Common Airborne Instrumentation System

CAIS

CAIS Bus Interface Standard

A00.00-C001

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Rev A

CAIS Joint Program Office

Naval Air Warfare Center

Aircraft Division

Patuxent River, MD 20670-5304

Department of the Navy
Naval Air Warfare Center Aircraft Division
Patuxent River, Maryland 20670-5304

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Released by:

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Revision History

Revision	Date	Sections Affected	Comments
Original	--/--/--		Never released. Original document exists as a collection of papers, documents, and notes. Original CAIS units were built to this.
A	7/31/97	All	Document was rewritten from an Interface Control Document to an Interface Standard. This allows standardizing on more than just the interface. One of the major changes increased the "Command Type" field from 3 to 4 bits to allow for growth. New commands will be added carefully since current DAUs do not decode the 4th bit.

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1. INTRODUCTION

1.1 Purpose

This Interface Standard was written to provide a single document that designers of CAIS Bus Controllers (CBCs), Data Acquisition Units (DAUs), and CAIS bus monitors could reference to ensure interoperability on the CAIS bus. It is not the intent of this document to provide operational details for any CAIS units.

1.2 Responsibility

The Office of the Secretary of Defense (OSD) has established the CAIS Joint Program Office (CAIS JPO) as the overall controlling activity for the CAIS program. The CAIS JPO is responsible for the content and changes to this standard. The government shall not be responsible for any ambiguities in this document. If any ambiguities are identified, the burden is on the contractor to bring the ambiguities to the attention of the government. Additional copies of this document may be obtained from the CAIS web page (www.nawcad.navy.mil/cais) or the Defense Technical Information Center (DTIC).

1.3 Scope

This standard establishes the requirements for digital command/response, time division multiplexing techniques for a single CAIS bus. It encompasses the physical, electrical, and protocol aspects of the CAIS bus.

1.4 General

The CAIS bus is a full duplex communications network interconnecting a CAIS bus controller with Data Acquisition Units. The CAIS bus is a star/daisy-chain hybrid configuration. The bus carries commands from the CAIS bus controller to the various DAUs and returns the collected data to the CAIS bus controller for output. The command/response bus provides the open architecture feature of the CAIS system.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. In the event of a conflict between the documents referenced herein and the contents of this document, the contents of this document shall be considered a superseding requirement.

2.1 Government Documents

2.1.1 Specifications

None.

2.1.2 Standards

CAIS Configuration ID, A00.00-C009

2.2 Non-Government Documents

Copies of non-government documents should be obtained from the organizations indicated. Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

2.2.1 Specifications

None

2.2.2 Standards

Telemetry Standards, IRIG 106-96, May 1996

3. DEFINITIONS & ABBREVIATIONS

3.1 Definitions

Bi-phase-space - Code convention for representing serial binary ones and zeros with a level transition at the beginning of every bit period. A logic "one" is represented by no mid-bit level transition. A logic "zero" is represented by a mid-bit level transition.

Note: IRIG 106-96 redefined the BIϕ-S definitions and shall not be used.

Bit - Contraction of binary digit: may be either zero or one. In information theory a binary digit is equal to one binary decision or the designation of one of two possible values or states of anything used to store or convey information.

Buffer bits - Extra BIϕ-S encoded zero bits added to the end of the command word to avoid collisions on the reply bus. The number of buffer bits is fixed according to the CAIS bus system word size.

Bus monitor - a unit assigned the task of receiving bus traffic and extracting selected information to be used at a later time.

Bus splitter - The bus splitter is a combination splitter and combiner. One half splits the command bus into 'n' branches while the other half combines the reply bus from 'n' branches.

CAIS bus - The synchronous communications link between the CBC and the DAUs located throughout the test vehicle. The CAIS bus is physically two buses, a command bus and a reply bus. The term CAIS bus refers to the command-reply bus pair.

Command/response - Operation of a data bus system s uch that data acquisition units receive and transmit data only when commanded to do so by the CAIS bus controller.

Configuration ID - An ID unique to each DAU type. When requested by the CAIS bus controller, each DAU shall respond with its configuration ID. The configuration ID is assigned at time of manufacture.

DAU address - See DAU ID.

DAU ID - An address unique to each DAU on a CAIS bus. The DAU ID is normally assigned at time of installation by configuring a code plug (or equivalent).

Filler bits - Extra BIϕ-S encoded zero bits added between command words when the command rate is less than maximum. Filler bits provide constant activity on the command bus to maintain system synchronization. The number of filler bits is determined by the command rate.

Mid-zero crossing - The zero crossing in the middle of the bit time or sync waveform.

Nominal value - The expected or target value.

Star/daisy-chain hybrid - All of the units on the CAIS bus are daisy-chained together. A bus splitter creates a star by splitting the single bus into *n* different legs. The DAUs on each leg are daisy-chained together.

System - A system may be one unit operating standalone or a CAIS bus controller with one or more DAUs. The CAIS bus controller may employ more than one CAIS bus to achieve its requirements.

System word size - The number of data bits in the reply word as dictated by the CAIS bus controller.

Word - In CAIS there are two kinds of words: command and reply. A command word is 16 bits plus sync and parity. A reply word is the system word size plus sync and parity.

Word rate - The rate at which words appear on the bus.

3.2 Abbreviations and Acronyms

Biϕ-S	Bi-phase-Space
CAIS	Common Airborne Instrumentation System
CBC	CAIS Bus Controller
DAU	Data Acquisition Unit
JPO	Joint Program Office

4. GENERAL REQUIREMENTS

4.1 General

4.1.1 Test and operating requirements

All requirements as specified herein shall be valid over the environmental conditions which the units shall be required to operate.

4.1.2 Data bus operation

The data bus system in its most elemental configuration shall be as shown in Figure 1. The data bus system shall function synchronously in a command/response mode, and transmission shall occur in a full-duplex manner by means of a command bus and a reply bus. Sole control of information transmission on the bus shall reside with the CAIS bus controller, which shall initiate all transmissions. The information flow on the data bus shall be comprised of broadcast commands which set the operating mode of the units and DAU commands which request DAU specific actions. All data on the reply bus is a result of DAU command request.

