CAN-USB/400, CAN-USB/400-IRIG-B, CAN-USB/400-FD

2x CAN (Layer 2, CANopen®, J1939 or ARINC 825) with optional IRIG-B Input or 2x CAN FD

Hardware Manual

to Products   C.2069.04,
                C.2069.06,
                C.2069.64

N O T E

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

Document file:	I:\Texte\Doku\MANUALS\CAN\CAN-USB400\Englisch\CAN-USB400_Hardware_en_14.odt
Date of print:	2020-06-04
Document type number:	DOC0800

Hardware version:	CAN_USB_402 Rev. 1.0

Document History

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

Revision	Chapter	Changes versus previous version	Date
1.0	-	First revision.	2014-05-06
1.1	-	Safety Instructions revised	2015-06-05
	2.	Figure 3 and 4 new	
	3.	Description of step 2 changed	
	4.1	Current consumption inserted	
	4.4	Electrical isolation of CAN interface, value changed	
	4.5.2, 4.5.3	Notes concerning EMC / conformity inserted	
	5.3	Connector is only equipped on CAN-USB/400-IRIG-B, wiring guidelines inserted	
	6., 7.	Chapters updated	
	8.	New Chapter: "Declaration of Conformity"	
	9.	Chapter moved	
1.2	-	Classification of Warning Messages and Safety Instructions inserted	2018-01-29
	1.	Description of CAN-USB/400-FD inserted	
	1.3	New chapter, Description of CAN-USB/400-FD	
	2.1	Chapter "Indicator states of CAN LEDs" revised	
	4.5	New Chapter "CAN FD Interfaces on CAN-USB/400-FD"	
	4.7	Chapter "Software Support" revised	
	8.	New Declaration of Conformity inserted	
	9.	Order Information revised	
1.3	6.	Note on CAN FD inserted	2018-03-27
1.4	8.	Declaration of Conformity updated	2020-06-04

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-Module follow the instructions below and read the manual carefully to protect yourself from injury and the CAN-USB/400-Module from damage.
- Do not use damaged or defective cables to connect the CAN-USB/400-Module and follow the CAN wiring hints in chapter: "Correct Wiring of Electrically 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.
- Current circuits which are connected to the device have to be sufficiently protected against hazardous voltage (SELV according to EN 60950-1).
- The CAN-USB/400-Module may only be driven by current circuits, that are contact protected. A power supply, that provides a safety extra-low voltage (SELV) according to EN 60950-1, complies with this conditions.

- Do not open the housing of the CAN-USB/400-Module.
- The CAN-USB/400-Modules have to be securely installed before commissioning.
- Never let liquids get inside the CAN-USB/400-Module. Otherwise, electric shocks or short circuits may result.
- Protect the CAN-USB/400-Module from dust, moisture and steam.
- Protect the CAN-USB/400-Module from shocks and vibrations.
- The CAN-USB/400-Module may become warm during normal use. Always allow adequate ventilation around the CAN-USB/400-Module and use care when handling.
- Do not operate the CAN-USB/400-Module adjacent to heat sources and do not expose it to unnecessary thermal radiation. Ensure an ambient temperature as specified in the technical data.

Qualified Personnel

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-Module 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-Module may cause radio interferences in which case the user may be required to take adequate measures.

Intended Use

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

Service Note

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

Disposal

Devices which have become defective in the long run have to be disposed in an appropriate way or have to be returned to the manufacturer for proper disposal. Please, make a contribution to environmental protection.

Table of contents

1. Overview

This document describes the hardware of the following CAN-USB/400-Modules:
- CAN-USB/400
- CAN-USB/400-IRIG-B
- CAN-USB/400-FD

The CAN-USB modules have an identical structure, except of the additional IRIG-B and I/O interfaces at the CAN-USB/400-IRIG-B and the CAN FD interfaces at the CAN-USB/400-FD.
If identical features or procedures are described in this manual, the term CAN-USB/400-Module is used for the three modules. Differences are noted explicitly.

1.1 CAN-USB/400
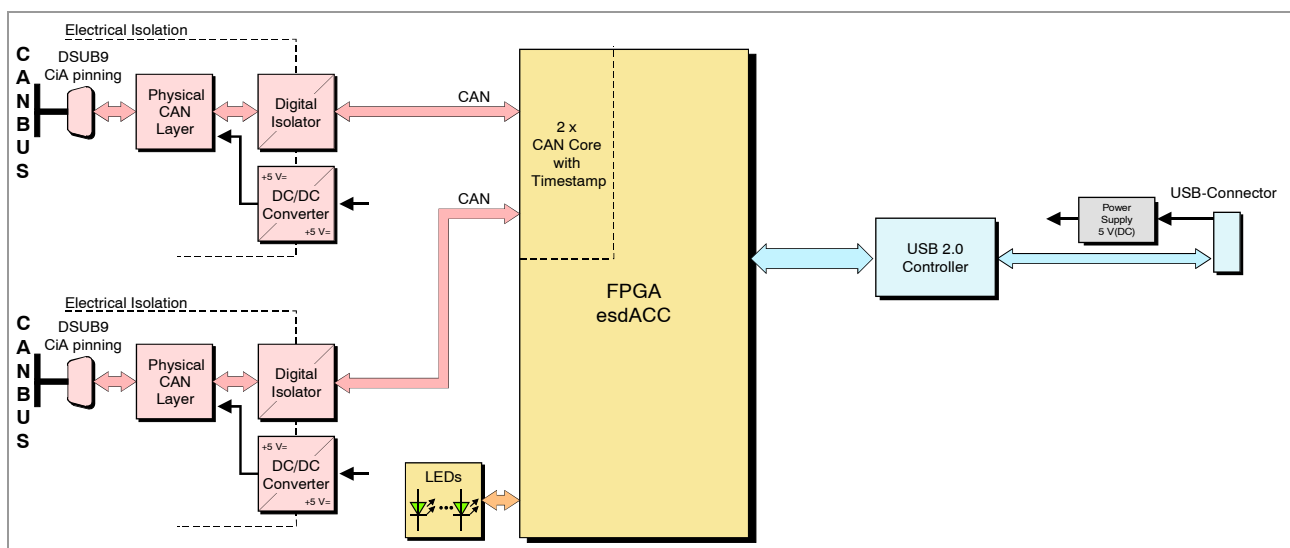
Figure 1: Block circuit diagram of CAN-USB/400

The basic version CAN-USB/400 offers two high-speed CAN interfaces, according to ISO 11898-2, for USB. The CAN interfaces are electrically isolated and support bit rates up to 1 Mbit/s.
The independent CAN nets, according to ISO 11898-1, are driven by the ISO 16845:2004 certified esdACC (esd Advanced CAN Core), implemented in the Altera® FPGA .
Attached to USB via FIFO's and driven by the esdACC, the CAN-USB/400 is designed for minimum latency CAN communication via USB.

