3

Commercial Standard Digital Bus

Lee H. Harrison
Galaxy Scientific Corp.

3.1 Introduction

The Commercial Standard Digital Bus (CSDB) is one of three digital serial integration data buses that currently predominate in civilian aircraft. The CSBD finds its primary implementations in the smaller business and private General Aviation (GA) aircraft, but has also been used in retrofits of some commercial transport aircraft.

CSDB, a unidirectional data bus, was developed by the Collins General Aviation Division of Rockwell International. The bus used in a particular aircraft is determined by which company the airframe manufacturer chooses to supply the avionics. Collins is one of only a handful of major contributors to avionics today.

CSDB is an **asynchronous linear** broadcast bus, specifying the use of a twisted, shielded pair cable for device interconnection. Two bus speeds are defined in the CSDB specification. A low-speed bus operates at 12,500 bits per second (bps) and a high-speed bus operates at 50,000 bps. The bus uses twisted, unterminated, shielded pair cable and has been tested to lengths of 50 m.

The CSDB standard also defines other physical characteristics such as modulation technique, voltage levels, load capacitance, and signal rise and fall times. Fault protection for short-circuits of the bus conductors to both 28 VDC and 115 VAC is defined by the standard.

3.2 Bus Architecture

Only one transmitter can be attached to the bus, while it can accommodate up to ten receivers. Figure 3.1 illustrates the unidirectional bus architecture.

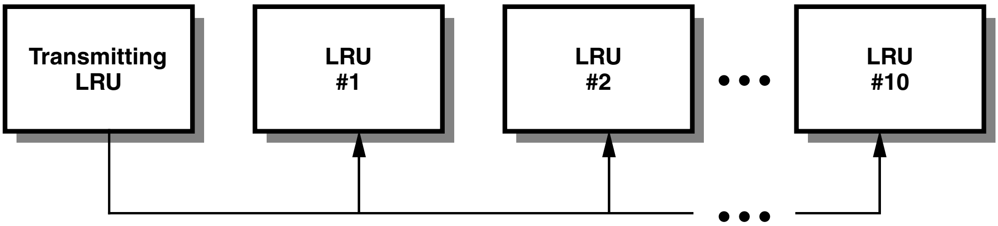

FIGURE 3.1 Unidirectional CSDB communication.

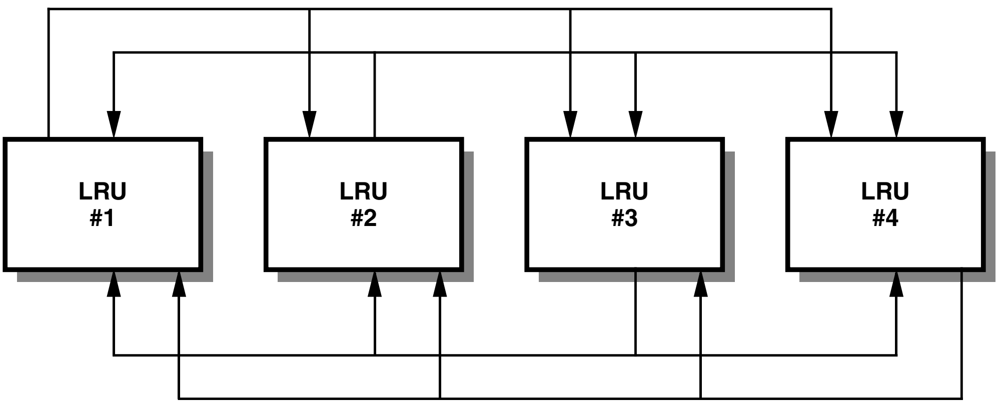

FIGURE 3.2 Bidirectional CSDB communication.

Bidirectional transmission can take place between two bus users. If a receiving bus user is required to send data to any other bus user, a separate bus must be used. Figure 3.2 shows how CSDB may implement bidirectional transmissions between bus users. It can be seen that if each bus user is required to communicate with every other bus user, a significantly greater amount of cabling would be required. In general, total interconnectivity has not been a requirement for CSDB-linked bus users.