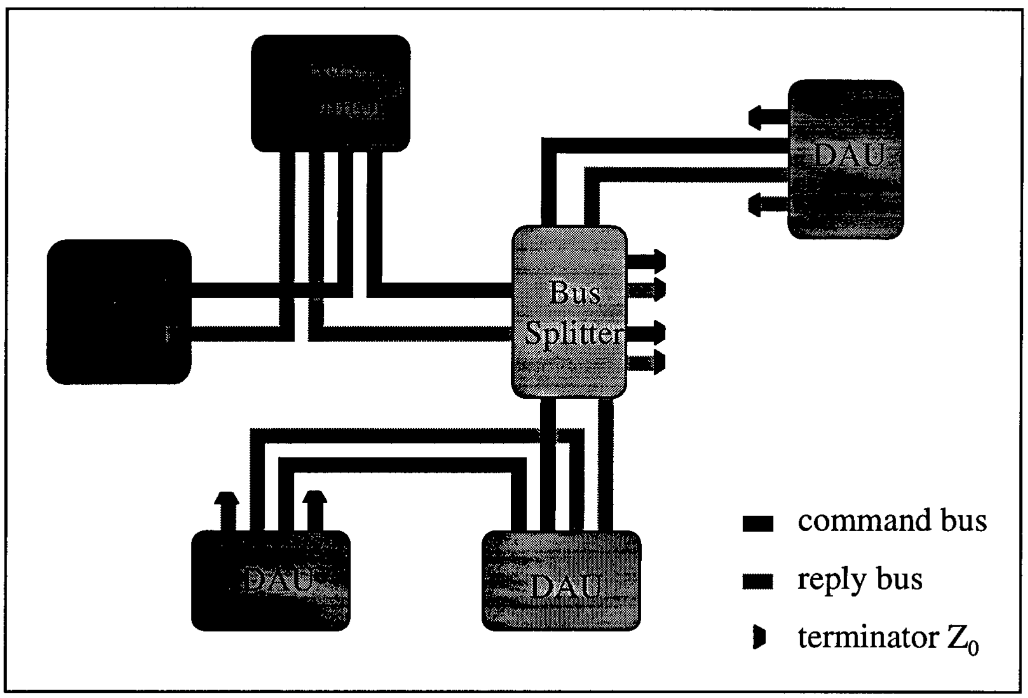


Figure 1. *Example CAIS architecture*

4.2 PHYSICAL CHARACTERISTICS

4.2.1 General

The CAIS bus is physically a 4 wire bus consisting of a 2 wire command bus and a 2 wire response bus. The CAIS bus is configured in a daisy-chain fashion, originating at the CBC and terminating at the last DAU. In order to accommodate larger quantities of DAUs on the bus, a bus splitter should be used. The bus splitter couples the CAIS bus into 2 or more legs giving it a star configuration.

4.2.2 Components

The components that form the CAIS bus are twinaxial cables, bus interface, connectors, bus terminators.

4.2.2.1 Cables

One of the most important system components is the bus cable. Each CAIS bus cable shall be a twisted, shielded wire pair used to transmit and receive a differential signal. Care must be taken to ensure the appropriate cable is selected for the bus. The minimum cable requirements are described below. Section 6.1 gives some of the characteristics of the recommended CAIS bus cable.

4.2.2.1.1 Characteristic impedance

The characteristic impedance of the cable (Z_0) shall be within the range of 73 to 83 ohms at a sinusoidal frequency of 10 MHz.

4.2.2.1.2 Attenuation

At the sinusoidal frequency of 10 MHz, the cable power loss shall not exceed 4.5 dB per 100 feet.

4.2.2.1.3 Propagation delay

The propagation delay of the CAIS bus cable shall not exceed 2.0 ns/ft.

4.2.2.1.4 Shielding

The cable shield shall provide a minimum of 90.0% coverage.

4.2.2.2 Bus interface

All connections to the CAIS bus shall be transformer coupled.

4.2.2.3 Bus connectors

All DAUs on the CAIS bus shall use jacks that mate with PL150 series TRS subminiature twinax plugs. A four lug plug shall be used for the command bus and a three lug plug shall be used for the reply bus. These connectors have three terminals, Center, Ring and Shield. The pin assignments for the CAIS bus connectors are defined in Table 1.

Table 1. *CAIS bus pin assignments*

	Command Bus	*Reply Bus*
Connector	4 lug	3 lug
Center	+	-
Ring	-	+
Shield	Shield	Shield

4.2.2.4 Bus terminators

The two ends of the cable shall be terminated with a resistance equal to the selected cable nominal characteristic impedance (Z_0) with a tolerance of ± 2.0%

4.2.3 Bus length

A CAIS system shall operate with a minimum cable length of 1 foot as measured from the output connector on the controller to the input connector of the next unit.

4.3 ELECTRICAL CHARACTERISTICS

The CAIS bus operates at 10 Mbps utilizing bi-phase-space (BIϕ-S) encoding. The CAIS bus is a full duplex, transformer coupled communications link with simultaneous transmission of signals on the differential command and reply buses.

4.3.1 General

4.3.1.1 Transmission bit rate

Regardless of the word rate used, the transmission bit rate on both the command and reply bus shall be 10.0 Mbps, ± 0.1%.

4.3.1.2 Direct coupled stubs

All connections to the CAIS bus shall be made using direct coupled stubs. Direct coupling shall employ an internal or external coupling scheme as shown in Figure 2. Internal coupling or daisy-chain is the preferred method. When using external coupling, the stub length should not exceed 1 foot.

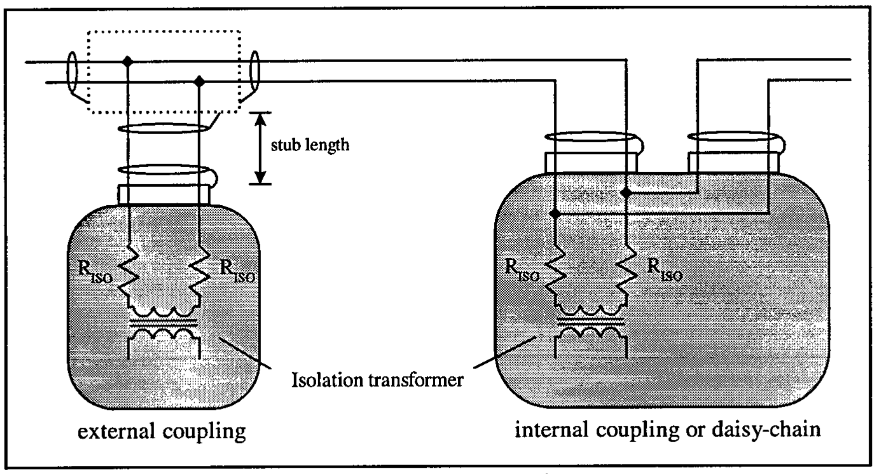


Figure 2. *Bus coupling*

4.3.1.2.1 Isolation transformer

All units coupled to the CAIS bus shall have an isolation transformer.

4.3.1.2.2 Shielding

All bus-stub junctions, cable to connector junctions, and cable terminations, shall have continuous 360 degree shielding which shall provide a minimum of 75.0 percent coverage.

4.3.2 Controllers

The CAIS bus controller is assigned the task of initiating information transfers on the bus.

4.3.2.1 Command bus transmit requirements

All measurements in the following subsections shall be taken at point A on Figure 3, where R_L is equal to the nominal characteristic impedance of the cable ±2.0%. The length x is as described in 4.2.3. Figure 3 shows the timing and amplitude requirements of the transmitted waveform as seen at the output connector of the controller. Table 2 provides an overview of the transmitted waveform requirements. See the subparagraphs for more detail.

