2
ARINC 429

Daniel A. Martinec
ARINC

2.1 Introduction

ARINC Specifications 419, 429, and 629 and Project Paper 453 are documents prepared by the Airlines Electronic Engineering Committee (AEEC) and published by Aeronautical Radio, Inc. These are among over 300 air transport industry avionics standards published since 1949. These documents, commonly referred to as ARINC 419, ARINC 429, ARINC 453, and ARINC 629, describe data communication systems used primarily on commercial transport airplanes. A limited number of general aviation and military airplanes also use these data systems. The differences between the systems are described in detail in the subsequent sections.

2.2 ARINC 419

ARINC Specification 419, "Digital Data Compendium," provides detailed descriptions of the various interfaces used in the ARINC 500 series of avionics standards prior to 1980. ARINC Specification 419 is often incorrectly assumed to be a standalone bus standard. ARINC Specification 419 provides a summary of electrical interfaces, protocols, and data standards for avionics built prior to the airlines' selection of a single standard, i.e., ARINC 429, for the distribution of digital information aboard aircraft.

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2.3 ARINC 429

2.3.1 General

ARINC Specification 429, "Digital Information Transfer System (DITS)," was first published in 1977 and has since become the ARINC standard most widely used by the airlines. The title of this airline standard was chosen so as not to describe it as a "data bus." Although ARINC 429 is a vehicle for data transfer, it does not fit the normal definition of a data bus. A typical data bus provides multidirectional transfer of data between multiple points over a single set of wires. ARINC 429's simplistic one-way flow of data significantly limits this capability, but the associated low cost and the integrity of the installations have provided the airlines with a system exhibiting excellent service for more than two decades. Additional information regarding avionics standards may be found at URL http://www.arinc.com/aeec.

2.3.2 History

In the early 1970s the airlines recognized the potential advantage of implementation of digital equipment. Some digital equipment had already been implemented to a certain degree on airplanes existing at that time. However, there were three new transport airplanes on the horizon. These were the Airbus A-310 and the Boeing B-757 and B-767. The airlines, along with the airframe and equipment manufacturers, established a goal to create an all-new suite of avionics using digital technology.

Obviously, with digital avionics came the need for an effective means of data communications among the avionics units. The airlines recognized that the military was also in the early stages of development of a data bus that could perform the data transfer functions among military avionics. The potential for a joint program to produce a data bus common to the air transport industry and the military exhibited a potential for significant economical benefits.

The early work to develop the military's data bus was taken on by the Society of Automotive Engineers (SAE). Participants in the SAE program emanated from many parts of the military and private sectors of aviation. A considerable effort went into defining all aspects of the data bus with the goal of meeting the needs of both the military and air transport users. That work culminated in the development of the early version of the data bus identified by Mil-Std 1553 (see Chapter 1).

Early in the process of the Mil-Std 1553 development, representatives from the air transport industry realized that the stringent and wide range of military requirements would cause the Mil-Std 1553 to be overly complex for the commercial user and would not exhibit the flexibility to accommodate the varying applications of transport airplanes. Difficulty in certification also was considered a potential problem. The decision was made to abandon a cooperative data bus development program with the military and pursue work on a data bus to more closely reflect commercial airplane requirements.

Numerous single transmitter/multiple receiver data transfer systems were being used on airplanes built in the early 1970s. These proved to be reliable and efficient compared to the more complex data buses of the time. These transfer systems, described in ARINC Specification 419, were considered as candidates for the new digital aircraft.

While none of the systems addressed in the ARINC Specification could adequately perform the task, each exhibited desirable characteristics that could be applied to a new design. The result was the release of a new data transfer system exhibiting a high level of efficiency, extremely good reliability, and ease of certification. ARINC 429 became the industry standard. Subsequent to release of the standard, numerous low-cost integrated circuits were produced by solid-state component manufacturers. ARINC 429 was used widely by the air transport industry and even found applications in non-aviation commercial and military applications. ARINC 429 has been used as the standard for virtually all ARINC 700-series standards for "digital avionics" used by the air transport industry.

Aeronautical Radio Inc. has maintained and provided the necessary routine updates for new data word assignments and formats. There were no significant changes in the basic design until 1980 when operational experience showed that certain shorted wire conditions would allow the bus to operate in

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a faulty condition. The bus would operate in this condition with much reduced noise immunity. This condition also proved to be very difficult to locate during routine maintenance. In response, the airlines suggested that the design be changed in order to ensure that the bus would not continue to operate when this condition occurred. A change to the receiver voltage thresholds and impedances solved this problem.

No basic changes to the design have been made since that time. ARINC 429 has remained a reliable system and even today is used extensively in the most modern commercial airplanes.

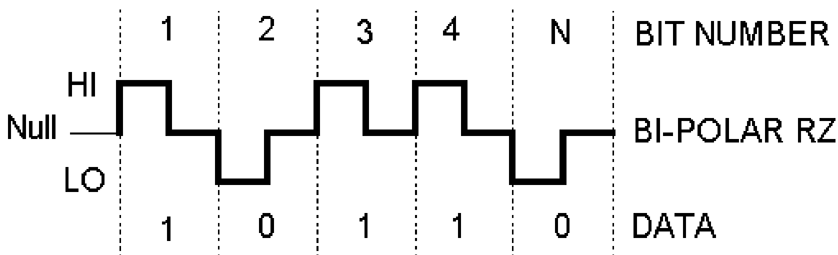
2.3.3 Design Fundamentals

2.3.3.1 Equipment Interconnection

A single transmitter is connected with up to 20 data receivers via a single twisted and shielded pair of wires. The shields of the wires are grounded at both ends and at any breaks along the length of the cable. The shields are kept as short as possible.