It is possible to interface CSDB to other data buses. When this is done, a device known as a **gateway** interfaces to CSDB and the other bus. If the other bus is ARINC 429 compliant, then messages directed through the gateway from CSDB are converted to the ARINC 429 protocol (see Chapter 2), and vice versa. The gateway would handle bus timing, error checking, testing, and other necessary functions. The system designers would ensure that data latency introduced by the gateway would not cause a "stale data" problem, resulting in a degradation of system performance. Data are stale when they do not arrive at the destination line replaceable unit (LRU) when required, as specified in the design.

3.3 Basic Bus Operation

In Section 2.1.4 of the CSDB standard, three types of transmission are defined:

- Continuous repetition,
- Noncontinuous repetition, and
- "Burst" transmissions

Continuous repetition transmission refers to the periodic updates of certain bus messages. Some messages on CSDB are transmitted at a greater repetition rate than others. The CSDB standard lists these

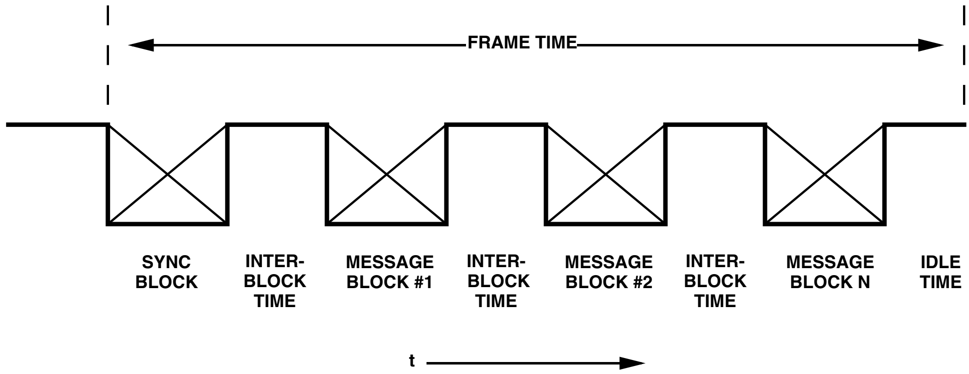

FIGURE 3.3 CSDB data frame structure.

update rates, along with the message address and message block description. Noncontinuous repetition is used for parameters that are not always valid, or available, such as mode or test data. When noncontinuous repetition transmission is in use, it operates the same as continuous repetition. Burst transmission initiates an action (such as radio tuning), or may be used to announce a specific event. Operation in this mode initiates 16 repetitions of the action in each of 16 successive **frames**, using an update rate of 20 per second.

For CSDB, bytes consist of 11 bits: a start bit, 8 data bits, a **parity** bit, and a stop bit. The least significant bit (bit 0) follows the start bit. The CSDB standard defines the message block as "a single serial message consisting of a fixed number of bytes transmitted in a fixed sequence." Essentially, a message block consists of a number of bytes concatenated together, with the first byte always being an address byte. A status byte may or may not be included in the message block. When it is, it immediately follows the address byte. The number of data bytes in a message block vary.

Data are sent as frames consisting of a **synchronization block** followed by a number of message blocks. A particular frame is defined from the start of one synchronization block to the start of the next synchronization block. A "sync" block consists of N bytes of the sync character, which is defined as the hexadecimal character "A5." The sync character is never used as an address. While the data may contain a sync character, it may occur in the data a maximum of $N - 1$ times. Frames consist of message blocks, preceded by a sync block. The start of one sync block to the start of the next sync block is one frame time. Figure 3.3 shows what transpires during a typical frame time.

3.4 CSDB Bus Capacity

The CSDB is similar to the ARINC 429 data bus in that it is an asynchronous broadcast bus and operates using character-oriented protocol. Data are sent as frames consisting of a synchronization block followed by a number of message blocks. A particular frame is defined from the start of one synchronization block to the start of the next synchronization block. A message block contains an address byte, a status byte, and a variable number of data bytes. The typical byte consists of one start bit, eight data bits, a parity bit, and a stop bit.

The theoretical bus data rate for a data bus operating at 50,000 bps with an 11-bit data byte, is 4545 bytes per second. For CSDB, the update rate is reduced by the address byte and synchronization block overhead required by the standard.

