CAN-USB/400

Dual-Channel CAN FD or CAN CC Modules for connecting with USB, optional with I/Os and IRIG-B Input

CAN-USB/400-IRIG-B
(C.2069.66)

Hardware Manual

For Product C.2069.64, C.2069.04
C.2069.66, C.2069.06

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Notes

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This manual contains important information and instructions on safe and efficient handling of the CAN-USB/400. Carefully read this manual before commencing any work and follow the instructions.
The manual is a product component, please retain it for future use.

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The changes in the document listed below affect changes in the hardware as well as changes in the description of the facts, only.

Rev.	Chapter	Changes versus previous version	Date
1.3	6.	Note on CAN FD inserted	2018-03-27
1.4	8.	Declaration of Conformity updated	2020-06-04
1.5	-	Safety instructions (Page 5) revised	2025-02-12
	all	Description of CAN-USB/400-FD-IRIG-B added	
	1., 3., 10.	Chapters revised	
	4.4	Description of CAN CC and CAN FD ports merged	
	9.	Declaration of Conformity has been updated	

Technical details are subject to change without further notice.

Classification of Warning Messages and Safety Instructions

This manual contains noticeable descriptions, warning messages and safety instructions, which you must follow to avoid personal injuries or death and property damage.

This is the safety alert symbol.
It is used to alert you to potential personal injury hazards. Obey all safety messages and instructions that follow this symbol to avoid possible injury or death.

DANGER, WARNING, CAUTION

Depending on the hazard level the signal words DANGER, WARNING or CAUTION are used to highlight safety instructions and warning messages. These messages may also include a warning relating to property damage.

DANGER
Danger statements indicate a hazardous situation which, if not avoided, will result in death or serious injury.

WARNING.
Warning statements indicate a hazardous situation that, if not avoided, could result in death or serious injury.

CAUTION
Caution statements indicate a hazardous situation that, if not avoided, could result in minor or moderate injury.

NOTICE

Notice statements are used to notify people on hazards that could result in things other than personal injury, like property damage.

NOTICE
This NOTICE statement indicates that the device contains components sensitive to electrostatic discharge.

NOTICE
This NOTICE statement contains the general mandatory sign and gives information that must be heeded and complied with for a safe use.

INFORMATION

INFORMATION
Notes to point out something important or useful.

Safety Instructions

- When working with the CAN-USB/400 follow the instructions below and read the manual carefully to protect yourself from injury and the CAN-USB/400 from damage.
- Do not use damaged or defective cables to connect the CAN-USB/400 and follow the CAN wiring hints in chapter: "Correct Wiring of Galvanically Isolated CAN Networks".
- In case of damages to the device, which might affect safety, appropriate and immediate measures must be taken, that exclude an endangerment of persons and domestic animals and property.
- The galvanic isolation of the CAN-USB/400 has only functional tasks and is not a protection against hazardous electrical voltage.
- The CAN-USB/400 is a device of protection class III according to DIN EN IEC 61140 and may only be operated on supply circuits that offer sufficient protection against dangerous voltages.
- External circuits connected to the interfaces of the CAN-USB/400 must be sufficiently protected against dangerous voltage.
- The user is responsible for compliance with the applicable national safety regulations.

- Do not open the housing of the CAN-USB/400 .
- The CAN-USB/400 must be securely installed before commissioning.
- The permitted operating position is specified as shown (chapter 2). Other operating positions are not allowed.
- Never let liquids get inside CAN-USB/400
- Protect the CAN-USB/400 from dust, moisture, and steam.
- Protect the CAN-USB/400 from shocks and vibrations.
- The CAN-USB/400 may become warm during normal use. Always allow adequate ventilation around the CAN-USB/400 and use care when handling
- Do not operate the CAN-USB/400 adjacent to heat sources and do not expose it to unnecessary thermal radiation. Ensure that the ambient temperature remains within the limits specified in the technical data..

NOTICE
Electrostatic discharges may cause damage to electronic components.

→ Take the appropriate precautions for handling electrostatic discharge sensitive devices.

Qualified Personnel

This documentation is directed exclusively towards personnel qualified in control and automation engineering. The installation and commissioning of the product may only be carried out by qualified personnel, which is authorized to put devices, systems, and electric circuits into operation according to the applicable national standards of safety engineering.

Conformity

The CAN-USB/400 is an industrial product and meets the demands of the EU regulations and EMC standards printed in the conformity declaration at the end of this manual.

WARNING.
In a residential, commercial, or light industrial environment the CAN-USB/400 may cause radio interferences in which case the user may be required to take adequate measures.

Data Safety

This device is equipped with an interface which is suitable to establish a connection to data networks. Depending on the software used on the device, these interfaces may allow attackers to compromise normal function, get illegal access or cause damage.

esd does not take responsibility for any damage caused by the device if operated at any networks. It is the responsibility of the user of the device to ensure that the necessary safety precautions are taken for the network interface of the device.

Intended Use

The intended use of the CAN-USB/400 is the operation as USB-CAN interface.
The guarantee given by esd does not cover damages which result from improper use, usage not in accordance with regulations or disregard of safety instructions and warnings.

- The CAN-USB/400 is intended for indoor operation only.
- The operation of the CAN-USB/400 in hazardous areas, or areas exposed to potentially explosive materials is not permitted.
- The operation of the CAN-USB/400 for medical purposes is prohibited.

Service Note

The CAN-USB/400 does not contain any parts that require maintenance by the user. The CAN-USB/400 does not require any manual configuration of the hardware. Unauthorized intervention in the device voids warranty claims

Disposal

Products marked with a crossed-out dustbin must not be disposed of with household waste. Devices which have become defective in the long run must be disposed in an appropriate way or must be returned to the manufacturer for proper disposal. Please, contribute to environmental protection.

Table of Contents

Safety Instructions 5
Overview 9
1.1 About this Manual 9
1.2 Description of CAN-USB/400(-FD) 9
1.3 Description of CAN-USB/400(-FD)-IRIG-B 10
1.4 Glossary 10
2 Case View with LEDs and Connectors 11
2.1 Indicator States of CAN LEDs 12
3 Installing and Uninstalling Hardware 13
3.1 Installing the Hardware 13
3.2 Uninstalling the Hardware 14
4 Technical Data 15
4.1 General Technical Data 15
4.2 USB Device Port 15
4.3 CAN Ports 16
4.4 Interfaces available at IRIG-B-Variants only 16
4.4.1 IRIG-B Inputs 16
4.4.2 Sync I/Os 17
4.4.3 Miscellaneous I/Os 17
4.4.4 Microcontroller for IRIG-B 17
4.5 Software Support 18
5 Connector Assignments 19
5.1 USB 19
5.2 CAN (DSUB9, Pin Contacts) 20
5.3 IRIG-B (DSUB15, Socket-Contacts) 21
6 Correct Wiring of Galvanically Isolated CAN Networks 23
6.1 CAN Wiring Standards 23
6.2 Light Industrial Environment (*Single* Twisted Pair Cable) 24
6.2.1 General Rules 24
6.2.2 Cabling 25
6.2.3 Branching 25
6.2.4 Termination Resistor 25
6.3 Heavy Industrial Environment (Double Twisted Pair Cable) 26
6.3.1 General Rules 26
6.3.2 Device Cabling 27
6.3.3 Branching 27
6.3.4 Termination Resistor 27
6.4 Electrical Grounding 28
6.5 Bus Length 28
6.6 Examples for CAN Cables 29
6.6.1 Cable for Light Industrial Environment Applications (Two-Wire) 29
6.6.2 Cable for Heavy Industrial Environment Applications (Four-Wire) 29
7 CAN Troubleshooting Guide 30
7.1 Electrical Grounding 31
7.2 Short Circuit in CAN Wiring 31
7.3 Correct Voltage Levels on CAN_H and CAN_L 31
7.4 CAN Transceiver Resistance Test 32
7.5 Support by esd 32
8 Software Licenses 33
8.1 3rd Party Software License Terms 33
8.1.1 Open-Source Software Copy 33
9 Declaration of Conformity 34
10 Order Information 35
10.1 Hardware 35

10.2 Software 36
10.3 Manuals 36

List of Tables

Table 1: Overview of CAN-USB/400 variants 9
Table 2: Special indicator states 12
Table 3: Description of LEDs 12
Table 4: General data of the module 15
Table 5: Data of the USB port 15
Table 6: Data of the CAN ports 16
Table 7: Data of the IRIG-B interface 16
Table 8: Data of the Sync I/Os 17
Table 9: Data of the Miscellaneous I/Os 17
Table 10: Data of the optional microcontroller 17
Table 11: Recommended cable lengths at typical bit rates (with esd-CAN interfaces) 28
Table 12: License and Identifier 33
Table 13: Order information hardware 35
Table 14: Order information software 36
Table 15: Available Manuals 36