Advanced diagnostics and high resolution hardware timestamping are supported.

A feature pretty unique on standard CAN interfaces is the Error Injection. It provides means to simulate error conditions on CAN bus. Bit patterns can be injected into any living CAN bus. Several trigger conditions and modes are provided.

Power is supplied via USB.

1.2 CAN-USB/400-IRIG-B
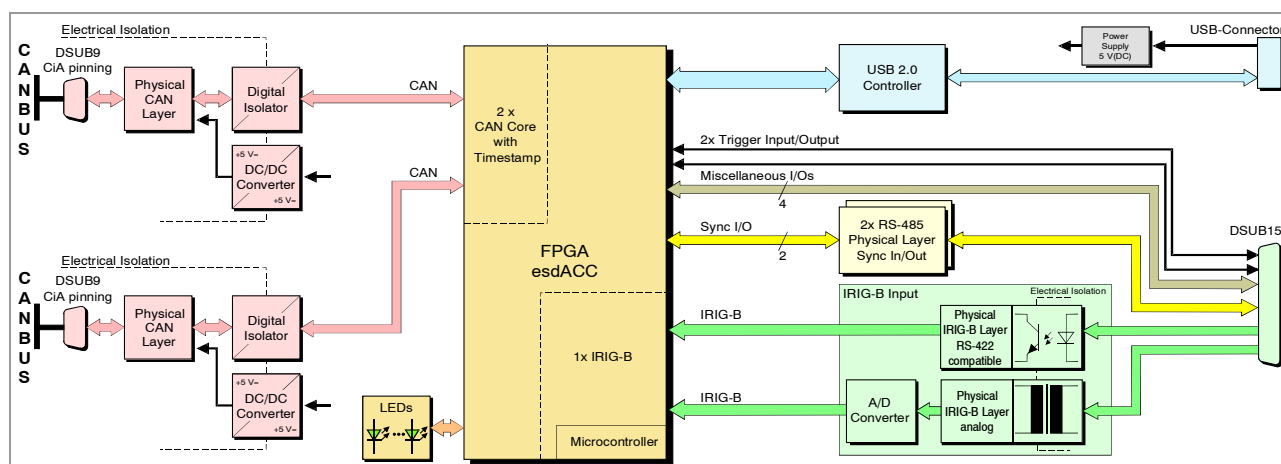
Figure 2: Block circuit diagram of CAN-USB/400-IRIG-B

In addition to the standard features of the CAN-USB/400, the CAN-USB/400-IRIG-B offers analog and digital IRIG-B inputs, synchronized timestamps (even without IRIG-B signal) over several CAN-USB/400-IRIG-B via additional RS-485 interface, external trigger I/Os for Error Injection and miscellaneous I/Os for customized functionality.

1.3 CAN-USB/400-FD
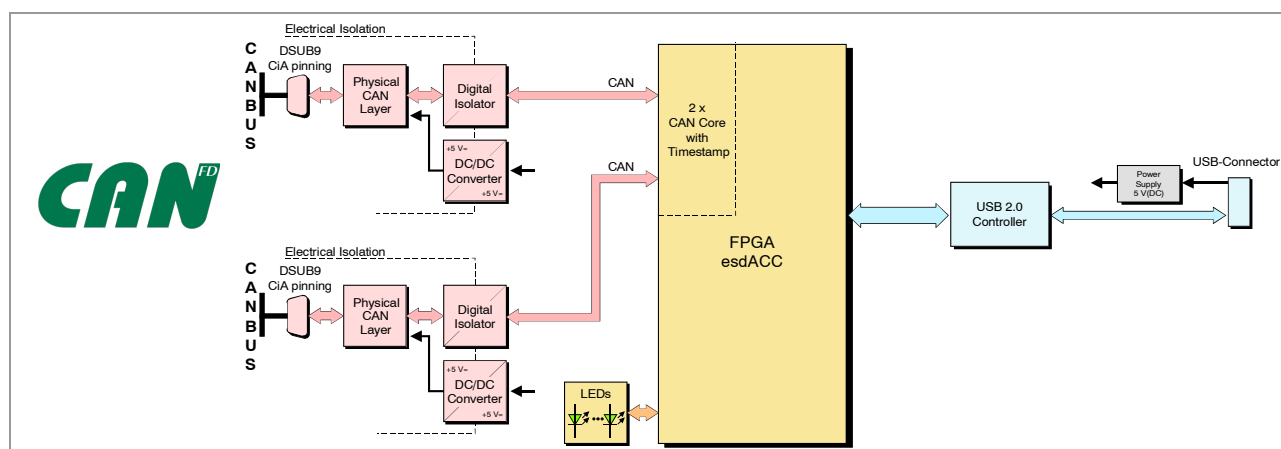
Figure 3: Block circuit diagram of CAN-USB/400-IRIG-B

The CAN-USB/400-FD comes with two independent CAN FD interfaces according to ISO 11898-1:2015, instead of the Classical CAN interfaces of the CAN-USB/400.
The CAN FD interfaces are driven by the ISO 16845:2004 certified esdACC (esd advanced CAN Core) implemented in an Altera® FPGA. The interfaces are able to send and receive ISO conform CAN FD (up to 5 Mbit) or CAN 2.0 A/B messages. The CAN FD bit rate range is validated for the esdACC CAN FD core from 10 kbit/s up to 5 Mbit/s.
The CAN-USB/400-FD can also be used in Classical CAN Applications, because CAN FD is fully backwards-compatible with CAN.