2.3.3.2 Modulation

Return-To-Zero (RZ) modulation is used. The voltage levels are used for this modulation scheme.



2.3.3.3 Voltage Levels

The differential output voltages across the transmitter output terminal with no load is described in the following table:

	HI(V)	NULL(V)	LO(V)
Line A to Line B	$+10 \pm 1.0$	0 ± 0.5	-10 ± 1.0
Line A to Ground	5 ± 0.5	0 ± 0.25	-5 ± 0.5
Line B to Ground	-5 ± 0.5	0 ± 0.25	$+5 \pm 0.5$

The differential voltage seen by the receiver will depend on wire length, loads, stubs, etc. With no noise present on the signal lines the nominal voltages at the receiver terminals (A and B) would be

HI	$+7.25$V to $+11$V
NULL	$+0.5$V to -0.5V
LO	-7.25V to -11V

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In practical installations impacted by noise, etc. The following voltages ranges will be typical across the receiver input (A and B):

HI	$+6.5V$ to $+13V$
NULL	$+2.5V$ to $-2.5V$
LO	$-6.5V$ to $-13V$

Line (A or B) to ground voltages are not defined.

Receivers are expected to withstand without damage steady-state voltages of 30 VAC RMS applied across terminals A and B, or ± 29 VDC applied between terminal A or B and the ground.

2.3.3.4 Impedance Levels

2.3.3.4.1 Transmitter Output Impedance

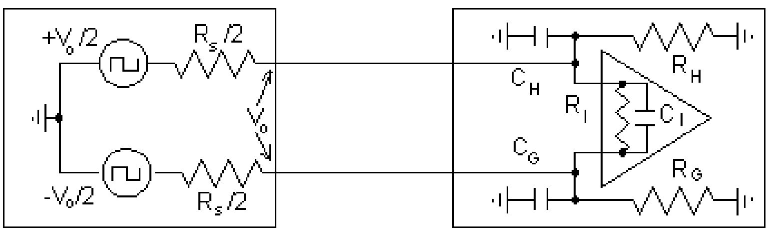
The transmitter output impedance is 70 to 80 (nominal 75) ohms and is divided equally between lines A and B for all logic states and transitions between those states.

2.3.3.4.2 Receiver Input Impedance

The typical receiver input characteristics are as follows:

Differential Input Resistance $R_I = 12{,}000$ ohms minimum
Differential Input Capacitance $C_I = 50$ pF maximum
Resistance to Ground R_H and $R_G \geq 12{,}000$ ohms
Capacitance to Ground C_H and $C_G \leq 50$ pF

The total receiver input resistance including the effects of R_I, R_H and R_G in parallel is 8000 ohms minimum (400 ohms minimum for 20 receivers). A maximum of 20 receivers is specified for any one transmitter. See below for the circuit standards.



2.3.3.4.3 Cable Impedance

The wire gauges used in the interconnecting cable will typically vary between 20 and 26 depending on desired physical integrity of the cable and weight limitations. Typical characteristic impedances will be in the range of 60 to 80 ohms. The transmitter output impedance was chosen at 75 ohms nominal to match this range.

2.3.3.5 Fault Tolerance

The electrical power on an airplane is provided by a generator on each engine. The airplane electrical system is designed to take into account any variation in engine speeds, phase differentials, power bus switching, etc. However, it is virtually impossible to ensure that the power source will be perfect at all times. Failures within a system can also cause erratic power levels. The design of the ARINC 429 components take power variation into account and are not generally susceptible to either damage or erratic operation when those variations occur. The ranges of those variations are provided in the following sections.

2.3.3.5.1 Transmitter External Fault Voltage

Transmitter failures caused by external fault voltages will not typically cause other transmitters or other circuitry in the unit to function outside of their specification limits or to fail.

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2.3.3.5.2 Transmitter External Fault Load Tolerance

Transmitters should indefinitely withstand without sustaining damage a short circuit applied:

a. across terminals A and B, or
b. from terminal A to ground, or
c. from terminal B to ground, or
d. b and c above, simultaneously.

2.3.3.6 Fault Isolation

2.3.3.6.1 Receiver Fault Isolation

Each receiver incorporates isolation provisions to ensure that the occurrence of any reasonably probable internal LRU or bus receiver failure does not cause any input bus to operate outside its specification limits (both undervoltage or overvoltage).

2.3.3.6.2 Transmitter Fault Isolation

Each transmitter incorporates isolation provisions to ensure that it does not under any reasonably probable equipment fault condition provide an output voltage in excess of:

a. a voltage greater than 30 VAC RMS between terminal A and B, or
b. greater than ±29VDC between A and ground, or
c. greater than ±29 VDC between B and ground.

2.3.3.7 Logic-Related Elements

This section describes the digital transfer system elements considered to be principally related to the logic aspects of the signal circuit.

