CAN-CBM-DP

Profibus-DP / CAN-Gateway

DN-CBM-DP

Profibus-DP / DeviceNet-Gateway

Hardware Manual

to Product C.2844.03/.05 and C.2846.02

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N O T E

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This manual contains important information and instructions on safe and efficient handling of the 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.

Trademark Notices

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PCB versions:	CPU331 Rev. 1.1 CBM-DP Rev. 1.1 CBMPB Rev. 1.1

Changes in the chapters

The changes in the user's manual listed below affect changes in the *hardware* as well as changes in the *description* of the facts only.

Version	Chapter	Changes versus previous version
1.7	1.1	Description of PROFIBUS-DP data range inserted.
	1.2	Description of PROFIBUS-DP data range inserted.
1.8	-	Safety Instructions and Classification of Warning Messages inserted
	1.1, 1.2	Chapter revised
	1.3	Note concerning LEDs inserted
	2.	Chapter "Hardware Installation inserted"
	4.	Chapter restructured and renamed to "Connector Assignment"
	4.1.1	Description of connector inserted
	4.4	Safety notes and instructions inserted
	4.5	Chapter "Conductor Cross Section"
	6.	Chapter "Order Information" moved and revised
1.9	3.2	Figure corrected, 100Ω resistor R126 inserted
	4.2	Description of shield potential inserted

Technical details are subject to change without 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 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 CBM-DP modules follow the instructions below and read the manual carefully to protect yourself and the CBM-DP module from damage.
- Do not use damaged or defective cables to connect the CBM-DP 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 CBM-DP module may only be driven by power supply current circuits, that are contact protected. A power supply, that provides a safety extra-low voltage (SELV or PELV) according to EN 60950-1, complies with this conditions.

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

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 CBM-DP module is to be integratred.

→ All current circuits which are connected to the device have to be sufficiently protected against hazardous voltage (SELV according to EN 60950-1).

→ Ensure the absence of voltage before starting any electrical work

NOTICE

The CBM-DP-module shall not be connected to a DC power supply network without protection against surge voltage.

→ Use an external overvoltage protection.

Qualified Personnel

This documentation is directed exclusively towards qualified personnel 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.

Intended Use

The intended use of the CAN-CBM-DP is the operation as PROFIBUS-DP/CAN-Gateway.
The intended use of the DN-CBM-DP is the operation as PROFIBUS-DP/DN-Gateway
The esd guarantee does not cover damages which result from improper use, usage not in accordance with regulations or disregard of safety instructions and warnings.

- The CBM-DP module is intended for indoor installation only.
- The operation of the CBM-DP in hazardous areas, or areas exposed to potentially explosive materials is not permitted.
- The operation of the CBM-DP for medical purposes is prohibited.

Service Note

The CBM-DP does not contain any parts that require maintenance by the user. The CBM-DP does not require any manual configuration of the hardware. Unauthorized intervention in the device voids warranty claims.
Remove all cables before cleaning. Clean the device with a lint-free cloth. Cleaning agents or solvents are not suitable.

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.

Typographical Conventions

Throughout this manual the following typographical conventions are used to distinguish technical terms.

Convention	Example
File and path names	`/dev/null or <stdio.h>`
Function names	***open()***
Programming constants	`NULL`
Programming data types	`uint32_t`
Variable names	*Count*

Number Representation

All numbers in this document are base 10 unless designated otherwise. Hexadecimal numbers have a prefix of 0x.
For example, 42 is represented as 0x2A in hexadecimal.

Contents

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1. Overview

This manual describes the hardware of the CAN-interface CAN-CBM-DP and the hardware of the DeviceNet-interface DN-CBM-DP module together. Differences are noted.

1.1 Module Description CAN-CBM-DP

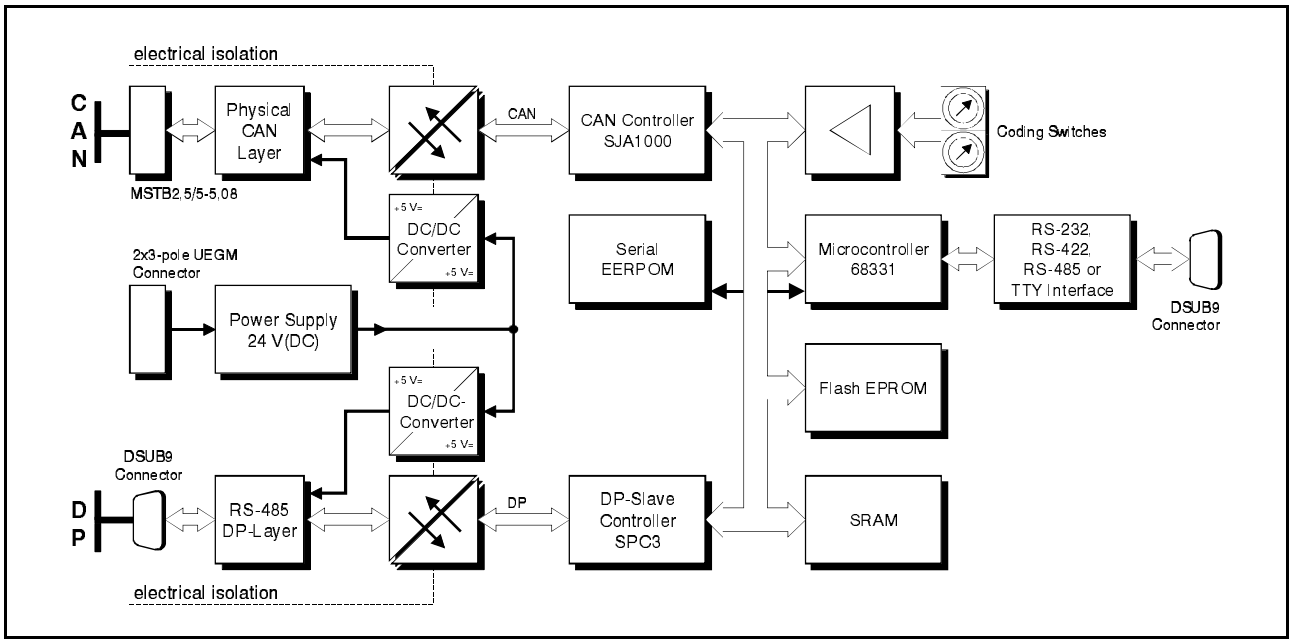


Figure 1: Block-circuit diagram of the CAN-CBM-DP module

By means of the module CAN-CBM-DP any Profibus-DP master can be connected to a CAN network. The DP/CAN gateway acts like a slave I/O component on the DP-bus, with a total of up to 300 bytes input and output data. Maximum 240 bytes of the total of 300 bytes can be used as input data (with 60 byte output data) or maximum 240 bytes can be used as output data (with 60 bytes input data).

The module operates internally with a 68331 micro controller, which buffers the CAN and Profibus DP data into the local SRAM. The firmware and configuration data are kept in the Flash EEPROM. Parameters are stored by means of a serial EEPROM.

The ISO 11898-compliant CAN interface allows a maximum data-transfer rate of 1 Mbit/s. The Profibus-DP slave interface automatically recognizes all usual bit rates up to 12 Mbit/s.The DP interface as well as the CAN interface are electronically insulated by optocouplers and DC/DC converters. CAN is connected by means of a 5-pin screw/plug connector in Combicon design. According to standard, the DP interface is equipped with a 9-pin female DSUB connector.

The CAN-CBM-DP can be configured with a PROFIBUS-tool as for example the SIMATIC Manager S7 or the TIA Portal.
The module comes with a serial interface (default: RS-232) for servicing and configuration. It is connected by means of a DSUB9 connector.