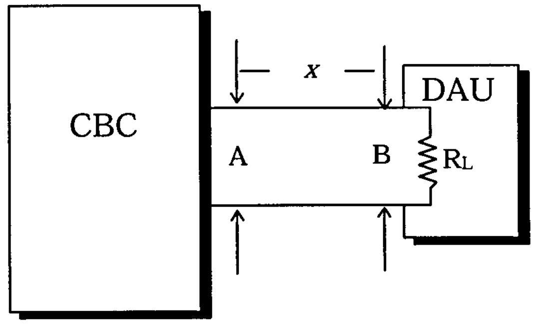


Figure 3. *Measurement location*

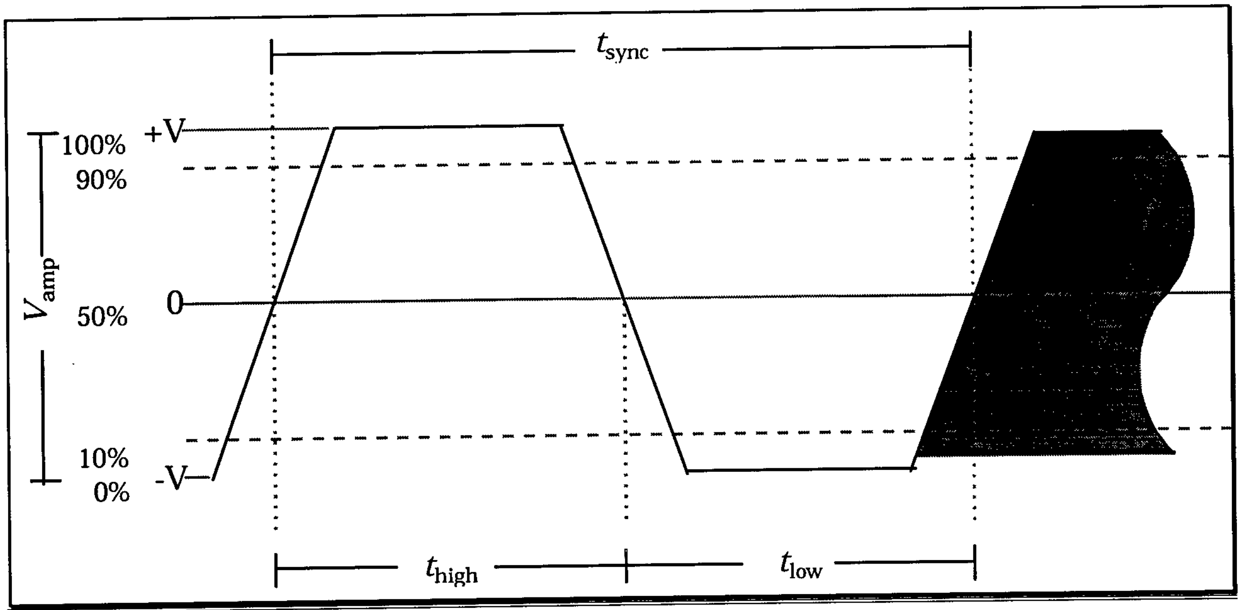


Figure 4. *CAIS waveform*

Table 2. *Command transmit requirements*

	min (Vpp)	max (Vpp)		nominal (ns)	deviation (ns)	(ns)
V_{amp}	4.0	5.0	t_{sync}	300	---	$10 \leq t_{rise} \leq 20$
			t_{high}	150	±3	$10 \leq t_{fall} \leq 20$
			t_{low}	150	±3	

4.3.2.1.1 Amplitude

The amplitude of the transmitted waveform (V_{amp}) when measured at the high and low portions of a CAIS waveform shall be 4.0 to 5.0 volts peak-to-peak (V_{pp}) line-to-line. Figure 4.

4.3.2.1.2 Impedance

The output impedance at 10 MHz shall be 60 Ω maximum line-to-line when transmitting, 2.5 kΩ minimum line-to-line when not transmitting -- power on and power off.

4.3.2.1.3 Rise and fall times

The rise time (t_{rise}) of a CAIS waveform shall be from 10 ns to 20 ns measured between 10% and 90% of V_{amp}. The fall time (t_{fall}) of a CAIS waveform shall be from 10 ns to 20 ns measured between 90% and 10% of V_{amp}. Figure 4.

4.3.2.1.4 Sync timing

An invalid bi-phase-space waveform with a nominal duration (t_{sync}) of 300 ns defines the sync at the beginning of each word transmitted on the bus. The ideal waveform shall be positive for the first 150 ns and negative for the last 150 ns. The measurements for t_{high} and t_{low} shall be taken at the 50% level as shown in Figure 4.

4.3.2.1.5 Noise

Any noise transmitted when the CBC is receiving or has power removed, shall not exceed a value of 5.0 mv, rms, line-to-line.

4.3.2.1.6 Output waveform

The waveform transmitted from the CBC shall have zero crossing deviations that are ≤3.0ns from the ideal crossing point, measured with respect to the previous zero crossing.

4.3.2.2 Reply bus receive characteristics

The CBC shall be capable of receiving and operating with the incoming signals specified in following subsections. All characteristics are specified at point A on Figure 3, where R_L is equal to the nominal characteristic impedance of the cable ±2.0%. The length *x* is as described in 4.2.3. Figure 4 shows the timing and amplitude characteristics of the received waveform as seen at the input connector of the controller. Table 3 provides an overview of the received waveform characteristics. See the subparagraphs for more detail.

Table 3. *Reply receive characteristics*

	min (Vpp)	max (Vpp)		nominal (ns)	deviation (ns)	(ns)
V_{amp}	0.40	5.0	t_{sync}	300	---	$10 \le t_{rise} \le 30$
			t_{high}	150	±15	$10 \le t_{fall} \le 30$
			t_{low}	150	±15	

4.3.2.2.1 Amplitude

The amplitude of the received waveform (V_{amp}) when measured at the high and low portions of a CAIS waveform shall be 0.40 to 5.0 V_{pp} line-to-line. Figure 4.

4.3.2.2.2 Impedance

The unterminated input impedance shall be 2.5 kΩ within the frequency range of 75.0kHz to 10.0MHz, at all conditions.

4.3.2.2.3 Settling time

The ring amplitude shall be less than 2.0% of the signal amplitude (V_{amp}) 100 ns after the final bit time of a word.

4.3.2.2.4 Rise and fall times

The rise time (t_{rise}) of a CAIS waveform shall be from 10 ns to 30 ns measured between 10% and 90% of V_{amp}. The fall time (t_{fall}) of a CAIS waveform shall be from 10 ns to 30 ns measured between 90% and 10% of V_{amp}. Figure 4

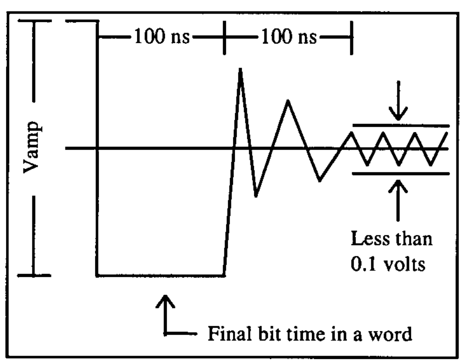


Figure 5. *Settling time*

4.3.2.2.5 Sync timing

An invalid bi-phase-space waveform with a nominal duration (t_{sync}) of 300 ns defines the sync at the beginning of each word transmitted on the bus. The ideal waveform shall be positive for the first 150 ns and negative for the last 150 ns. The measurements for t_{high} and t_{low} shall be taken at the 50% level as shown in Figure 4

4.3.2.2.6 Noise rejection

The CBC shall exhibit a maximum bit error rate of one part in 10^9, on all bits received by the CBC, when operating in the presence of additive white gaussian noise distributed over a bandwidth of 10kHz to 40MHz at an rms amplitude of 200 mV. The bit error rate shall be measured with a 4.0 V_{pp}, line-to-line, input to the CBC.

4.3.2.2.7 Common mode rejection

Any signals from DC to 20.0 MHz, with amplitudes equal to or less than ±10.0 V peak, line-to-ground, measured at point A on Figure 3, shall not degrade the performance of the controller.

4.3.2.2.8 Input waveform

The CBC shall accept waveforms varying from a square wave to a sine wave that shall have zero crossing deviations that are ≤15.0 ns from the ideal crossing point, with respect to the previous zero crossing.

4.3.3 Data acquisition units

Data acquisition units are those units not operating as the bus controller or as a bus monitor.

