ARINC 429 REVISITED

The ARINC 429 bus has been around now for over two decades and this article is intended to refresh us with its structure and definition. In the early 1980's the ARINC Committee decided to take knowledge gained from ARINC specification 419 that had become a collection of several digital data protocols such as ARINC 561(LRN), 568(DME), 573(FDR) and 575(DADS) to name a few. The avionics systems evolving then where incorporating more computer components and requiring more processing functions. As a result of this growth a demand was seen to pass this volume of information to other systems. The new standard became known as the "Mark 33 Digital Information Transfer System" (DITS). This is a scheme where a source will transmit information out a designated port over a single twisted and shielded wire pair to multiple receivers. The committee realized a more comprehensive digital information transfer system could evolve from this philosophy that would allow multiple label groups to be sent. A single directional asynchronous bus that could be extremely flexible and expandable was required. Bi-directional data flow on a given data bus is not permitted and therefore separate transmit/receive ports would need to be assigned. This data format would also contain the clock within the bit stream and then be re-generated at the receiving equipment. There are five application groups for this 32 bit word and they are: BNR data, BCD data, discrete data, maintenance data and acknowledgement. This new philosophy could then integrate all systems on the aircraft by using different encoding formats. The first format use's a two's complement fractional binary notation (BNR) and the second format implements a Binary Coded Decimal (BCD) notation. The large majority of assigned labels implement BNR notation because it yields better resolution. This bus operates open loop in that it requires no feedback directly however some equipment manufacturers through software will echo back some data from a receiver to confirm system integrity. The committee also recognized that data validity would be very important and so the bus structure would also contain a parity bit.

The bus employs a bi-polar, return to zero (RZ) form of logic that is typically driven by +/-10v supplies. The bit rate employed within the arinc word can be in the range of 12.5-14.5kilobits/sec (Low Speed) or 100kilobits/sec (High Speed). The transfer rate or refresh rate that each label operates at is determined by its criticality within the affected systems and so defined in the specification. An example of different refresh rates can be seen for example in Label 204, Baro-Corrected Altitude, where the minimum transfer rate is 31msec vs. Label 012, which represents Ground Speed where its minimum transfer rate is 250msec. This specific detail is one that never comes to the forefront in any troubleshooting process however it does show the importance of the details embedded within the software handling the data. The transmitter port should be able to handle up to twenty receiver ports without any degradation in signal. The amount of data or label content on any particular transmitter port will vary depending on the equipment manufacturer and the systems that are interfaced.

The digital word is made up of 32 discrete bits with the least significant bit sent first. If in any word all locations are not used then they are filled in with binary zeros unless BNR/BCD numeric data is present and in this case valid data bits are used. Labels that contain numeric data by nature require more resolution and will typically use all available data bits. A case in point would be the previously mentioned Label 204 where the required data resolution is 17 bits (2e17).

LABEL

The Label or first eight bits of the thirty-two bit word serve to define the content and meaning of the data. Labels are typically represented in octal numbers and these first eight bits are transmitted in reverse order with the MSB transmitted first. In all cases the label is always transmitted ahead of the data so the receiving equipment can identify and decode or just disregard the data. There are some differences among the labels as you go from the original ARINC 429P1-15 specification to the GAMA ARINC 429 specification and most equipment configuration routines will reflect this. Label 371 is used to identify the equipment by manufacturer. This label contains a hexadecimal equipment ID code (bits 11-18) followed by a binary company ID code (bits 19-24). This identification information is important if specific software sub-routines need to be implemented. Shown in the table below is a breakdown for label 012 which represents Groundspeed.

BIT POSITION	BIT 1	BIT 2	BIT 3	BIT 4	BIT 5	BIT 6	BIT 7	BIT 8
BIT WEIGHT	MSB							LSB
OCTAL WEIGHT	2	1	4	2	1	4	2	1
DATA	0	0	0	0	1	0	1	0

SDI

Bits 9 and 10 in the data contain what is called the Source Destination Identifier or SDI. This two bit field contains equipment condition, operating mode (System 1, 2, 3 or All Call) or data validity. When you configure a GPS or FMS as LRN1 or LRN2 for example you are setting the SDI bit pattern. A situation where bits 9 and 10 are required for part of the data field would be the BCD encoding of present position latitude/longitude as in Label 010(Lat.) and Label 011(Long.). When the receiving equipment is configured as System #1 then it will only want to decode and process data that is identified for System #1 and other data will be ignored. The table below depicts the SDI bit weighting.