2.3.3.7.1 Digital Language

Numeric Data — The ARINC 429 accommodates numeric data encoded in two digital languages, (a) BNR expressed in two's complement fractional notation, and (b) BCD per the numerical subset of ISO Alphabet No. 5. An information item encoded in both languages is assigned a unique address for each (see Section 2.4.3).

Discrete Data — In addition to handling numeric data as specified above, ARINC 429 is also capable of accommodating discrete items of information either in the unused (pad) bits of data words or, when necessary, in dedicated words.

The rule in the assignment of bits in discrete numeric data words is to start with the least significant bit of the word and to continue towards the most significant bit available in the word. There are two types of discrete words. These are general purpose discrete words, and dedicated discrete words. Seven labels (270 XX–276 XX) are assigned to the general purpose discrete words. These words are assigned in ascending label order (starting with 270 XX), where XX is the equipment identifier.

32	31 30	29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11	10 9	8 7 6 5 4 3 2 1
P	SSM	DATA → ← PAD ← DISCRETES MSB ... LSB	SDI	LABEL

Generalized BCD Word Format

P	SSM		BCD CH #1			BCD CH #2				BCD CH #3				BCD CH #4				BCD CH #5				SDI		8	7	6	5	4	3	2	1
			4	2	1	8	4	2	1	8	4	2	1	8	4	2	1	8	4	2	1										
0	0	0	0	1	0	0	1	0	1	0	1	1	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1
Example			2			5				7				8				6				DME DISTANCE									

BCD Word Format Example (No Discretes)

32	31 30 29	28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11	10 9	8 7 6 5 4 3 2 1
P	SSM	DATA → ← PAD ← DISCRETES MSB ... LSB	SDI	LABEL

Generalized BCD Word Format

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Maintenance Data (General Purpose)—The general purpose Maintenance words are assigned labels in sequential order as are the labels for the general purpose Discrete words. The lowest octal value label assigned to the Maintenance words is used when only one Maintenance word is transmitted. When more than one word is transmitted the lowest octal value label is used first and the other labels used sequentially until the message has been completed. The General Purpose Maintenance words may contain Discrete, BCD, or BNR Numeric data. They do not contain ISO Alphabet No. 5 messages. The General Purpose Maintenance words are formatted according to the layouts of the corresponding BCD/BNR/Discrete data words shown above.

2.4 Message and Word Formatting

2.4.1 Direction of Information Flow

The information output of a system element is transmitted from a designated port (or ports) to which the receiving ports of other system elements in need of that information are connected. In no case does information flow into a port designated for transmission. A separate data bus (twisted and shielded pair of wires) is used for each direction when data are required to flow both ways between two system elements.

2.4.2 Information Element

The basic information element is a digital word containing 32 bits. There are five application groups for such words, BNR data, BCD data, Discrete data, Maintenance data (general) and Acknowledgment, ISO Alphabet No. 5 and Maintenance (ISO Alphabet No. 5) data (AIM). The relevant data handling rules are set forth in Section 2.4.6. When less than the full data field is needed to accommodate the information conveyed in a word in the desired manner, the unused bit positions are filled with binary zeros or, in the case of BNR/BCD numeric data, valid data bits. If valid data bits are used, the resolution may exceed the accepted standard for an application.

2.4.3 Information Identifier

The type of information contained in a word is identified by a six-character label. The first three characters are octal characters coded in binary in the first eight bits of the word. The eight bits will identify the information contained within BNR and BCD numeric data words (e.g., DME distance, static air temperature, etc.) and identify the word application for Discrete, Maintenance, and AIM data.

The last three characters of the six-character label are hexadecimal characters used to provide for identification of ARINC 429 bus sources. Each triplet of hexadecimal characters identifies a system element with one or more DITS ports. Each three character code (and black box) may have up to 255 eight-bit labels assigned to it. The code is used administratively to retain distinction between unlike parameters having like labels assignments.

Octal label 377 has been assigned for the purpose of electrically identifying the system element. The code appears in the three least significant digits of the 377 word in a BCD Word format. The transmission of the equipment identifier word on a bus will permit receivers attached to the bus to recognize the source of the DITS information. Since the transmission of the equipment identifier word is optional, receivers should not depend on that word for correct operation.

2.4.4 Source/Destination Identifier

Bit numbers 9 and 10 of numeric data words are used for a data source/destination identification function. They are not available for this function in alpha/numeric (ISO Alphabet No. 5) data words of this document or when the resolution needed for numeric (BNR/BCD) data necessitates their use for valid data. The source/destination identifier function may find application when specific words need to be directed to a specific system of a multisystem installation or when the source system of a multisystem installation needs to be recognizable from the word content. When it is used, a source equipment encodes its aircraft installation number in bits 9 and 10 as shown in the following table. A

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sink equipment will recognize words containing its own installation number code *and* words containing code "00," the "all-call" code.

Equipment will fall into the categories of source only, sink only, or both source and sink. Use of the SDI bits by equipment functioning only as a source or only as a sink is described above. *Both* the source and sink texts above are applicable to equipment functioning as both a source and a sink. Such equipment will recognize the SDI bits on the inputs and also encode the SDI bits, as applicable, on the outputs. DME, VOR, ILS, and other sensors, are examples of source and sink equipment generally considered to be only source equipment. These are actually sinks for their own control panels. Many other types of equipment are also misconstrued as source only or sink only. If a unit has a 429 input port and a 429 output port, it is a source and sink! With the increase of equipment consolidation, e.g., centralized control panels, the correct use of the SDI bits cannot be overstressed.