4.3.3.1 Reply bus transmit requirements

All measurements in the following subsections shall be taken at point B on Figure 3, where R_L is equal to the nominal characteristic impedance of the cable ±2.0%. The length *x* is as described in 4.2.3. Figure 4 shows the general timing and amplitude requirements of the transmitted waveform as seen at the output connector of the DAU. Table 4 provides an overview of the transmitted waveform requirements. See the subparagraphs for more detail.

Table 4. *Reply transmit requirements*

	min (Vpp)	max (Vpp)		nominal (ns)	deviation (ns)	(ns)
V_{amp}	4.0	5.0	t_{sync}	300	---	$10 \leq t_{rise} \leq 20$
			t_{high}	150	±3	$10 \leq t_{fall} \leq 20$
			t_{low}	150	±3	

4.3.3.1.1 Amplitude

The amplitude of the transmitted waveform (V_{amp}) when measured at the high and low portions of a CAIS waveform shall be 4.0 to 5.0 V_{pp} line-to-line. Figure 4.

4.3.3.1.2 Impedance

The output impedance at 10 MHz shall be 60 Ω maximum line-to-line when transmitting, 2.5 kΩ minimum line-to-line when not transmitting -- power on and power off.

4.3.3.1.3 Settling time

The ring amplitude shall be less than 2.0% of the signal amplitude (V_{amp}) 100 ns after the final bit time of a word as shown in Figure 5.

4.3.3.1.4 Rise and fall times

The rise time (t_{rise}) of a CAIS waveform shall be from 10 ns to 20 ns measured between 10% and 90% of V_{amp}. The fall time (t_{fall}) of a CAIS waveform shall be from 10 ns to 20 ns measured between 90% and 10% of V_{amp}. Figure 4

4.3.3.1.5 Sync timing

An invalid bi-phase-space waveform with a nominal duration (t_{sync}) of 300 ns defines the sync at the beginning of each word transmitted on the bus. The ideal waveform shall be positive for the first 150 ns and negative for the last 150 ns. The measurements for t_{high} and t_{low} shall be taken at the 50% level as shown in Figure 4.

4.3.3.1.6 Noise

Any noise transmitted when the DAU is receiving or has power removed, shall not exceed a value of 5.0 mv, rms, line-to-line.

4.3.3.1.7 Output waveform

The waveform transmitted from the DAU shall have zero crossing deviations that are ≤3.0 ns from the ideal crossing point, measured with respect to the previous zero crossing.

4.3.3.2 Command bus receive characteristics

The DAU shall be capable of receiving and operating with the incoming signals specified in following subsections. All characteristics are specified at point B on Figure 3, where R_L is equal to the nominal characteristic impedance of the cable ±2.0%. The length x is as described in 4.2.3. Figure 4 shows the timing and amplitude characteristics of the received waveform as seen at the input connector of the DAU. Table 5 provides an overview of the received waveform characteristics. See the subparagraphs for more detail.

Table 5. *Command receive characteristics*

	min (Vpp)	max (Vpp)		nominal (ns)	deviation (ns)	(ns)
V_{amp}	0.40	5.0	t_{sync}	300	---	$10 \le t_{rise} \le 30$
			t_{high}	150	±15	$10 \le t_{fall} \le 30$
			t_{low}	150	±15	

4.3.3.2.1 Amplitude

The amplitude of the received waveform (V_{amp}) when measured at the high and low portions of a CAIS waveform shall be 0.40 to 5.0 V_{pp} line-to-line. Figure 4.

4.3.3.2.2 Impedance

The unterminated input impedance of a DAU shall be a minimum of 2.5 kΩ line-to-line within the frequency range of 75.0 kHz to 10 MHz at all conditions.

4.3.3.2.3 Fault isolation

An isolation resistor shall be placed in series between the isolation transformer and the CAIS bus connector with each connection to the data bus cable as shown in Figure 2. This resistor shall have a value of 150.0 Ω ±2.0%.

4.3.3.2.4 Rise and fall times

The rise time (t_{rise}) of a CAIS waveform shall be from 10 ns to 30 ns measured between 10% and 90% of V_{amp}. The fall time (t_{fall}) of a CAIS waveform shall be from 10 ns to 30 ns measured between 90% and 10% of V_{amp}. Figure 4

4.3.3.2.5 Sync timing

An invalid bi-phase-space waveform with a nominal duration (t_{sync}) of 300 ns defines the sync at the beginning of each word transmitted on the bus. The ideal waveform shall be positive for the first 150 ns and negative for the last 150 ns. The measurements for t_{high} and t_{low} shall be taken at the 50% level as shown in Figure 4.

4.3.3.2.6 Noise rejection

The DAU shall exhibit a maximum bit error rate of one part in 10^9, on all bits received by the DAU, when operating in the presence of additive white gaussian noise distributed over a bandwidth of 10kHz to 40MHz at an rms amplitude of 200mv. The bit error rate shall be measured with a 4.0 V_{pp}, line-to-line, input to the DAU.

4.3.3.2.7 Common mode rejection

Any signals from DC to 20.0 MHz, with amplitudes equal to or less than ±10.0 V peak, line-to-ground, measured at point B on Figure 3, shall not degrade the performance of the DAU.

4.3.3.2.8 Input waveform

The DAU shall accept waveforms varying from a square wave to a sine wave that shall have zero crossing deviations that are ≤15.0ns from the ideal crossing point, with respect to the previous zero crossing.

4.3.4 Bus monitor

Bus monitors shall monitor CAIS bus traffic in accordance with 4.3.2.2 and 4.3.3.2.

4.3.5 Bus splitter

The CAIS bus allows 16 DAUs to be daisy-chained together. In order to achieve 60 (maximum) DAUs on one CAIS bus, a bus splitter is required. The bus splitter is used to couple the CAIS bus signal into two to *n* signals of equal power. Each leg of the bus can accommodate up to 16 DAUs. Each DAU placed prior to the splitter reduces the number of DAUs allowed on each leg of the splitter by one. The bus splitter and combiner shall have a minimum isolation of 20 dB and a maximum attenuation of 7.5 dB. The unterminated input impedance shall be a minimum of 2.5 kΩ within the frequency range of 75.0kHz to 10.0MHz, at all conditions.

4.4 PROTOCOL

The CAIS bus is a synchronous command/response bus. Only the CAIS bus controller issues commands.

4.4.1 General

4.4.1.1 Data form

Digital data may be transmitted in any desired form. The chosen form shall be compatible with the reply format described in this standard. Any unused bit positions in a word shall be transmitted as logic zeros.

4.4.1.2 Bit priority

The most significant bit shall be transmitted first with the less significant bits following in descending order of value in the data word. The number of bits required to define a quantity shall be consistent with the resolution or accuracy required. In the event that multiple precision quantities (information accuracy or resolution requiring more than the system word size) are transmitted, the most significant bits shall be transmitted first, followed by the word(s) containing the lesser significant bits in numerical descending order. Bit packing of multiple quantities in a single data word is permitted.

4.4.1.3 Modulation

The signal shall be transferred over the data bus in serial digital pulse code modulation form.

4.4.1.4 Data code

The data code shall be bi-phase-space (BI ϕ-S) as defined in 3.1.

4.4.1.5 Reply data

Units on the CAIS bus shall operate with system word sizes of 12 bits, 16 bits or both.