List of Figures

Figure 1: Block circuit diagram of CAN-USB/400(-FD) 9
Figure 2: Block circuit diagram of CAN-USB/400(-FD)-IRIG-B 10
Figure 3: CAN connectors and LEDs (CAN-USB/400-IRIG-B view) 11
Figure 4: USB and IRIG-B (CAN-USB/400-IRIG-B view) 11
Figure 5: IRIG-B wiring guidelines 22
Figure 6: CAN wiring for light industrial environment 24
Figure 7: Example for proper wiring with single shielded single twisted pair wires 25
Figure 8: CAN wiring for heavy industrial environment 26
Figure 9: Example of proper wiring with single shielded double twisted pair cables 27
Figure 10: Simplified diagram of a CAN network 30
Figure 11: Simplified schematic diagram of ground test measurement 31
Figure 12: Measuring the internal resistance of CAN transceivers 32

Overview

1.1 About this Manual

In this hardware manual all variants of the CAN-USB/400 are collectively referred to as CAN-USB/400. Available features, options and supplied items may vary depending on the CAN-USB/400 variant you selected. The CAN-USB modules have an identical structure, except of the CAN FD ports at the CAN FD variants (CAN-USB/400-FD and USB/400-FD-IRIG-B), and the additional IRIG-B and I/O interfaces at the IRIG-B variants (CAN-USB/400-IRIG-B and USB/400-FD-IRIG-B).
Differences of the CAN-USB/400 variants are noted accordingly where relevant.
This document describes the hardware of the following CAN-USB/400-Modules:

Name	Number of CAN ports	CAN FD capable	Analog and digital IRIG-B input and Multiple IOs	esd order No.
CAN-USB/400-FD	2	✓	-	C.2069.64
CAN-USB/400	2	-	-	C.2069.04
CAN-USB/400-FD-IRIG-B	2	✓	✓	C.2069.66
CAN-USB/400-IRIG-B	2	-	✓	C.2069.06

Table 1: Overview of CAN-USB/400 variants

1.2 Description of CAN-USB/400(-FD)

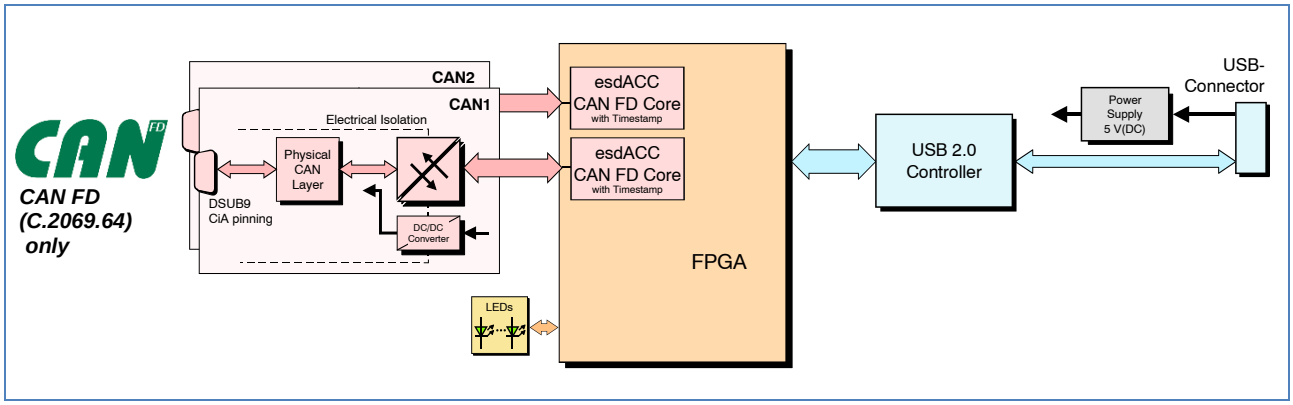


Figure 1: Block circuit diagram of CAN-USB/400(-FD)

The CAN-USB/400 module is developed for CAN communication with minimum latency via USB. For this purpose, USB is connected internally via FIFOs and the data management is controlled by the esd Advanced CAN Controller (esdACC).

Two independent CAN ports in accordance with ISO 11898-1 offer extensive options for using the CAN bus. Each port has its own ISO 16845:2004 certified esdACC. Depending on the variant, the port can send and receive ISO-compliant CAN FD and/or CAN 2.0 A/B messages.
The CAN-USB/400-FD comes with two CAN FD ports with bit rates up to 8 Mbit/s and the basic CAN CC variant (CAN-USB/400) with two CAN CC ports with bit rates up to 1 Mbit/s.
Power is supplied via USB.

esd has developed error injection technology to simplify the testing of fail-safety, diagnostics and optimization of CAN-based systems. This technology makes it possible to inject error situations into

the CAN bus during active operation. Multiple trigger conditions and modes offer flexible and extensive options for sending almost any bit pattern to the CAN bus.
The CAN drivers for Windows are included in the scope of delivery.

1.3 Description of CAN-USB/400(-FD)-IRIG-B

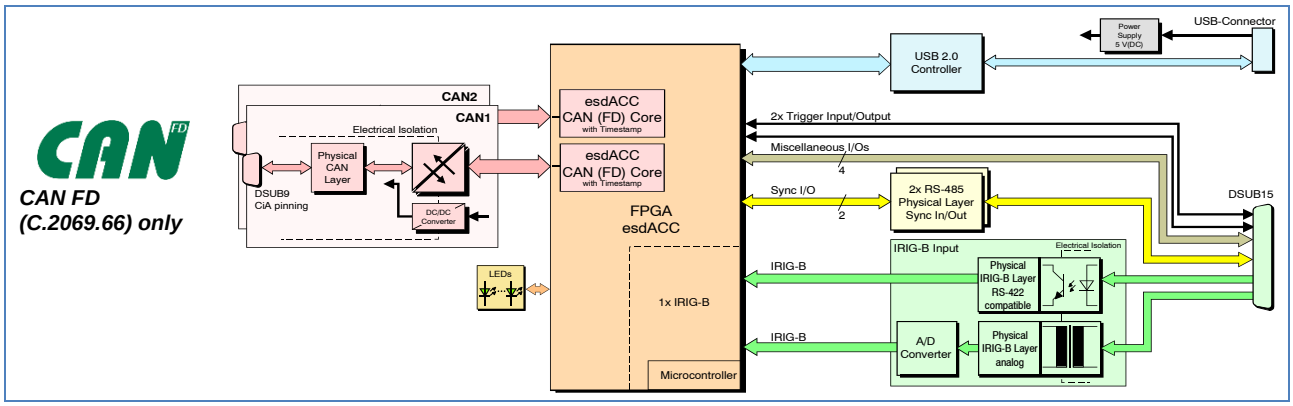


Figure 2: Block circuit diagram of CAN-USB/400(-FD)-IRIG-B

In addition to the standard features of the CAN-USB/400 module, the CAN FD variant CAN-USB/400-FD-IRIG-B and the CAN CC variant CAN-USB/400-IRIG-B come with IRIG-B inputs. The analog and digital IRIG-B inputs provide synchronized timestamps, ideal for use with ARINC825.
External trigger I/Os enable extended error injection functions, and additional I/Os offer a wide range of possible applications.

1.4 Glossary

Abbreviations

Abbreviation	Term	Description
API	Application Programming Interface	
CAN	Controller Area Network	In this manual the term CAN only includes CAN CC and CAN FD. CAN XL is not supported
CAN CC	CAN classic	
CAN FD	CAN flexible data rate	
CPU	Central Processing Unit	
CiA	CAN in Automation	
HW	Hardware	
I/O	Input/Output	
LSB	Least Significant Bit	
MSB	Most Significant Bit	
n.a.	not applicable	
OS	Operating System	
SDK	Software Development Kit	

2 Case View with LEDs and Connectors

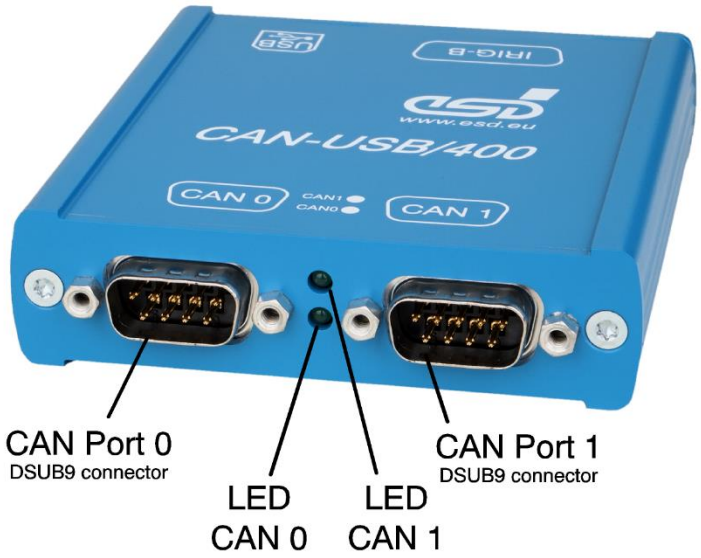


Figure 3: CAN connectors and LEDs (CAN-USB/400-IRIG-B view)

Figure 4: USB and IRIG-B (CAN-USB/400-IRIG-B view)

See also page 19 for signal assignment of the CAN connectors.