1.2 Module Description DN-CBM-DP

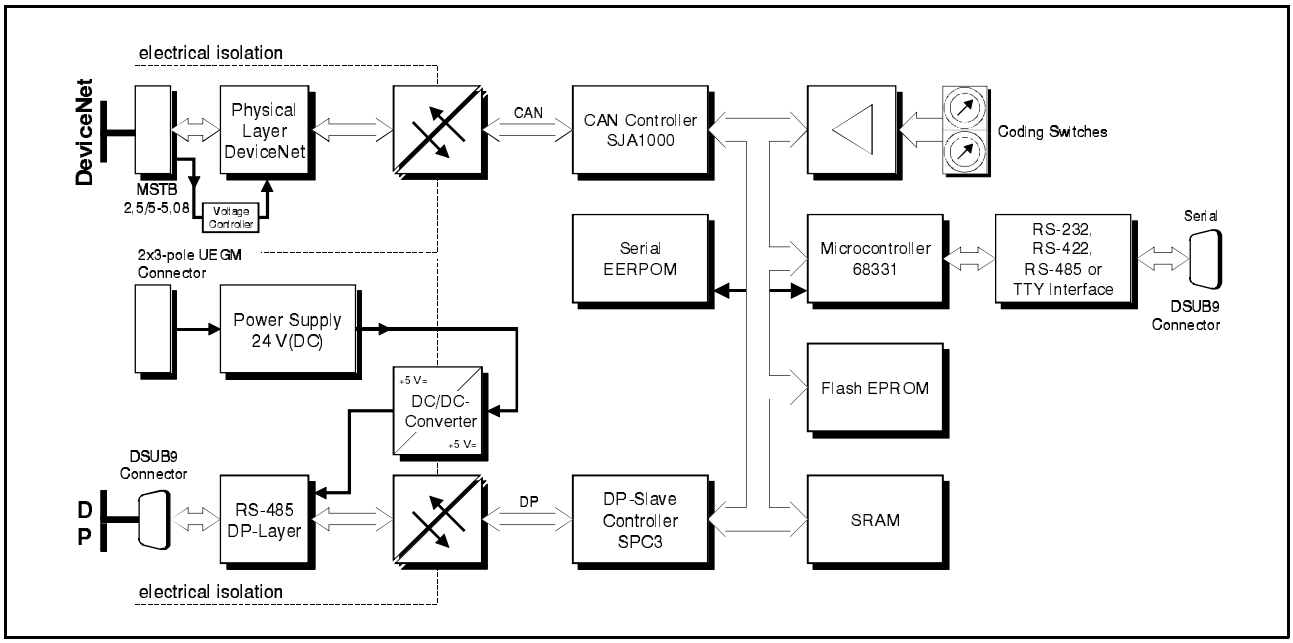


Figure 2: Block-circuit diagram of the DN-CBM-DP module

The module DN-CBM-DP can link any Profibus-DP master to DeviceNet. The DN-CBM-DP gateway acts like a slave I/O component on the DP-bus, with a total of up to 312 bytes input and output data. Maximum 244 bytes of the total of 312 bytes can be used as input data (with 68 byte output data) or maximum 244 bytes can be used as output data (with 68 bytes input data).

The module operates internally with a 68331 micro controller, which buffers the DN and Profibus DP data into the local SRAM. The firmware and configuration data are kept in the Flash EEPROM. Parameters are stored by means of a serial EEPROM.

The DeviceNet interface is designed according to the DeviceNet Specification Rev.2.0. All DeviceNet bit rates are supported.
The Profibus-DP slave interface automatically recognizes all usual bit rates up to 12 Mbit/s. The DP interface as well as the DeviceNet interface are electronically insulated by optocouplers and DC/DC converters.
The DeviceNet is connected by means of a 5-pin screw/plug connector in Combicon design. According to standard, the DP interface is equipped with a 9-pin female DSUB connector.

The DN-CBM-DP can be configured with a PROFIBUS-tool as for example the SIMATIC Manager S7 or the TIA Portal.
The module has a serial interface (default: RS-232) for servicing and configuration. It is connected by means of a male DSUB9.

1.3 Front View with Connectors and Coding Switches

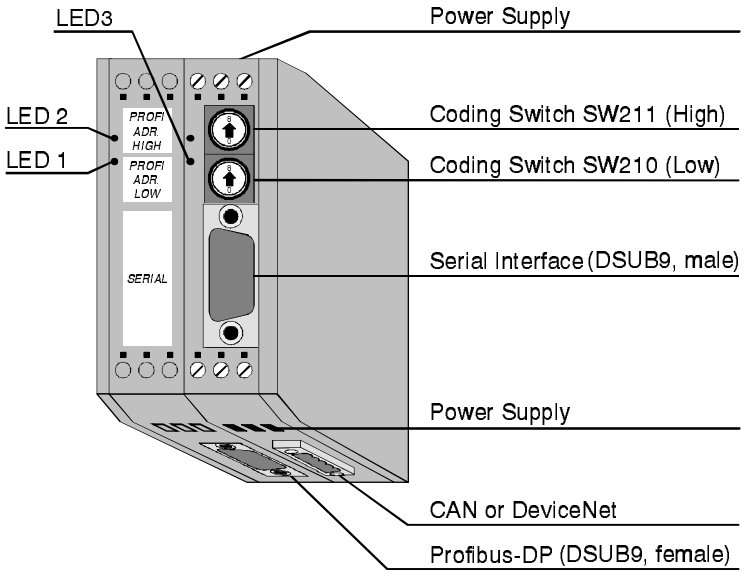


Figure 3: Position of connectors and control elements

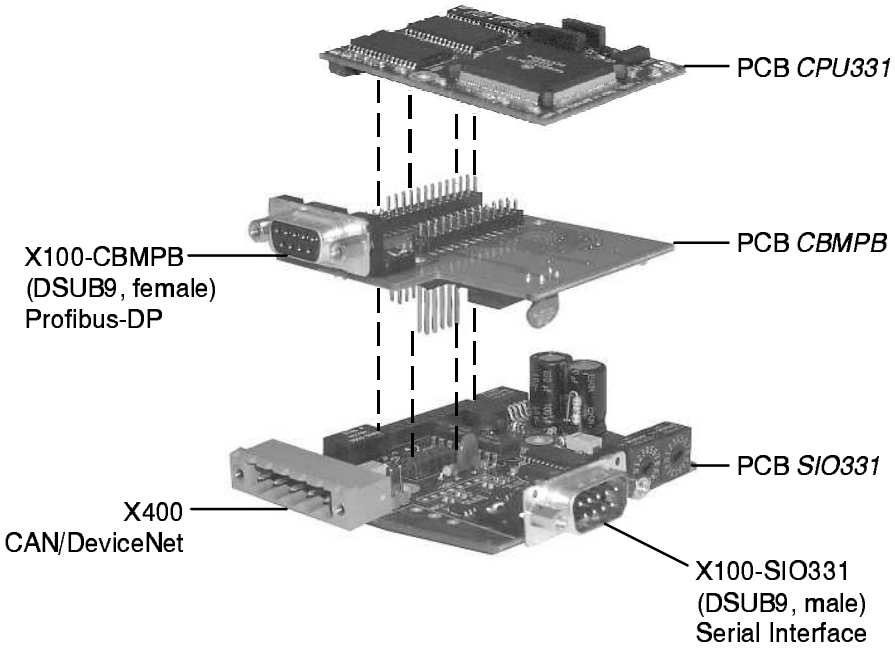


Figure 4: Internal module structure with PCB designations and connector names
(Figure without connector for supply voltage)

INFORMATION
The LEDs are described in detail in the software manuals of the modules.

1.4 Summary of Technical Data

1.4.1 General Technical Data

Supply voltage	Nominal voltage 24 V/DC ±10%, Current (at 20°C): max. 125 mA (+20 mA in TTY operation of serial interface)
Connectors	X100-SIO331 (DSUB9, male) - serial interface X100-CBMPB (DSUB9, female) - Profibus-DP-interface X101 (6-pin screw connector UEGM) - 24V-voltage supply X400 (Phoenix Contact connector, 5-pin MSTB2.5/5-5.08) - CAN or DeviceNet
Temperature range	0...50 ˚C ambient temperature
Humidity	max. 90%, non-condensing
Case dimensions (W x H x D)	Width: 40 mm, height: 85 mm, depth: 83 mm (including hat rail mounting and jutted out connectors DSUB9, without CAN/DeviceNet connectors)
Weight	approx. 200 g

Table 1: General data of the CAN-CBM-DP and DN-CBM-DP

1.4.2 Microcontroller Circuit

Microcontroller	68331
Memory	SRAM: 128 k x 16 Bit (optional 512 k x 16 Bit) Flash-EPROM: 128 k x 8 Bit EEPROM: serial I²C-EEPROM (1024 k x 8 Bit)
Debug interface	for service and programming

Table 2: Microcontroller circuit

1.4.3 CAN/DeviceNet Interface

Number of interfaces	CAN-CBM-DP: 1 x CAN DN-CBM-DP: 1 x DeviceNet
Connection	5-pin Phoenix Contact connector MSTB2.5/5-5.08
CAN controller	SJA1000,according to ISO 11898-1 (CAN 2.0A/B)
Electrical insulation of CAN interface from other circuits	via optocouplers and DC/DC converters (CAN-CBM-DP)
Physical Layer CAN (CAN-CBM-DP)	Physical Layer according to ISO 11898-2, transmission rate programmable from 10 kbit/s to 1 Mbit/s
Physical Layer DeviceNet (DN-CBM-DP)	Physical Layer according to DeviceNet specification Rev. 2.0, bit rate: 125 kbit/s, 250 kbit/s, 500 kbit/s
Bus termination	A terminating resistor has to be set externally, if required

Table 3: Data of CAN/DeviceNet interface

1.4.4 Profibus-DP Interface

Number of Profibus-DP interfaces	1x Profibus-DP
Connection	9-pin DSUB female
DP controller	Siemens Profibus Controller SPC3, DP-Slave
Electrical insulation of Profibus-DP from other circuits	via optocouplers and DC/DC converters
Physical Layer	RS-485