4.4.2 Command bus

4.4.2.1 Command word structure

All bus command words, regardless of type, contain the same structure. Each command word shall be twenty bit periods long. Each command shall begin with a three bit-time sync waveform. This shall be followed by the six bit DAU ID field, a ten bit command field and a one bit parity field.

4.4.2.1.1 Sync waveform

The sync waveform shall be an invalid bi-phase-space waveform as shown on Figure 4. The width shall be three bit times, with the sync being positive for the first one and one-half bit times, and then negative for the following one and one-half bit times.

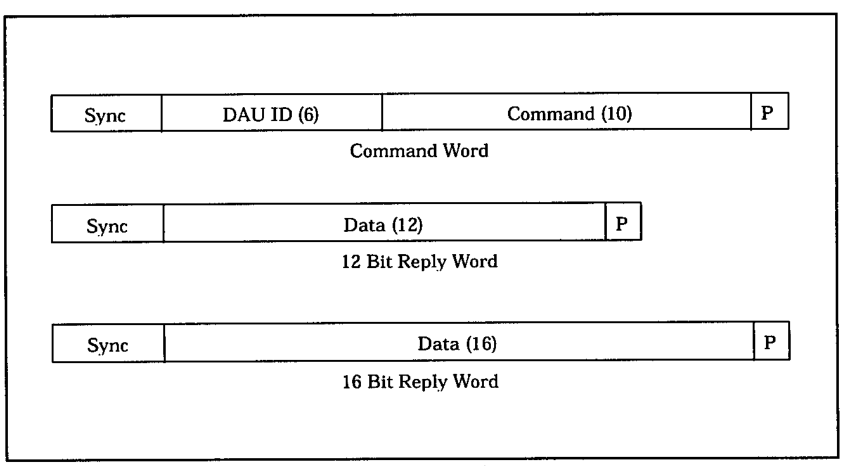


Figure 6. *Bus word structures*

4.4.2.1.2 DAU ID

The six bit DAU ID number to which the command is being addressed shall be placed here. Valid DAU IDs are 1 through 60. DAU IDs of 0, 61, 62, and 63 are reserved.

4.4.2.1.3 Command

The ten bit command shall be placed here. A list of valid commands is given in section 4.4.6.

4.4.2.1.4 Parity

The last bit in each word shall be the parity bit. The parity bit shall be set to maintain even parity for the word.

4.4.3 Command word rate

At the maximum command rate, $1/t_{effcmd}$, the commands are back to back. As the command rate is reduced, t_{effcmd} remains constant and filler bits are placed between commands as shown in Figure 7.

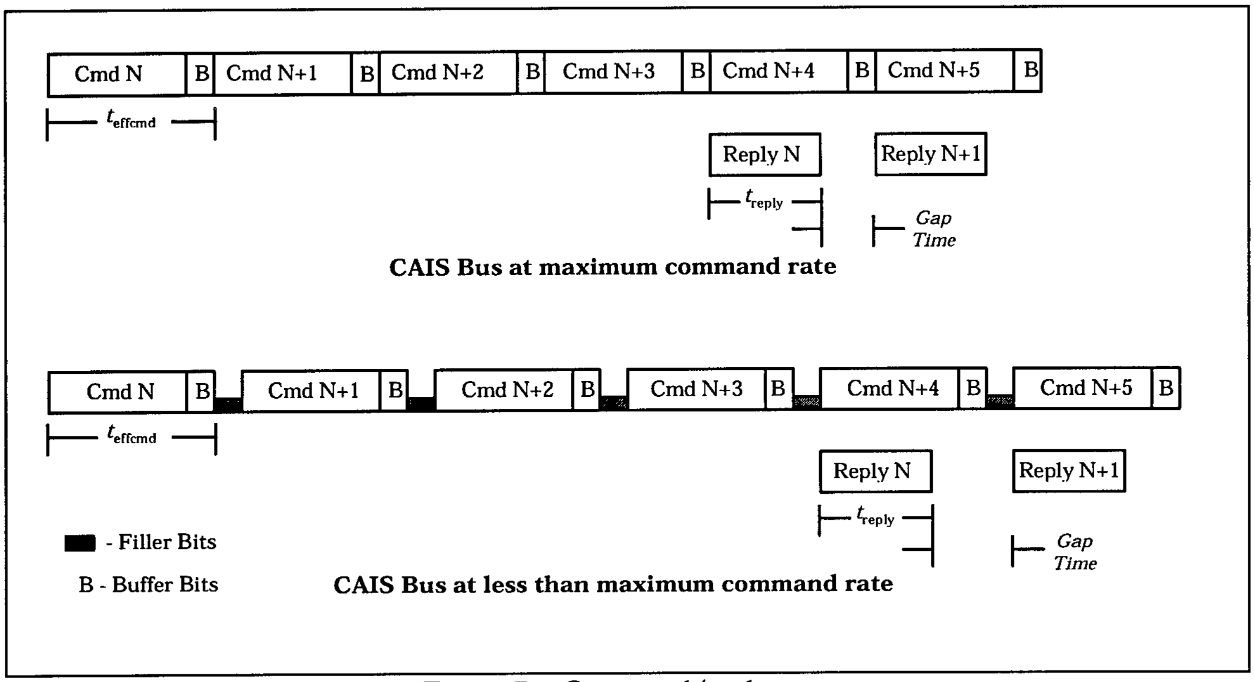


Figure 7. *Command/reply rates*

4.4.3.1 Buffer bits

Buffer bits shall be appended to the command word to avoid collisions on the reply bus. The minimum number of buffer bits shall be fixed for a given system word size, see Table 6. Buffer bits shall be encoded as BIϕ-S zeros.

4.4.3.1.1 12 bit mode

A minimum of four buffer bits shall be appended to the command word resulting in an effective command word size (Eff Size) length of 24 bits. The maximum command rate is ≈417 kwords/sec (= 1 / t_{effcmd} = 1 / 2.4 μs). See Table 6.

Table 6. *Command/reply sizes*

Mode (bpw)	Command Word (bits)	Buffer (bits)	Eff Size (bits)	t_{effcmd} (μs)	Reply Word (bits)	Min Gap Time (ns)	t_{reply} (μs)
12	20	4	24	2.4	16	350	1.6
16	20	8	28	2.8	20	350	2.0

4.4.3.1.2 16 bit mode

A minimum of eight buffer bits shall be appended to the command word resulting in an effective command word size (Eff Size) length of 28 bits. The maximum command rate is ≈357 kwords/sec (= 1 / t_{effcmd} = 1 / 2.8 μs). See Table 6.

4.4.3.2 Filler bits

Filler bits shall be transmitted between command words to maintain system synchronization. Filler bits shall be encoded as BIϕ-S zeros.

4.4.4 Reply bus

4.4.4.1 Reply word structure

All DAUs shall continuously receive all commands, however, only the particular DAU addressed shall respond to a given command. DAUs not being addressed shall be placed into an inactive state. The reply word size shall vary depending on the system word size as shown in Figure 6. As in the command word, all replies shall begin with a sync waveform and end with one parity bit.

4.4.4.1.1 Sync waveform

The sync waveform shall be an invalid bi-phase-space waveform as shown on Figure 4. The width shall be three bit times, with the sync being positive for the first one and one-half bit times, and then negative for the following one and one-half bit times.

4.4.4.1.2 Data

The size of this field shall be equal to the system word size as defined by the CBC. This field shall be utilized for data transmission as specified in 4.4.1.2

4.4.4.1.3 Parity

The last bit in each word shall be the parity bit. The parity bit shall be set to maintain even parity for the word.