Bit No.		Installation No.
10	9	See text
0	0	
0	1	1
1	0	2
1	1	3

Note: In certain specialized applications of the SDI function the all-call capability may be forfeited so that code "00" is available as an "installation no. 4" identifier.

When the SDI function is not used, binary zeros or valid data should be transmitted in bits 9 and 10.

2.4.5 Sign/Status Matrix

This section describes the coding of the Sign/Status Matrix (SSM) field. In all cases the SSM field uses bits 30 and 31. For BNR data words, the SSM field also includes bit 29.

The SSM field is used to report hardware equipment condition (fault/normal), operational mode (functional test), or validity of data word content (verified/no computed data). The following definitions apply:

Invalid Data—Is defined as any data generated by a source system whose fundamental characteristic is the inability to convey reliable information for the proper performance of a user system. There are two categories of invalid data, namely, "No Computed Data" and "Failure Warning."

No Computed Data—Is a particular case of data invalidity where the source system is unable to compute reliable data for reasons other than system failure. This inability to compute reliable data is caused exclusively by a definite set of events or conditions whose boundaries are uniquely defined in the system characteristic.

Failure Warning—Is a particular case of data invalidity where the system monitors have detected one or more failures. These failures are uniquely characterized by boundaries defined in the system characteristic.

Displays are normally "flagged invalid" during a "Failure Warning" condition. When a "No Computed Data" condition exists, the source system indicates that its outputs are invalid by setting the sign/status matrix of the affected words to the "No Computed Data" code, as defined in the subsections which follow. The system indicators may or may not be flagged depending on system requirements.

While the unit is in the functional test mode, all output data words generated within the unit (i.e., pass-through words are excluded) are coded with "Functional Test." Passthrough data words are those words received by the unit and retransmitted without alteration.

When the SSM code is used to transmit status and more than one reportable condition exists, the condition with the highest priority is encoded in bits number 30 and 31. The order of condition priorities

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is shown in the table below.

Failure Warning	Priority 1
No Computed Data	Priority 2
Functional Test	Priority 3
Normal Operation	Priority 4

Each data word type has its own unique utilization of the SSM field. These various formats are described in the following sections.

2.4.5.1 BCD Numeric

When a failure is detected within a system which would cause one or more of the words normally output by that system to be unreliable, the system stops transmitting the affected word or words on the data bus.

Some avionic systems are capable of detecting a fault condition which results in less than normal accuracy. In these systems, when a fault of this nature (for instance, partial sensor loss which results in degraded accuracy) is detected, each unreliable BCD digit is encoded "1111" when transmitted on the data bus. For equipment having a display, the "1111" code should, when received, be recognized as representing an inaccurate digit and a "dash" or equivalent symbol is normally displayed in place of the inaccurate digit.

The sign (plus/minus, north/south, etc.) of BCD Numeric Data is encoded in bits 30 and 31 of the word as shown in the table below. Bits 30 and 31 of BCD Numeric Data words are "zero" where no sign is needed.

The "No Computed Data" code is annunciated in the affected BCD Numeric Data word(s) when a source system is unable to compute reliable data for reasons other than system failure. When the "Functional Test" code appears in bits 30 and 31 of an instruction input data word, it is interpreted as a command to perform a functional test.

BCD Numeric Sign/Status Matrix

Bit No		
31	30	Function
0	0	Plus, North, East, Right, To, Above
0	1	No Computed Data
1	0	Functional Test
1	1	Minus, South, West, Left, From, Below

2.4.5.2 BNR Numeric Data Words

The status of the transmitter hardware is encoded in the Status Matrix field (bit numbers 30 and 31) of BNR Numeric Data words as shown in the table below.

A source system annunciates any detected failure that causes one or more of the words normally output by that system to be unreliable by setting bit numbers 30 and 31 in the affected word(s) to the "Failure Warning" code defined in the table below. Words containing this code continue to be supplied to the data bus during the failure condition.

The "No Computed Data" code is annunciated in the affected BNR Numeric Data word(s) when a source system is unable to compute reliable data for reasons other than system failure.

When the "Functional Test" code appears as a system output, it is interpreted as advice that the data in the word result from the execution of a functional test. A functional test produces indications of 1/8 of positive full-scale values unless indicated otherwise in an ARINC equipment Characteristic.

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If, during the execution of a functional test, a source system detects a failure which causes one or more of the words normally output by that system to be unreliable, it changes the states of bits 30 and 31 in the affected words such that the "Functional Test" annunciation is replaced with a "Failure Warning" annunciation.

Status Matrix

Bit No		
31	30	Function
0	0	Failure Warning
0	1	No Computed Data
1	0	Functional Test
1	1	Normal Operation

The sign (plus, minus, north, south, etc.) of BNR Numeric Data words are encoded in the Sign Matrix field (bit 29) as shown in the table below. Bit 29 is "zero" when no sign is needed.

