MODBUS Network Guide
Merlin Gerin

Technical Guide

2000

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Introduction

Overview

Networks can be classified according to the area they cover:

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■ WAN: Wide Area Network.

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■ MAN: Metropolitan Area Network.

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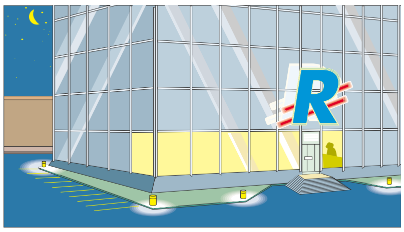

■ LAN: Local Area Network.

There are two types of LANs:
□ Company LANs

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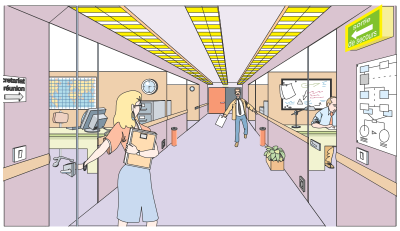

□ Factory LANs

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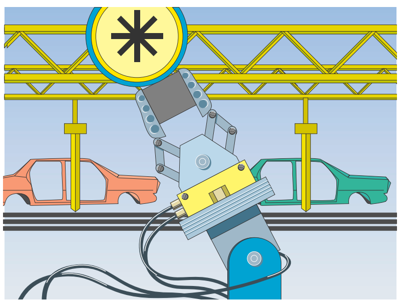
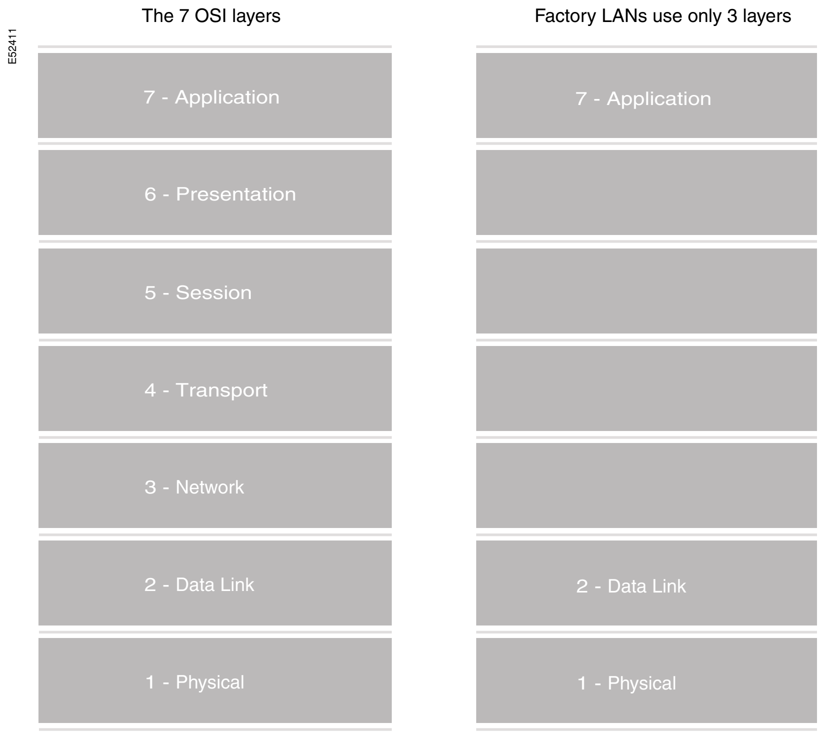


Local Area Networks

Local Area Networks have been standardized according to the OSI model.

Definition: OSI, Open Systems Interconnection.

This standard includes seven layers:



This document describes in detail the characteristics of the communication medium used for "Power Logic System" products. The following aspects will be discussed:

- Physical implementation (Layer 1)
- The Modbus protocol supported by this medium, which can be classified in layer 2 of the OSI model.

Some aspects of the application layer are discussed in Chapter 3 (Implementing products), but the application layer is directed more towards the application software, which is not the subject of this guide.

Concerning the other layers:

- Layer 3, the "Network" layer, manages the interconnection of local area networks (layers 1, 2 and 7).
- Layer 4, the "Transport" layer, compensates for problems that may be encountered in layer 3.
- Layers 5 and 6, "Session" and "Presentation", deal with the Operating System. They manage the synchronization of messages, priorities, language, security aspects, etc.

Warning

If the recommendations in this manual are incompatible with instructions for a given device, the device instructions should be followed. As regards EMC, safety rules take precedence.

Because of rapid changes in industrial electronics, problems with Electromagnetic Compatibility (EMC) can no longer be ignored. Care must be taken when connecting devices (equipment in a network, automatic control devices, remote inputs/outputs, etc.) so that they fulfill the functions for which they were designed, even in an environment with electromagnetic disturbances.