Table 4: Data of Profibus-DP interface

1.4.5 Serial Interface

Controller	68331
Interface	Standard: RS-232 Options: RS-422, RS-485, TTY active/passive
Connection	9-pin DSUB male

Table 5: Data of serial interface

2. Hardware Installation

To put the CAN/DN-CBM-DP 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
	**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 CBM-DP module is to be integrated. → All current circuits which are connected to the device have to be sufficiently protected against hazardous voltage (SELV according to EN 60950-1) before you start with the installation. → Ensure the absence of voltage before starting any electrical work.	
	**NOTICE** The CBM-DP module shall not be connected to a DC power supply network without protection against surge voltage. → Use an external overvoltage protection.	
1	Mount and connect the CBM-DP module and connect the interfaces (Power supply, CAN or DeviceNet, PROFIBUS-DP).	11
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”. Any CAN node that does not support a galvanic isolation represents the equivalent of a Ground (GND) connection.	35
3	Turn on the 24 V-power supply voltage of the CBM-DP module.	-

3. Circuit Description

3.1 CAN/DeviceNet Circuit

3.1.1 Interface Circuit

The CAN-CBM-DP module is equipped with an ISO 11898-compliant CAN interface, the DN-CBM-DP with a DeviceNet interface. The same connector in Combicon design is used for the two types, the assignment of the connector, however, differs. The following figures show both interfaces.