As customized option, the analog and digital IRIG-B inputs are available on request
Customized options are available for customized series production in reasonable quantities. Please contact our sales team for detailed information.

2. Case View with LED and Connector Description
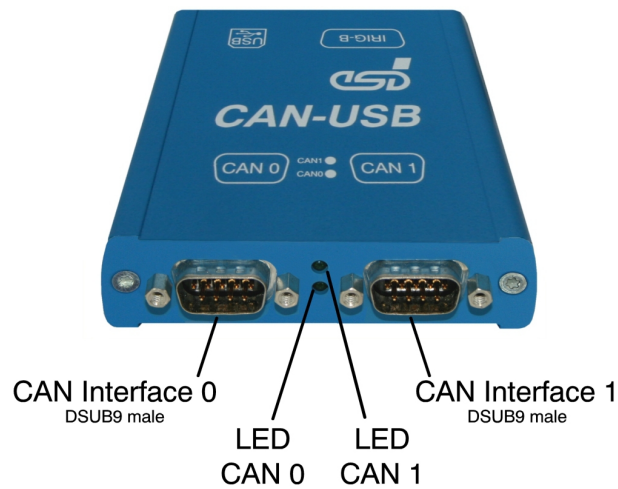
Figure 4: CAN connectors and LEDs (CAN-USB/400-IRIG-B view)
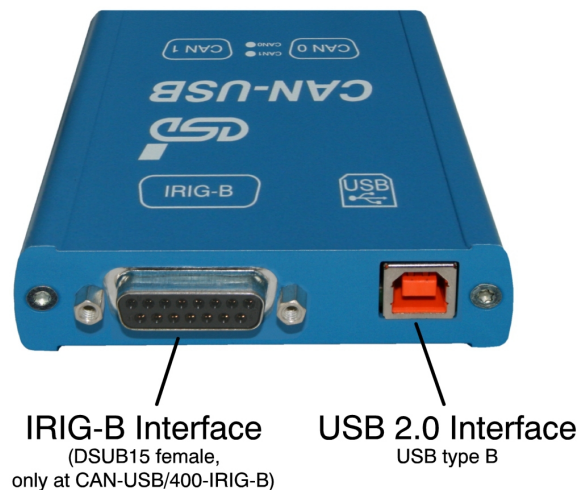
Figure 5: USB and IRIG-B (CAN-USB/400-IRIG-B view)

See page 18 for signal assignment of the connectors.

2.1 Indicator states of CAN LEDs

The CAN-USB/400-Modules come with two green CAN LEDs (CAN0, CAN1).
See Figure 4 on page 10 for the position of the LEDs.

The **Special Indicator States** are indicated by both LEDs together.
The state **CAN Traffic** 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 traffic on CAN0 or CAN1
CAN1			

CAN Traffic

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

LED	Indicator State	Indication	LED Description
CAN0	blinking	CAN Traffic	CAN traffic on CAN0
CAN1	blinking	CAN Traffic	CAN traffic on CAN1

Table 1: Description of LED display

3. Hardware Installation

To put the CAN-USB/400-Modules into operation, please follow the installation notes.

Step	Procedure	see page
⚠️	**Read the safety instructions at the beginning of this document carefully, before you start with the hardware installation!**	5
1.	Connect the CAN or CAN FD interfaces (CAN0, CAN1) to the DSUB9 connectors of your CAN-USB/400-Module as described in figure 4, page 10. CAN-USB/400-IRIG-B: Connect the IRIG-B interface to the DSUB15 connector as described in figure 5, page 10.	
🛈	**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.	
2.	Please note that the CAN bus has to be terminated at both ends! **esd** offers special T-connectors and termination connectors for external termination. Additionally the CAN_GND signal has to be connected to earth at **exactly one** point in the CAN network. For details please read chapter "Correct Wiring of Electrically Isolated CAN Networks"	22
3.	Connect the CAN-USB/400-Module via USB to your computer. The module is powered via USB.	10

i	**INFORMATION** The software installation is described in the manual 'NTCAN-API: Driver Installation Guide'.

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 male CAN-USB/400-IRIG-B only: IRIG-B 15-pin DSUB female

Temperature range	ambient temperature
	      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
Weight	145 g

Table 2: General data of the module

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

4.2 USB Device Interface

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

Table 3: Data of the USB interface

4.3 Local Controller

Controller	esdACC in FPGA acc. to ISO 898-1
BlockRAM	62 kB

Table 4: Controller

4.4 CAN Interfaces on CAN-USB/400(-IRIG-B)

> **i** **INFORMATION**
> The Classical CAN interfaces are equipped on CAN-USB/400 and CAN-USB/400-IRIG-B (C.2069.04, C.2069.06).

Number of CAN interfaces	2x CAN
CAN controller	esdACC in FPGA Altera® Cyclone® IV, acc. to ISO 11898-1 (CAN 2.0 A/B)
Physical Layer	High-speed CAN interface according to ISO 11898-2, bit rate up to 1 Mbit/s
Electrical isolation	electrical 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, according to DS-303-1

Table 5: Data of the CAN interface on CAN-USB/400(-IRIG-B)

4.5 CAN FD Interfaces on CAN-USB/400-FD

> **i** **INFORMATION**
> The CAN FD interfaces are only available on CAN-USB/400-FD (C.2069.64).

Number of CAN FD interfaces	2 x CAN FD
CAN controller	esdACC in FPGA Altera® Cyclone® IV, according to ISO11898-1:2015
Physical Layer	Physical layer according to ISO 11898-2, CAN bit rates from 10 kbit/s up to 5 Mbit/s
Electrical isolation	electrical 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, according to DS-303-1

Table 6: Data of the CAN FD interface

4.6 Interfaces available at CAN-USB/400-IRIG-B only

> **i** **INFORMATION**
> The IRIG-B option is only available on CAN-USB/400-IRIG-B (C.2069.06).