Status Matrix

Bit No. 29	Function
0	Plus, North, East, Right, To, Above
1	Minus, South, West, Left, From, Below

Some avionic systems are capable of detecting a fault condition which results in less than normal accuracy. In these systems, when a fault of this nature (for instance, partial sensor loss which results in degraded accuracy) is detected, the equipment will continue to report "Normal" for the sign status matrix while indicating the degraded performance by coding bit 11 as follows:

Accuracy Status

Bit No. 11	Function
0	Nominal Accuracy
1	Degraded Accuracy

This implies that degraded accuracy can be coded only in BNR words not exceeding 17 bits of data.

2.4.5.3 Discrete Data Words

A source system annunciates any detected failure that could cause one or more of the words normally output by that system to be unreliable. Three methods are defined. The first method is to set bits 30 and 31 in the affected word(s) to the "Failure Warning" code defined in the table below. Words containing the "Failure Warning" code continue to be supplied to the data bus during the failure condition. When using the second method, the equipment may stop transmitting the affected word or words on the data bus. This method is used when the display or utilization of the discrete data by a system is undesirable. The third method applies to data words which are defined such that they contain failure information within the data field. For these applications, the associated ARINC equipment Characteristic specifies the proper SSM reporting. Designers are urged not to mix operational and BITE data in the same word.

The "No Computed Data" code is annunciated in the affected Discrete Data word(s) when a source system is unable to compute reliable data for reasons other than system failure. When the "Functional

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Test" code appears as a system output, it is interpreted as advice that the data in the Discrete Data word contents are the result of the execution of a functional test.

Discrete Data Words

Bit No.		
31	30	Function
0	0	Verified Data, Normal Operation
0	1	No Computed Data
1	0	Functional Test
1	1	Failure Warning

2.4.6 Data Standards

The units, ranges, resolutions, refresh rates, number of significant bits, pad bits, etc. for the items of information to be transferred by the Mark 33 DITS are administered by the AEEC and tabulated in ARINC Characteristic 429.

ARINC Characteristic 429 calls for numeric data to be encoded in BCD and binary, the latter using two's complement fractional notation. In this notation, the most significant bit of the data field represents one half of the maximum value chosen for the parameter being defined. Successive bits represent the increments of a binary fraction series. Negative numbers are encoded as the two's complements of positive value and the negative sign is annunciated in the sign/status matrix.

In establishing a given parameter's binary data standards, the unit's maximum value and resolution are first determined in that order. The least significant bit of the word is then given a value equal to the resolution increment, and the number of significant bits is chosen such that the maximum value of the fractional binary series just exceeds the maximum value of the parameter, i.e., equals the next whole binary number greater than the maximum parameter value less one least significant bit value. For example, to transfer altitude in units of feet over a range of zero to 100,000 ft with a resolution of 1 ft, the number of significant bits is 17 and the maximum value of the fractional binary series is 131,071 (i.e., 131,072 − 1).

Note that because accuracy is a quality of the measurement process and not the data transfer process, it plays no part in the selection of word characteristics. Obviously, the resolution provided in the data word should equal or exceed the accuracy in order not to degrade it.

For the binary representation of angular data, the ARINC 429 employs "degrees divided by 180°" as the unit of data transfer and ±1 (semicircle) as the range for two's complement fractional notation encoding (ignoring, for the moment, the subtraction of the least significant bit value). Thus the angular range 0 through 359.XXX degrees is encoded as 0 through ±179.XXX degrees, the value of the most significant bit is one half semicircle and there are no discontinuities in the code.

This may be illustrated as follows. Consider encoding the angular range 0° to 360° in 1° increments. Per the general encoding rules above, the positive semicircle will cover the range 0° to 179° (one least significant bit less than full range). All the bits of the code will be "zeros" for 0° and "ones" for 179°, and the sign/status matrix will indicate the positive sign. The negative semicircle will cover the range 180° to 359°. All the bits will be "zeros" for 180°. The codes for angles between 181° to 359° will be determined by taking the two's complements of the fractional binary series for the result of subtracting each value from 360. Thus, the code for 181° is the two's complement of the code for 179°. Throughout the negative semicircle, which includes 180°, the sign/status matrix contains the negative sign.

2.5 Timing-Related Elements

This section describes the digital data transfer system elements considered to be principally related to the timing aspects of the signal circuit.

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2.5.1 Bit Rate

2.5.1.1 High-Speed Operation

The bit rate for high-speed operation of the system is 100 kilobits per second (kbps) ±1%.

2.5.1.2 Low-Speed Operation

The bit rate for low-speed operation of the system is within the range 12.0 to 14.5 kbps. The selected rate is maintained within 1%.

2.5.2 Information Rates

The minimum and maximum transmit intervals for each item of information are specific by ARINC Specification 429. Words with like labels but with different SDI codes are treated as unique items of information. Each and every unique item of information is transmitted once during an interval bounded in length by the specified minimum and maximum values. Stated another way, a data word having the same label and four different SDI codes will appear on the bus four times (once for each SDI code) during that time interval.

Discrete bits contained within data words are transferred at the bit rate and repeated at the update rate of the primary data. Words dedicated to discretes should be repeated continuously at specified rates.