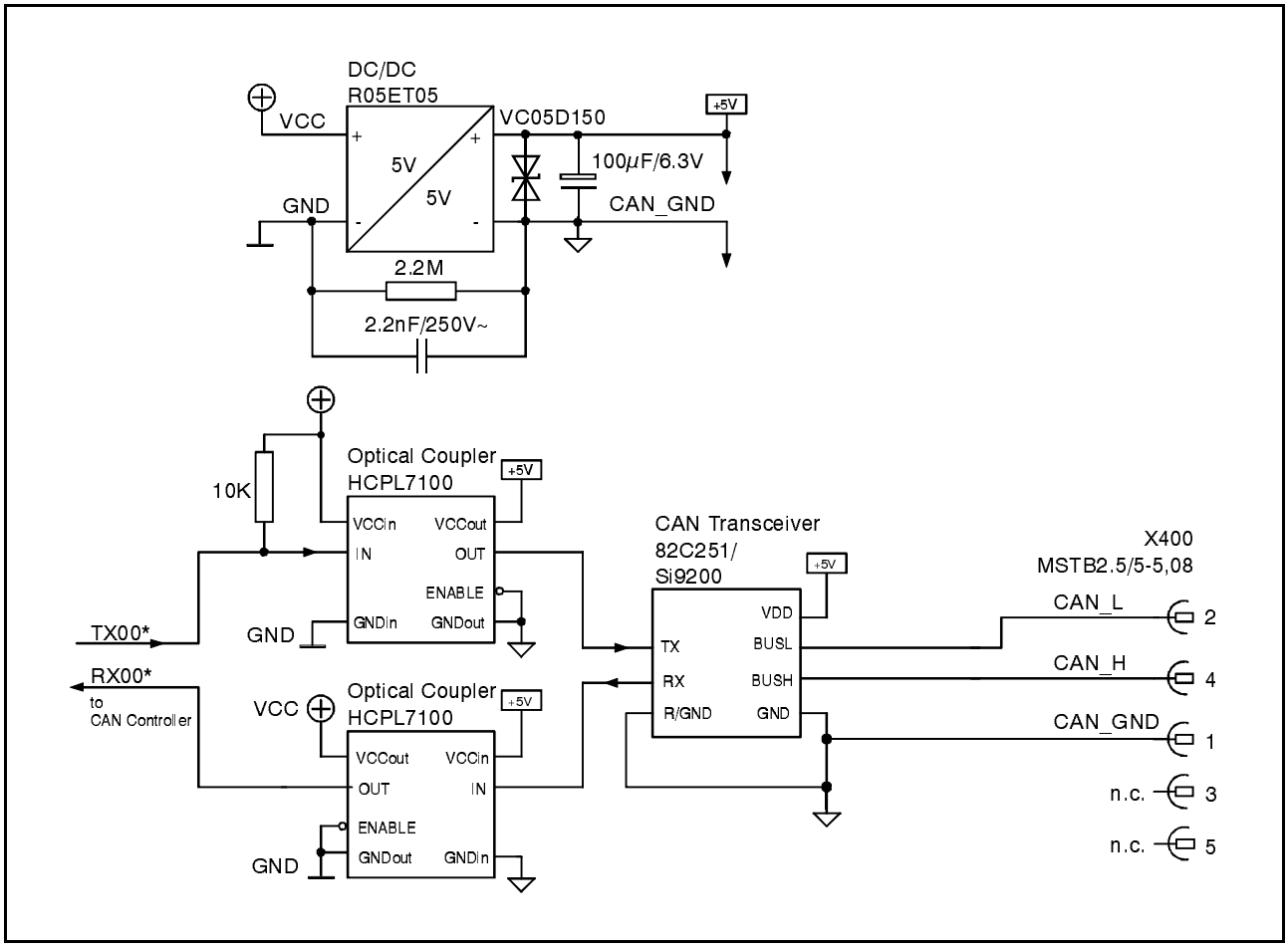


Figure 5: Circuit of CAN interface CAN-CBM-DP

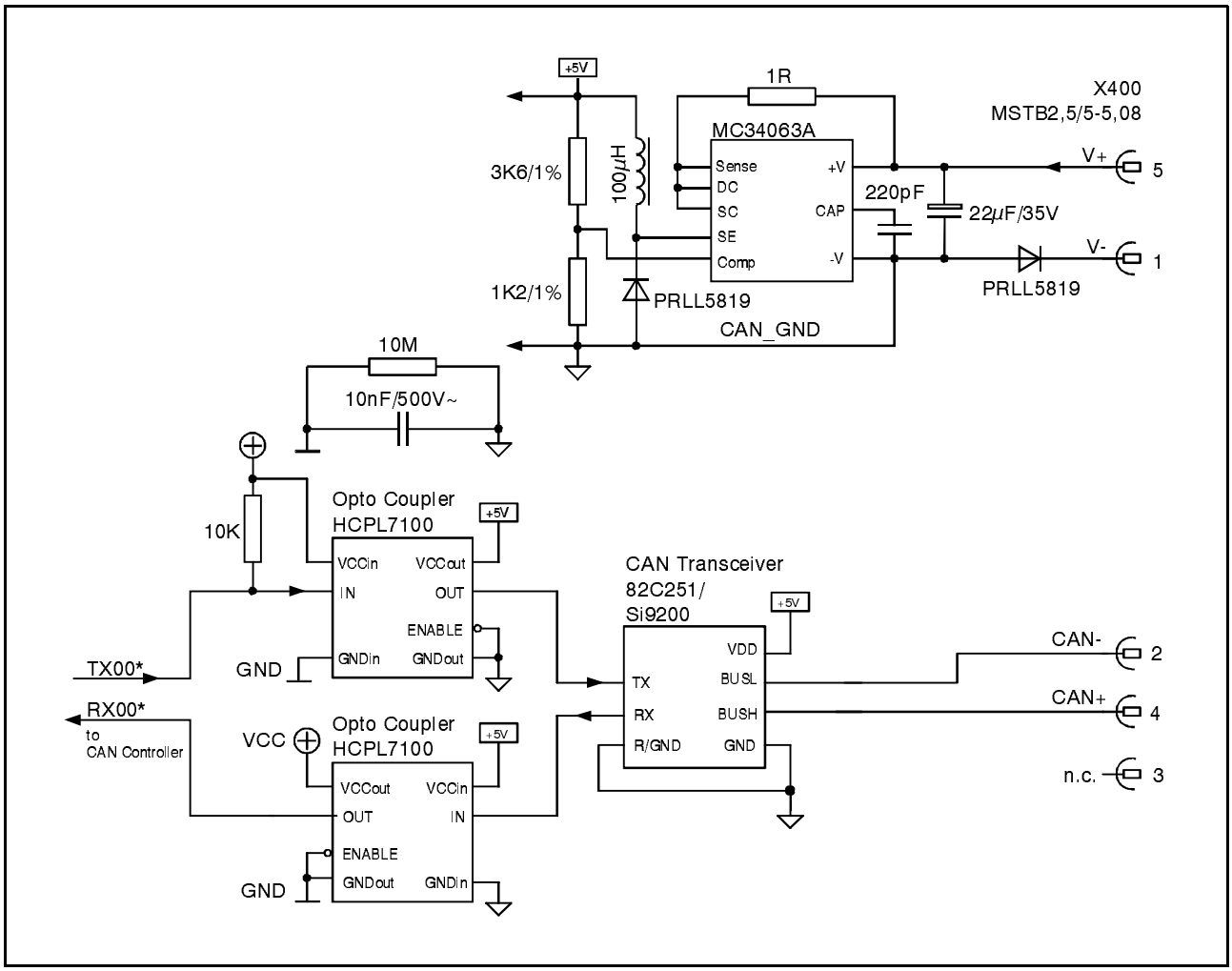
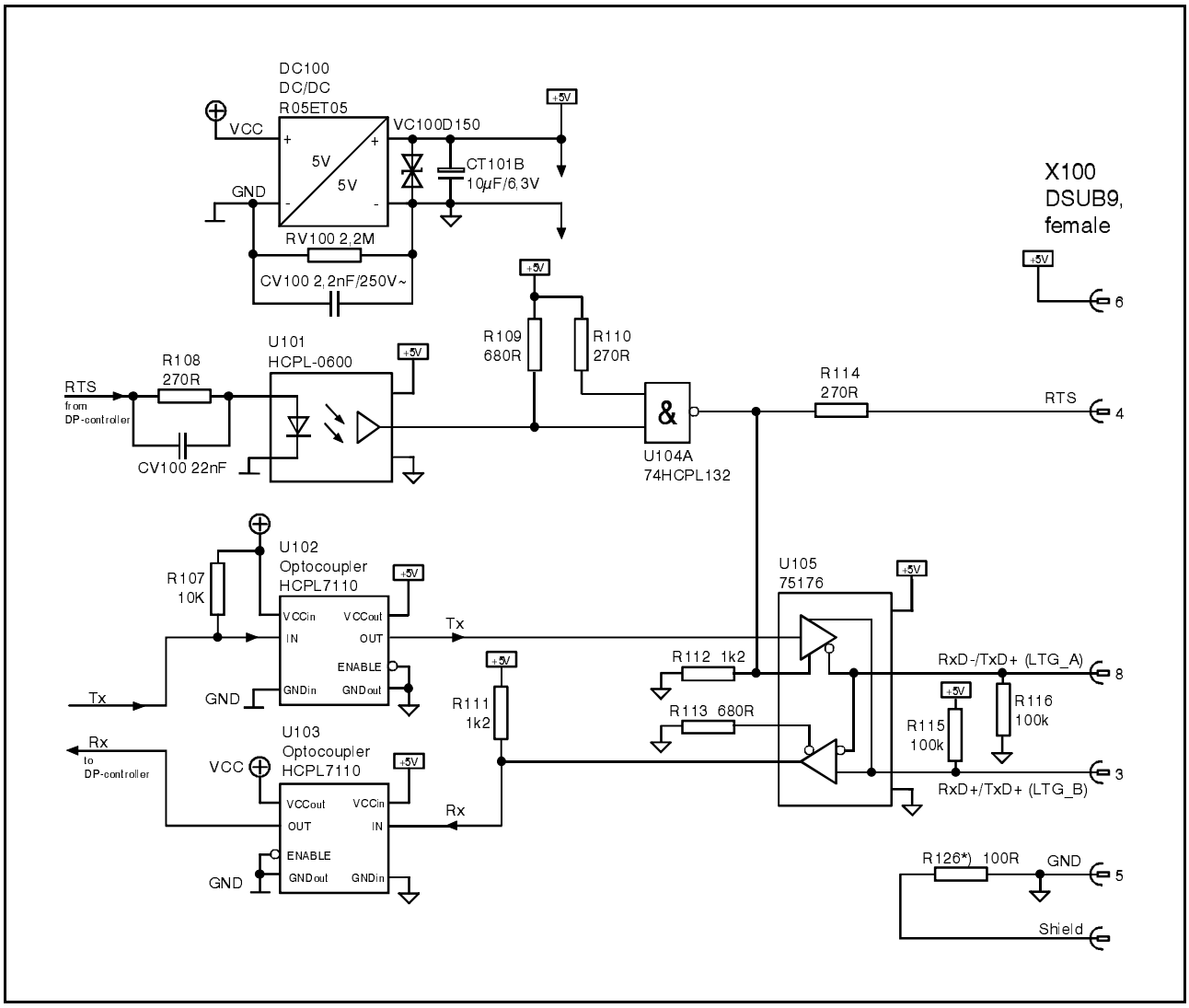


Figure 6: Circuit of DeviceNet interface DN-CBM-DP

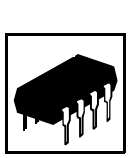
3.2 Profibus-DP Circuit



*)... The 100Ω resistor R126 is equipped from serial number IS....

Figure 7: Circuit of Profibus-DP interface

NOTICE
The terminating resistors of the Profibus-DB networks have to be connected externally (see EN 50 170)!



3.3 Serial Interface

3.3.1 Configuration

The physical interface of the serial configuration interface can be configured as an RS-232, RS-422, RS-485, TTY-active or TTY-passive interface. For RS-232 operation an RS-232A driver component is used and for the other interfaces piggy-backs are used.

The serial interface is controlled by the 68331. The bit rate of the interface can be set by parameters. For each interface type (RS-232, RS-422, RS-485, TTY) a bit rate of up to 38.4 kbit/s is supported.

The following bit rates can be set by means of the software. The values in the second column show the actual bit rates, which result from the controller-internal conversion.

Bit rate (set value) [bit/s]	Bit rate (actual value) [bit/s]
38,400	38,462
19,200	19,231
9,600	9,615
4,800	4,808
2,400	2,404
1,200	1,199
600	600.2
300	299.9

Table 6: Adjustable bit rates

3.3.2 Connection of Various Serial Interfaces

Below the wiring of the serial interfaces is shown. The figures are used to explain the terms for the signals used in the appendix. In the appendix you can also find the circuit diagrams of the various available piggy-backs.
The signal terms are exemplary for the connection of the CBM-DP as transmitter (terminal DTE).

3.3.2.1 The RS-232 Interface

The input signals CTS, DSR and DCD are not evaluated by the CAN-CBM-DP and DN-CBM-DP!

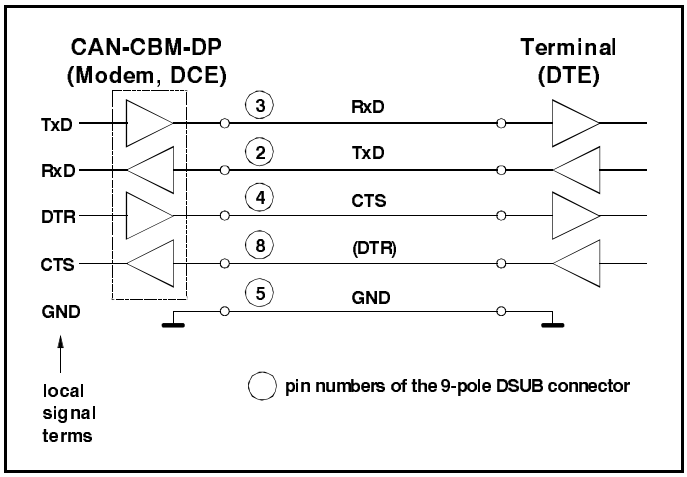
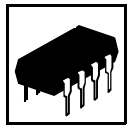


Figure 8: Connection diagram for RS-232 operation



3.3.2.2 The RS-422 Interface

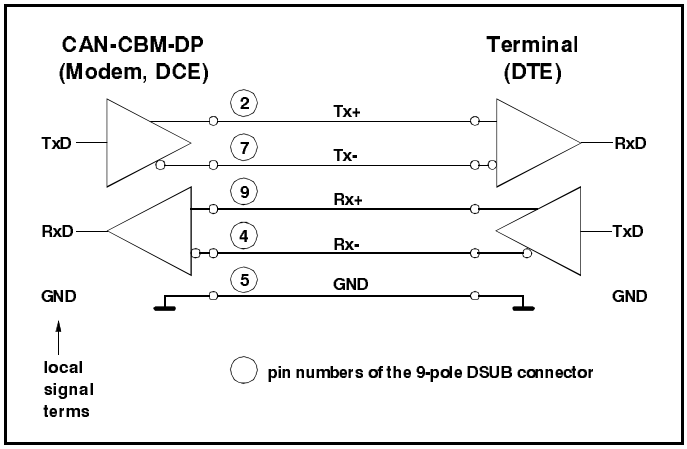


Figure 9: Connection diagram for RS-422 operation

3.3.2.3 The RS-485 Interface

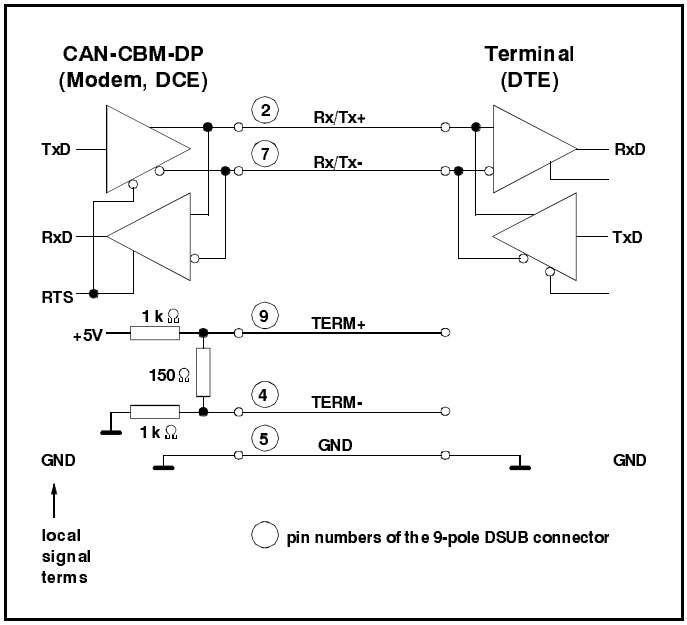


Figure 10: Connection diagram for RS-485 operation

In order to activate the terminating resistor network on the piggy-back, you have to connect pins 9 and 2 and pins 4 and 7 in the DSUB9 connector, for example.