NOTICE
Read chapter “Installing and Uninstalling Hardware” from page 13, before you start with the installation of the hardware!

2.1 Indicator States of CAN LEDs

The CAN-USB/400-Modules come with two green CAN LEDs (CAN0, CAN1).
See Figure 3 on page 11 for the position of the LEDs.

The **Special Indicator States** are indicated by both LEDs together.
The state **CAN Activity** is indicated individually for each CAN channel.

Special Indicator States

LED	Indicator State	Indication	LED Description
CAN0	off	Power off	Power off and no CAN bus connection
CAN1			
CAN0	alternate blinking	Power on (Module ready)	Power on but the driver has not yet been loaded. Both LEDs are blinking in alternating sequence.
CAN1			
CAN0	on	Driver loaded	Driver loaded and no activity on CAN0 or CAN1
CAN1			

Table 2: Special indicator states

CAN Activity
This indicator state is indicated individually by the LED of the corresponding CAN bus channel. The driver must be loaded for this. The LED is on and turns off shortly when a CAN frame is transmitted. If there is a lot of data transfer on a CAN channel, the corresponding LED does not turn off completely but is blinking.

LED	Indicator State	Indication	LED Description
CAN0	blinking	Activity CAN0	Driver loaded and CAN data transfer on CAN0
CAN1	blinking	Activity CAN1	Driver loaded and CAN data transfer on CAN1

Table 3: Description of LEDs

3 Installing and Uninstalling Hardware

To install or uninstall the CAN-USB/400, please follow the installation notes.

Step	Procedure	See Page
	**NOTICE** **Read the safety instructions at the beginning of this document carefully before you start with the hardware installation/!**	5
	**DANGER** Hazardous voltage - Risk of electric shock due to unintentional contact with uninsulated live parts with high voltages inside of the system into which the CAN-USB/400 is to be integrated. → The CAN-USB/400 is a device of protection class III according to DIN EN IEC 61140 and may only be operated on supply circuits that offer sufficient protection against dangerous voltages. → External circuits connected to the ports of the CAN-USB/400 must be sufficiently protected against dangerous voltages. → Compliance with the applicable national safety regulations is the responsibility of the user. → Ensure the absence of voltage before starting any electrical work.	
To install, continue as described in chapter 3.1 ‘Installing the Hardware’. To uninstall, continue as described in chapter 3.2 ‘Uninstalling the Hardware’		

3.1 Installing the Hardware

Step	Procedure	See Page
1.	Observe the safety instructions at the beginning of chapter 3	13
2.	Connect the CAN or CAN FD ports (CAN0, CAN1) to the DSUB9 connectors of your CAN-USB/400 module as described in Figure 3. CAN-USB/400(-FD)-IRIG-B- variants only: Connect the IRIG-B interface to the DSUB15 connector as described in Figure 4.	11.
	See also chapter 5 for Connector Assignments	19
	**NOTICE** To ensure the EC Conformity shielded cables have to be used. In an adapter cable FE (functional earth) shall be connected to the cable shield.	
3.	Please note that the CAN bus must be terminated at both ends! esd offers special T-connectors and termination connectors for external termination. Additionally, the CAN_GND signal must be connected to earth at exactly one point in the CAN network. For details, please read chapter “Correct Wiring of Galvanically Isolated CAN Networks”.	23
4.	Connect the CAN-USB/400-Module via USB to your computer. The module is powered via USB.	11

INFORMATION
The software installation is described in the manual ‘NTCAN-API, Driver Installation Guide’.

3.2 Uninstalling the Hardware

Step	Procedure	See Page
1.	Observe the safety instructions at the beginning of chapter 3	13
2.	Make sure that all connected interfaces and power supply are switched off.	
3.	Disconnect the CAN-USB/400 from the connected interfaces.	

4 Technical Data

4.1 General Technical Data

Power supply voltage	Via USB 2.0 bus, Nominal voltage: 4.5 ... 5.5 V Current consumption: max. 350 mA
Connectors	USB USB type B connector CAN0, CAN1 2x 9-pin DSUB pin-contacts CAN-USB/400(-FD)-IRIG-B only: IRIG-B 15-pin DSUB socket-contacts
Temperature range	Ambient temperatures operating: 0...55 °C storage: -40...70 °C transport: -40...70 °C
Humidity	Max. 90%, non-condensing
Protection class	IP20
Housing material	Aluminium
Dimensions	86 mm x 19 mm x 86 mm (without connector excess length)
Weight	145 g

Table 4: General data of the module

INFORMATION
Please note that the current consumption of the module must be supplied (high powered bus-powered device). The maximum current consumption must be guaranteed also if a hub is used. Therefore, it is highly recommended to use a self-powered hub.

4.2 USB Device Port

Number	1x USB
Controller	Integrated in FPGA
USB interface	USB 2.0, High-Speed, 480 Mbit/s
Connector	USB type B plug

Table 5: Data of the USB port

4.3 CAN Ports

INFORMATION
The CAN FD ports are only available on CAN-USB/400-FD (C.2069.64) and CAN-USB/400-FD-IRIG-B (C.2069.66).
The CAN FD ports are fully backwards compatible with CAN CC environments.

Number of CAN ports	CAN-USB/400-FD (C.2069.64), CAN-USB/400-FD-IRIG-B (C.2069.66): 2x CAN FD CAN-USB/400 (C.2069.04), CAN-USB/400-IRIG-B (C.2069.06): 2x CAN CC
CAN controller	esdACC in FPGA acc. to ISO 11898-1
Physical Layer	Physical layer according to ISO 11898-2, CAN FD bit rates from 10 kbit/s up to 8 Mbit/s CAN CC bit rates from 10 kbit/s up to 1 Mbit/s
Galvanic isolation	Galvanic isolation via digital isolator and DC/DC-converters: Voltage over CAN isolation (CAN to module case/connector housing; CAN to host/system ground; CAN to CAN): 1000V DC @ 1s (I < 1 mA)
Bus termination	Terminating resistor has to be set externally
Connector	DSUB9, pin contacts, according to technical report CiA® 106

Table 6: Data of the CAN ports

4.4 Interfaces available at IRIG-B-Variants only

INFORMATION
The IRIG-B option and the I/Os are only available on CAN-USB/400-IRIG-B (C.2069.06) and CAN-USB/400-FD-IRIG-B (C.2069.66).

4.4.1 IRIG-B Inputs

Number of inputs	1x analog (IRIG-B_RX+, IRIG-B_RX-) 1x digital (IRIG-B_A+, IRIG-B_A-)
Standard	IRIG-B inputs acc. to standard 200-87, Format B122 (analog) and B003 (digital)
Galvanic isolation	Both inputs are galvanically isolated
Connector	15-pin DSUB, socket contacts

Table 7: Data of the IRIG-B inputs

4.4.2 Sync I/Os

Number of I/Os	2 (SYNC1+/-, SYNC2+/-)
Interface	RS-485 trigger channels, Programmable as input or output
Evaluation	Timestamp synchronisation of CAN-USB/400(-FD)-IRIG-B modules
Galvanic isolation	None
EMC / conformity	This interface is not examined with regard to the electromagnetic compliance and immunity. This interface is for custom built evaluation kits destined for professionals to be used solely at research and development facilities for such purposes.
Connector	15-pin DSUB, socket contacts

Table 8: Data of the Sync I/Os

4.4.3 Miscellaneous I/Os

Number of I/Os	6 (TRIG0...TRIG5)
Interface	3.3 LVTTL level, programmable as input or output
Evaluation	digital I/Os, e.g. trigger inputs for CAN Error Injection
Galvanic isolation	none
EMC / conformity	This interface is not examined with regard to the electromagnetic compliance and immunity. This interface is for custom built evaluation kits destined for professionals to be used solely at research and development facilities for such purposes.
Connector	15-pin DSUB, socket contacts

Table 9: Data of the Miscellaneous I/Os

4.4.4 Microcontroller for IRIG-B

CPU	8051
Clock rate	48 MHz
Memory	32 KByte
EEPROM	16 KByte (firmware)

Table 10: Data of the optional microcontroller

4.5 Software Support

esd offers the sophisticated NTCAN-API for accessing the CAN bus via the CAN-USB/400, which provides extensive functions for making the best possible use of the CAN bus. Device drivers for Windows® are included in the scope of delivery of the CAN-USB/400.
Higher layer protocols (CANopen, J1939, ARINC825) are supported for CAN CC applications.
For detailed information about the driver availability for your operating system, please contact our sales team: sales@esd.eu

The CAN layer 2 (CAN-API) software installation and the software drivers are described in the manuals:

“NTCAN-API Part 1: Structure, Function and C/C++ API” Application Developers Manual and
“NTCAN-API Part 2: Installation, Configuration and Firmware Update” Installation Guide

The manuals can be downloaded free of charge from our website via the product page of the CAN-USB/400 or the CAN-SDK page: https://esd.eu/produkte/can-sdk.