4.6.1 IRIG-B Interface

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)
Electrical isolation	both inputs are electrically isolated
Connector	15-pin DSUB, female

Table 7: Data of the IRIG-B interface

4.6.2 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-IRIG-B modules
Electrical 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, female

Table 8: Data of the Sync I/Os

4.6.3 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
Electrical 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, female

Table 9: Data of the Miscellaneous I/Os

4.6.4 Microcontroller for IRIG-B

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

Table 10: Data of the optional microcontroller

4.7 Software Support

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

"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
esd-order No.: C.2001.21

4.7.1 CAN-USB/400(-IRIG-B)

The CAN-USB/400 and the CAN-USB/400-IRIG-B support the CAN layer 2 API (NTCAN) for Windows®. The CAN layer 2 drivers for Windows are included in the scope of delivery.
Multiple higher level protocols are available for Windows:
- CANopen® Master- and Slave-Stack
- J1939
- ARINC825

Drivers and software support for other operating systems are available on request.
For more information on software support see order information on page 33 or contact our Sales team: sales@esd.eu.

4.7.2 CAN-USB/400-FD

The CAN layer 2 (NTCAN-API) drivers for Windows are included in the scope of delivery of CAN-USB/400-FD.
Higher layer protocols (CANopen, J1939, ARINC825) are supported for Classical CAN applications on CAN-USB/400-FD only.
See Order Information on page for availability of the drivers. For detailed information about the driver availability for your operating system, please contact our sales team: sales@esd.eu.

4.7.3 CAN Tools

esd offers additional free-of-charge tools for Windows 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:
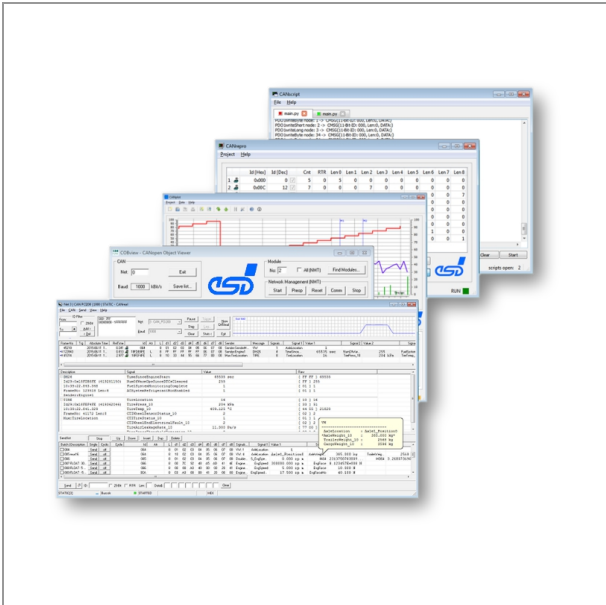
CANreal	Display and record of CAN message frames
CANplot	Graphical display of CAN data
CANrepro	Replay of pre-recorded CAN messages
CANscript	Python based scripting tool
COBview	Analysis and diagnostics of CANopen® nodes

System Requirements:
- Windows 32 bit or 64 bit system
- 30 MB free HD drive space
- 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:
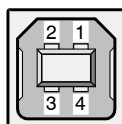
Pin Assignment:

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 CAN0, CAN1

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

Device connector: 9-pin DSUB connector, male

Pin Position:

Pin Assignment:

Signal	Pin	Pin	Signal
		1	reserved
CAN GND	6	2	CAN L
CAN H	7	3	CAN GND
reserved	8	4	reserved
reserved	9	5	-

Signal Description:

CAN_L, CAN_H ...   CAN signal lines
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, Trigger and I/Os (CAN-USB/400-IRIG-B only)

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

Device connector: 15-pin DSUB connector, female

Pin Position:
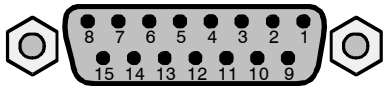
Pin Assignment:

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-IRIG-B 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 an 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 6.

Wiring of the analog and the digital IRIG-B interface at DSUB15
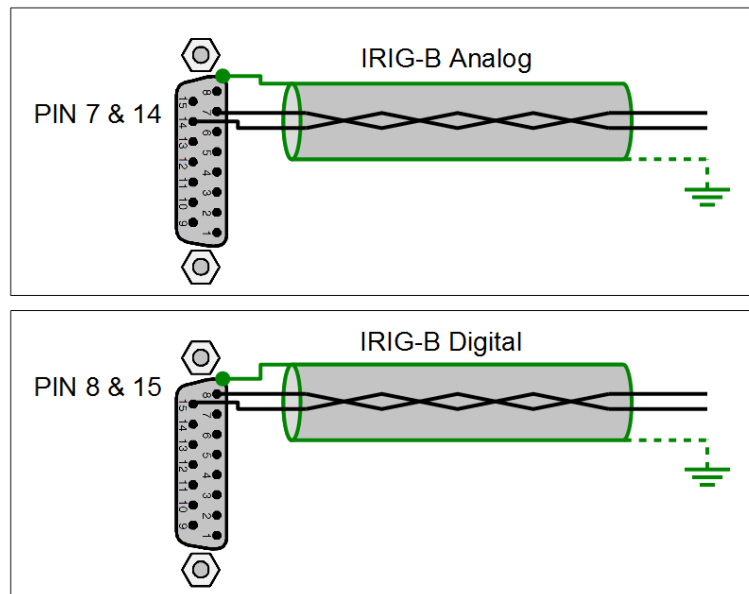
Figure 6: IRIG-B wiring guidelines

6. Correct Wiring of Electrically 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), e.g. regarding electromagnetic compatibility, security distances, cable cross-section or material, have to be observed.