4.4.4.2 Reply word rate

Whereas commands on the command bus are constant, the reply bus shall only have data when a DAU is asked to reply; the reply bus shall be silent at all other times. The reply word length shall be the data field plus 4 bit periods as shown in Figure 6. The reply word rate corresponds to the command word rate.

4.4.5 Bus Timing

4.4.5.1 Reply skew time

There shall be a four word delay from the beginning of a command to the corresponding reply. The reply bus offset, t_{skew}, is measured at point B in Figure 3 from the mid-zero crossing of the fifth command word sync as received by the DAU to the mid-zero crossing of the reply sync. The skew time shall be a minimum of 525 ns and a maximum of 625 ns as shown in Figure 8.

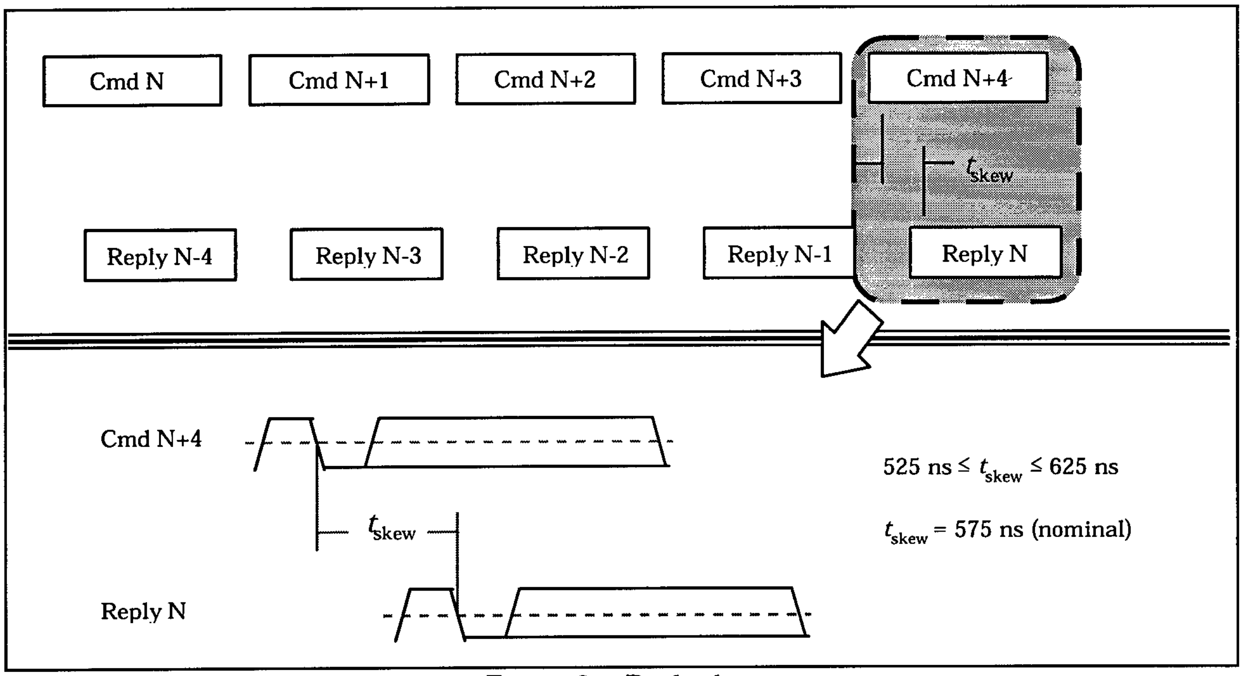


Figure 8. *Reply skew*

4.4.5.2 Reply gap time

The gap time (t_{gap}) as seen at point A on Figure 3 shall be measured from the zero crossing marking the beginning of the parity bit on reply n to the mid-zero crossing of the sync waveform of reply n+1 as shown in Figure 9. The minimum gap time for all modes and rates shall be 350 ns.

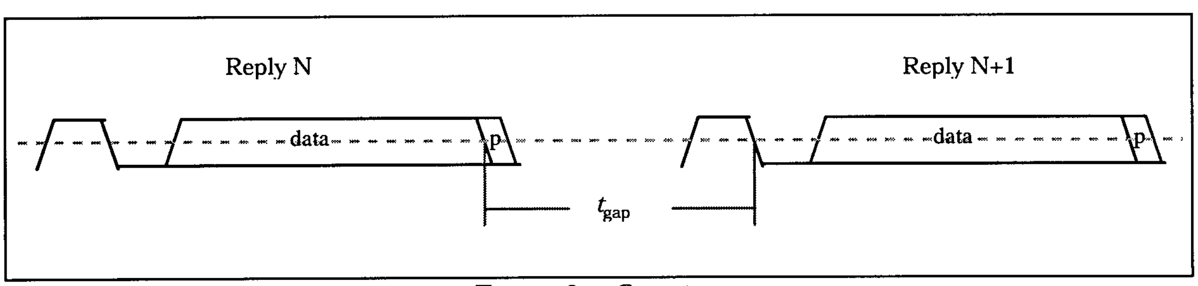


Figure 9. *Gap time*

4.4.6 Bus Commands

There are two types of bus commands: the broadcast command and the DAU command. The broadcast command shall cause all DAUs to perform certain functions or enter specific modes based upon the type of broadcast command. The DAU command shall cause one DAU to perform an action unique to that DAU type.

4.4.6.1 Broadcast commands

Broadcast commands are used to change operating modes, cause simultaneous samples, or to provide other information to the DAUs. A broadcast command shall be identified by all 0's in the DAU ID field. DAUs shall not respond to broadcast commands. In order to change modes, a broadcast mode command shall be sent. Once in a new operating mode, DAU commands may be sent to each DAU. A four bit field (cmd type) in the broadcast command defines the command type. The following subparagraphs detail the broadcast commands. Since all broadcast commands have a DAU ID of zero, bits 15-10 are not presented in the subparagraphs.

Table 7. *CAIS bus broadcast commands*

	DAU ID								Cmd Type							
Bit #	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
No Reply command	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Program mode	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Verify mode	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Initiated BIT mode	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Configuration mode	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Normal mode	0	0	0	0	0	0	0	(1)	1	0	1	(2)	(3)			0
System command	0	0	0	0	0	0	(4)	(1)	1	1	0	(2)	(5)		(6)	
Sim. Sample command	0	0	0	0	0	0	0	(1)	1	1	1	0	0	0	0	0

Notes:
(1) Mode change flag
(2) Sub-command flag
(3) Bit rate field (optional)
(4) Sync flag
(5) Format ID field
(6) System word size

4.4.6.1.1 NO REPLY command

9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0

The NO REPLY command allows for a consistent message rate on the command bus; no data sampling shall be initiated. The NO REPLY command shall not change the current operating mode of a DAU. This command is issued to maintain the command rate and bus synchronization during periods when DAU replies are not required. This command may be present during all modes of operation.

4.4.6.1.2 PROGRAM mode command

9	8	7	6	5	4	3	2	1	0
0	0	0	0	1	0	0	0	0	0

The PROGRAM mode command shall place the DAUs into the load memory mode. During this mode a DAU's non-volatile memory can be written to by the CAIS bus controller. The DAU shall not respond with reply words while in this mode.

4.4.6.1.3 VERIFY mode command

9	8	7	6	5	4	3	2	1	0
0	0	0	1	0	0	0	0	0	0

The VERIFY mode command shall place the DAUs in the verify memory mode. While in this mode the DAU's non-volatile memory can be read by the CAIS bus controller.