The CSDB Interblock and Interbyte times also reduce bus throughput. According to the specification, there are no restrictions on these idle times for the data bus. These values, however, are restrained by the defined update rate chosen by the designer. If the update rate needs to be faster, the Interblock time and the Interbyte time can be reduced as required, until bus utilization reaches a maximum.

3.5 CSDB Error Detection and Correction

Two methods of error detection are referenced in the standard. They are the use of parity and **checksums**. A parity bit is appended after each byte of data in a CSDB transmission. The "burst" transmission makes use of the checksum for error detection. As the General Aviation Manufacturers Association (GAMA) specification states:

> It is expected that the receiving unit will accept as a valid message the first message block which contains a verifiable checksum. (GAMA CSDB 1986.)

3.6 Bus User Monitoring

Although many parameters are defined in the CSDB specification, there is no suggestion that they be monitored by receivers. The bus frame, consisting of the synchronization block and message block, may be checked for proper format and content. A typical byte, consisting of start, stop, data, and parity bits, may be checked for proper format.

The bus hardware should include the functional capability to monitor these parameters. Parity, frame errors, and buffer overrun errors are typically monitored in the byte format of character-oriented protocols. The message format can be checked and verified by the processor if the hardware does not perform these checks.

3.7 Integration Considerations

The obvious use of a data bus is for integrating various LRUs that need to share data or other resources. In the following sections, integration considerations for CSDB are examined at various levels. These include physical, logical, software, and functional considerations.

3.7.1 Physical Integration

The physical integration of LRUs connected to the CSDB is addressed by the standardization of the bus medium and connectors. These must conform to the Electronic Industries Association (EIA) Recommended Standard (RS)-422-A (1978), "Electrical Characteristics of Balanced Voltage Digital Interface Circuits." The CSDB standard provides for the integration of up to 10 receivers on a single bus, which can be up to 50 m in length. No further constraints or guidelines on the physical layout of the bus are given.

Each LRU connected to a CSDB must satisfy the electrical signals and bit timing that are specified in the EIA RS-422-A. Physical characteristics of the CSDB are given in Table 3.1. The non-return to zero (NRZ) data format used by CSDB LRUs is shown in Figure 3.4. NRZ codes remain constant throughout a bit interval and either use absolute values of the signal elements or differential encoding where the polarity of adjacent elements is compared to determine the bit value.

TABLE 3.1 CSDB Physical Characteristics

Modulation Technique	Non-Return to Zero (NRZ)
Logic Sense for Logic "0"	Line B Positive with Respect to Line A
Logic Sense for Logic "1"	Line A Positive with Respect to Line B
Bus Receiver	High Impedance, Differential Input
Bus Transmitter	Differential Line Driver
Bus Signal Rates	Low Speed: 12,500 bps
	High Speed: 50,000 bps
Signal Rise-Time and Fall-Time	Low Speed: 8 μs
	High-Speed: 0.8–1.0 μs
Receiver Capacitance Loading	Typical: 600 pF
	Maximum: 1,200 pF
Transmitter Driver Capability	Maximum: 12,000 pF

Source: Commercial Standard Digital Bus, 8th ed., Collins General Aviation Division, Rockwell International Corporation, Cedar Rapids, IA, January 30, 1991.

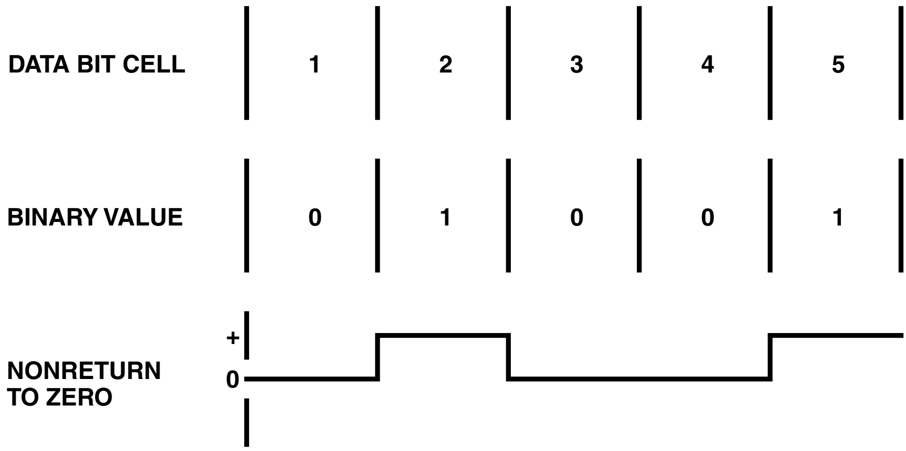

FIGURE 3.4 Non-Return to Zero data example.