6.1 Standards concerning CAN Wiring

The flexibility in CAN network design is one of the key strengths of the various extensions and additional standards like e.g. CANopen, ARINC825, DeviceNet and NMEA2000 that have been built on the original ISO 11898-2 CAN standard. In using this flexibility comes the responsibility of good network design and balancing these tradeoffs.

Many CAN organizations and standards have scaled the use of CAN for applications outside the original ISO 11898. They have made system level tradeoffs for data rate, cable length, and parasitic loading of the bus.

However for CAN network design margin must be given for signal loss across the complete system and cabling, parasitic loadings, network imbalances, ground offsets against earth potential and signal integrity. **Therefore the practical maximum number of nodes, bus length and stub length are typically much lower.**

esd has concentrated her recommendations concerning CAN wiring on the specifications of the ISO 11898-2. Thus this wiring hints forgoes to describe the special features of the derived standards CANopen, ARINC825, DeviceNet and NMEA2000.

The consistent compliance to ISO 11898-2 offers significant advantages:

- Durable operation due to well proven design specifications
- Minimizing potential failures due to sufficient margin to physical limits
- Trouble-free maintenance during future network modifications or during fault diagnostics due to lack of exceptions

Of course reliable networks can be designed according 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 cable type with a wave impedance of about 120 Ω ±10% with an adequate conductor cross-section (≥ 0.22 mm²) has to be used. The voltage drop over the wire has to be considered.
2	For light industrial environment use at least a two-wire CAN cable. Connect • the two twisted wires to the data signals (CAN_H, CAN_L) and • the cable shield to the reference potential (CAN_GND).
3	The reference potential CAN_GND has to be connected to the functional earth (FE) at exactly **one** point.
4	A CAN net must not branch (exception: short cable stubs) and has to 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.
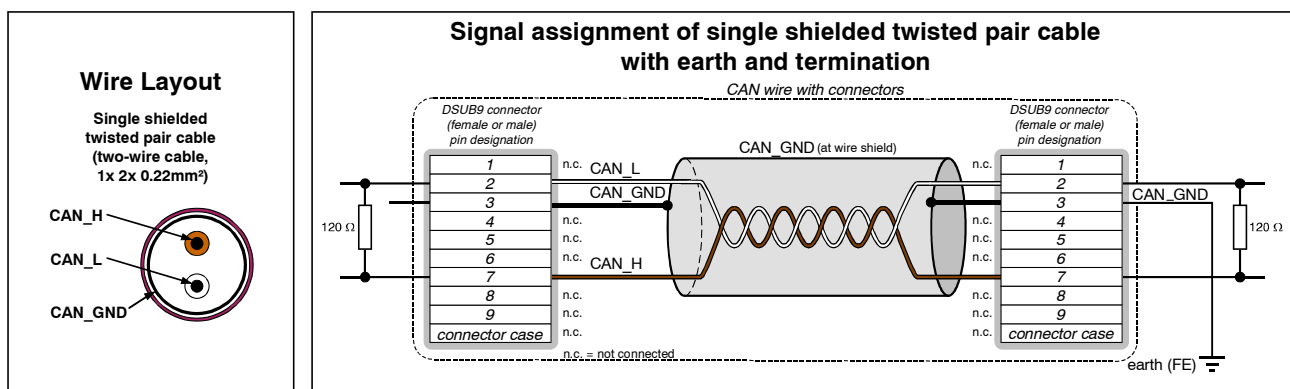
Figure 7: CAN wiring for light industrial environment

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 this devices are located at the end of the CAN network, the CAN terminator "CAN-Termination-DSUB9" can be used.

Figure 8: Example for proper wiring with single shielded single twisted pair wires

6.2.3 Branching

- In principle the CAN bus has to be realized in a line. The participants 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 is unavoidable, take care that the CAN_GND line is not interrupted!
- Deviations from the bus structure can be realized by the usage of repeaters.

6.2.4 Termination

- A termination resistor has to be connected at both ends of the CAN bus.
  If an integrated CAN termination resistor which is equipped at the CAN interface at the end of the bus is connected, this one has to be used for termination instead of an external CAN termination plug.
- 9-pin DSUB-termination connectors with integrated termination resistor and male and female contacts are available from esd (order no. C.1303.01).
- DSUB termination connectors with male contacts (order no. C.1302.01) or female contacts (order no. C.1301.01) and additional functional earth contact are available, if CAN termination and grounding of CAN_GND is required.

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 cable type with a wave impedance of about 120 Ω ±10% with an adequate conductor cross-section (≥ 0.22 mm²) has to be used. The voltage drop over the wire has to be considered.
2	For heavy industrial environment use a four-wire CAN cable. Connect • two twisted wires to the data signals (CAN_H, CAN_L) and • the other two twisted wires to the reference potential (CAN_GND) and • the cable shield to functional earth (FE) at least at one point.
3	The reference potential CAN_GND has to be connected to the functional earth (FE) at exactly **one** point.
4	A CAN bus line must not branch (exception: short cable stubs) and has to 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 can not be avoided, double shielded cables are recommended.
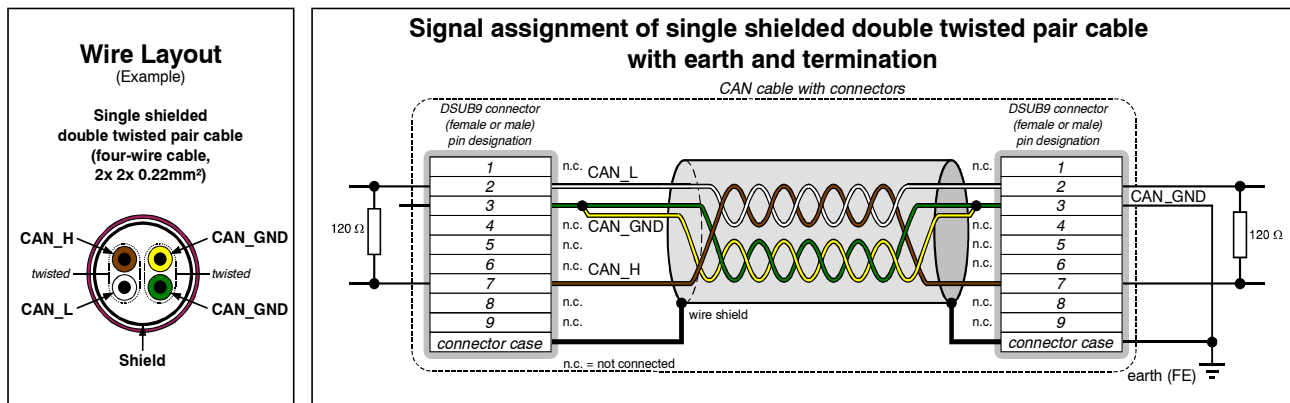
Figure 9: CAN wiring for heavy industrial environment