4.4.6.1.4 INITIATED BIT mode command

9	8	7	6	5	4	3	2	1	0
0	0	0	1	1	0	0	0	0	0

The INITIATED BIT mode command shall place all DAUs in the Initiated Built-In-Test (IBIT) mode. All DAUs capable of executing IBIT shall do so. IBIT results shall be stored in specified data memory locations within each DAU for sampling across the CAIS bus. While in the Initiated BIT mode each DAU shall continue to respond to its DAU commands. The interpretation of DAU commands may be different when the DAU is in IBIT mode.

4.4.6.1.5 CONFIGURATION mode command

9	8	7	6	5	4	3	2	1	0
0	0	1	0	0	0	0	0	0	0

The CONFIGURATION mode command shall place each DAU in a mode where its identification can be read by the CAIS bus controller. This mode can be used during a roll call to confirm the configuration of the installed hardware in the system. Upon receipt of the CONFIGURATION mode command, the DAU shall enter configuration mode and respond to configuration ID commands.

4.4.6.1.6 NORMAL mode command

9	8	7	6	5	4	3	2	1	0
0	MCF	1	0	1	SC	BR	BR	BR	0

MCF: Mode Change Flag, 0 return to normal sample mode.
1 remain in current mode.

SC: Sub-command 0 - normal
1 - extended bit rate command (access additional bit rate set)

BR: Bit rate used to set the output bit rate (optional)

000	bit rate #1	100	bit rate #5
001	bit rate #2	101	bit rate #6
010	bit rate #3	110	bit rate #7
011	bit rate #4	111	bit rate #8

The NORMAL mode command shall place the DAUs in the normal sample mode. While in this mode the DAUs shall acquire sampled or other data upon command from the CAIS bus controller. The NORMAL mode command shall return the DAUs to the normal sample mode from any other operating mode if MCF is zero. If MCF is one, the DAUs shall remain in their current operating mode.

The sub-command flag shall be used to expand the bit rate selection capability. When the sub-command flag is set to "1", extended bit rate values shall be used.

The optional bit rate field shall pass the currently selected bit rate number (000_2-111_2) to units on the bus. The sub-command flag is used to indicate whether the bit rate field is representing extended rates. With the sub-command flag set to one, the bit rate field has an implied high order bit set. The bit rate field would then represent $(1)000_2$ through $(1)111_2$. The bit rate values assigned to each bit rate number will be unique to each controller.

4.4.6.1.7 SYSTEM command

9	8	7	6	5	4	3	2	1	0
S	MCF	1	1	0	SC	F	F	SW	SW

S: Sync flag, 0 - No sync information
1 - Sync indicator

MCF: Mode Change Flag, 0 return to normal sample mode.
1 remain in current mode.

SC: Sub-command 0 - normal
1 - extended format command (access format IDs 5-8)

F: Format ID 00 - format 1 10 - format 3
01 - format 2 11 - format 4

SW: system word size, 00 - 16 bits.
10 - 12 bits.

The sync flag shall indicate the start of the command cycle. This allows synchronization information to be placed on the command bus. The CAIS bus controller normally issues the system command at the start of a frame.

The SYSTEM command shall return the DAUs to the normal sample mode from any other operating mode if MCF is zero. If MCF is one, the DAUs shall remain in their current operating mode.

The sub-command flag shall be used to expand the format addressing capability. When the sub-command flag is set to "1", the extended format values shall be used in the format ID field.

The format ID field shall pass the current operating format number (00_2-11_2) to units on the bus. The sub-command flag shall be used to indicate whether the format ID field is representing extended formats. With the sub-command flag set to one, the format ID field shall have an implied high order bit set. The format ID field shall then represent $(1)00_2$ through $(1)11_2$.

The system word size shall be independent of the Mode Change Flag setting. The system word size shall be used to inform the DAU's of the word size they are expected to reply with.

4.4.6.1.8 SIMULTANEOUS SAMPLE command

9	8	7	6	5	4	3	2	1	0
0	MCF	1	1	1	0	0	0	0	0

MCF: Mode Change Flag, 0 return to normal sample mode.
1 remain in current mode.

The SIMULTANEOUS SAMPLE command shall cause the acquisition of simultaneously sampled data from predetermined channels. The acquired data shall be retrieved subsequently by a DAU command. The SIMULTANEOUS SAMPLE command shall not change the current operating mode of the DAUs if MCF is one. If MCF is zero, the DAUs shall return to normal sample mode.

4.4.6.2 DAU commands

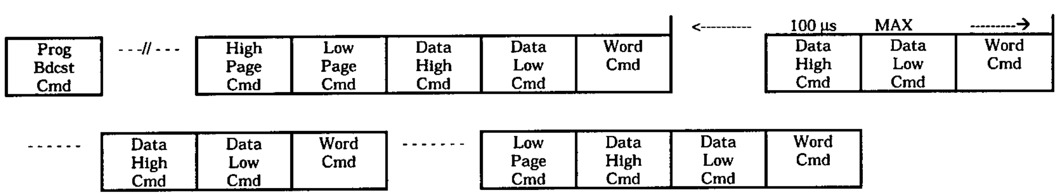
DAU commands are used to acquire data or command a specific DAU. The 10 bit field is decoded based on the mode of operation. A DAU command is defined as having a valid non-zero DAU ID. The following subsections show general DAU commands. Specific DAU commands are defined in the appropriate DAU documentation. Since all DAU commands have a non-zero DAU ID, bits 15-10 are not presented in the subparagraphs.

4.4.6.2.1 Program mode

The program mode command places the DAUs into the load memory mode. For each memory location programmed in a DAU, the following sequence of commands shall be required:

9	8	7	6	5	4	3	2	1	0	
1	1	1	A21	A20	A19	A18	A17	A16	A15	**High Page** command directs the DAU to hold the 7 MSBs of the memory address to be programmed
1	1	0	A14	A13	A12	A11	A10	A9	A8	**Low Page** command directs the DAU to hold the next 7 bits of the memory address to be programmed
0	1	D15	D14	D13	D12	D11	D10	D9	D8	**Data High** command, high byte, directs the DAU to hold the 8 MSBs of the data word to be stored.
0	0	D7	D6	D5	D4	D3	D2	D1	D0	**Data Low** command, low byte, directs the DAU to hold the 8 LSBs of the data word to be stored.
1	0	A7	A6	A5	A4	A3	A2	A1	A0	**Word** command gives the DAU the 8 LSBs of the memory address to be programmed. Initiates programming cycle.

Command Sequence



It shall be necessary to send a High Page Command, Low Page Command, Data High Command, Data Low Command, and a Word Command to program one memory location. To program multiple memory locations, the user shall send the High Page and Low Page to initialize the page address and then send up to *n* consecutive locations using the Data High Command, Data Low Command, and Word Command for each location in that page to be programmed. The number of consecutive locations is dependent upon the DAU being programmed. The DAU must receive these three commands within 100 µs of the last command or the EEPROM memory programming will begin. The user only needs to transmit either of the Page Commands when the address exceeds the corresponding page word boundary.