Typical circuit designs for transmitter and receiver interfaces are given in the CSDB standard. Protection against short-circuits is also specified for receivers and transmitters. Receiver designs should include protection against bus conductor shorts to 28 VDC and to 115 VAC. Transmitter designs should afford protection against faults propagating to other circuits of the LRU in which the transmitter is located.

To ensure successful integration of CSDB LRUs, and avoid potential future integration problems, the electrical load specification must be applied to a fully integrated system, even if the initial design does not include a full complement of receivers. As a result, additional receivers can be integrated at a later time without violating the electrical characteristics of the bus.

3.7.2 Logical Integration

The logical integration of the hardware is controlled by the CSDB standard, which establishes the bit patterns that initiate a message block, and the start bit, data bits, parity bit, and stop bit pattern that comprises each byte of the message. The system designer, however, must control the number of bytes in each message and ensure that all the messages on a particular bus are of the same length.

3.7.3 Software Integration

Many software integration tasks are left to the system designer for implementation. Hence, CSDB does not fully specify software integration. The standard is very thorough in defining the authorized messages and in constraining their signaling rate and update rate. The synchronization message that begins a new frame of messages is also specified. However, the determination of which messages are sent within a frame for a particular bus is unspecified. Also, there are no guidelines given for choosing the message sequence or frame loading. The frame design is left to the system designer.

In general, the sequencing of the messages does not present an integration problem since receivers recognize messages by the message address, not by the sequence. However, this standard does not disallow an LRU from depending on the message sequence for some other purpose. The system designer must be aware of whether any LRU is depending on the sequence for something other than message recognition since once the sequence is chosen, it is fixed for every frame.

The bus frame loading is more crucial. There are three types of messages that can occur within a frame: continuous repetition, noncontinuous repetition, and burst transmissions. The system designer must specify which type of transmission to use for each message and ensure that the worst maximum coincidence of the three types within one frame does not exhaust the frame time. The tables of data needed to support this system design are provided, but the system designer must ensure that no parts of the CSDB standard are violated.

3.7.4 Functional Integration

The CSDB standard provides much of the data needed for functional integration. The detailed message block definitions give the interpretation of the address, status byte, and data words for each available message. Given that a particular message is broadcast, the standard completely defines the proper interpretation of the message. The standard even provides a system definition, consisting of a suite of predefined buses which satisfy the integration needs of a typical avionics system.

If this predefined system is applicable, most of the system integration questions are already answered. But if there is any variation from the standard, the designer of a subsystem in a CSDB integrated system must inquire to find out which LRUs are generating the messages that the subsystem needs, on which bus each message is transmitted, at what bus speed the messages are transmitted, and the type of transmission. The designer must also ensure that the subsystem provides the messages required by other LRUs. The system designer needs to coordinate this information accurately and comprehensively. The system design must ensure that all the messages on a particular bus are of the same length. It must also control the data latencies that may result as data are passed from bus to bus by various LRUs. All testing is left to the system designer.

There are no additional guidelines published for the CSDB. Whatever problems are unaddressed by the standard are addressed by Collins during system integration. Furthermore, Collins has not found the need to formalize their integration and testing in internal documents since this work is done by CSDB-experienced engineers.

3.8 Bus Integration Guidelines

The CSDB, like the ARINC 429 bus, has only one LRU that is capable of transmitting with (usually) multiple LRUs receiving the transmission. Thus, the CSDB has few inherent subsystem integration problems. However, the standard does not address them. The preface to the CSDB standard clearly states its position concerning systems integration:

> This specification pertains only to the implementation of CSDB as used in an integrated system. Overall systems design, integration, and certification remain the responsibility of the systems integrator. (GAMA CSDB 1986.)