3.3.2.4 The TTY(20 mA) Interface

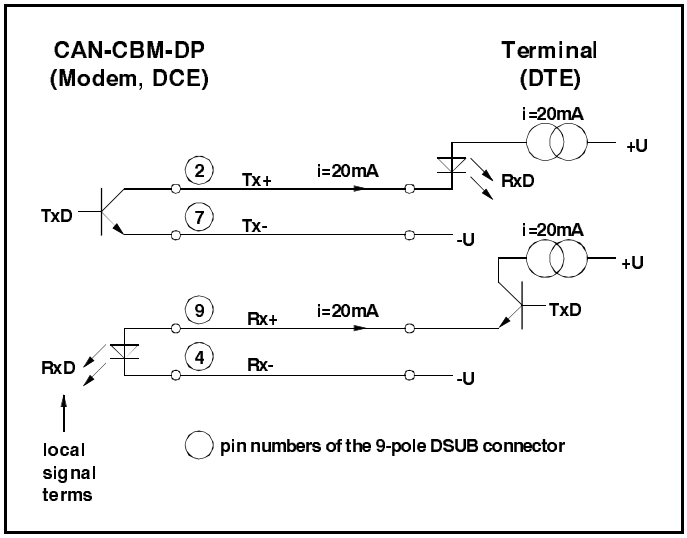


Figure 11: Connection diagram for TTY operation (passive)

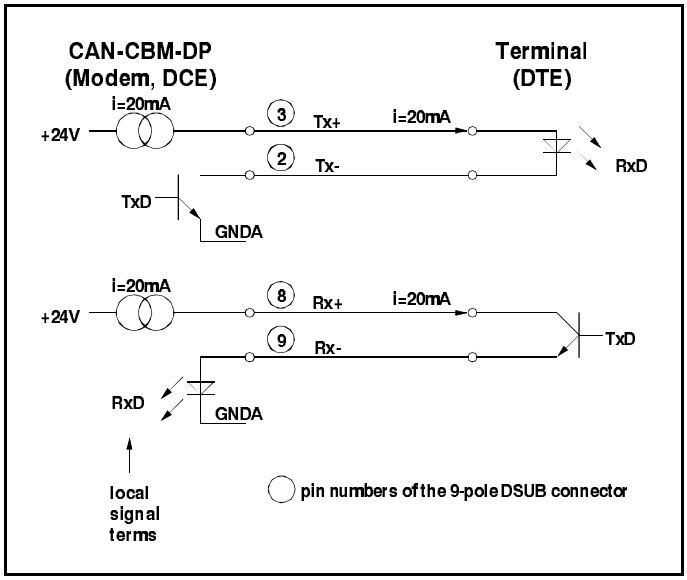
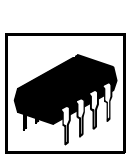


Figure 12: Connection diagram for TTY operation (active)



3.4 Function of Coding Switches

The coding switches are used to set the PROFIBUS address. On power-on the PROFIBUS address is read from the coding switches. The settings have to be changed before switching on, because changes have no effect during operation.

The CAN-CBM-DP/DN-CBM-DP is operated as a slave station whose addresses can be set in the range *decimally* from 3 to 124 or *hexadecimally* from 0x03 to 0xC7. If an address smaller than 3 is set, address 3 is valid. If an address larger than 124 (decimal) or 0xC7 (Hex) is set, address 124 is valid.

The upper coding switch (SW211) is used to set the MSBs, the lower coding switch (SW210) is used to set the LSBs.

The CAN identifiers (CAN-CBM-DP) are set by means of a PROFIBUS-DP configuration tool (e.g. SIMATIC manager). Information about this can be found in the 'CAN-CBM-DP Software Manual'.

The MACID for the operation of the DN-CBM-DP module is set by the configuration received from the PLC via PROFIBUS-DP, too.

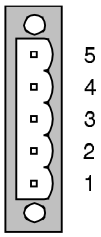
4. Connector Assignments

4.1 CAN/DeviceNet (X400)

4.1.1 CAN-CBM-DP: CAN-Bus (X400, 5-pin Combicon Style)

Device connector: Phoenix Contact MSTB 2,5/5-5,08 (male contacts)
Cable connector: Phoenix Contact MSTB 2,5/ 5-STF-5,08.. with screw connections
For conductor connection and conductor cross section see page 34.

Pin Assignment of the Combicon socket of the module

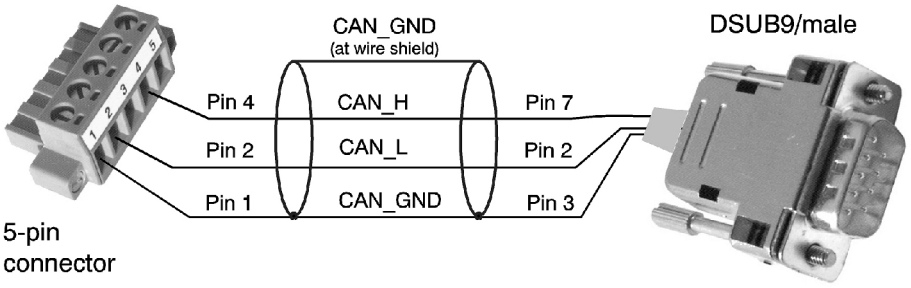


Pin	Signal
5	n.c.
4	CAN_H
3	Shield
2	CAN_L
1	CAN_GND

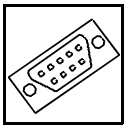
Signal Terms:

CAN_L, CAN_H ...	CAN signals
CAN_GND...	reference potential of the CAN physical layers
Shield...	connection of shield line (Shield signal is not connected locally on the CAN-CBM-DP)

Pin assignment of an adapter cable 5-pole Phoenix Contact connector to 9-pole DSUB:

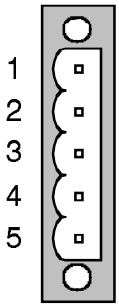


The 9-pin DSUB connector is assigned in accordance with CiA DS 102.



4.1.2 DN-CBM-DP: DeviceNet (X400, 5-pin Combicon Style)

Pin Position:



Pin Assignment:

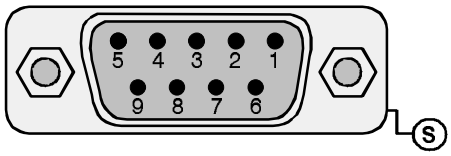
Pin	Signal
1	V-
2	CAN-
3	Shield
4	CAN+
5	V+

Signal terms:

V+...	Voltage supply feed (U_{VCC} = 24 V ± 4%)
V-...	Reference potential to V+ and CAN+/CAN-
CAN+, CAN-...	CAN-signal lines
Shield...	Connection of shield line (Shield signal is not connected locally on the DN-CBM-DP)

4.2 Profibus-DP Interface (X100-CBMPB, 9-pin DSUB female)

Pin Position:



Pin Assignment:

Signal	Pin		Signal
n.c.	1	6	+5 V (output)
n.c.	2	7	n.c.
RxD+/TxD+ (I/O)	3	8	RxD-/TxD- (I/O)
RTS (output)	4	9	n.c.
GND	5		

9-pin DSUB female

Shield	S

Signal Terms:

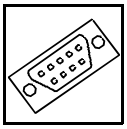
RxD+/TxD+... Receive and transmission data
RxD-/TxD-

RTS... Control signal for repeater (‘Request To Send’)

+5 V... Voltage supply for external terminating resistor networks (max. 50 mA)

GND... Reference potential

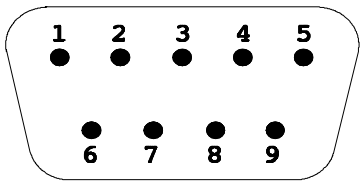
Shield... Shielding (connected with the case of the 9-pin DSUB, female)



4.3 Serial Interface (X100)

4.3.1 RS-232 Interface (X100-SIO331, 9-pin DSUB male)

Pin Position:



Pin Assignment:

Signal		Pin		Signal	
(DSR)	(input)	6	1	(DCD)	(input)
RTS	(output)	7	2	RxD	(input)
(CTS)	(input)	8	3	TxD	(output)
RIN	(input)	9	4	DTR	(output)
			5	GND	

9-pin DSUB male

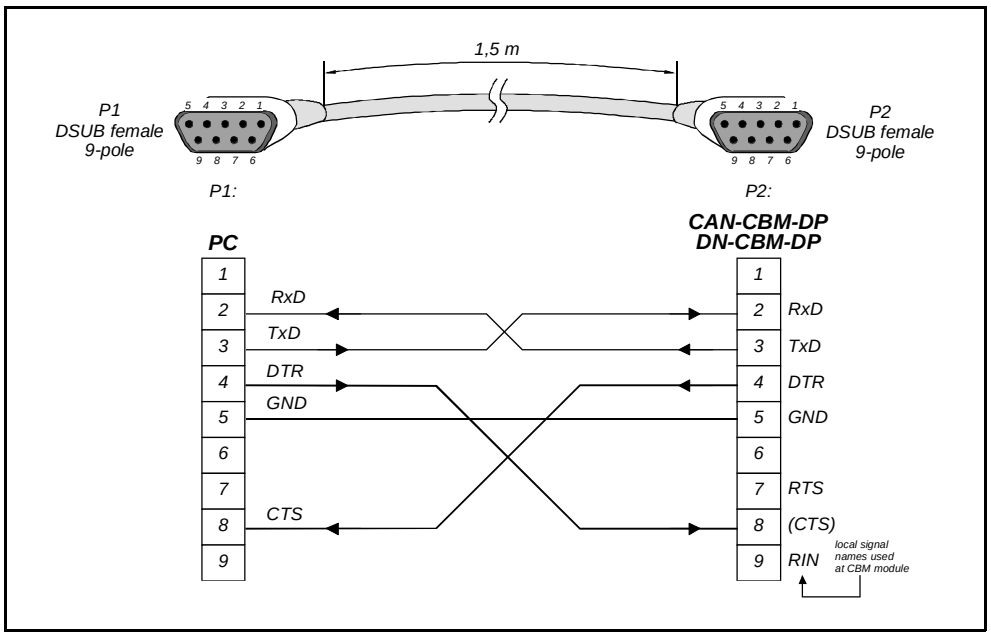
The signal name is indicated looked by the CAN-CBM-module.

The input signals CTS, DSR and DCD are not evaluated by the CAN-CBM-DP / DN-CBM-DP!

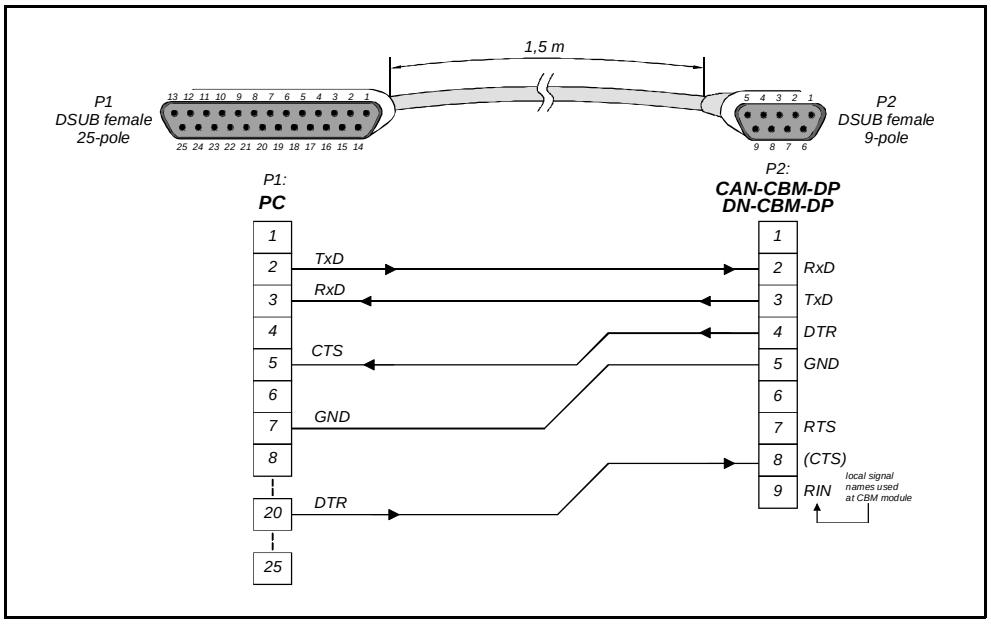
4.3.1.1 Connection Lines for the RS-232 Interface to a PC

The following two figures show the required assignment for RS-232 connection lines between PC and CAN-CBM-DP/DN-CBM-DP.

Adapter cable 9-pin DSUB female to 9-pin DSUB female

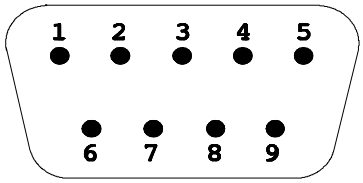


Adapter cable 25-pin DSUB female to 9-pin DSUB female



4.3.2 RS-422 Interface (X100-SIO331, 9-pin DSUB male)

Pin Position:



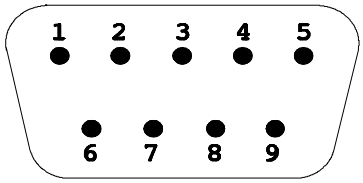
Pin Assignment:

Signal	Pin		Signal
-	6	1	-
Tx- (output)	7	2	Tx+ (output)
-	8	3	-
Rx+ (input)	9	4	Rx- (input)
		5	GND

9-pin DSUB male

4.3.3 RS-485 Interface (X100-SIO331, 9-pin DSUB male)

Pin Position:

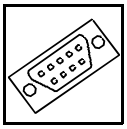


Pin Assignment:

Signal	Pin		Signal
-	6	1	-
		2	Rx/Tx+
Rx/Tx-	7	3	-
-	8	4	Term- (for Rx/Tx-) *1)
Term+ (for Rx/Tx+) *1)	9	5	GND

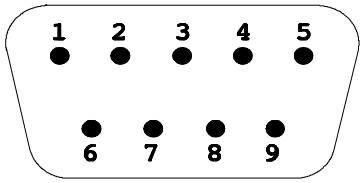
9-pin DSUB male

*1)... The signals Term+ and Term- are connected to a terminating resistor network on the PCB. In order to activate the connection, Term+ has to be connected to the Rx/Tx+ signal and Term- with the Rx/Tx- signal.



4.3.4 TTY-passive Interface (X100-SIO331, 9-pin DSUB male)

Pin Position:



Pin Assignment:

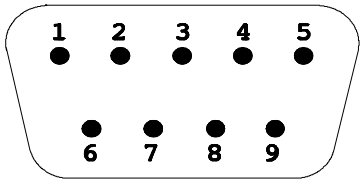
Signal	Pin		Signal
-	6	1	-
		2	Tx+ (transmitter)
Tx- (transmitter)	7	3	I1+ *1)
I2+ *1)	8		
		4	Rx- (receiver)
Rx+ (receiver)	9	5	GND

9-pin DSUB male

*1)... Signals I2+ and I1+ are assigned, but are not required for operating this physical interface.

4.3.5 TTY-active Interface (X100-SIO331, 9-pin DSUB male)

Pin Position:



Pin Assignment:

Signal	Pin		Signal
-	6	1	-
GNDA *1)	7	2	Tx- (transmitter)
Rx+ (receiver)	8	3	Tx+ (transmitter)
Rx- (receiver)	9	4	GNDA *1)
		5	GND

9-pin DSUB male

*1)... The GNDA signals have been assigned but are not required for operating this physical interface.

4.4 Voltage Supply (X101, UEGM)

DANGER
The CBM-DP module may only be driven by power supply current circuits, that are contact protected. A power supply, that provides a safety extra-low voltage (SELV or PELV) according to EN 60950-1, complies with this conditions.

NOTICE
The CAN-CBM-Bridge/2 shall not be connected to a DC power supply network without protection against surge voltage.
→ Use an external overvoltage protection.

Voltage is supplied by means of the screw connector UEGM, integrated in the case. It can be connected to lines with a cross-section of up to 2.5 mm².
Assignment of the screw connectors is the same on both sides of the case. They can be used alternatively. The middle contact is for +24 V and the two outer contacts are for GND.

NOTICE
It is **not permissible** to feed-through the supply voltage, i.e. To use one side as 24 V input and the other side as 24 V output in order to supply other devices!

