubs are connected with the data bus wherease in 629 there is no stub and even there is no master controller in 629. All the functions MC does in 429 are done by RTs. These RTs have both transmiter and receiver [D]. ARINC 629 can be implemented in three media: wire, inductive or voltage coupling and optical fiber [P]. Optical implementation offers the same alternative bus configuration as of DOD-STD-1773 which is the optical equivalent of MIL-STD 1553 having the same word structure and length and bus protocol. The optical power levels, wavelengths and means of distributing optical power in any specific implementation must be contained in a specification which refers this standard. This feature ensures that the best available technology is used when the system is built [M].

4.0 KEY DIFFERENCES BETWEEN ARINC 426 AND ARINC 629

Features	**ARINC 429**	**ARINC 629**
Year of introduction	1977	1995
Bus Architecture	Simplex point to point	Time division multiplex
Ports	2	1ststandard, 2nd optional
Wires	Shielded twisted pair of wires	Unshielded twisted pair of wires
Transmission mode & coupling	Voltage direct connection	Current coupling

Encoding	Bipolar, return to zero	Bipolar, doublets Manchester
Data Rate	12.5 & 100 kbps	2 Mbps
Bus frequency	12.0 kHz, 12.5 kHz, 14.5 kHz, or 100 kHz	2 MHz
Words Selectable	Max 128 words per channel	620 words per word string, 32 word strings
Word Update	1 ms to 10 sec, (selectable)	1 ms to 10 sec, update rate displayed instantaneous, min or max value
Divination of areas	Three areas : logic 0, logic 1 and Null	Four areas: Periodic traffic, Urgent aperiodic traffic ,Non Urgent aperiodic traffic (backlog, new)
Maximum terminal supported	20	128
Bit wise Comparison		
Data Bit	Bits (11-29) carrying data	Bits (4-19) carrying data
Bits 1 to 8	Bits(1-8) for label	First three bits are related to word time synchronization.
Parity Bit	Bit no. 32 is parity bit	Bit no. 20 is parity bit

Table.2: Comparison between ARINC 429 & ARINC 629

5.0 CONCLUSION

Aviation parameters like air speed, atmospheric pressure, altitude, engine RPM, navigation status, control surface position etc are measured in analog domain and transmitted to on-board processors, displays and controls in electrical domain (ARINC 429 & 629). Over the years complexity of avionics systems has increased and so is the requirement of high data bandwidth and speed of on-board avionics network. As a result developments are on for commercially adopting optical standards for avionics networks. Hence, ARINC 629 is being rapidly adopted for optical networks in aircraft. This paper gives a comparative overview of the two communication protocols used in avionics data bus. From an assessment of their key features it can be concluded that ARINC 429 is an easy-to-implement, inexpensive protocol whose reliability has been adequate for most applications in the early ages. But, for high data rates, ARINC 629 has been advantageous, also in case of redundancy as well and hence, gradually optical fiber based airborne avionics are emerging for commercial aviation applications.

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