CAN Tools

esd offers additional free-of-charge tools which support efficient setup and analysis of CAN applications and networks.
The CAN Tools are operational with all esd PC-CAN interfaces (e.g. PCIe, USB, EtherCAN/2 ...)

The following CAN Tools are available:

CANreal	Display and record of CAN message frames
CANplot	Graphical display of CAN data
CANrepro	Replay of pre-recorded CAN messages
CANscript	Python based scripting tool
COBview	Analysis and diagnostics of CANopen® nodes

System Requirements:
- Windows 32-bit or 64-bit system
- esd CAN driver installed

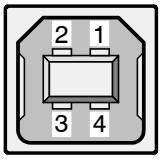
As part of the esd software development kit (CAN SDK) of the NTCAN-API the CAN Tools are included in delivery of the CAN-CD.
The CAN SDK can also be downloaded free-of-charge from the esd website.

5 Connector Assignments

5.1 USB

Device connector: USB receptacle, increased retention force, type B

Pin Position:



Pin Assignment:

Pin	Signal
1	V_{BUS}
2	D-
3	D+
4	GND

Signal Description:

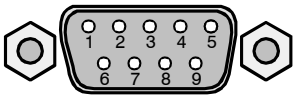
V_{BUS} ...	+5 V power supply voltage
D+, D-...	USB signal lines Data+, Data-
GND...	Reference potential
Connector housing...	Connector housings of CAN0, CAN1, USB and (if applicable) IRIG-B are connected to each other and via 10 nF to both CAN_GNDs of CAN0 and CAN1

5.2 CAN (DSUB9, Pin Contacts)

The connector type and pin assignment of CAN0 and CAN1 are identical.

Device connector: DSUB9 connector with pin contacts

Pin Position:



Pin Assignment:

Signal	Pin		Signal
CANx_GND	6	1	Reserved
CANx_H	7	2	CANx_L
Reserved	8	3	CANx_GND
Reserved	9	4	Reserved
		5	-

Signal Description:

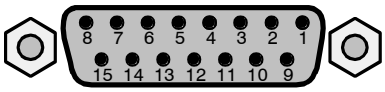
CANx_L, CANx_H …	CAN signal lines of net CANx (x = 0 or 1)
CAN_GND …	Reference potential of the local CAN physical layer
Reserved …	Reserved for future applications, do not connect!
- ...	Not connected
Connector housing...	Connector housings of CAN0, CAN1, USB and (if applicable) IRIG-B are connected to each other and via 10 nF to both CAN_GNDs of CAN0 and CAN1

5.3 IRIG-B (DSUB15, Socket-Contacts)

INFORMATION
The IRIG-B, Trigger and I/O-option is only available on CAN-USB/400-IRIG-B (C.2069.06) and CAN-USB/400-FD-IRIG-B (C.2069.66).

Device connector: 15-pin DSUB connector, socket-contacts

Pin Position:



Pin Assignment:

Signal	Pin		Signal
TRIG0	1	9	TRIG1
TRIG2	2	10	TRIG3
TRIG4	3	11	TRIG5
SYNC1-	4	12	SYNC1+
SYNC2-	5	13	SYNC2+
GND	6	14	IRIG-B_RX+
IRIG-B_RX-	7	15	IRIG-B_A+
IRIG-B_A-	8		

Signal Description:

TRIG0...TRIG5 ...	Miscellaneous I/Os, 3.3 LVTTL level, E.g. usable as trigger inputs for CAN Error Injection
SYNC1+/-, SYNC2+/- ...	RS-485 interface for timestamp synchronisation of CAN-USB/400 modules
GND ...	Signal reference GND
IRIG-B_RX+/- ...	Digital IRIG-B input acc. to standard 200-87, format B003
IRIG-B_A+/- ...	Analog IRIG-B input acc. to standard 200-87, format B122
Connector housing ...	Connector housings of IRIG-B, CAN0, CAN1 and USB are connected to each other and via 10 nF to both CAN_GNDs of CAN0 and CAN1

NOTICE
To ensure the EC Conformity for the wiring of the IRIG-B interface at the 15-pin DSUB connector a shielded twisted pair cable must be used.
In this adapter cable FE (functional earth) shall be connected to the cable shield.
The shield is intended to be connected to functional earth, via the host system or via the remote station or via a separate connection of the shield. See Figure 5.

Wiring of the analog and the digital IRIG-B interface at DSUB15

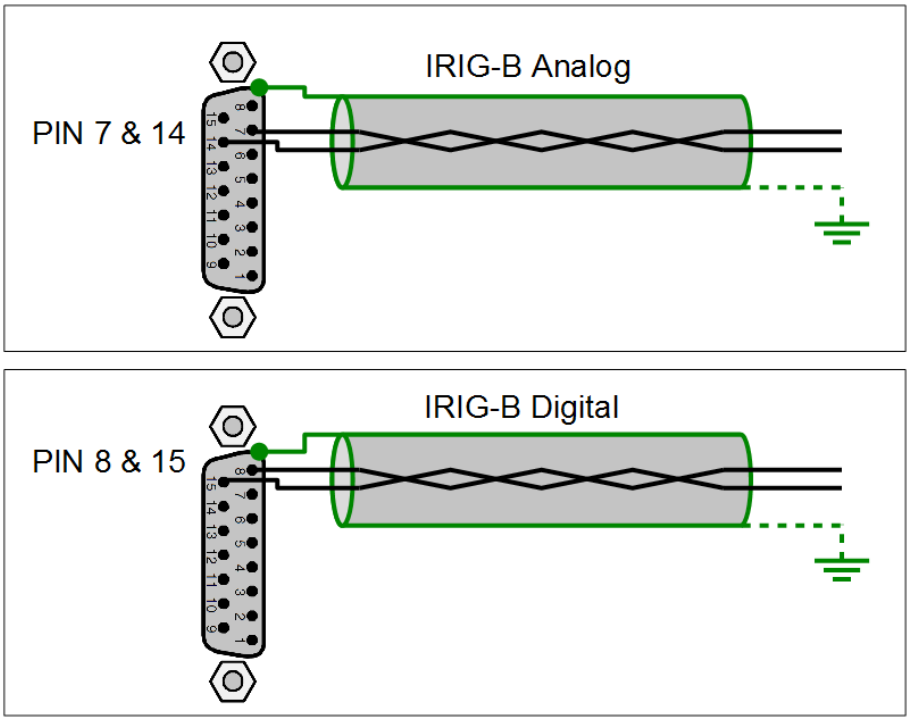


Figure 5: IRIG-B wiring guidelines

Use a shielded twisted pair cable to connect the IRIG-B interfaces.
The housing of the DSUB15 connector of the CAN-USB/400 must be connected to the cable shield.
The cable shield is intended to be connected to functional earth, via the host system or via the remote station or via a separate connection of the shield.

6 Correct Wiring of Galvanically Isolated CAN Networks

NOTICE
This chapter applies to CAN networks with bit rates up to 1 Mbit/s.
If you work with higher bit rates, as for example used for CAN FD, the information given in this chapter must be examined for applicability in each individual case.
For further information refer to the CiA® CAN FD guidelines and recommendations (https://www.can-cia.org/).

For the CAN wiring all applicable rules and regulations (EU, DIN), such as regarding electromagnetic compatibility, security distances, cable cross-section or material, must be observed.