Thus this document was written for:

- Engineering and design departments, who must plan the use of communications cables (connecting terminals, length of wiring, definition of topology,etc.)
- Those who implement Modbus, to help them install communications cables.
- Integrators, who must take communications into account in applications that include SCHNEIDER products.

Cabling Guidelines

Review

This document defines minimum requirements that in no way supersede specific instructions or standards that may be applicable to a given installation.

⚠ Although regulatory in Europe, CE marking does not guarantee the actual EMC performance of a system.

Definition: EMC (ElectroMagnetic Compatibility) is the ability of a system or equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

The main problem that may be encountered if these recommendations are not respected is an increased sensitivity to electromagnetic phenomena.

Definitions and limitations

Warning

Choosing components
Only components complying with EMC standards should be used.

Cabling
A number of rules concerning communication cabling must be respected to ensure optimum operation in a given environment.

Installation
Always follow the installation instructions provided by the manufacturer, without modifying the product.

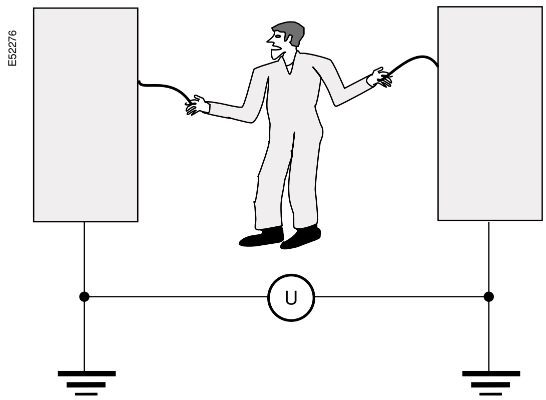
Important: Implementation of an appropriate solution right from the start always costs less than a quick initial solution plus subsequent remedial measures.

Definition: An earthing network has the following purposes:
■ Divert equipment earth-fault and earth-leakage currents to earth
■ Divert common-mode currents of outside cables (mainly power and telecommunications cables) to earth
■ Divert lightning currents to earth
■ Meet requirements concerning the protection of persons (25 V AC or 50 VDC).

Protective earthing vs. grounding (equipotential bonding)

Earth

The interconnection of the various exposed conductive parts of equipment by earthing conductors (green/yellow or PE) represents a low-impedance path at low frequencies.
The resulting equipotentiality avoids the presence of potentials that can be dangerous to human beings (greater than 25 V AC or 50 V DC) between two exposed conductive parts that can be touched simultaneously.
Earthing satisfies the requirements concerning the protection of persons.
This low-impedance path is connected to earth at a single point for each building (e.g. by an earthing electrode, ring, grid, etc.) through which common-mode currents flow.
The connection of the various exposed conductive parts by earthing conductors does not however provide the high-frequency equipotentiality required for effective immunity against interference because the impedance of the PE conductors is too high (1 µH/m). High-frequency circuits therefore require special equipotential bonding, referred to in Europe as grounding.
The various types of power system earthing arrangements (TT, TN, TI, etc.) affect the security of persons but have little influence on the immunity of equipment to interference.
Simultaneous access to two non-interconnected earths presents hazard and they must therefore be interconnected.



To ensure trouble-free operation of equipment and the safety of persons, all exposed conductive parts must be interconnected and earthed to ensure equipotentiality.

The earthing network provides:
- Protection of persons.
- Protection against electrostatic discharges.
- Protection against lightning currents.

Protective earthing

Protection of persons

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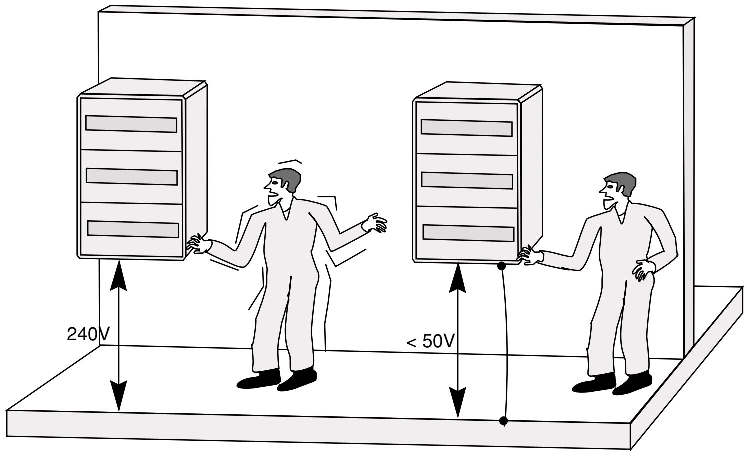

