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Nationales Vorwort

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Dieses Dokument wurde speziell zur Behandlung von Raumfahrtsystemen erarbeitet und hat daher Vorrang vor jeglicher Europäischer Norm, die denselben Anwendungsbereich hat, jedoch über einen größeren Geltungsbereich (z. B. Luft- und Raumfahrt) verfügt.

Nationaler Anhang NA (informativ)

Begriffe und Abkürzungen

Die Benummerung der folgenden Begriffe und Abkürzungen ist identisch mit der Benummerung in der Englischen Fassung.

3.1 Begriffe aus anderen Normen

Für die Anwendung dieses Dokuments gelten die Begriffe nach ECSS-S-ST-00-01.

3.2 Für diese Norm spezifische Begriffe

3.2.1

asynchrone Datenübertragung

Datenübertragung von einer ursprünglichen Quelle, die nicht mit einem Taktsignal oder externen allgemeinen Ereignis synchronisiert wird

Anmerkung 1 zum Begriff: Der Datenrahmen wird mit (z. B.) Start- und Stoppsignalen eingeschränkt. Die lokalen Uhren beider Kommunikationsterminals müssen nicht synchronisiert werden.

Anmerkung 2 zum Begriff: Datenübertragungssysteme, die einen asynchronen Datentransfer vorsehen, können Absendern den Versuch eines Datentransfers zu jeder Zeit ermöglichen. Wenn zwei oder mehr Absender Daten gleichzeitig abschicken, entsteht ein Konflikt und es wird mit Hilfe eines Entscheidungssystems bestimmt, in welcher Reihenfolge die Absender ihre Daten in den Bus eingeben können. Dann wird durch Anwendung von Prioritäten zwischen Informationen unterschieden, deren Zustellung dringend ist, und Daten, deren Zustellung weniger zeitkritisch ist. Bei einem Konflikt zwischen zwei oder mehr Absendern darf derjenige mit der höchsten Priorität seine Daten zuerst senden.

3.2.2

CAN-ID

11- oder 29-Bit-Kennung, die im Entscheidungs- und Kontrollfeld des CAN-Rahmens verwendet wird

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.3

Bus-basierte kalte Redundanz

Redundanzschema, wobei Daten nur auf einen der verfügbaren Busse übertragen werden

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.4

Systemlatenz am Kommunikationsbus

Zeit vom Absenden eines Datenpakets durch die Quelle bis zum Erhalt am Bestimmungsort

3.2.5

Überkreuzverbindung

zwei identische Einheiten, die mit dem übrigen System derartig verbunden sind, dass jede Einheit die geforderte Funktionalität ausführen kann

Anmerkung 1 zum Begriff: In einem Avioniksystem, in dem jede Einheit mit ihrem identischen Backup vorhanden ist, liefern Einheiten mit Überkreuzverbindungen alle möglichen Zusammenschaltungen untereinander. Bei Systemen mit

Busverbindungen werden alle Untersysteme, Komponenten und Instrumente mit Busverbindungen jeweils mit ihren Datenbussen über Kreuz verbunden. Die Gesamtsystemzuverlässigkeit eines Raumfahrt-Avioniksystems wird durch Überkreuzverbindungen wesentlich verbessert, da bei einem Ausfall einer Einheit eine redundante Einheit übernehmen kann, ohne komplette Umschaltung auf eine Redundanzkette.

3.2.6

zyklische Datenübertragung

siehe 3.2.11, „**isochrone Datenübertragung**“

3.2.7

dominante und rezessive Zustände von CANBus-Signalen

CAN-Übertragung auf Basis von Differenzialsignalübertragung

Anmerkung 1 zum Begriff: In diesem Fall werden die Unterschiede zwischen den Signalen CAN (en: Controller Area Network) high (CAN_H) und CAN low (CAN_L) verwendet. Ein Bus-Betrieb ist abhängig von der genauen Auswertung von dominanten und rezessiven Datenbits innerhalb eines CAN-Rahmens. Signalpegel werden in Unterabschnitt 5.3.2 dieser Norm angegeben.

3.2.8

dominante Bit-Ebene

logische Ebene, die bei einer Anwendung an einen Bus den gesamten Bus auf die gleiche logische Ebene zwingt

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.9

fest einprogrammierte Daten

fest einkodierte Daten

Einbettung von Daten, die, möglicherweise nur im Rückblick, als Eingabe oder Konfigurationsdaten direkt in den Quellcode/Festwertspeicher eines feldprogrammierbaren Gatterfelds (FPGA, en: field programmable gate array)/Geräts betrachtet werden können, oder feste Formatierung der Daten, anstelle des Bezugs der Daten aus externen Quellen

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.10

Bus-basierte heiße Redundanz

Redundanzschema, wobei Daten auf alle verfügbaren Busse gleichzeitig übertragen werden

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.11

isochrone Datenübertragung

Form einer **synchronen Datenübertragung**, wobei (logisch oder in ihrer Größe) ähnliche Datenrahmen gesendet werden, die mit einem regelmäßigen Taktsignal oder externen allgemeinen Ereignis verbunden sind

Anmerkung 1 zum Begriff: Bei einer isochronen Übertragung werden Sender und Empfänger in einer Weise synchronisiert, dass sie im gleichen Zeitfenster senden/empfangen. Dies impliziert die Existenz einer impliziten oder expliziten **Zeitsteuerungstabelle**, die für das gesamte Netzwerk einheitlich sein muss.