6.1 CAN Wiring Standards

The flexibility in CAN network design is a major strength of the various extensions based on the original CAN standard ISO 11898-2, such as CANopen®, ARINC825, DeviceNet® and NMEA2000. However, taking advantage of this flexibility absolutely requires a network design that considers the interactions of all network parameters.

In some cases, the CAN organizations have adapted the scope of CAN in their specifications to enable applications outside the ISO 11898 standard. They have imposed system-level restrictions on data rate, line length and parasitic bus loads.

However, when designing CAN networks, a margin must always be planned for signal losses over the entire system and cabling, parasitic loads, network imbalances, potential differences against earth potential, and signal integrities. **Therefore, the maximum achievable number of nodes, bus lengths and stub lengths may differ from the theoretically possible number!**

esd has limited its recommendations for CAN wiring to the specifications of ISO 11898-2.
A description of the special features of the derived specifications CANopen, ARINC825, DeviceNet, and NMEA2000 is omitted here

The consistent compliance with the ISO 11898-2 standard offers significant advantages:

- Reliable operation due to proven design specifications
- Minimization of error sources due to sufficient distance to the physical limits.
- Easy maintenance because there are no "special cases" to consider for future network modifications and troubleshooting.

Of course, reliable networks can be designed according to the specifications of CANopen, ARINC825, DeviceNet and NMEA2000, **however it must be observed that it is strictly not recommended to mix the wiring guidelines of the various specifications!**

6.2 Light Industrial Environment (*Single* Twisted Pair Cable)

6.2.1 General Rules

NOTICE
esd grants the EU Conformity of the product if the CAN wiring is carried out with at least single shielded **single** twisted pair cables that match the requirements of ISO 11898-2. Single shielded *double* twisted pair cable wiring as described in chapter 6.3 ensures the EU Conformity as well.

The following **general rules** for CAN wiring with single shielded *single* twisted pair cable should be followed:

1	A suitable cable type with a wave impedance of about 120 Ω ±10% with an adequate conductor cross-section (≥ 0.22 mm²) must be used. The voltage drop over the wire must be considered.
2	For light industrial environment use at least a two-wire CAN cable, the wires of which must be assigned as follows: • Two twisted wires must be assigned to the data signals (CAN_H, CAN_L). • The cable shield must be connected to the reference potential (CAN_GND).
3	The reference potential CAN_GND must be connected to the functional earth (FE) at exactly **one** point.
4	A CAN bus line must not branch (exception: short cable stubs) and must be terminated with the characteristic impedance of the line (generally 120 Ω ±10%) at both ends (between the signals CAN_L and CAN_H and **not** at CAN_GND).
5	Keep cable stubs as short as possible (l < 0.3 m).
6	Select a working combination of bit rate and cable length.
7	Keep away cables from disturbing sources. If this cannot be avoided, double shielded wires are recommended.

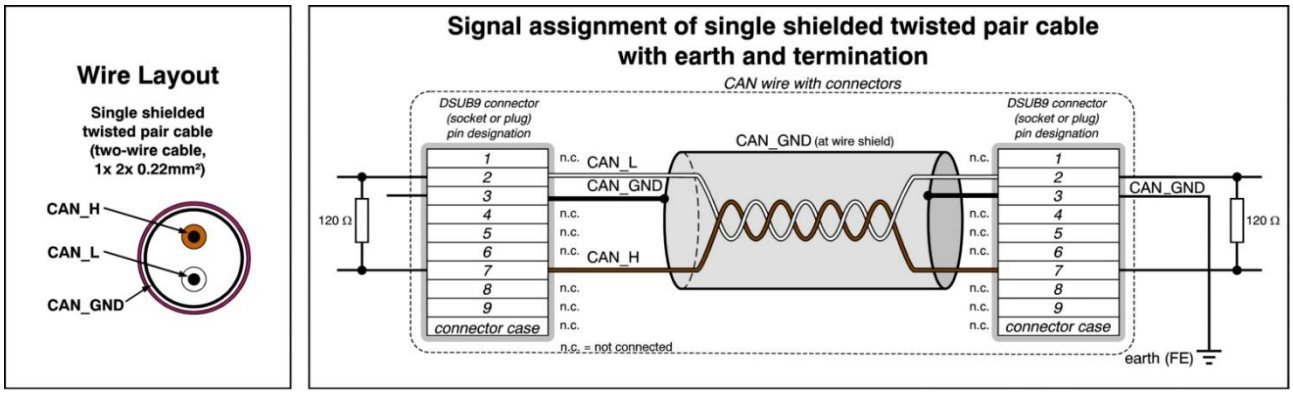


Figure 6: CAN wiring for light industrial environment

6.2.2 Cabling

- To connect CAN devices with just one CAN connector per net use a short stub (< 0.3 m) and a T-connector (available as accessory). If these devices are located at the end of the CAN network, the CAN terminator “CAN-Termination-DSUB9” can be used.

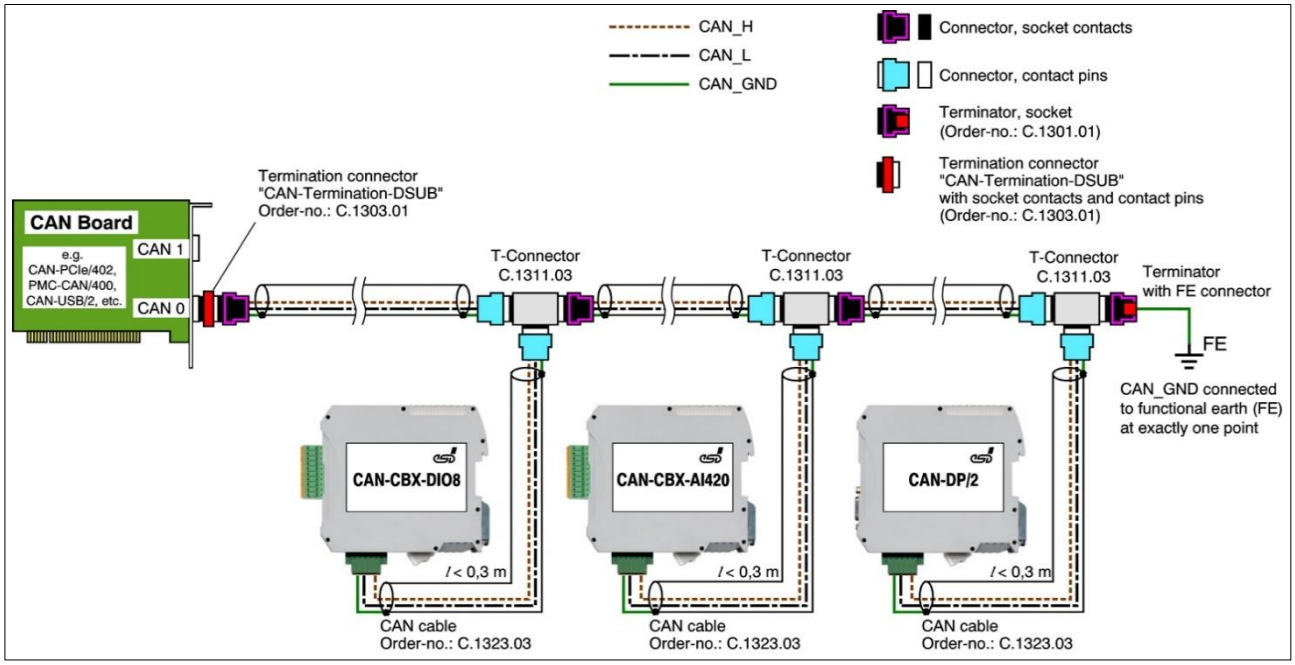


Figure 7: Example for proper wiring with single shielded single twisted pair wires

6.2.3 Branching

- In principle the CAN bus must be realized in a line. The nodes are connected to the main CAN bus line via short cable stubs. This is normally realised by so called T-connectors. esd offers the CAN-T-Connector (Order No.: C.1311.03)
- If a mixed application of single twisted and double twisted cables cannot be avoided, ensure that the CAN_GND line is not interrupted!
- Deviations from the bus structure can be realized by using repeaters.

6.2.4 Termination Resistor

- A termination resistor must be connected at both ends of the CAN bus.
  If an integrated CAN termination resistor is connected to the CAN interface at the end of the CAN bus, this integrated termination must be used instead of an external CAN termination resistor.
- 9-pole DSUB-termination connectors with integrated termination resistor and pin contacts and socket contacts are available from esd (order no. C.1303.01).
- For termination of the CAN bus and grounding of the CAN_GND, DSUB terminators with pin contacts (order no. C.1302.01) or socket contacts (order no. C.1301.01) and with additional functional earth contact are available.