Although this appears to be a problem for the reliability of CSDB-integrated systems, the GA scenario is quite different from the air transport market. The ARINC standards are written to allow any manufacturer to independently produce a compatible LRU. In contrast, the General Aviation Manufacturers Association standard states the following in the preface:

> This specification ... is intended to provide the reader with a basic understanding of the data bus and its usage. (CSDB 1986.)

The systems integrator for all CSDB installations is the Collins General Aviation Division of Rockwell International. That which is not published in the standard is still standardized and controlled because the CSDB is a sole source item.

Deviations from the standard are allowed, however, for cases where there will be no further interfaces to other subsystem elements. When variations are made, the change must first be approved in a formal design review and the product specification is then updated accordingly. Integration standards and guidelines for CSDB include the CSDB standard and EIA RS-422-A by the Electronic Industries Association.

3.9 Bus Testing

The CSDB connects avionic LRUs point-to-point to provide an asynchronous broadcast method of transmission. Before the bus was used in the avionic environment, it was put through validation tests similar to those used on other commercial data buses. These included the environmental tests presented in RTCA DO-160 and failure analyses. Most environmental tests were done transparently on the bus after it was installed in an aircraft.

As with other avionic data buses, Rockwell's Collins Division had to develop external tests to show that the bus satisfied specifications in the standard. Test procedures of this nature are not included in the CSDB standard.

Internal bus tests that the CSDB standard describes include a checksum test and a parity check. Both of these are used to ensure the integrity of the bus's data. Care should be taken when using these tests because their characteristics do not allow them to be used in systems of all criticality levels.

Simulation is used for development and testing of LRUs with a CSDB interface. Manufacturers make black box testers that are used to simulate an LRU connection to the bus. They are made to generate and evaluate messages according to the electrical and logical standards for the bus. They consist of a general purpose computer connected to bus interface cards. The simplest ones may simulate a single LRU transmitting or receiving. The more complex ones may be able to simulate multiple LRUs simultaneously.

These are not the only external and internal tests that the CSDB manufacturer can perform. Many more characteristics which may require testing are presented in the CSDB specification. Again, it remains the manufacturer's responsibility to prove that exhaustive validation testing of the bus and its related equipment has met all the requirements of the Federal Aviation Regulations.

3.10 Aircraft Implementations

This section gives a sampling of the aircraft in which the CSDB is installed. Table 3.2 lists some of the commercial transport aircraft and regional airliners using CSDB. CSDB is used both in retrofit installations and as the main integration bus. Additionally, a number of rotorcraft use the CSDB to communicate between the Collins-supplied LRUs.

TABLE 3.2 Aircraft and Their Use of the CSDB

Boeing 727	Retrofit
Boeing 737	Retrofit
McDonnell-Douglas DC-8	Retrofit
Saab 340, Saab 2000	Primary Integration Bus
Embraer	Primary Integration Bus
Short Brothers SD330 and SD360	Primary Integration Bus
ATR42 and ATR72	Primary Integration Bus
De Haviland Dash 8	Primary Integration Bus
Canadair Regional	Primary Integration Bus

Source: Collins Division of Rockwell International, Cedar Rapids, IA.

Defining Terms

Asynchronous: Operating at a speed determined by the circuit functions rather than by timing signals.

Checksum: An error detection code produced by performing a binary addition, without carry, of all the words in a message.

Frame: A formatted block of data words or bits used to construct messages.

Gateway: A bus user that is connected to more than one bus for the purpose of transferring bus messages from one bus to another, where the buses do not follow the same protocol.

Linear Bus: A bus where users are connected to the bus medium, one on each end, with the rest connected in-between.

Parity: An error detection method that adds a bit to a data word based on whether the number of "one" bits is even or odd.

Synchronization Block: A special bus pattern, consisting of a certain number of concatenated "sync byte" data words, used to signal the start of a new frame.

References

1. GAMA, *Commercial Standard Digital Bus (CSDB),* General Aviation Manufacturers Association, Washington, D.C., June 10, 1986.
2. Eldredge, D. and E. F. Hitt, "Digital System Bus Integrity," DOT/FAA/CT-86/44, Federal Aviation Administration Technical Center, Atlantic City International Airport, NJ, March 1987.
3. Elwell, D., L. Harrison, J. Hensyl, and N. VanSuetendael, "Avionic Data Bus Integration Technology," DOT/FAA/CT-91-19, Federal Aviation Administration Technical Center, Atlantic City International Airport, NJ, December 1991.
4. Collins, "Serial Digital Bus Specification," Part No 523-0772774, Collins General Aviation Division/ Publications Dept, 1100 West Hibiscus Blvd., Melbourne, FL 32901.