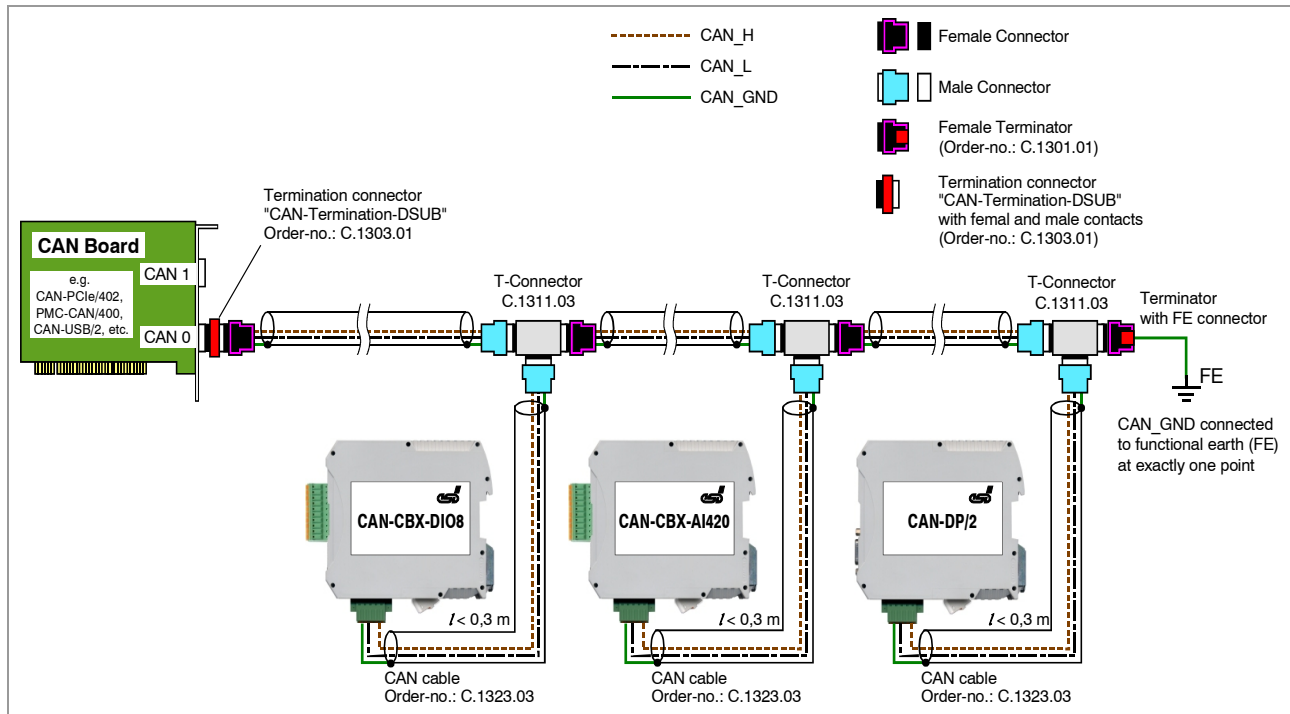## 6.3.2 Device Cabling

Figure 10: Example of proper wiring with single shielded double twisted pair cables

6.3.3 Branching

- In principle the CAN bus has to be realized in a line. The participants are connected to the main CAN bus line via short cable stubs. This is normally realised by so called T-connectors. When using esd's CAN-T-Connector (order no.: C.1311.03) it should be noted that the shield potential of the conductive DSUB housing is not looped through this T-Connector type. Thus the shielding is interrupted. Therefore you have to take adequate measures to connect the shield potentials, as described in the manual of the CAN-T-Connector. For further information on this read 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, e.g. the DSUB9 connector from ERNI (ERBIC CAN BUS MAX, order no.:154039).
- If a mixed application of single twisted and double twisted cables is unavoidable, take care that the CAN_GND line is not interrupted!
- Deviations from the bus structure can be realized by the usage of repeaters.

6.3.4 Termination

- A termination resistor has to be connected at both ends of the CAN bus.
  If an integrated CAN termination resistor which is equipped at the CAN interface at the end of the bus is connected, this one has to be used for termination instead of an external CAN termination plug.
- 9-pin DSUB-termination connectors with integrated termination resistor and male and female contacts are available from esd (order no. C.1303.01).
- 9-pin DSUB-connectors with integrated switchable termination resistor can be ordered e.g. from ERNI (ERBIC CAN BUS MAX, female 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 made e.g. at a termination connector (e.g. order no. C.1302.01 or C.1301.01).

6.5 Bus Length

> **NOTICE**
> Please note that the cables, connectors and termination resistors used in CANopen networks shall meet the requirements defined in ISO11898-2.
> 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 1.8.0, Table 2).

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,$\bar{6}$	80	-	
500	130	100	
333,$\bar{3}$	180	-	
250	270	250	
166	420	-	0,5 to 0,6
125	570	500	
100	710	650	0,75 to 0,8
83,$\bar{3}$	850	-	
66,$\bar{6}$	1000	-	
50	1400	1000	
33,$\bar{3}$	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 reach a wire length of 37 m at 1 Mbit/s within a proper terminated CAN network without impedance disturbances like e.g. caused by cable stubs > 0.3 m.