6.3 Heavy Industrial Environment (Double Twisted Pair Cable)

6.3.1 General Rules

The following **general rules** for the CAN wiring with single shielded *double* twisted pair cable should be followed:

1	A suitable cable type with a wave impedance of about 120 Ω ±10% with an adequate conductor cross-section (≥ 0.22 mm²) must be used. The voltage drop over the wire must be considered.
2	For heavy industrial environment use a four-wire CAN cable, the wires of which must be assigned as follows: • Two twisted wires must be assigned to the data signals (CAN_H, CAN_L) and • The other two twisted wires must be assigned to the reference potential (CAN_GND). • The cable shield must be connected to functional earth (FE) at least at one point.
3	The reference potential CAN_GND must be connected to the functional earth (FE) at exactly **one** point.
4	A CAN bus line must not branch (exception: short cable stubs) and must be terminated with the characteristic impedance of the line (generally 120 Ω ±10%) at both ends (between the signals CAN_L and CAN_H and **not** to CAN_GND).
5	Keep cable stubs as short as possible (l < 0.3 m).
6	Select a working combination of bit rate and cable length.
7	Keep away CAN cables from disturbing sources. If this cannot be avoided, double shielded cables are recommended.

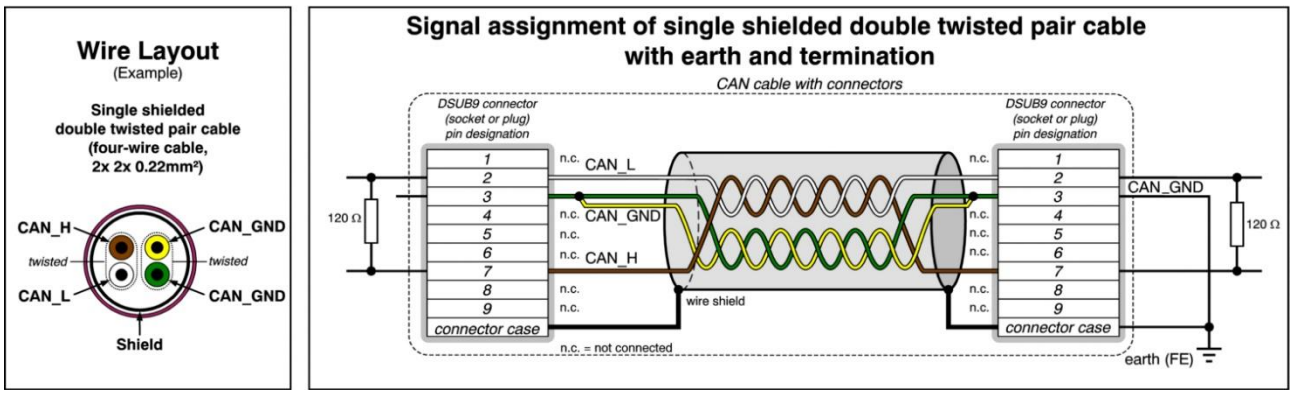


Figure 8: CAN wiring for heavy industrial environment

6.3.2 Device Cabling

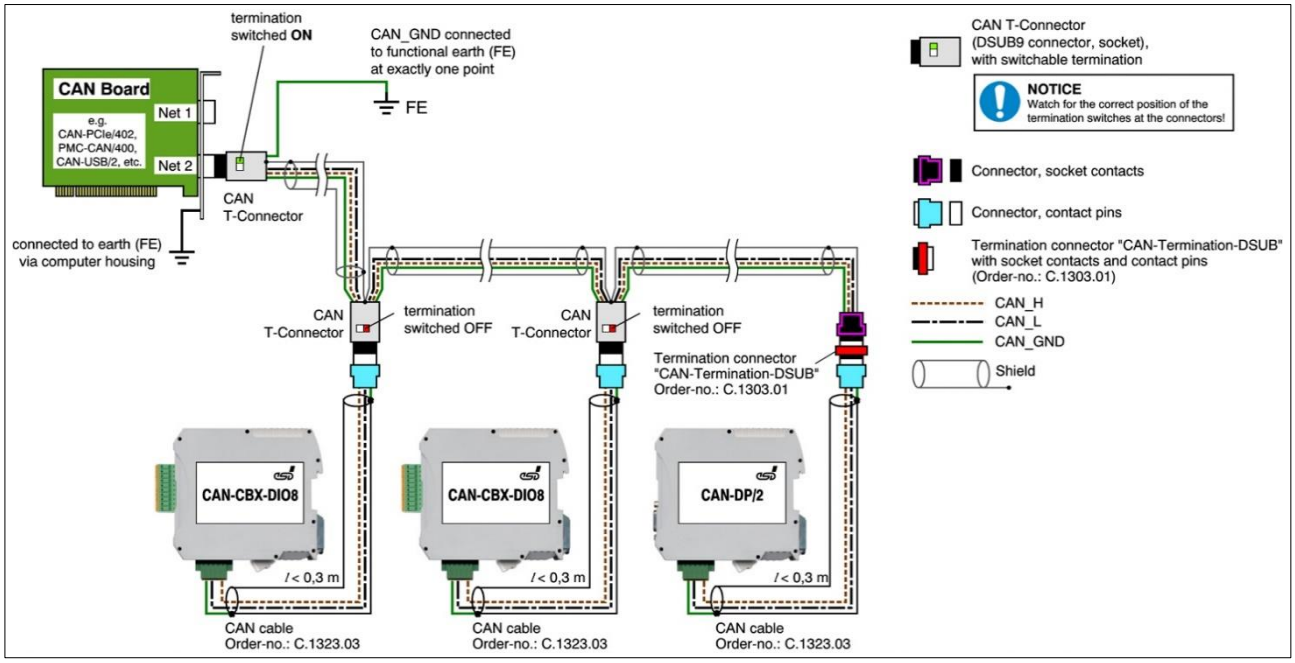


Figure 9: Example of proper wiring with single shielded double twisted pair cables

6.3.3 Branching

- In principle, the CAN bus must be realized in a line. The nodes are connected to the main CAN bus line via short cable stubs. This is usually realised via so called T-connectors. When using esd's CAN-T-Connector (order no.: C.1311.03) in heavy industrial environment and with four-wire twisted cables, it must be noted that the shield potential of the conductive DSUB housing is not looped through this type of T-connector. This interrupts the shielding. Therefore, you must take appropriate measures to connect the shield potentials, as described in the manual of the CAN-T-Connector. For further information on this, please refer to the CAN-T-Connector Manual (order no.: C.1311.21).
  Alternatively, a T-connector can be used, in which the shield potential is looped through, for example the DSUB9 connector from ERNI (ERBIC CAN BUS MAX, order no.:154039).
- If a mixed application of single twisted and double twisted cables cannot be avoided, ensure that the CAN_GND line is not interrupted!
- Deviations from the bus structure can be realized by using repeaters.

6.3.4 Termination Resistor

- A termination resistor must be connected at both ends of the CAN bus.
  If an integrated CAN termination resistor is connected to the CAN interface at the end of the CAN bus, this integrated termination must be used instead of an external CAN termination resistor.
- 9-pole DSUB-termination connectors with integrated termination resistor and pin contacts and socket contacts are available from esd (order no. C.1303.01).
- 9-pole DSUB-connectors with integrated switchable termination resistor can be ordered for example from ERNI (ERBIC CAN BUS MAX, socket contacts, order no.:154039).

6.4 Electrical Grounding

- For CAN devices with electrical isolation the CAN_GND must be connected between the CAN devices.
- CAN_GND should be connected to the earth potential (FE) at **exactly one** point of the network.
- Each *CAN interface with electrical connection to earth potential* acts as a grounding point. For this reason, it is recommended not to connect more than one *CAN device with electrical connection to earth potential.*
- Grounding can be done for example at a termination connector (e.g. order no. C.1302.01 or C.1301.01).

6.5 Bus Length

The bus length of a CAN network must be adapted to the set bit rate. The maximum values result from the fact that the time required for a bit to be transmitted in the bus system is shorter the higher the transmission rate is. However, as the line length increases, so does the time it takes for a bit to reach the other end of the bus. It should be noted that the signal is not only transmitted, but the receiver must also respond to the transmitter within a certain time. The transmitter, in turn, must detect any change in bus level from the receiver(s). Delay times on the line, the transceiver, the controller, oscillator tolerances and the set sampling time must be considered.
In the following table you will find guide values for the achievable bus lengths at certain bit rates.