Anmerkung 2 zum Begriff: Der Begriff ist ein Synonym für zyklische Datenübertragungen (3.2.6) oder Rate Monotonic Scheduling.

3.2.12

lokale SCET

in einem Knotenpunkt implementierter und beibehaltener Zeitzähler, der mit einer SCET zusammenhängt

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.13

multimasterfähige, ereignisorientierte Nachrichtenübertragung

Übertragungsmodus, wobei jeder Knotenpunkt eines Kommunikationsnetzwerks die Nachrichtenübertragung initiieren kann, sobald der Bus frei ist

Anmerkung 1 zum Begriff: (siehe 3.2.7, Anmerkung 1 zum Begriff). Da jeder Knotenpunkt einen Nachrichtentransfer initiieren kann (Multimaster), ist ein direkter Nachrichtentransfer zwischen allen Knotenpunkten des Netzwerks möglich.

Anmerkung 2 zum Begriff: Es wird erwartet, dass jeder Knotenpunkt eines multimasterfähigen Netzwerks autonom den Bus zu einer Nachrichtenübertragung bringen kann. Da es möglich ist, dass mehr als ein Netzwerknotenpunkt mit der Übertragung einer Nachricht zur gleichen Zeit beginnt, ist ein Entscheidungsprozess notwendig, der gewährleistet, dass tatsächlich nur ein Knotenpunkt mit der Nachrichtenübertragung fortfährt.

Anmerkung 3 zum Begriff: Im Vergleich zu einem zyklischen Nachrichtentransfer bewertet eine wesentlich niedrigere Buslast oder eine Reduzierung der geforderten Datenübertragung die Ergebnisse.

3.2.14

NMT-Master

Knotenpunkt in einem CANopen-Netzwerk, verantwortlich für das Verwalten aller anderen Knotenpunkte auf dem Bus mit Hilfe der NMT-Services

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.15

NMT-Slave

Knotenpunkt in einem CANopen-Netzwerk, der mit Hilfe der NMT-Services vom NMT-Master verwaltet wird

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.16

Laufzeit

kritische Länge einer Busleitung, gegeben an dem Punkt, wo die Rücklaufzeitverzögerung (t_{prop} (total)) eines Signals durch eine Leitung gleich der Übergangszeit (t_{r}) eines Signals (das größere zwischen Anstiegs- und Abfallzeit) ist

Anmerkung 1 zum Begriff: Kritische Länge eines Netzwerks = $t_{\text{r}} = t_{\text{prop}}$ (total).

Anmerkung 2 zum Begriff: Ein typischer ISO- oder RS-485-Treiber besitzt eine Übergangszeit von 50 ns und unter Berücksichtigung einer typischen Twisted-Pair-Übertragungsleitung mit einer Verzögerung von 5 ns/m beträgt die Rücklaufverzögerung für einen Meter 10 ns/m. Die kritische Länge beträgt 5 m ($50 \text{ ns} / 10 \text{ ns/m} = 5 \text{ m}$) und die maximale ununterbrochene Stichleitung für das Netzwerk ist 1/3 der kritischen Länge oder 5/3 m (1,67 m).

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.17

rezessive Bit-Ebene

logische Ebene, die bei einer Anwendung auf einen Bus Auswirkungen auf die Ebene des Busses hat, wenn kein Treiber vorhanden ist, der gleichzeitig eine dominante Bit-Ebene anwendet

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.18

Redundanz-Master

für die Verwaltung der Bus-Redundanz bestimmter Knotenpunkt

Anmerkung 1 zum Begriff: Dies beinhaltet insbesondere die Steuerung der Schaltung von einem nominalen zu einem redundanten Bus in einem Bussystem mit kalter Redundanz.

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.19

redundanter Bus

Bussystem, das für die Erhöhung einer Zuverlässigkeit oder Verfügbarkeit des Busses aus zwei oder mehr identischen physikalischen Kommunikationskanälen besteht

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.20

redundanter Knotenpunkt

Knotenpunkt, der eine identische Funktionalität wie ein anderer Knotenpunkt, der mit dem gleichen physikalischen Bus verbunden ist, liefert

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.21

im Raumfahrzeug abgelaufene Zeit

SCET

(en: spacecraft elapsed time)

zentraler zeitlicher Bezugspunkt, der an Bord des Raumfahrzeugs beibehalten wird

Anmerkung 1 zum Begriff: Die SCET kann auf die Bodenzeit bezogen werden und darf an andere bordseitige Knotenpunkte verteilt werden.

[QUELLE: CANopen – CiA Standard 301 V4.2.0]

3.2.22

synchrone Datenübertragung

Datenübertragung, bei der eine Uhr die Übertragungszeiten der Daten bestimmt

Anmerkung 1 zum Begriff: Eine Datenübertragung von einer ursprünglichen Quelle wird ausgelöst von (oder erfolgt im Zusammenhang mit) einem Taktsignal oder externen allgemeinen Ereignis.