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) UNITRONIC ®-BUS-FD P CAN UL/CSA (1x 2x 0.25) (UL/CSA approved)	Part No.: 2170260 Part No.: 2170272
ConCab GmbH Äußerer Eichwald 74535 Mainhardt Germany www.concab.de	e. g. BUS-PVC-C (1x 2x 0.22 mm²) BUS-Schleppflex-PUR-C (1x 2x 0.25 mm²)	Order No.: 93 022 016 (UL appr.) 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) UNITRONIC ®-BUS-FD P CAN UL/CSA (2x 2x 0.25) (UL/CSA approved)	Part No.: 2170261 Part No.: 2170273
ConCab GmbH Äußerer Eichwald 74535 Mainhardt Germany www.concab.de	e. g. BUS-PVC-C (2x 2x 0.22 mm²) BUS-Schleppflex-PUR-C (2x 2x 0.25 mm²)	Order No.: 93 022 026 (UL appr.) Order No.: 94 025 026 (UL appr.)

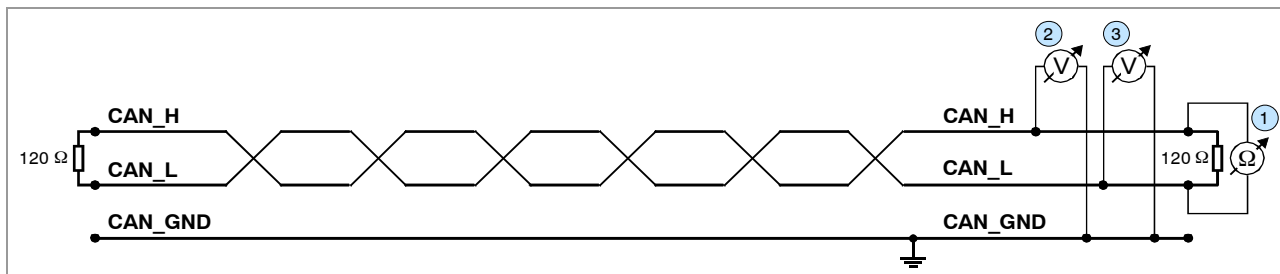> **i** **INFORMATION**
> Ready-made CAN cables with standard or custom length can be ordered from **esd**.

7. CAN Troubleshooting Guide

The CAN Troubleshooting Guide is a guide to find and eliminate the most frequent hardware-error causes in the wiring of CAN networks.

Figure 11: Simplified diagram of a CAN network

7.1 Termination

The termination is used to match impedance of a node to the impedance of the transmission line being used. When impedance is mismatched, the transmitted signal is not completely absorbed by the load and a portion is reflected back into the transmission line. If the source, transmission line and load impedance are equal these reflections are avoided. This test measures the series resistance of the CAN data pair conductors and the attached terminating resistors.

To test it ,please

1.   Turn off all power supplies of the attached CAN nodes.
2.   Measure the DC resistance between CAN_H and CAN_L at one end of the network ① (see figure above).

The measured value should be between 50 Ω and 70 Ω.

If the value is below 50 Ω, please make sure that:
-   there is no **short circuit** between CAN_H and CAN_L wiring
-   there are **not more than two** terminating resistors connected
-   the nodes do not have faulty transceivers.

If the value is higher than 70 Ω, please make sure that:
-   there are no open circuits in CAN_H or CAN_L wiring
-   your bus system has two terminating resistors (one at each end) and that they are 120 Ω each.

7.2 Electrical Grounding

The CAN_GND of the CAN network should be connected to the functional earth potential (FE) at only **one** point. This test will check if the CAN_GND is grounded in several places.
To test it, please

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).

3. Reconnect CAN_GND to earth potential.
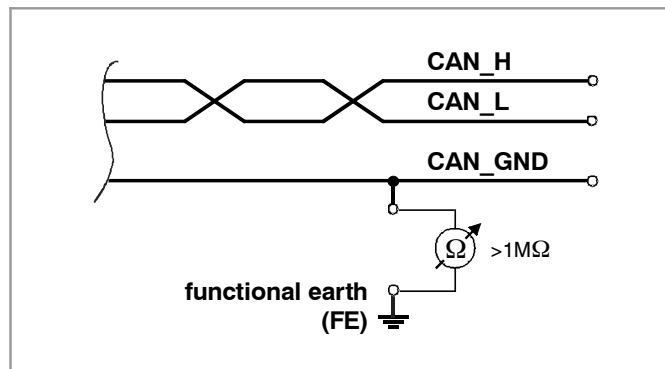
Figure 12: Simplified schematic diagram of ground test measurement

The measured resistance should be higher than 1 MΩ. If it is lower, please search for additional grounding of the CAN_GND wires.

7.3 Short Circuit in CAN Wiring

A CAN bus might possibly still be able to transmit data if there is a short circuit between CAN_GND and CAN_L, but generally the error rate will increase strongly. Make sure that there is no short circuit between CAN_GND and CAN_L!

7.4 CAN_H/CAN_L-Voltage

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. Faulty transceivers can cause the idle voltages to vary and disrupt network communication.

To test for faulty transceivers, please

1. Turn on all supplies.
2. Stop all network communication.
3. Measure the DC voltage between CAN_H and CAN_GND ② (see figure at previous page).
4. Measure the DC voltage between CAN_L and CAN_GND ③ (see figure at previous page).

Normally the voltage should be between 2.0 V and 3.0 V.

If it is lower than 2.0 V or higher than 3.0 V, it is possible that one or more nodes have faulty transceivers. For a voltage lower than 2.0 V please check CAN_H and CAN_L conductors for continuity.