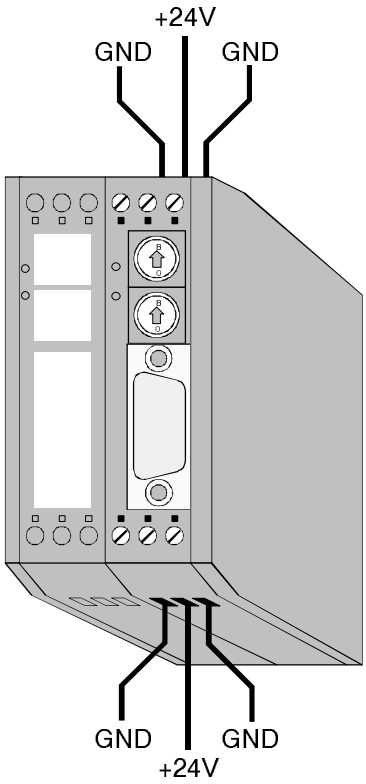


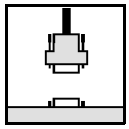
Figure 13: Voltage supply

4.5 Conductor Connection/Conductor Cross Sections

The following table contains an extract of the technical data of the cable connectors.

Interface	**CAN / DeviceNet**[1]
Connector type plug component	MSTB 2,5/ 5-STF-5,08
Connection method	screw connection
Conductor cross section solid min. / max.	0.2 mm² /2.5 mm²
Conductor cross section stranded min. / max.	0.2 mm² /2.5 mm²
Conductor cross section stranded, with ferrule without plastic sleeve min. / max.	0.25 mm² /2.5 mm²
Conductor cross section stranded, with ferrule with plastic sleeve min. / max.	0.25 mm² /2.5 mm²
Conductor cross section AWG/kcmil min. / max.	24 / 12
2 conductors with same cross section, solid min. / max.	0.2 mm² /1 mm²
2 conductors with same cross section, stranded min. max.	0.2 mm² /1.5 mm²
2 conductors with same cross section, stranded, ferrules without plastic sleeve, min./max.	0.25 mm² / 1 mm²
2 conductors with same cross section, stranded, TWIN ferrules with plastic sleeve, min. / max.	0.5 mm² /1.5 mm²
Minimum AWG according to UL/CUL	30
Maximum AWG according to UL/CUL	12

[1] Technical Data from Phoenix Contact website printed circuit board connector, plug component



5. Correct Wiring of Electrically Isolated CAN Networks

For the CAN wiring all applicable rules and regulations (EC, DIN), e.g. regarding electromagnetic compatibility, security distances, cable cross-section or material, have to be observed.

5.1 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 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!**

5.2 Light Industrial Environment (Single Twisted Pair Cable)

5.2.1 General Rules

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.

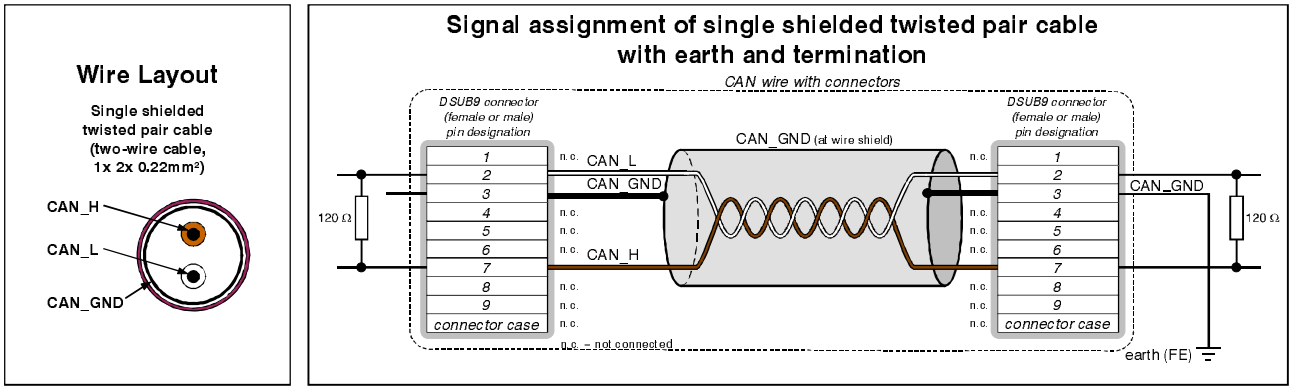


Figure. 14: CAN wiring for light industrial environment

5.2.2 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.

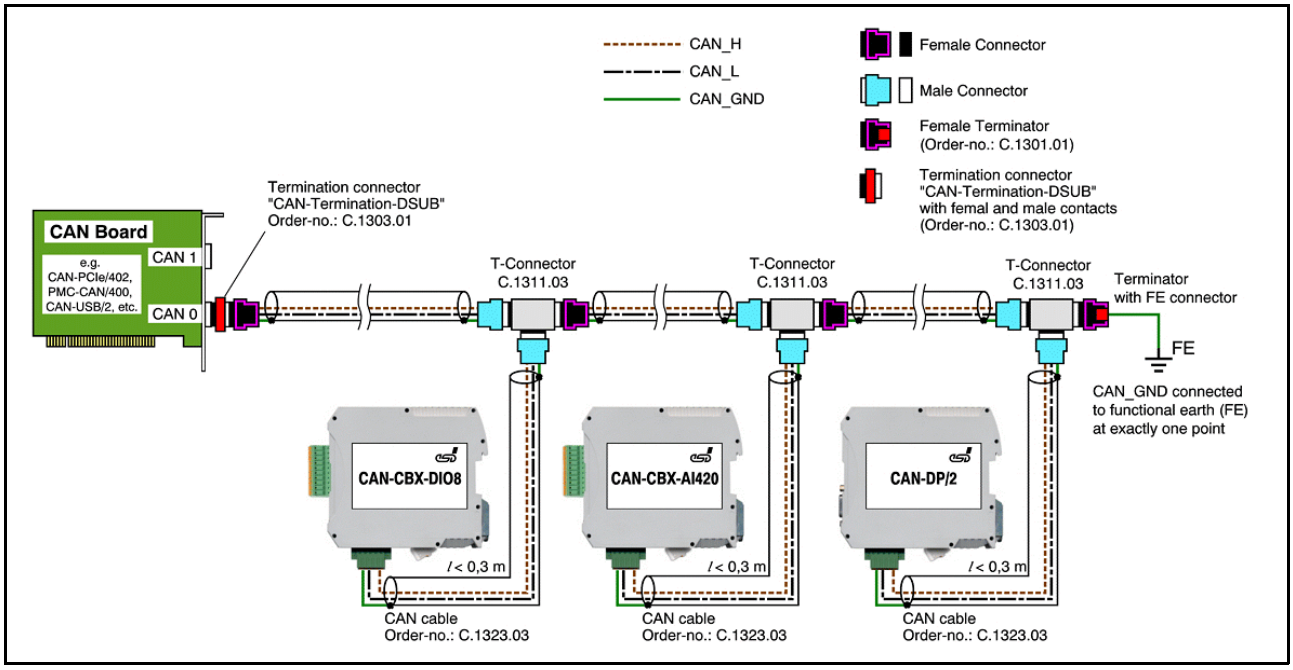


Figure. 15: Example for proper wiring with single shielded single twisted pair wires

5.2.3 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.

5.2.4 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.

5.3 Heavy Industrial Environment (Double Twisted Pair Cable)

5.3.1 General Rules

The following **general rules** for 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 cannot be avoided, double shielded cables are recommended.