Anmerkung 2 zum Begriff: Da Start- und Stopp-Bits nicht für jedes Zeichen benötigt werden, ist eine größere Bandbreite für Nachrichten-Bits verfügbar.

Anmerkung 3 zum Begriff: Siehe auch **isochrone Datenübertragung** (3.2.11).

3.3 Abkürzungen

Für die Anwendung dieses Dokuments gelten die Abkürzungen nach ECSS-S-ST-00-01 und die folgenden Abkürzungen:

Abkürzung	Bedeutung	
CAN	Kontrollbereich-Netzwerk	(en: controller area network)
CCSDS	Consultative Committee for Space Data Systems	
COB-ID	Kennung des Kommunikationsobjekts	(en: communication object identifier)
ECSS	European Cooperation for Space Standardisation	
EDS	elektronisches Datenblatt	(en: electronic data sheet)
EMC	elektromagnetische Kompatibilität	(en: electromagnetic compatibility)
EMCY	Fehlermeldung	(en: emergency object)
FIFO	der Reihe nach	(en: first in first out)
LDUT	Datentransfer großer Einheiten	(en: large data unit transfer)
LSB	Bit mit dem niedrigsten Stellenwert	(en: least significant bit)
MSB	Bit mit dem höchsten Stellenwert	(en: most significant bit)
NMT	Netzwerkmanagement	(en: network management)
OSI	Verbindung zwischen offener Systeme	(en: open systems interconnection)
PCB	Leiterplatte	(en: printed circuit board)
PDU	Protokolldateneinheit	(en: protocol data unit)
PDO	Prozessdatenobjekt	(en: process data object)
RPDO	erhalte Prozessdatenobjekt	(en: receive PDO)
RTR	Anfrage für Fernübertragung	(en: remote transmission request)
SAP	Service-Zugriffspunkt	(en: service access point)
SCET	Im Raumfahrzeug abgelaufene Zeit	(en: spacecraft elapsed time)
SDO	Servicedatenobjekt	(en: service data object)
SYNC	Synchronisierungsobjekt	(en: synchronisation object)
TPDO	übertrage Prozessdatenobjekt	(en: transmit PDO)

3.4 Bit-Nummerierungskonvention

- Das Bit mit dem höchsten Stellenwert in einem n-Bit-Feld ist:
 - das mit n-1 nummerierte Bit;
 - das erste übertragene Bit;
 - das äußerste linke Bit in einem Formatdiagramm.

- Das Bit mit dem niedrigsten Stellenwert in einem n-Bit-Feld ist:
 - das mit 0 (Null) nummerierte Bit;
 - das letzte übertragene Bit;
 - das äußerste rechte Bit in einem Formatdiagramm.

Dies wird in Bild 3-1 dargestellt.

Diese Konvention widerspricht den meisten ECSS- und CCSDS-Dokumenten. Ihre Auswahl wird von der in der CAN-Netzwerkspezifikation angewandten Bit-Nummerierungskonvention vorgeschrieben.

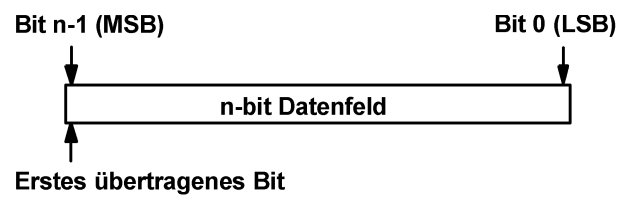


Bild 3-1 — Bit-Nummerierungskonvention

English version

Space engineering - CANbus extention protocol

Ingénierie spatiale - Protocole d'extension du CANbus

Raumfahrttechnik - CANbus-Erweiterungsprotokoll

This European Standard was approved by CEN on 11 May 2017.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN and CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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**CEN-CENELEC Management Centre:
Avenue Marnix 17, B-1000 Brussels**

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European foreword

This document (EN 16603-50-15:2017) has been prepared by Technical Committee CEN-CENELEC/TC 5 "Space", the secretariat of which is held by DIN.

This standard (EN 16603-50-15:2017) originates from ECSS-E-ST-50-15C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2017, and conflicting national standards shall be withdrawn at the latest by December 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g.: aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European Standard specifies requirements for the use of the CAN (Controller Area Network) data bus in spacecraft onboard applications. These requirements extend the CAN Network specification to cover the aspects required to satisfy the particular needs of spacecraft data handling systems. This standard is one of a series of ECSS standards relating to data link interfaces and communication protocols e.g. MIL-STD-1553 and ECSS-E-ST-50-5x Space Wire.

In order to provide a uniform set of communication services across these standards the CCSDS Spacecraft Onboard Interface Services (SOIS) Subnetwork Recommendations have been applied as driving requirements for protocol specification.

The CAN Network has been successfully used for three decades in automotive and critical control industry. In particular, its use in applications that have demanding safety and reliability requirements, or operate in hostile environments have similarities to spacecraft onboard applications.