4.4.6.2.2 Verify mode

The verify mode command places the DAU in the verify memory mode. Upon receipt of the Verify Command, the DAU waits for the following sequence of commands:

9	8	7	6	5	4	3	2	1	0	
1	1	1	A21	A20	A19	A18	A17	A16	A15	**High Page** command directs the DAU to hold the 7 MSBs of the memory address to be verified
1	1	0	A14	A13	A12	A11	A10	A9	A8	**Low Page** command directs the DAU to hold the next 7 bits of the memory address to be verified
1	0	A7	A6	A5	A4	A3	A2	A1	A0	**Word** command gives the DAU the 8 LSBs of the memory address to be verified. Initiates read cycle.

Command Sequence

Cmd Bus	Verify Bdcst	High Page Cmd	Low Page Cmd	Word Cmd n	Word Cmd n+1	Word Cmd N+2	Word Cmd n+3	Word Cmd n+4
Reply Bus							----------	Memory Contents n

Once the High and Low Page Commands are sent, a page of locations can be read back by sending only the Word Command. Once the page boundary is reached it is necessary to send a new Page Command. When the Word command is received, the DAU replies with the contents of the address specified by the Page and Word commands.

While in Verify mode, the DAU shall respond with its reply data inverted. The Reply Bus sync shall not be inverted and the reply data parity shall be set properly for the data pattern. This allows the CAIS bus controller to "exclusive OR" the verify data received on a location with the data written to the location and obtain a result of all ones for a successful verify of the memory location.

4.4.6.2.3 Initiated BIT mode

The initiated BIT mode command shall place the DAUs in initiated built-in-test mode. Results of IBIT routines shall be available through the use of Normal mode commands. The memory address space during IBIT mode may be different from Normal mode.

4.4.6.2.4 Configuration Mode

The configuration mode command shall place the DAUs in configuration mode. While in configuration mode, the DAUs shall respond with their configuration ID values. For DAUs with add-on slices, modules or cards, the Sub-DAU IDs shall be ascertained by setting the unit subcode command address bits (D9-D0) to the appropriate value.

The configuration ID sampling command is shown below:

9	8	7	6	5	4	3	2	1	0		
U	U	U	U	U	U	U	U	U	U	U:	Unit subcode (see below)

9	8	7	6	5	4	3	2	1	0		
0	0	0	0	0	0	0	0	0	0	-	Core Unit
A	A	A	A	A	A	A	A	A	A	-	Slice/Module/Card Address

The actual address required to access configuration information for slices, modules, or cards residing in a DAU will be DAU specific. The configuration identification for the DAUs, slices, modules, and cards is controlled by the CAIS Joint Program Office and assigned in the CAIS Configuration ID document.

4.4.6.2.5 Normal mode

The normal mode command shall place the DAUs in normal sample mode. Data gathered by each DAU shall be accessible from the controller through the following commands. Data gathered during other modes of operation may also be accessible.

4.4.6.2.5.1 Address command

9	8	7	6	5	4	3	2	1	0
0	A	A	A	A	A	A	A	A	A

A: Address of the packet to be sampled, relative to the current page.

The Address command causes the DAU to return the information specified by the address field. The Address command has the ability to address up to 512 memory locations within one page. DAUs that contain more than 512 data locations and less than 1024 data locations may elect to forego the page change and specialty commands for a single addressable page of 1024 locations. All ten bits would then be used for addressing.

4.4.6.2.5.2 Page change command

9	8	7	6	5	4	3	2	1	0
1	0	P	P	P	P	P	P	P	P

P: New page number.

To address the entire Data Memory contents of a DAU with greater than 1024 data locations, it shall be necessary to use a memory paging scheme. The PAGE CHANGE Command shall be used to specify the page from which the next Data Memory request will come. When a PAGE CHANGE Command is received, the DAU should reply with the first syllable of location zero of the new page. The first memory page shall be numbered zero.

4.4.6.2.5.3 Specialty command

9	8	7	6	5	4	3	2	1	0
1	1	S	S	S	S	S	S	S	S

S: Specialty command. DAU specific.

Specialty commands shall be used to perform specialty functions unique to the addressed DAU. Refer to each DAU's documentation for more information. An example is the Periodic Built-In-Test (PBIT) status during normal sampling.

5. DETAILED REQUIREMENTS

None

6. NOTES

(This section contains information of a general or explanatory nature which may be helpful, but is not mandatory.)

6.1 Physical

6.1.1 CAIS bus cable characteristics

It is recommended a cable equal to or better than the cable in Table 8 be used. This cable has been successfully used in a CAIS flight environment.

Table 8. *MIL-C-17/176-00002 critical cable characteristics*

CABLE TYPE	MIL-C-17/176-00002
Temp. Range	-55°C to +200°C
Char. Impedance	77 ± 7 ohms @ 1 MHz
Capacitance (max)	24 pF/ft
Attenuation/100 Feet (max)	1.4 dB @ 1 MHz
Propagation Delay (typical)	1.5 ns per ft
Shielding	93.3% coverage, nominal

6.1.2 Cable selection

Factors considered in cable selection include maximum cable length from the CBC to the last DAU in the longest branch, outer diameter of the cable, temperature range, cable weight and connector requirements.

6.1.3 Connectors

All DAUs should have a pair of Command Bus connectors and a pair of Reply Bus connectors to facilitate daisy-chaining units together.

6.2 Electrical

6.2.1 Grounding considerations

The shield terminals of the CAIS bus cable should be tied to the mounting surface of the connector and in turn should be connected to chassis ground.

6.3 Protocol

6.3.1 System word size

This document is based on a single bus. The entire bus operates on a common system word size. This does preclude a controller having multiple buses using one bus with 12 bits and another with 16 bits.

6.3.2 Program mode

When in Program Mode, all program operations should be done in word lengths of 16 bits. The DAU should not enter or leave 16 bit mode until commanded to do so by the CBC.

6.3.3 Verify mode

When in Verify Mode, all verify operations should be done in word lengths of 16 bits. The DAU should not enter or leave 16 bit mode until commanded to do so by the CBC.

6.3.4 IBIT mode

If the DAU executes a self-test program when commanded to IBIT, then it should only execute it once and store the results for subsequent access by the CAIS system controller. While in IBIT, receipt of another IBIT command should be ignored. To cause the DAU to execute the IBIT program again, the DAU should be commanded into another mode and then commanded back into IBIT. IBIT may be active during flight or when connected to ground equipment and does not require external stimulus to report valid results.

6.3.5 Configuration mode

The DAU should be placed in 16 bit mode prior to obtaining configuration ID data. The CONFIGURATION mode command is generally used when the CAIS system is connected to ground support equipment.

6.3.6 Normal mode

This is the mode most often used when executing a format during normal operations.

6.3.7 Multiple syllable

When designing a DAU to retrieve multiple syllables, do not require a different DAU command be interspersed in order to get a new sample. For example, if in 12 bit mode there are only 2 valid syllables, provide a new sample on the third hit.

7. INDEX

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13. ABSTRACT (Maximum 200 words)

The Department of Defense has developed the Common Airborne Instrumentation System (CAIS) to promote standardization, commonality, and interoperability among aircraft test instrumentation systems. The value of CAIS is that it allows aircraft test and evaluation facilities to use common airborne systems and ground support equipment, as well as common technical knowledge and procedures for these systems. It is the responsibility of the CAIS Program Office, a tri-service group, to conduct requirements analyses, manage system upgrades, and provide full life-cycle support for this system. This interface control document (ICD) was written to provide a single document that designers of CAIS bus controllers and data acquisition units could reference to ensure interoperability on the CAIS bus. This ICD establishes the requirements for digital command/response, time division multiplexing techniques for a single CAIS bus. It encompasses the physical, electrical, and protocol aspects of the CAIS bus.

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