BIT POSITION	BIT 9	BIT 10	IDENTIFICATION
	0	0	ALL CALL
	1	0	SYSTEM #1
	0	1	SYSTEM #2
	1	1	SYSTEM #3

DATA FIELD

The data field will contain the information so designated by the label preceding it. This field also may contain pad bits or discrete bits as mentioned previously. The pad bit would be used to fill out the field if that bit location was not required. A discrete bit might be imbedded through association such as the Marker light bits in VOR Label 222 where they occupy bits positions 11, 12 and 13. The bit weighting will be in the form of BCD or BNR as described in the 429 specification. The two tables below show the differences in the data fields between BCD and BNR encoding.

BIT 32	31 ← 30	29 ← 11
PARITY	SSM	BCD DATA FIELD / PAD / DISCRETES
		MSB LSB

BIT 32	31 ← 29	28 ← 11	10	9
PARITY	SSM	BNR DATA FIELD / PAD / DISCRETES		
		MSB		LSB

SSM FIELD

The Sign and Status Matrix field can represent many different conditions based on whether the data is encoded in BCD or BNR form. The BCD form utilizes only bits 30 and 31 as shown above where BNR encoding also employs bit 29. The tables below depict these two encoding forms and how they differ. There all always exceptions to rules, a case in point is for Label 030G which represents VHF Comm Frequency (BCD). This label will identify a logic "1" at bits 30 and 31 as a "Squelch Disable" condition.

BCD ENCODING

Bit 31	Bit 30	IDENTIFIED AS
0	0	PLUS, NORTH, EAST, RIGHT, TO, ABOVE
0	1	NO COMPUTED DATA (NCD)
1	0	FUNCTIONAL TEST
1	1	MINUS, SOUTH, WEST, LEFT, FR, BELOW

BNR ENCODING (SYSTEM STATUS)

Bit 31	Bit 30	IDENTIFIED AS
0	0	FAILURE WARNING
0	1	NO COMPUTED DATA (NCD)
1	0	FUNCTIONAL TEST
1	1	NORMAL OPERATION

BNR ENCODING (DATA SIGN)

	Bit 29	IDENTIFIED AS
	0	PLUS, NORTH, EAST, RIGHT, TO, ABOVE
	1	MINUS, SOUTH, WEST, LEFT, FROM, BELOW

PARITY

The Parity bit which occupies the last bit in the data stream (32) is intended for error detection and correction. This bit will constantly change as the label and data change in order to provide “Odd Parity”. What this means is that at any time the 32 bit word will always have an odd number of 1’s contained within it.

TROUBLESHOOTING

There are some simple checks that can be made to increase one’s confidence in the operation of the bus. Digital Storage oscilloscopes like the Agilent 54622D model can be a technician’s best friend. Storage scopes will allow you to freeze data in memory and then search through memory in time to analyze that data. This simple check will allow the technician to confirm the signal integrity of the transmit port. Normally if data is present on both the TX-A and TX-B lines the source is considered operational, just make sure the lines are not reversed. Selecting between High Speed and Low Speed bus operation is another simple check that will help confirm bus operation. The transmitted data does come out in a complimentary fashion and this is clearly seen by comparing the TX-A line to the TX-B line. If data is present and changing then specific Label verification is the next step. There are many bus analyzers out there from portable models to computer based cards. If your shop has invested in an analyzer then verifying just one label is all the confidence one needs to prove bus integrity. Next it’s on to Installation and/or Software Bulletins that might be applicable to your symptoms. The field support team for the equipment manufacturers can always be helpful to isolate a problem however sometimes only the software engineer may know the answer to your problem. In today’s environment where technical data is becoming more restricted, the systems more complex and integration more software dependent the technician needs to constantly sharpen his/her troubleshooting and insight skills as well as be provided the tools to perform the task. Persistence and knowledge are certainly important tools to have in this ever changing world. With respect to general knowledge a good tool to put in your shop library would be the Bendix/King training document entitled “Common Digital Circuitry”. This publication has proven very helpful over the years in not only maintaining their equipment but also just providing a good knowledge base. Reference documents from both ARINC and GAMA are also available on the 429 standard discussed in this article.

Kim Wiolland
Tech-Aid Products
Tulsa, Ok
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