The CAN Network is being adopted for a variety of space applications and care has therefore been taken during the drafting of this standard to include existing experience and feedback from European Space industry.

In addition to the CAN Network data link specifications, this standard also specifies the optional use of the CANopen standard as an application layer protocol operating over CANbus.

The set of CANopen specifications comprises the application layer and communication profile as well as application, device, and interface profiles. CANopen provides very flexible configuration capabilities.

1

Scope

This European Standard is applicable to spacecraft projects that opt to use the CAN Network for spacecraft on-board communications and control. It also defines the optional use of the CANopen standard as an application layer protocol operating in conjunction with the CAN Network data link layer.

This standard does not modify the basic CAN Network specification and complies with ISO 11898-1/-2:2003. This standard does define protocol extensions needed to meet spacecraft specific requirements.

This standard covers the vast majority of the on-board data bus requirements for a broad range of different mission types. However, there can be some cases where a mission has particularly constraining requirements that are not fully in line with those specified in this standard. In those cases this standard is still applicable as the basis for the use of CAN Network, especially for physical layer and redundancy management.

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
EN 16603-20	ECSS-E-ST-20	Space engineering - Electrical and electronic
EN 16603-20-07	ECSS-E-ST-20-07	Space engineering - Electromagnetic compatibility
EN 16602-70-08	ECSS-Q-ST-70-08	Space product assurance - Manual soldering of high-reliability electrical connections
EN 16602-70-26	ECSS-Q-ST-70-26	Space product assurance - Crimping of high-reliability electrical connections
	ESCC 3401/029 Issue 1, October 2002	Connectors Electrical Rectangular Microminiature, based on type MDM
	ESCC 3401/01 Issue 2, March 2010	Connectors, Electrical, Rectangular, Microminiature, Solder Bucket Contacts, with EMI Backshell, based on Type MDM
	ANSI/TIA/EIA-485-A-1998 (reaffirmed 28 March 2003)	Electrical Characteristics of Balanced Voltage Digital Interface Circuits. NOTE: This standard referenced in this document as RS-485.
	DIN 41652-1 (1990-06)	Rack and panel connectors, trapezoidal, round contacts Ø 1 mm; common mounting features and dimensions; survey of types
	ISO 11898-1:2003	Road vehicles – Controller Area Network (CAN) - Part 1: Data link layer and physical signalling
	ISO 11898-2:2003	Road vehicles – Controller Area Network (CAN) - Part 2: High-speed medium access unit
	CiA 102 v. 2.0	CAN physical layer for industrial applications (available from www.can-cia.org)

	CiA 301 Version 4.2.0	CANopen Application Layer and Communication Profile, CAN in Automation (available from www.can-cia.org)
	CiA 306 Version 1.3.0	CANopen electronic data sheet specification (available from www.can-cia.org)
	iCC 2012	CAN in Automation - Computation of CAN Bit Timing Parameters Simplified - Meenanath Taralkar, OTIS ISRC PVT LTD, Pune, India (available from www.can-cia.org)
	MIL-DTL-38999 (formerly MIL-C D38999 Series 3)	Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, and Breech Coupling), Environment Resistant, Removable Crimp and Solder Contacts, General Specification for. U.S. Department of Defense. 30 May 2008.
	RS-485	The current reference of this standard is ANSI/TIA/EIA-485-A-1998 (reaffirmed 28 March 2003)

Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 shall apply.

3.2 Terms specific to the present standard

3.2.1 asynchronous data transmission

data transmission from an originating source that is not synchronized to any clock pulse or external common event

NOTE 1 The data frame is delimited with (e.g.) start and stop signals. Both communication terminals do not need to have local clocks synchronized.

NOTE 2 Data transmission systems that foresee asynchronous data transfer can allow senders to attempt to transfer data at any time. If two or more senders send data at the same time then there is a conflict and an arbitration scheme is used to determine the order in which the senders can put their data on the bus. Priority is then used to differentiate between information to be delivered urgently, and data whose delivery is less time critical. When there is a conflict between two or more senders the one with highest priority is allowed to send its data first.

3.2.2 CAN-ID

11- or 29-bit identifier used in the arbitration and control field of the CAN frame

[CANopen – CiA Standard 301 V4.2.0]

3.2.3 cold redundant bus

redundancy scheme whereby data is only transmitted on one of the available busses

[CANopen – CiA Standard 301 V4.2.0]

3.2.4 communication bus system latency

time from the source sending a packet to the time when it is received by the intended destination

3.2.5 cross-strapping

two identical units that are interconnected with the remaining system in such a way that either unit can provide the required functionality

NOTE In an avionics system, where each unit appears with its identical backup, cross-strapped units provide all possible interconnections between them. For bus-connected systems all bus connected subsystems, components, and instruments are cross-strapped to their respective data buses. The overall system reliability of a space avionics system is significantly enhanced by cross strapping, as if one unit fails a redundant unit can take over without implying a complete switch-over to a redundant chain.

3.2.6 cyclic data transmission

see "isochronous data transmission" 3.2.11.