2.5.3 Clocking Method

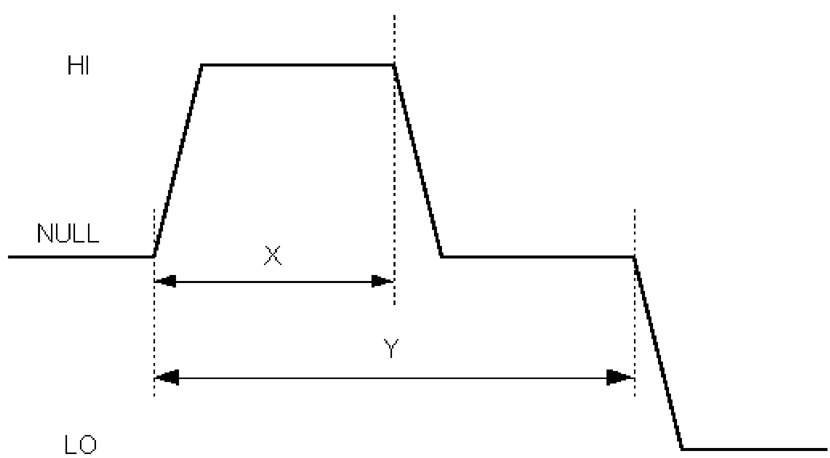
Clocking is inherent in the data transmission. The identification of the bit interval is related to the initiation of either a HI or LO state from a previous NULL state in a bipolar RZ code.

2.5.4 Word Synchronization

The digital word should be synchronized by reference to a gap of four bit times (minimum) between the periods of word transmissions. The beginning of the first transmitted bit following this gap signifies the beginning of the new word.

2.5.5 Timing Tolerances

The waveform timing tolerances are shown below:



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Parameter	High-Speed Operation	Low-Speed Operation
Bit Rate	100 kbps ± 1%	12–14.5 kbps
Time Y	10 μsec ± 2.5%	Z[a] μsec ± 2.5%
Time X	5 μsec ± 5%	Y/2 ± 5%
Pulse Rise Time	1.5 ± 0.5 μsec	10 ± 5 μsec
Pulse Fall Time	1.5 ± 0.5 μsec	10 ± 5 μsec

Note: Pulse rise and fall times are measured between the 10% and 90% voltage amplitude points on the leading and trailing edges of the pulse and include time skew between the transmitter output voltages A-to-ground and B-to-ground.

[a]Z = 1/R where R = bit rate selected from 12–14.5 kbps range.

2.6 Communications Protocols

2.6.1 Development of File Data Transfer

ARINC Specification 429 was adopted by AEEC in July 1977. Specification 429 defined a broadcast data bus. General provisions were made for file data transfer. In October 1989, AEEC updated a file data transfer procedure with a more comprehensive process that will support the transfer of both bit- and character-oriented data. The new protocol became known popularly as the "Williamsburg Protocol."

2.6.1.1 File Data Transfer Techniques

This "File Data Transfer Techniques" specification describes a system in which an LRU may generate binary extended length messages "on demand." Data is sent in the form of Link Data Units (LDU) organized in 8-bit octets. System Address Labels (SAL) are used to identify the recipient. Two data bus speeds are supported.

2.6.1.2 Data Transfer

The same principles of the physical layer implementation apply to file data transfer. Any avionics system element having information to transmit does so from a designated output port over a single twisted and shielded pair of wires to all other system elements having need of that information. Unlike the simple broadcast protocol that can deliver data to multiple recipients in a single transmission, the file transfer technique can be used only for point-to-point message delivery.

2.6.1.3 Broadcast Data

The broadcast transmission technique described above can be supported concurrently with file data transfer.

2.6.1.4 Transmission Order

The most significant octet of the file and least significant bit (LSB) of each octet should be transmitted first. The label is transmitted ahead of the data in each case. It may be noted that the Label field is encoded in reverse order, i.e., the least significant bit of the word is the most significant bit of the label. This "reversed label" characteristic is a legacy from past systems in which the octal coding of the label field was, apparently, of no significance.

2.6.1.5 Data Bit Encoding Logic

A HI state after the beginning of the bit interval returning to a NULL state before the end of the same bit interval signifies a logic "one." A LO state after the beginning of the bit interval returning to a NULL state before the end of the same bit interval signifies a logic "zero."

2.6.1.6 Bit-Oriented Protocol Determination

An LRU will require logic to determine which protocol (character- or bit-oriented) and which version to use when prior knowledge is not available.

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2.6.2 Bit-Oriented Communications Protocol

This subsection describes Version 1 of the bit-oriented (Williamsburg) protocol and message exchange procedures for file data transfer between units desiring to exchange bit-oriented data assembled in data files. The bit-oriented protocol is designed to accommodate data transfer between sending and receiving units in a form compatible with the Open Systems Interconnect (OSI) model developed by the International Standards Organization (ISO). This document directs itself to an implementation of the Link layer, however, an overview of the first four layers (Physical, Link, Network, and Transport) is provided.

Communications will permit the intermixing of bit-oriented file transfer data words (which contain System Address Labels [SALs]) with conventional data words (which contain label codes). If the sink should receive a conventional data word during the process of accepting a bit-oriented file transfer message, the sink should accept the conventional data word and resume processing of the incoming file transfer message.