Further Information

The most detailed information available for CSDB is the GAMA CSDB Standard, Part Number 523-0772774. It is available from the Collins Division of Rockwell International, Cedar Rapids, IA.

Bibliography

ARINC Specification 600-7, "Air Transport Avionics Equipment Interfaces," Aeronautical Radio, Inc., Annapolis, MD, January 1987.

ARINC Specification 607, "Design Guidance for Avionic Equipment," Aeronautical Radio, Inc., Annapolis, MD, February 17, 1986.

ARINC Specification 607, "Design Guidance for Avionic Equipment," Supplement 1, Aeronautical Radio, Inc., Annapolis, MD, July 22, 1987.

ARINC Specification 617, "Guidance for Avionic Certification and Configuration Control," Draft 4, Aeronautical Radio, Inc., Annapolis, MD, December 12, 1990.

Card, M. Ace, "Evolution of the Digital Avionic Bus," *Proceedings of the IEEE/AIAA 5th Digital Avionics Systems Conference,* Institute of Electrical and Electronics Engineers, New York, NY, 1983.

Eldredge, Donald and Ellis F. Hitt, "Digital System Bus Integrity," DOT/FAA/CT-86/44, U.S. Department of Transportation, Federal Aviation Administration, March 1987.

Eldredge, Donald and Susan Mangold, "Digital Data Buses for Aviation Applications," *Digital Systems Validation Handbook, Volume II,* Chapter 6, DOT/FAA/CT-88/10, U.S. Department of Transportation, Federal Aviation Administration, February 1989.

GAMA, "Commercial Standard Digital Bus (CSDB)," General Aviation Manufacturers Association, Washington, DC, June 10, 1986.

Hubacek, Phil, "The Advanced Avionics Standard Communications Bus," Business and Commuter Aviation Systems Division, Honeywell, Inc., Phoenix, Arizona, July 10, 1990.

Jennings, Randle G., "Avionics Standard Communications Bus - Its Implementation And Usage," *Proceedings of the IEEE/AIAA 7th Digital Avionics Systems Conference,* Institute of Electrical and Electronics Engineers, New York, NY, 1986.

RS-422-A, "Electrical Characteristics of Balanced Voltage Digital Interface Circuits," Electronic Industries Association, Washington, DC, December 1978.

RTCA DO-160C, "Environmental Conditions and Test Procedures for Airborne Equipment," Radio RTCA DO Technical Commission for Aeronautics, Washington, DC, December 1989.

RTCA DO-178A, "Software Considerations in Airborne Systems and Equipment Certification," Radio RTCA DO Technical Commission for Aeronautics, Washington, DC, March 1985.

Runo, Steven C., "Gulfstream IV Flight Management System," *Proceedings of the 1990 AIAA/FAA Joint Symposium on General Aviation Systems,* DOT/FAA/CT-90/11, U.S. Department of Transportation, Federal Aviation Administration, May 1990.

Spitzer, Cary R., "Digital Avionics Architectures — Design and Assessment," *Tutorial of the IEEE/AIAA 7th Digital Avionics Systems Conference,* Institute of Electrical and Electronics Engineers, New York, NY, 1986.

Spitzer, Cary R., *Digital Avionics Systems,* Prentice Hall, Englewood Cliffs, NJ, 1987.

Thomas, Ronald E., "A Standardized Digital Bus For Business Aviation," *Proceedings of the IEEE/AIAA 5th Digital Avionics Systems Conference,* Institute of Electrical and Electronics Engineers, New York, NY, 1983.

"WD193X Synchronous Data Link Controller," Western Digital Corporation, Irvine, CA, 1983.

"WD1931/WD1933 Compatibility Application Notes," Western Digital Corporation, Irvine, CA, 1983.

"WD1993 ARINC 429 Receiver/Transmitter and Multi-Character Receiver/Transmiter," Western Digital Corporation, Irvine, CA, 1983.