3.2.7 dominant and recessive states of CANbus signals

CAN transmission based on differential signal transmission

NOTE In this case, the difference between the CAN (controller area network) high (CAN_H) and CAN low (CAN_L) signals are used. Bus operation is dependent on accurate interpretation of Dominant and Recessive data bits within a CAN frame. Signal levels are reported in Clause 5.3.2 of this standard.

3.2.8 dominant bit level

logical level that when applied to a bus forces the entire bus to the same logical level

[CANopen – CiA Standard 301 V4.2.0]

3.2.9 hard coded (or Hardcoded) data

embedding what can, perhaps only in retrospect, be regarded as input or configuration data directly into the source code/read only memory of a FPGA/device, or fixed formatting of the data, instead of obtaining that data from external sources

[CANopen – CiA Standard 301 V4.2.0]

3.2.10 hot redundant bus

redundancy scheme whereby data is transmitted simultaneously on all of the available busses

[CANopen – CiA Standard 301 V4.2.0]

3.2.11 isochronous data transmission

form of **synchronous data transmission** where similar (logically or in size) data frames are sent linked to a periodic clock pulse or external common event

NOTE 1 In an Isochronous transmission the sender and the receiver are synchronized in such a way that they send/receive during the same time slots. This implies the existence of an implicit or explicit **time schedule table** that needs to be consistent over the entire network.

NOTE 2 The term is synonymous to cyclic data transmission (3.2.6) or to Rate Monotonic Scheduling.

3.2.12 local SCET

time counter implemented and maintained in a node, that is correlated with the SCET

[CANopen – CiA Standard 301 V4.2.0]

3.2.13 multimaster-capable, event-oriented message transmission

transmission mode where each node of a communication network can initiate the transmission of a message as soon as the bus is free

NOTE 1 (see 3.2.7 NOTE). As every node can initiate a message transfer (multi-master), a direct message transfer between all nodes of the network is possible.

NOTE 2 It is expected that each node of a Multi-master-network is able to autonomously contend the bus to initiate the transmission of a message. As it can happen that more than one network node begins transmission of a message at the same time, an arbitration process is necessary, which ensures only one node actually continues with the transmission of its message.

NOTE 3 Compared to a cyclic message transfer, a considerably lower bus load or a reduction in the required data transmission rate results.

3.2.14 NMT master

node in a CANopen network, responsible for managing all other nodes on the bus using the NMT services

[CANopen – CiA Standard 301 V4.2.0]

3.2.15 NMT slave

node in a CANopen network that is managed by the NMT master using the NMT services

[CANopen – CiA Standard 301 V4.2.0]

3.2.16 propagation time

critical length of a bus line occurring at the point where the return propagation delay ($t_{\text{prop}}(\text{total})$) of a signal through a line, equals the transition time(t_t) of a signal (the greater between rise and fall times)

NOTE 1 Network Critical Length = $t_t = t_{\text{prop}}(\text{total})$

NOTE 2 typical ISO or RS-485 driver has a 50 ns transition time, and when considering a typical twisted-pair transmission line prop delay of 5 ns/m, the return delay for one meter becomes 10ns/m. The critical length becomes 5 m (50 ns / 10ns/m = 5 m), and the max un-terminated stub length for the network is 1/3rd of the critical length, or 5/3 m (1,67 m).

[CANopen – CiA Standard 301 V4.2.0]

3.2.17 recessive bit level

logical level that when applied to a bus only has effect on the level of the bus if there is no driver that simultaneously applies a dominant bit level

[CANopen – CiA Standard 301 V4.2.0]

3.2.18 redundancy master

dedicated node responsible for managing the bus redundancy

NOTE In particular, this includes controlling the switching from a nominal to a redundant bus in a cold redundant bus system.

[CANopen – CiA Standard 301 V4.2.0]

3.2.19 redundant bus

bus system that consists of two or more identical physical communication channels to increase the bus reliability or availability

[CANopen – CiA Standard 301 V4.2.0]

3.2.20 redundant node

node that provides identical functionality as another node connected on the same physical bus

[CANopen – CiA Standard 301 V4.2.0]

3.2.21 spacecraft elapsed time (SCET)

central time reference that is maintained on-board the spacecraft

NOTE The SCET can be correlated to the ground time, and may be distributed to other on-board nodes.

[CANopen – CiA Standard 301 V4.2.0]

3.2.22 synchronous data transmission

data transmission in which a clock defines transmission times for data

NOTE 1 Data transmission from originating source is triggered (or happens in conjunction with) a clock pulse or external common event.

NOTE 2 Since start and stop bits for each character are not needed, more of the transmission bandwidth is available for message bits.

NOTE 3 See also **isochronous data transmission** (3.2.11).