The data file and associated protocol control information are encoded into 32-bit words and transmitted over the physical interface. At the Link layer, data are transferred using a transparent bit-oriented data file transfer protocol designed to permit the units involved to send and receive information in multiple word frames. It is structured to allow the transmission of any binary data organized into a data file composed of octets.

1. *Physical Medium.* The physical interface is described above.
2. *Physical Layer.* The Physical layer provides the functions necessary to activate, maintain, and release the physical link which will carry the bit stream of the communication. The electrical interface, voltage, and timing, described above, is used by the interfacing units. Data words will contain 32 bits; bits 1 through 8 will contain the System Address Label (SAL) and bit 32 will be the parity (odd) bit.
3. *Link Layer.* The Link layer is responsible for transferring information from one logical network entity to another and for enunciating any errors encountered during transmission. The Link layer provides a highly reliable virtual channel and some flow control mechanisms.
4. *Network Layer.* It is the responsibility of the Network layer to ensure that data packets are properly routed between any two terminals. The Network layer performs a number of functions. The Network layer expects the Link layer to supply data from correctly received frames. The Network layer provides for the decoding of information up to the packet level to determine which node (unit) the message should be transferred to. To obtain interoperability, this process, though simple in this application, must be reproduced using the same set of rules throughout all the communications networks (and their subnetworks) on-board the aircraft and on the ground. The bit-oriented data link protocol was designed to operate in a bit-oriented Network layer environment. Specifically, ISO 8208 would typically be selected for the Subnetwork layer protocol for air/ground subnetworks. There are, however, some applications where the bit-oriented file transfer protocol will be used under other Network layer protocols.
5. *Transport Layer.* The Transport layer controls the transportation of data between a source end-system to a destination end-system. It provides "network independent" data delivery between these processing end-systems. It is the highest order of function involved in moving data between systems. It relieves higher layers from any concern with the pure transportation of information between them.

2.6.2.1 Link Data Units (LDU)

A Link Data Unit (LDU) contains binary encoded octets. The octets may be set to any possible binary value. The LDU may represent raw data, character data, bit-oriented messages, character-oriented messages, or any string of bits desired. The only restriction is that the bits be organized into full 8-bit octets. The interpretation of those bits is not a part of this Link layer protocol. The LDUs are assembled to make up a data file.

LDUs consist of a set of contiguous ARINC 429 32-bit data words, each containing the System Address Label (see Section 2.6.2.3) of the sink. The initial data word of each LDU is a Start of Transmission

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(SOT). The data described above are contained within the data words which follow. The LDU is concluded with an End of Transmission (EOT) data word. No data file should exceed 255 LDUs.

Within the context of this document, LDUs correspond to frames and files correspond to packets.

2.6.2.2 Link Data Unit (LDU) Size and Word Count

The Link Data Unit (LDU) may vary in size from 3 to 255 ARINC 429 words including the SOT and EOT words. When a LDU is organized for transmission, the total number of ARINC 429 words to be sent (word count) is calculated. The word count is the sum of the SOT word, the data words in the LDU, and the EOT word.

In order to obtain maximum system efficiency, the data is typically encoded into the minimum number of LDUs.

The word count field is 8 bits in length. Thus the maximum number of ARINC 429 words that can be counted in this field is 255. The word count field appears in the RTS and CTS data words. The number of LDUs needed to transfer a specific data file will depend upon the method used to encode the data words.

2.6.2.3 System Address Labels (SALs)

LDUs are sent point-to-point, even though other systems may be connected and listening to the output of a transmitting system. In order to identify the intended recipient of a transmission, the Label field (bits 1–8) is used to carry a System Address Label (SAL). Each on-board system is assigned a SAL. When a system sends an LDU to another system, the sending system (the "source") addresses each ARINC 429 word to the receiving system (the "sink") by setting the Label field to the SAL of the sink. When a system receives any data containing its SAL that is not sent through the established conventions of this protocol, the data received are ignored.

In the data transparent protocol, data files are identified by content rather than by ARINC 429 label. Thus, the label field loses the function of parameter identification available in broadcast communications.

2.6.2.4 Bit Rate and Word Timing

Data transfer may operate at either high speed or low speed. The source introduces a gap between the end of each ARINC 429 word transmitted and the beginning of the next. The gap should be 4 bit times (minimum). The sink should be capable of receiving the LDU with the minimum word gap of 4 bit times between words. The source should not exceed a maximum average of 64 bit times between data words of an LDU.

The maximum average word gap is intended to compel the source to transmit successive data words of an LDU without excessive delay. This provision prevents a source that is transmitting a short message from using the full available LDU transfer time. The primary value of this provision is realized when assessing a maximum LDU transfer time for short fixed-length LDUs, such as for Automatic Dependence Surveillance (ADS).

If a Williamsburg source device were to synchronously transmit long length or full LDUs over a single ARINC 429 data bus to several sink devices, the source may not be able to transmit the data words for a given LDU at a rate fast enough to satisfy this requirement because of other bus activity. In aircraft operation, given the asynchronous burst mode nature of Williamsburg LDU transmissions, it is extremely unlikely that a Williamsburg source would synchronously begin sending a long length or full LDU to more than two Williamsburg sink devices. A failure to meet this requirement will either result in a successful (but slower) LDU transfer, or an LDU retransmission due to an LDU transfer time-out.