Bit Rate [kbit/s]	Theoretical values of reachable wire length **with esd interface** l_{max} [m]	**CiA recommendations** (07/95) for reachable wire lengths l_{min} [m]	Standard values of the cross-section according to CiA 303-1 [mm²]
1000	37	25	0.25 to 0.34
800	59	50	0.34 to 0.6
666.$\overline{6}$	80	-	
500	130	100	
333.$\overline{3}$	180	-	
250	270	250	
166	420	-	0.5 to 0.6
125	570	500	
100	710	650	0.75 to 0.8
83.$\overline{3}$	850	-	
66.$\overline{6}$	1000	-	
50	1400	1000	
33.$\overline{3}$	2000	-	not defined in CiA 303-1
20	3600	2500	
12.5	5400	-	
10	7300	5000	

Table 11: Recommended cable lengths at typical bit rates (with esd-CAN interfaces)

Optical couplers are delaying the CAN signals. esd modules typically achieve a wire length of 37 m at 1 Mbit/s within a proper terminated CAN network without impedance disturbances, such as those caused by cable stubs > 0.3 m.

NOTICE
Please note that the cables, connectors, and termination resistors used in CANopen networks shall meet the requirements defined in ISO 11898-2.
In addition, further recommendations of the CiA, like standard values of the cross section, depending on the cable length, are described in the CiA recommendation CiA 303-1 (see CiA 303 CANopen Recommendation - Part 1: “Cabling and connector pin assignment,” Version 1.9.0, Table 2). Recommendations for pin-assignment of the connectors are described in CiA 106: “Connector pin-assignment recommendations ”.

6.6 Examples for CAN Cables

esd recommends the following two-wire and four-wire cable types for CAN network design. These cable types are used by esd for ready-made CAN cables, too.

6.6.1 Cable for Light Industrial Environment Applications (Two-Wire)

Manufacturer	Cable Type
U.I. LAPP GmbH Schulze-Delitzsch-Straße 25 70565 Stuttgart Germany www.lappkabel.com	e.g. UNITRONIC ®-BUS CAN UL/CSA (1x 2x 0.22) (UL/CSA approved) Part No.: 2170260 UNITRONIC ®-BUS-FD P CAN UL/CSA (1x 2x 0.25) (UL/CSA approved) Part No.: 2170272
ConCab GmbH Äußerer Eichwald 74535 Mainhardt Germany www.concab.de	e. g. BUS-PVC-C (1x 2x 0.22 mm²) Order No.: 93 022 016 (UL appr.) BUS-Schleppflex-PUR-C (1x 2x 0.25 mm²) Order No.: 94 025 016 (UL appr.)

6.6.2 Cable for Heavy Industrial Environment Applications (Four-Wire)

Manufacturer	Cable Type
U.I. LAPP GmbH Schulze-Delitzsch-Straße 25 70565 Stuttgart Germany www.lappkabel.com	e.g. UNITRONIC ®-BUS CAN UL/CSA (2x 2x 0.22) (UL/CSA approved) Part No.: 2170261 UNITRONIC ®-BUS-FD P CAN UL/CSA (2x 2x 0.25) (UL/CSA approved) Part No.: 2170273
ConCab GmbH Äußerer Eichwald 74535 Mainhardt Germany www.concab.de	e. g. BUS-PVC-C (2x 2x 0.22 mm²) Order No.: 93 022 026 (UL appr.) BUS-Schleppflex-PUR-C (2x 2x 0.25 mm²) Order No.: 94 025 026 (UL appr.)

INFORMATION
Ready-made CAN cables with standard or custom length can be ordered from **esd**.

7 CAN Troubleshooting Guide

The CAN Troubleshooting Guide is a guide to finding and eliminating the most common problems and errors when setting up CAN bus networks and CAN-based systems.

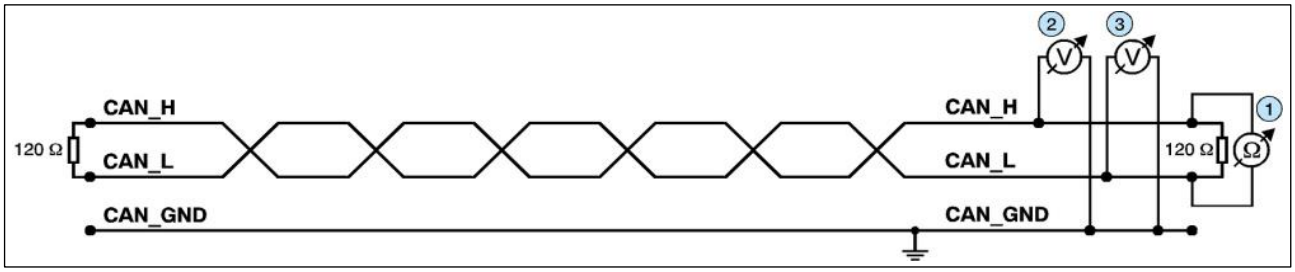


Figure 10: Simplified diagram of a CAN network

Termination
The bus termination is used to match impedance of a node to the impedance of the bus line used. If the impedance is mismatched, the transmitted signal is not completely absorbed by the load and will be partially reflected back into the transmission line.
If the impedances of the sources, transmission lines and loads are equal, the reflections are avoided. This test measures the total resistance of the two CAN data lines and the connected terminating resistors.

To **test this, please proceed as follows:**

1. Switch off the supply voltages of all connected CAN nodes.
2. Measure the DC resistance between CAN_H and CAN_L at one end of the network, measuring point ① (see figure above).

Expected result:
The measured value should be between 50 Ω and 70 Ω.

Possible causes of error:

- If the determined value is below 50 Ω, please make sure that:
  - There is no **short circuit** between CAN_H and CAN_L wiring.
  - **No more than two** terminating resistors are connected.
  - The transceivers of the individual nodes are not defective.

- If the determined value is higher than 70 Ω, please make sure that:
  - All CAN_H and CAN_L lines are correctly connected.
  - Two terminating resistors of 120 Ω each are connected to your CAN network (one at each end).

7.1 Electrical Grounding

The CAN_GND of the CAN network should be connected to the functional earth potential (FE) at only **one** point. This test indicates whether the CAN_GND is grounded at one or more points.

Please note that this test can only be performed with electrically isolated CAN nodes.

To test this, please proceed as follows:

1. Disconnect the CAN_GND from the earth potential (FE).
2. Measure the DC resistance between CAN_GND and earth potential (see figure on the right).

Do not forget to reconnect CAN_GND to earth potential after the test!

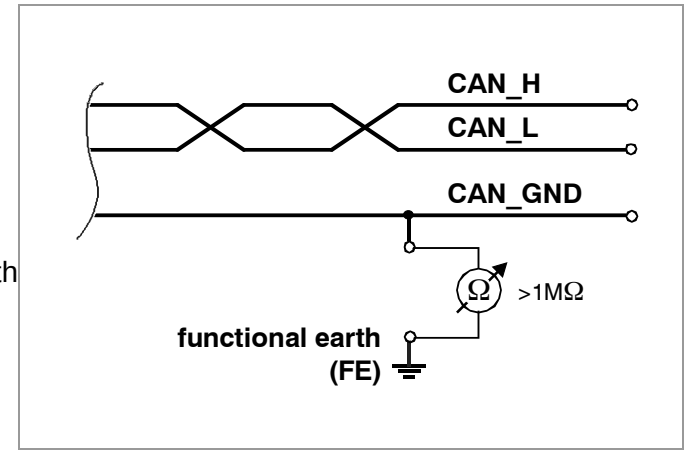


Figure 11: Simplified schematic diagram of ground test measurement

Expected result:
The measured resistance should be greater than 1 MΩ. If it is smaller, please search for additional grounding of the CAN_GND wires.

7.2 Short Circuit in CAN Wiring

A CAN bus might possibly still be able to transmit data even if CAN_GND and CAN_L are short-circuited. However, this will usually cause the error rate to rise sharply.
Ensure that there is no short circuit between CAN_GND and CAN_L!

7.3 Correct Voltage Levels on CAN_H and CAN_L

Each node contains a CAN transceiver that outputs differential signals. When the network communication is idle the CAN_H and CAN_L voltages are approximately 2.5 V measured to CAN_GND. Defective transceivers can cause the idle voltages to vary and disrupt network communication.

To test for defective transceivers, please proceed as follows:

1. Switch on all supply voltages.
2. Terminate all network communication.
3. Measure the DC voltage between CAN_H and CAN_GND, measuring point ②.
   (See “Simplified diagram of a CAN network” on previous page).
4. Measure the DC voltage between CAN_L and CAN_GND, measuring point ③.
   (See “Simplified diagram of a CAN network” on previous page).