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
CAN	controller area network
CCSDS	Consultative Committee for Space Data Systems
COB-ID	communication object identifier
ECSS	European Cooperation for Space Standardisation
EDS	electronic data sheet
EMC	electromagnetic compatibility
EMCY	Emergency Object
FIFO	first in first out
LDUT	large data unit transfer
LSB	least significant bit
MSB	most significant bit
NMT	network management
OSI	open systems interconnection
PCB	printed circuit board
PDU	protocol data unit
PDO	process data object
RPDO	receive PDO
RTR	remote transmission request

Abbreviation	Meaning
SAP	service access point
SCET	spacecraft elapsed time
SDO	service data object
SYNC	synchronisation object
TPDO	transmit PDO

3.4 Bit numbering convention

- The most significant bit of an n-bit field is:
 - numbered bit n-1,
 - the first bit transmitted,
 - the leftmost bit on a format diagram.
- The least significant bit of an n-bit field is:
 - numbered bit 0 (zero),
 - the last bit transmitted,
 - the rightmost bit on a format diagram.

This is illustrated in Figure 3-1.

This convention is the opposite of most ECSS and CCSDS documents. Its choice is dictated by the bit numbering convention used in the CAN Network specification.

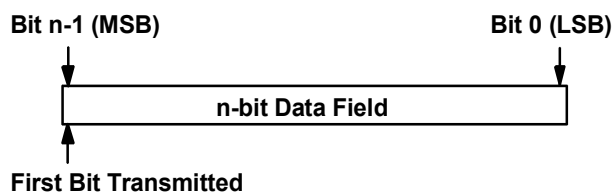


Figure 3-1: Bit numbering convention

3.5 Nomenclature

The following nomenclature applies throughout this document:

- The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.
- The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

- The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive

permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

- d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

- e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

Overview of the standard and principles

4.1 Document organization

The remainder of this document is organised as follows:

- Clause 5 specifies the CAN Network physical layer;
- Clause 6 specifies CANopen for use over a CAN Network in spacecraft applications;
- Clause 7 specifies the Time distribution protocol to be used over CAN Network;
- Clause 8 specifies the CAN Network redundancy management;
- Clause 9 specifies a minimal protocol set for highly asymmetric implementations;
- Clause 10 specifies connectors and pin assignments.

In addition to these normative clauses, annexes are provided describing:

- Annex A: CANopen Standard Applicability Matrix

The remainder of clause 4 provides informative information on each of the normative clauses.

4.2 Relationship of CAN Bus Network to existing Architectures

Figure 4-1 illustrates the relationship of the CAN Network to the ISO OSI model (as defined in [2]) and existing ECSS recommendations. The CAN Network specification covers the Physical and datalink layers of the ISO OSI model. The related ECSS-E-ST-50-15 standard covers only the physical layer.