2.6.2.5 Word Type

The Word Type field occupies bit 31–29 in all bit-oriented LDU words. The Word Type field is used to identify the function of each ARINC 429 data word used by the bit-oriented communication protocol.

2.6.2.6 Protocol Words

The protocol words are identified with a Word Type field of "100" and are used to control the file transfer process.

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2.6.2.6.1 Protocol Identifier

The protocol identifier field occupies bits 28–25 of the protocol word and identifies the type of protocol word being transmitted. Protocol words with an invalid protocol identifier field are ignored.

2.6.2.6.2 Destination Code

Some protocol words contain a Destination Code. The Destination Code field (bits 24–17) indicates the final destination of the LDU. If the LDU is intended for the use of the system receiving the message, the destination code may be set to null (hex 00). However, if the LDU is a message intended to be passed on to another on-board system, the Destination Code will indicate the system to which the message is to be passed. The Destination Codes are assigned according to the applications involved. The codes are used in the Destination Code field to indicate the address of the final destination of the LDU.

In an OSI environment, the Link layer protocol is not responsible for validating the destination code. It is the responsibility of the higher-level entities to detect invalid destination codes and to initiate error logging and recovery.

Within the pre-OSI environment, the Destination Code provides Network layer information. In the OSI environment, this field may contain the same information for routing purposes between OSI and non-OSI systems.

2.6.2.6.3 Word Count

Some protocol words contain a Word Count field. The Word Count field (bits 16–9) reflects the number of ARINC 429 words to be transmitted in the subsequent LDU. The maximum word count value is 255 ARINC 429 words and the minimum word count value is 3 ARINC 429 words. A LDU with the minimum word count value of 3 ARINC 429 words would contain a SOT word, one data word, and an EOT word. A LDU with the maximum word count value of 255 ARINC 429 words would contain a SOT word, 253 data words, and an EOT word.

2.7 Applications

2.7.1 Initial Implementation

ARINC 429 was first used in the early 1980s on the Airbus A-310 and Boeing B-757 and B-767 airplanes. Virtually all data transfer on these airplanes was accommodated by approximately 150 separate buses interconnecting computers, radios, displays, controls, and sensors. Most of these buses operate at the lower speed. The few that operate at the higher speed of 100 kbps are typically connected to critical navigation computers.

2.7.2 Evolution of Controls

The first applications of ARINC 429 for controlling devices were based on the federated avionics approach used on airplanes which comprised mostly analog interfaces. Controllers for tuning communications equipment used an approach defined as two-out-of-five tuning. Each digit of the desired radio frequency was encoded on each set of five wires. Multiple digits dictated the need for multiple sets of wires for each radio receiver.

The introduction of ARINC 429 proved to be a major step toward reduction of wires. A tuning unit needed only one ARINC 429 bus to tune multiple radios of the same type. An entire set of radios and navigation receivers could be tuned with a few control panels, using approximately the same number of wires previously required to tune a single radio.

As cockpit space became more critical, the need to reduce the number of control panels became critical. The industry recognized that a single control panel, properly configured, could replace most of the existing control panels. The Multi-Purpose Control/Display Unit (MCDU) emanated from the industry effort. The MCDU was derived essentially from the control and display approach used by the rather

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sophisticated controller for the Flight Management System. For all intents and purposes, the MCDU became the cockpit controller.

A special protocol had to be developed for ARINC 429 to accommodate the capability of addressing different units connected to a single ARINC 429 bus from the MCDU. The protocol employed two-way communications using two pairs of wires between the controlling unit and the controlled device. An addressing scheme provided for selective communications between the controlling unit and any one of the controlled units. Only one output bus from the controller is required to communicate addresses and commands to the receiving units. With the basic ARINC 429 design, up to 20 controlled units could be connected to the output of the controller. Each of the controlled units is addressed by an assigned SAL.

2.7.3 Longevity of ARINC 429

New airplane designs in the 21st century continue to employ the ARINC 429 bus for data transmission. The relative simplicity and integrity of the bus, as well as the ease of certification are characteristics that contribute to the continued selection of the ARINC 429 bus when the required data bandwidth is not critical. The ARINC 629 data bus developed as the replacement for ARINC 429 is used in applications where a large amount of data must be transferred or where many sources and sinks are required on a single bus.

2.8 ARINC 453

ARINC Project Paper 453 was developed by the Airlines Electronic Engineering Committee (AEEC) in response to an anticipated requirement for data transfer rates higher than achievable with ARINC 429. The original drafts of Project Paper 453 were based on techniques already employed at that time. The electrical characteristics, including the physical medium, voltage thresholds, and modulation techniques were based on Mil-Std 1553. The data protocols and formats were based on those used in ARINC Specification 429.

During the preparation of the drafts of Project Paper 453, the Boeing Company petitioned AEEC to consider the use of the Digital Autonomous Terminal Access Communications (DATAC) Bus developed by the Boeing Company to accommodate higher data throughput. AEEC accepted Boeing's recommendation for the alternative. ARINC 629 was based on the original version of the Boeing DATAC Bus. The work on Project 453 was then curtailed. The latest draft of Project Paper 453 is maintained by ARINC for reference purposes only.

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