Expected result:
The measured voltage should be between 2.0 V and 3.0 V.

Possible causes of error:

- If the voltage is lower than 2.0 V or higher than 3.0 V, it is possible that one or more nodes have defective transceivers.
    - If the voltage is lower than 2.0 V, please check the connections of the CAN_H and CAN_L lines.
- To find a node with a defective transceiver within a network, please check individually the resistances of the CAN transceivers of the nodes (see next section).

7.4 CAN Transceiver Resistance Test

CAN transceivers have circuits that control CAN_H and CAN_L. Experience shows that electrical damage can increase the leakage current in these circuits.

To measure the current leakage through the CAN circuits, please use an ohmmeter and proceed as follows:

1. Switch **off** the node ④ and **disconnect** it from the CAN network.
   (See figure below.)
2. Measure the DC resistance between CAN_H and CAN_GND, measuring point ⑤
   (See figure below.)
3. Measure the DC resistance between CAN_L and CAN_GND, measuring point ⑥
   (See figure below.)

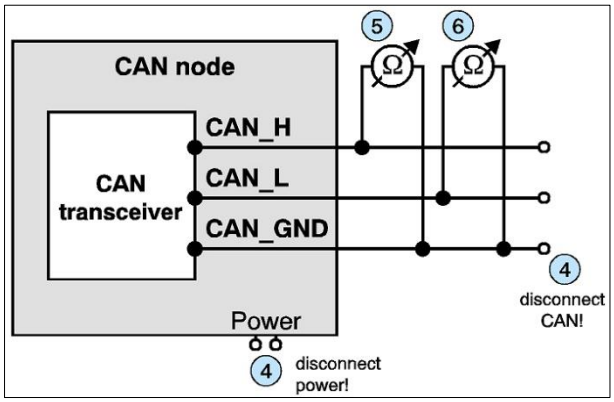


Figure 12: Measuring the internal resistance of CAN transceivers

Expected result:
The measured resistance should be greater than 10 kΩ for each measurement.

Possible causes of error:

- If the resistance is significantly lower, the CAN transceiver may be defective.
- Another indication of a defective CAN transceiver is a very high deviation of the two measured input resistances (>> 200 %).

7.5 Support by esd

If you have followed the troubleshooting steps in this troubleshooting guide and still cannot find a solution to your problem, our support team can help.
Please contact our support by email to support@esd.eu or by phone **+49-511-37298-130.**

8 Software Licenses

NOTICE
The software from esd and from third parties used in the CAN-USB/400 is subject to the license terms of the respective authors or rights holders. CAN-USB/400 may only be used in accordance with these license terms!
By using the CAN-USB/400 you agree to the terms of these software licenses.

You can download the license terms from our website, see the following chapters.

8.1 3rd Party Software License Terms

License Name	**Identifier** (from SPDX License List)
GNU Lesser General Public License v3.0 only	LGPL-3.0

Table 12: License and Identifier

- The IRIG-B variants (CAN-USB/400(-FD)-IRIG-B use the Oregano Systems 8051 IP Core. The 8051 IP Core is subject to the 3rd Party Software License Terms of GNU LGPL-3.0, see Table 12.

8.1.1 Open-Source Software Copy

You may obtain a copy of the source code, if and as required under the license by sending a mail

You may obtain a copy of the source code, if and as required under the license by sending a mail to oss-compliance@esd.eu

You may also obtain a copy of the source code, if and as required under the license, by sending a check or money of EUR 25.00 to:
esd electronics gmbh
Vahrenwalder Str. 207
30165 Hannover, Germany

9 Declaration of Conformity

EU-KONFORMITÄTSERKLÄRUNG
EU DECLARATION OF CONFORMITY

Adresse / *Address*
esd electronics gmbh
Vahrenwalder Str. 207
30165 Hannover
Germany

esd erklärt, dass das Produkt *esd declares, that the product*	Typ, Modell, Artikel-Nr. *Type, Model, Article No.*
CAN-USB/400	**C.2069.04**
CAN-USB/400-IRIG-B	**C.2069.06**
CAN-USB/400-FD	**C.2069.64**
CAN-USB/400-FD-IRIG-B	**C.2069.66**

die Anforderungen der Normen *fulfills the requirements of the standards*	**EN 61000-6-2:2005,** **EN 61000-6-3:2007/A1:2011**
gemäß folgendem Prüfbericht erfüllt. *according to test certificate.*	**H-K00-0557-14**
Das Produkt entspricht damit der EU-Richtlinie „EMV" *Therefore the product conforms to the EU Directive 'EMC'*	**2014/30/EU**
Das Produkt entspricht den EU-Richtlinien „RoHS" *The product conforms to the EU Directives 'RoHS'*	**2011/65/EU, 2015/863/EU**

Diese Erklärung verliert ihre Gültigkeit, wenn das Produkt nicht den Herstellerunterlagen entsprechend eingesetzt und betrieben wird, oder das Produkt abweichend modifiziert wird.
This declaration loses its validity if the product is not used or run according to the manufacturer's documentation or if non-compliant modifications are made.

Name / *Name*	T. Bielert
Funktion / *Title*	QM-Beauftragter / *QM Representative*
Datum / *Date*	Hannover, 2024-02-27

Rechtsgültige Unterschrift / *authorized signature*

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10 Order Information

10.1 Hardware

Type	Properties	Order No.
CAN-USB/400-FD	Two High-Speed CAN Ports for USB. with esd Advanced CAN IP-Core (esdACC) CAN-FD capable according to ISO 11898-1:2015 Physical Layer according to ISO 11898, High Speed, galvanically isolated 2x DSUB9 Connector USB 2.0, high-speed 480 Mbit/s Enhanced diagnostic features. High resolution hardware timestamping. Error injection capabilities. Drivers, tools and documentation for Windows on CD-ROM	C.2069.64
CAN-USB/400	Two High-Speed CAN Ports for USB. CAN ports according to ISO 11898-2 with galvanic isolation. USB 2.0, high-speed 480 Mbit/s Enhanced diagnostic features. High resolution hardware timestamping. Error injection capabilities. Drivers, tools and documentation for Windows on CD-ROM	C.2069.04
CAN-USB/400-FD-IRIG-B	As C.2069.64, but with analog and digital (RS422) IRIG-B input Synchronized timestamps. Drivers, tools and documentation for Windows on CD-ROM Ext. trigger I/Os for Error Injection	C.2069.66
CAN-USB/400-IRIG-B	As C.2069.04 but with analog and digital (RS422) IRIG-B input Synchronized timestamps. Drivers, tools and documentation for Windows on CD-ROM Ext. trigger I/Os for Error Injection	C.2069.06

Table 13: Order information hardware

10.2 Software

Type		Order No.
CAN software drivers for Windows on CD-ROM are included in delivery of the CAN-USB/400 modules.		
Higher-Layer Protocols including CD-ROM (CAN CC Applications only):		
CANopen-LCD Windows/Linux	Single user runtime license for CANopen Software Stack for Windows in connection with esd CAN hardware and NTCAN API. Includes CANopen Manager and Slave as dll's/lib's in one package. Delivery as license sticker and CD (LCD) with documentation. (Linux is not supported at the moment)	C.1101.06
CAN-OPC UA Server für Windows Licence	OPC UA server with integration for esd CAN interfaces. Operating system: Windows 7 or higher, CPU architecture: x86_64, Delivery as object code, Runtime license for single user/device	C.1103.31
ARINC 825-LCD Windows/Linux/LabVIEW	ARINC 825 object licence for Windows, Linux and LabVIEW (Windows), Usable with all esdACC based CAN interfaces, object licence, ARINC 825 dll's/lib's, documentation, includes CAN-Driver object licence (C.1101.02), manuals and CAN-Tools	C.1140.06
For detailed information about the driver availability for your special operating system, please contact our sales team.		

Table 14: Order information software

10.3 Manuals

PDF Manuals
For the availability of the manuals see table below.
Please download the manuals as PDF documents from our esd website https://www.esd.eu for free.

Manuals		Order No.
CAN-USB/400-MD	Hardware manual in German	C.2069.20
CAN-USB/400-ME	Hardware manual in English	C.2069.21
CAN-API-ME	NTCAN-API: Application Developers Manual NTCAN-API: Driver Installation Guide	C.2001.21
CANopen-ME	CANopen Manuals in English	C.2002.21

Table 15: Available Manuals

Printed Manuals
If you need a printout of the manual additionally, please contact our sales team (sales@esd.eu) for a quotation. Printed manuals may be ordered for a fee.