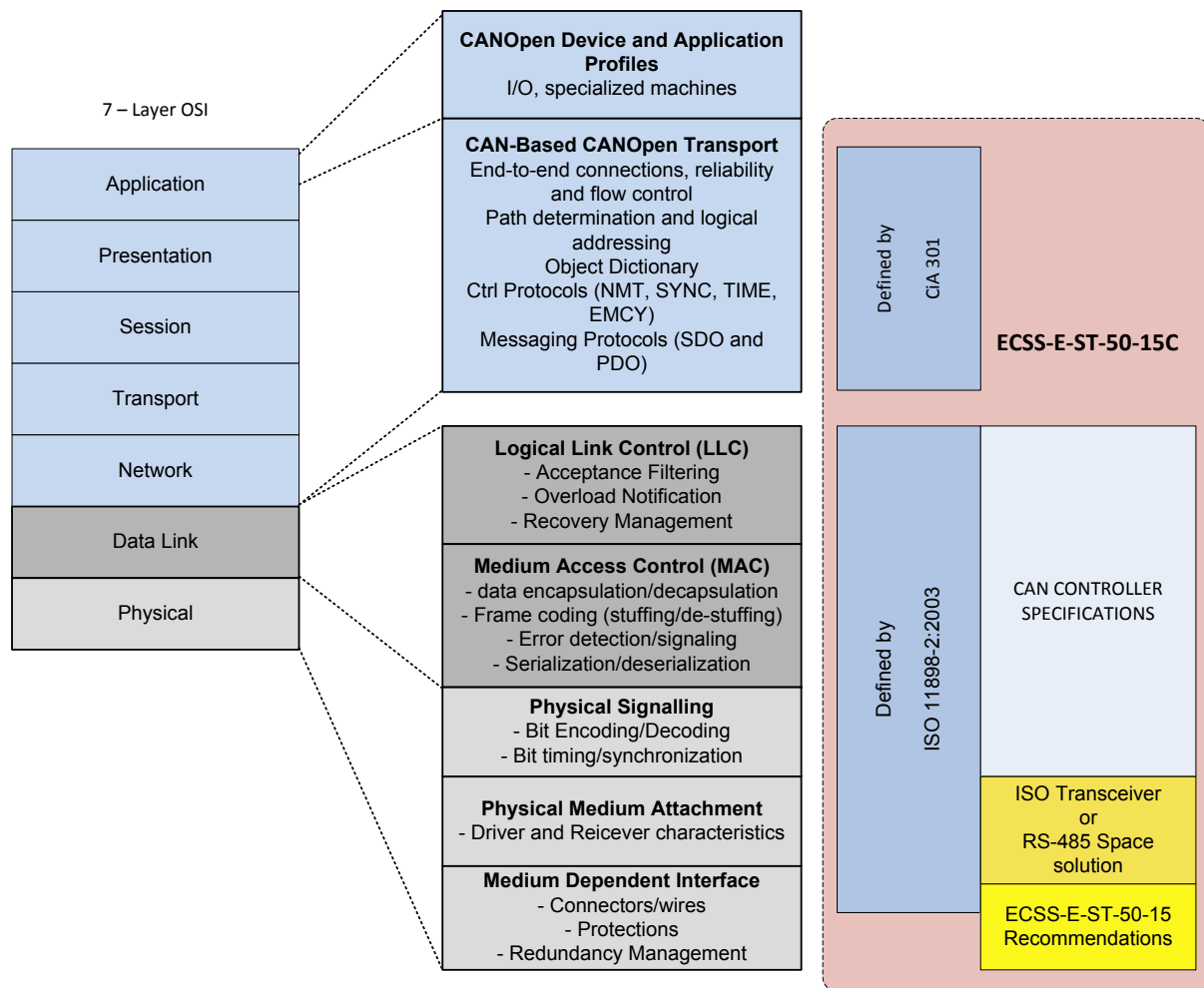


Figure 4-1: Relationship between ISO layering, ISO 11898, CiA 301 and ECSS CAN standard definitions

4.3 CANbus network

The Controller Area Network (CAN) is a serial communications protocol which efficiently supports distributed real-time control with a very high level of security.

For a detailed and authoritative introduction to the CAN features and characteristics refer to:

Texas Instrument's - Application Report SLOA101A – August 2002 – Revised July 2008 - Introduction to the Controller Area Network (CAN) by Steve Corrigan [4]

Extensive literature on use of CAN for high reliability command and control exists. Some of the most interesting articles are reported in the bibliography of this standard (see [9],[17],[18],[19],[20],[33],[34],[35],[36]).

4.4 Physical layer

Clause 5 lists the requirements related to the physical layer.

4.5 Communication model

The communication model is based on a CAN Network master connected to up to 126 slave nodes (the number of possible nodes depends on the physical layer capabilities).

The network is organized in a strict master/slave relationship (see Figure 4-2).

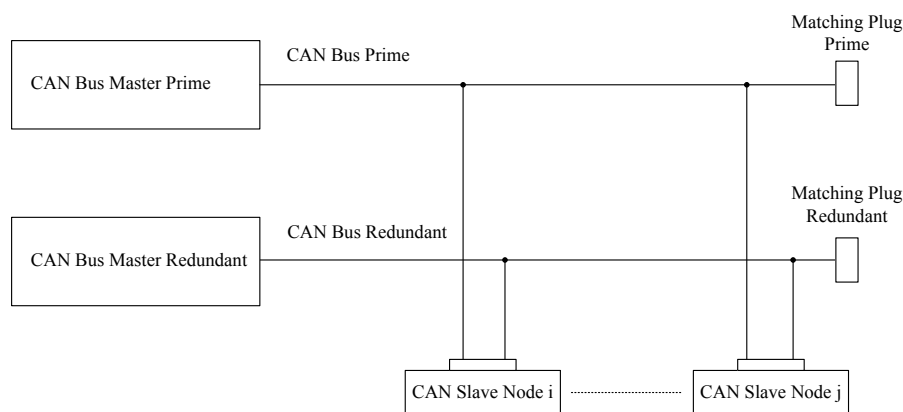


Figure 4-2: Example of minimal implementation topology

The CAN physical layer comprises the electrical, mechanical and performance characteristics of the cabling, connectors, termination resistors, CAN transceivers, and optional optical couplers.

The approach of this document is to make reference to ISO 11898-1:2003 and ISO 11898-2:2003 wherever possible; detailing only the specific restrictions where appropriate to satisfy the requirements for spacecraft applications.

For convenience, the Data Link layer description is included in this document within the physical layer clause. The Data Link conforms to ISO 11898-1:2003, which is based on the Bosch CAN 2.0B (1991) specification, [3].

4.6 CANopen higher layer protocol

The ISO 11898 standard specifies the CAN Network physical and data link layers. ISO 11898 provides fast, prioritized, reliable, broadcast message transmission with sophisticated error detection and error handling and can fulfil all requirements of small closed networks. However, it is not adapted to large, extendable, interconnected networks from different manufacturers

For this purpose this standard recommends the use of CANopen as a higher layer communication protocol operating over the CAN Network.

CANopen is a standard widely used in automation and industrial applications, including safety critical and maritime applications implementing redundant communication busses.

One of the strengths of CANopen is the simplicity of the redundancy management implementation. In addition, CANopen allows simple standardization of Electronic Data Sheets (EDS) making interoperability far more straightforward.

The description of a device's communication functionality and objects and its device-specific objects is provided in the form of an EDS, an ASCII or XML file with a strictly defined syntax.

A description of the object configuration of an individual device with its default parameter values, as well as maximum and minimum ranges is called a Device Configuration File (DCF) and has the same structure as an EDS (see [28], [29], [30] for reference).

Both file types are defined in the CANopen specification.

The CAN ISO 11898 standard defines only the layers 1 and 2; in practice these are completely handled by the CAN hardware, significantly reducing the implementation effort for node developers.