To find the node with a faulty transceiver within a network please test the CAN transceiver resistance (see below) of the nodes.
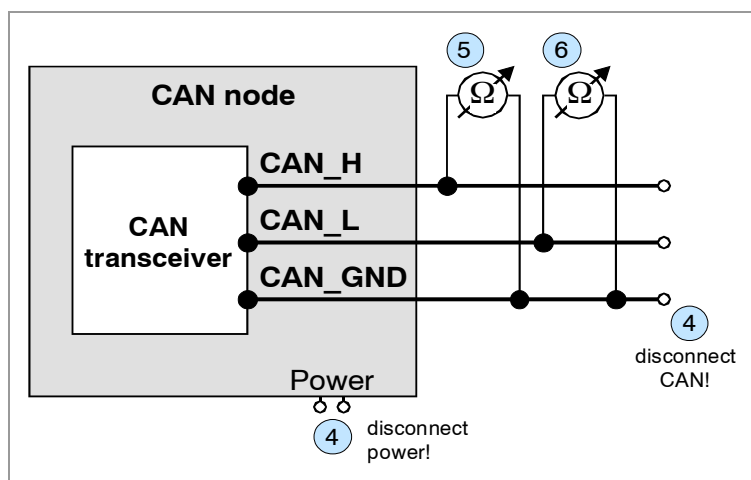
7.5 CAN Transceiver Resistance Test

CAN transceivers have circuits that control CAN_H and CAN_L. Experience has shown that electrical damage of the circuits may increase the leakage current in these circuits.

To measure the current leakage through the CAN circuits, please use a resistance measuring device and:

1.   Switch **off** the node and **disconnect** it from the network ④
      (see figure below).

2.   Measure the DC resistance between CAN_H and CAN_GND ⑤
      (see figure below).

3.   Measure the DC resistance between CAN_L and CAN_GND ⑥
      (see figure below).

The measured resistance has to be about 500 kΩ for each signal. If it is much lower, the CAN transceiver it is probably faulty.
Another indication for a faulty transceiver is a very high deviation between the two measured input resistances (>> 200 %).

Figure 13: Measuring the internal resistance of CAN transceivers

7.6 Support by esd

If you have executed the fault diagnostic steps of this troubleshooting guide and you even can not find a solution for your problem our support department will be able to assist.
Please contact our support via email at **support@esd.eu** or by phone **+49-511-37298-130**.

8. Declaration of Conformity

EU-KONFORMITÄTSERKLÄRUNG
EU DECLARATION OF CONFORMITY

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

esd erklärt, dass das Produkt	Typ, Modell, Artikel-Nr.
esd declares, that the product	*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**

die Anforderungen der Normen	**EN 61000-6-2:2005,**
fulfills the requirements of the standards	**EN 61000-6-3:2007+A1:2011**

gemäß folgendem Prüfbericht erfüllt.	**H-K00-0557-14**
according to test certificate.	

Das Produkt entspricht damit der EU-Richtlinie „EMV"	**2014/30/EU**
Therefore the product conforms to the EU Directive 'EMC'	

Das Produkt entspricht den EU-Richtlinien „RoHS"	**2011/65/EU, 2015/863/EU**
The product conforms to the EU Directives 'RoHS'	

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, 2020-01-03

T. Bielert

Rechtsgültige Unterschrift / *authorized signature*

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9. Order Information

Type	Properties	Order No.
CAN-USB/400	2x high-speed CAN interface for USB, with esd Advanced CAN IP-Core (esdACC), Physical Layer according ISO 11898, bit rate up to 1 Mbit/s, electrically isolated, 2x DSUB-9 connector, USB 2.0, high-speed 480 Mbit/s, Enhanced diagnostic features, Error injection capabilities, High resolution hardware timestamping, Drivers, tools and documentation for Windows on CD-ROM	C.2069.04
CAN-USB/400-IRIG-B	as C.2096.04 but additional analog and digital (RS422) IRIG-B input, Trigger I/Os, Misc. I/Os Synchronized timestamps.	C.2069.06
CAN-USB/400-FD	as C.2096.04 but 2x CAN FD according to ISO 11898-1:2015, instead of 2x Classical CAN, bit rate up to 5 Mbit/s	C.2069.64

Table 12: Order information

9.1 Software for CAN-USB/400 and CAN-USB/400-IRIG-B

Type		Order No.
CAN layer 2 software drivers for Windows on CD-ROM to CAN-USB/400 (C.2069.04) and CAN-USB/400-IRIG-B (C.2069.06) are included in delivery. Higher-Layer Protocols including CD-ROM (Classical CAN Applications only):		
CANopen-LCD Windows/Linux	CANopen Object Driver Licence + CD-ROM for Windows (Linux is not supported at the moment)	C.1101.06
J1939 Stack for Windows (Object)	J1939 Stack for esd CAN Hardware, Windows Object Code, incl. J1939 Simulation Tool, includes esd CAN Windows driver license	C.1130.10
ARINC 825-LCD Windows/Linux	Licence and CD for esdACC based CAN-Boards for Windows, incl. Object Driver Licence (Linux is not supported at the moment)	C.1140.06
For detailed information about the driver availability for your special operating system, please contact our sales team.		

Table 13: Order information software for CAN-USB/400 and CAN-USB/400-IRIG-B

9.2 Software for CAN-USB/400-FD

Type		Order No.
CAN layer 2 software drivers for Windows and Linux on CD-ROM to CAN-USB/400-FD (C.2069.64) are included in delivery.		
Higher-Layer Protocols including CD-ROM for Classical CAN Applications:		
CANopen-LCD Windows/Linux	These Windows drivers are available for **Classical CAN operation only!** (Linux is not supported at the moment)	C.1101.06
J1939 Stack for Windows (Object)		C.1130.10
ARINC 825-LCD Windows/Linux/LabVIEW		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 for CAN-USB/400-FD

9.3 PDF Manuals

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

Manuals		Order No.
CAN-USB/400-ME	Hardware manual in English to CAN-USB/400, CAN-USB/400-IRIG-B and CAN-USB/400-FD	C.2069.21
CAN-API-ME	NTCAN-API: Application Developers Manual (English) NTCAN-API: Driver Installation Guide (English)	C.2001.21
CANopen-ME	CANopen manuals in English	C.2002.21
J1939-ME	Manual 'J1939 Stack and SDK for esd CAN Hardware' in English	C.1130.21
ARINC825-ME	ARINC 825 Library manual in English	C.1140.21

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.