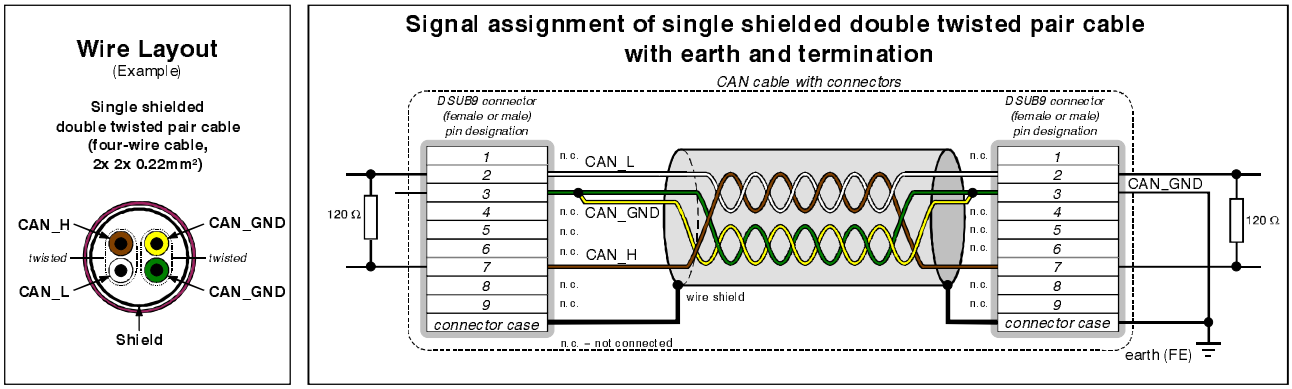


Fig. 16: CAN wiring for heavy industrial environment

5.3.2 Device Cabling

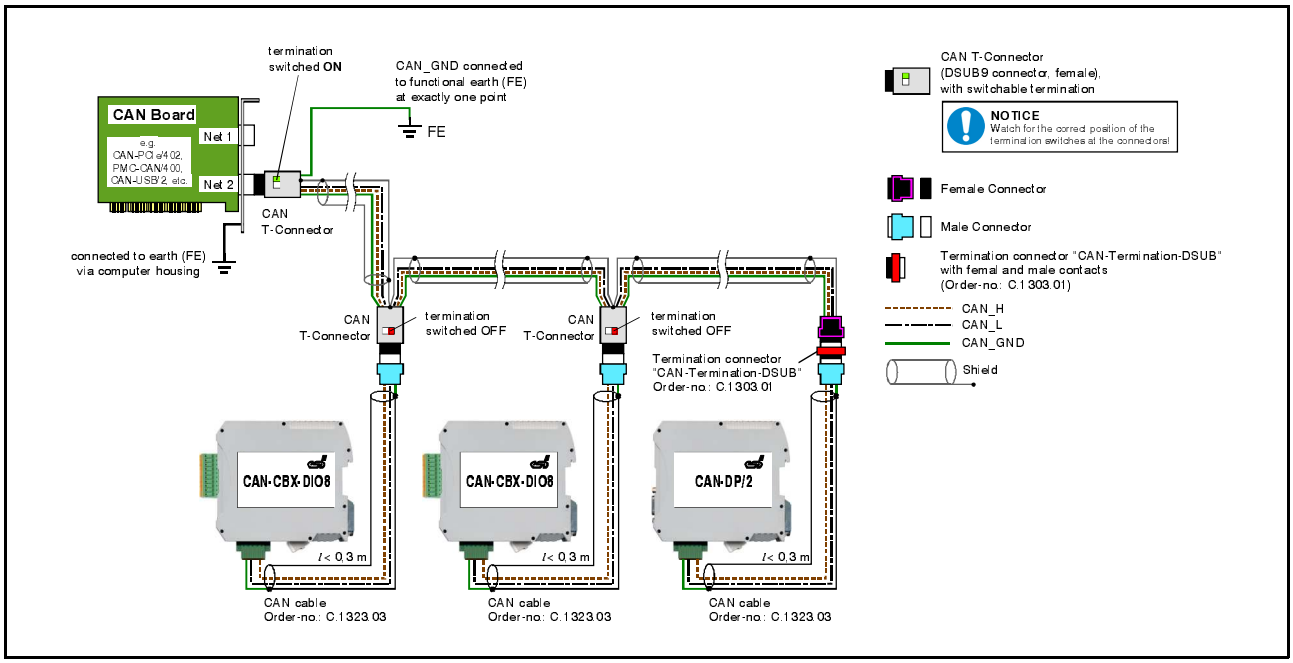


Fig. 17: Example for proper wiring with single shielded double twisted pair cables

5.3.3 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.

5.3.4 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).

5.4 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 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)

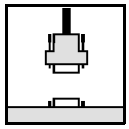
5.5 Bus Length

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 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 7: 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.



5.6 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.

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

Manufacturer	Cable Type
U.I. LAPP GmbH Schulze-Delitzsch-Straße 25 70565 Stuttgart Germany www.lappkabel.de	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) Part No.: 93 022 016 (UL appr.) BUS-Schleppflex-PUR-C (1x 2x 0.25 mm²) Part No.: 94 025 016 (UL appr.)

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

Manufacturer	Cable Type
U.I. LAPP GmbH Schulze-Delitzsch-Straße 25 70565 Stuttgart Germany www.lappkabel.de	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) Part No.: 93 022 026 (UL appr.) BUS-Schleppflex-PUR-C (2x 2x 0.25 mm²) Part No.: 94 025 026 (UL appr.)

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

6. 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.

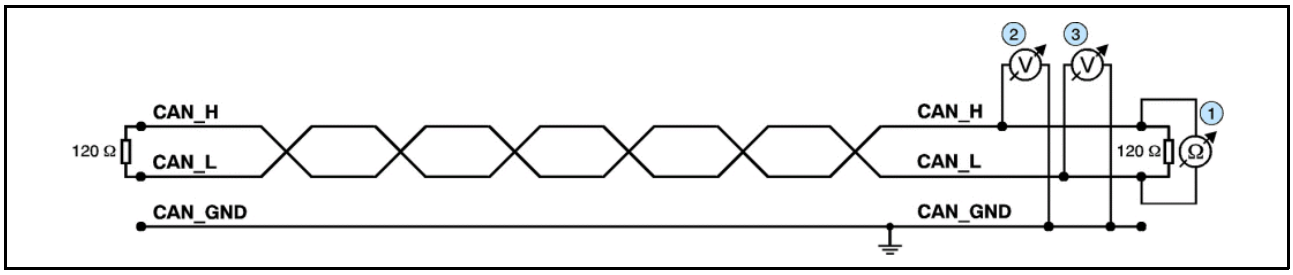


Figure. 18: Simplified diagram of a CAN network

6.1 Termination

The termination is used to match the 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.

6.2 Electrical Grounding

CAN_GND of the CAN network should be connected to 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.

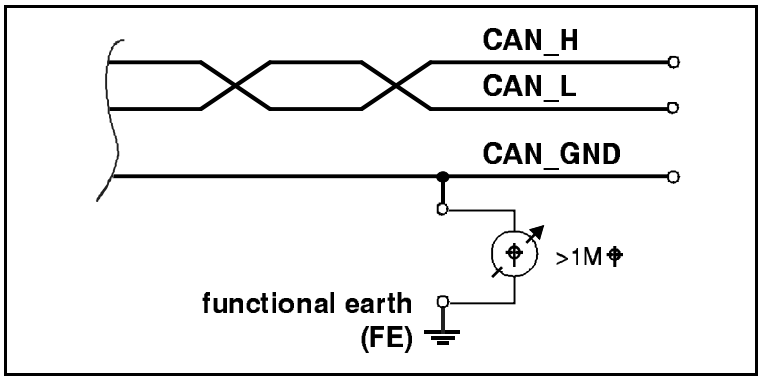


Fig. 19: Simplified schematic diagram of ground test measurement

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

6.3 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!

6.4 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.

6.5 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 is probably faulty. Another indication for a faulty transceiver is a very high deviation between the two measured input resistances (>> 200%).

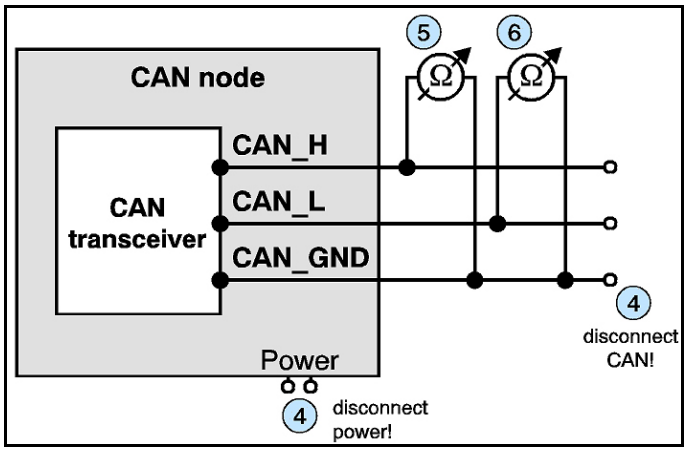


Figure 20: Simplified diagram of a CAN node

6.6 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 **+40-511-37298-130**.

7. Order Information

Type	Properties	Order No.
CAN-CBM-DP	DP-CAN-Gateway, CAN-layer 2, CAN 2.0A-firmware for 11 bit CAN identifier, RS-232 interface, GSD-file	C.2844.03
CAN-CBM-DP-2.0B	DP-CAN-Gateway, CAN-layer 2, CAN 2.0A/B-firmware for 11 and 29 bit CAN identifier, RS-232 interface, GSD-file	C.2844.05
DN-CBM-DP	DP-DeviceNet-Gateway, Firmware for 11 bit CAN identifier, RS-232 interface	C.2846.02
Instead of RS-232 supplemented by: (to be specified in order)	RS-422 adapter RS-485 adapter TTY-20mA passive TTY-20mA active	V.1930.02 V.1930.04 V.1930.06 V.1930.08

Table 8: Order information

PDF Manuals
Manuals are available in English. For availability of English manuals see the following table. Please download the manuals as PDF documents from our esd website www.esd.eu for free.

Manuals		Order No.
CAN-CBM-DP-ME	English manual for C.2844.03/05, incl. configuration software (includes hardware and software manual)	C.2844.21
DN-CBM-DP-ME	English manual for C.2846.02, incl. configuration software (includes hardware and software manual)	C.2846.21

Table 9: 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.