However, a high level protocol is necessary in order to define how the CAN message frame's 11-bit identifier and 8 data bytes are used. Building CAN-based space systems guaranteeing interoperability and interchangeability of devices of different manufacturers requires a standardized application layer and 'profiles', standardizing the communication system, the device functionality and the system administration:

- The application layer provides a set of services and protocols useful to every device on the network imaginable.
- The communication profile provides the means to configure devices and communication data and defines how data is communicated between devices.

Device profiles (not foreseen in the present standard) may add device-specific behaviour for (classes of) devices (e.g. digital I/O, analogue I/O, motion controllers, encoders).

The CANopen communication model defines four types of messages (communication objects):

1 Administrative messages (Layer management, network management and identifier distribution services):

These services are all based on a Master-Slave concept: in a CAN-network there is only one LMT.

2 Service Data Object (SDO):

An SDO provides a client access to entries (objects) of a device OD (the device is the server) using the object's OD index and sub-index, contained in the first few bytes of the CAN-message.

3 Process Data Object (PDO):

PDOs are used to transfer real-time data; data is transferred from one (and only one) producer to one or more consumers. Data transfer is limited to 1 to 8 bytes. It has no protocol overhead. The data content of a PDO is defined through its CAN-identifier and this content is assumed to be known to sender as well as receiver(s) of the PDO.

4 Predefined messages or Special Function Objects:

Synchronization (SYNC)

Time Stamp

Emergency

Node/Life Guarding

Boot-Up

Clause 6 specifies requirements applicable to application layer protocol.

Reference is made to the CiA Standard 301 Version 4.2.0 (CANopen). Note that this standard also specifies additional details or constraints in addition to those specified by CANopen.

4.7 Time distribution

4.7.1 Overview

This standard defines a time distribution protocol based on the use of CANopen PDOs. The protocol may be used over a CAN Network and in conjunction with CANopen. The time distribution service defined as part of the CANopen is considered inadequate for spacecraft requirements.

The time distribution and synchronization protocols specified in this standard distribute a sample of the central time to devices maintaining a local time.

The time distribution protocol provides a mechanism to transfer and read back the time with no specific requirements on accuracy. The optional high-resolution time distribution protocol allows for the best possible time synchronization via the CAN Network. It is possible to use both protocols on the same CAN Network.

This standard makes no assumptions on the relationship or maximum time error between the central time and the local time. In particular, the frequency of local time updating and any associated mechanisms for adjusting the local time without loss or duplication of time codes are device and application specific and outside the scope of this standard.

The time distribution protocol is based on a single PDO transmission from the Time producer to one or more Time consumers. Read-back of the local time is facilitated by means of dedicated PDOs. There are no specific features in this protocol to control the accuracy of the time distribution.

The High-resolution time protocol uses the SYNC object to achieve the highest possible synchronization accuracy when distributing time over the CAN Network. Read-back of the local times is facilitated by means of dedicated PDOs. The actual accuracy of the time distribution is implementation dependent. Accuracy in the microsecond range can be achieved with a bit rate of 1 Mbps.

4.7.2 SYNC message and protocol

Synchronous network behaviour in CANopen networks can be achieved with the SYNC protocol. The cyclically transmitted SYNC message indicates to the consumers to start their application-specific behaviour, which is coupled to the reception of the SYNC message. Synchronous PDOs use the SYNC message as a triggering event for PDO transmission and as indication for sending the data valid, which has been received previously to the SYNC message.

The SYNC Message format is defined in CANopen CiA 301 V4.2.0 section 7.3.5.

The SYNC protocol uses a producer/consumer communication coherence. There is one SYNC producer and several SYNC consumers. In case a device supports the SYNC consumer capability, this functionality can be switched on in the COB-ID entry for the SYNC object (1005h). This entry also provides the CAN-Identifier for the SYNC message. All consumers need to assign the same CAN-Identifier to that COB-ID entry. Furthermore, they indicate the consumer functionality in bit 30.

4.7.3 Bit timing

Even if minor errors in the configuration of the CAN bit timing do not result in immediate failure, the performance of a CAN network can be reduced significantly. In most of the cases, the CAN bit synchronization amends a faulty configuration of the CAN bit timing so that only an occasional error frame is generated.

In the case of arbitration however, when two or more CAN nodes simultaneously try to transmit a frame, a misplaced sample point may cause one of the transmitters to become Error Passive.

The analysis of such sporadic errors requires a detailed knowledge of the CAN bit synchronization inside a CAN node and of the CAN nodes' interaction on the CAN Network.

Further information about bit timing parameters are available in [11], [12], [21], [22], [23], [24].

4.8 Redundancy management and monitoring

4.8.1 Overview

Spacecraft on-board communication busses are typically implemented using a redundant physical media topology that is resilient to single point failure in cabling or connector faults.

Neither the CAN Network specification ISO 11898 nor the CANopen standard define redundancy management. However, both specifications define capabilities that are suitable for use when implementing a highly reliable bus system.

A redundant communication system requires redundant communication channels and also a redundancy management scheme. Components that can be