Protection against electrostatic discharges

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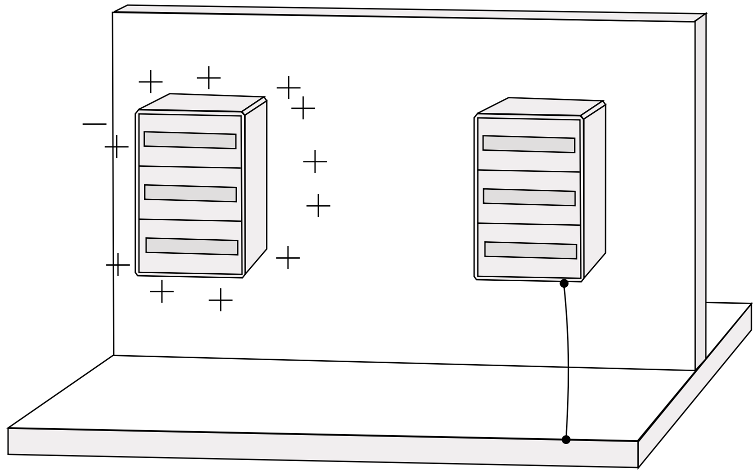

Protection against lightning currents

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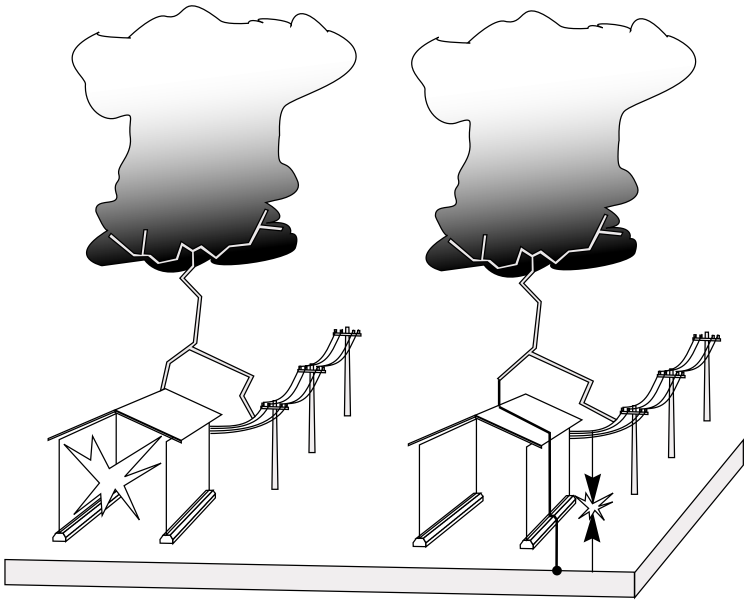

Definition: An exposed conductive part is an accessible metal part that is isolated with respect to the live parts of the equipment but which may accidentally become live.

Exposed conductive parts ensure proper operation of systems by providing immunity to various types of disturbances.
For high-frequencies, the best way to guarantee trouble-free operation is to ensure equipotentiality between the equipment. All equipment and electronic systems must therefore be bonded together (or grounded).

Grounding

The interconnection of all metal parts (building structures, pipes, cableways, equipment, equipment enclosures, etc.) represents a low-impedance path for high frequencies.
The resulting equipotentiality of this network of conductive parts provides effective immunity to interference by reducing all the high-frequency voltages that could otherwise exist between communicating equipment. This is true over a wide frequency band.
Grounding satisfies the requirements concerning operation.
Metal parts must be interconnected (bonded) by screws, nuts and bolts or short, wide metal braids (25 mm^2 cross-section and length less than 30 cm) or an equivalent metal part.
The impedance of PE protective conductors is too high to serve the purpose of grounding.
The grounding network must nevertheless be earthed.

Common-mode currents
As exposed conductive parts provide a reference potential for electronic equipment and a return path for common mode currents, any current that penetrates a cable in a piece of equipment insulated with respect to the exposed conductive parts exits via the other cables.
When the equipotential bonding network is of poor quality, a cable carrying a common mode current disturbs all the others. Effective equipotential bonding reduces this phenomenon.

As opposed to earthing, which is a low-frequency requirement related to carrying fault currents to earth for the safety of persons, grounding is designed to ensure equipotentiality of equipment up to very high frequencies, in particular for the proper operation of digital equipment.

To be effective, an underground network must be in the form of a grid:
■ For small premises (less than about 10 m²), a simple buried perimeter ring is sufficient.
■ For new buildings of large surface area, the installation of buried conductors in the form of a grid with a 10 m mesh size is recommended.
■ For areas housing equipment that is highly sensitive to electromagnetic disturbances, the mesh size should be no more than 2 m.

Definition: An equipotential grounding is formed by connecting all metal structures of the installation (frames, handrails, ducts, etc.).

Physically speaking, it is more important to obtain the local equipotentiality of the building than a low resistance (with respect to a distant earth).
The most sensitive lines are those that interconnect the various items of equipment. In order to limit the flow of common mode currents in the cables that do not leave the building, it is necessary to limit the voltages between interconnected equipment within the site.

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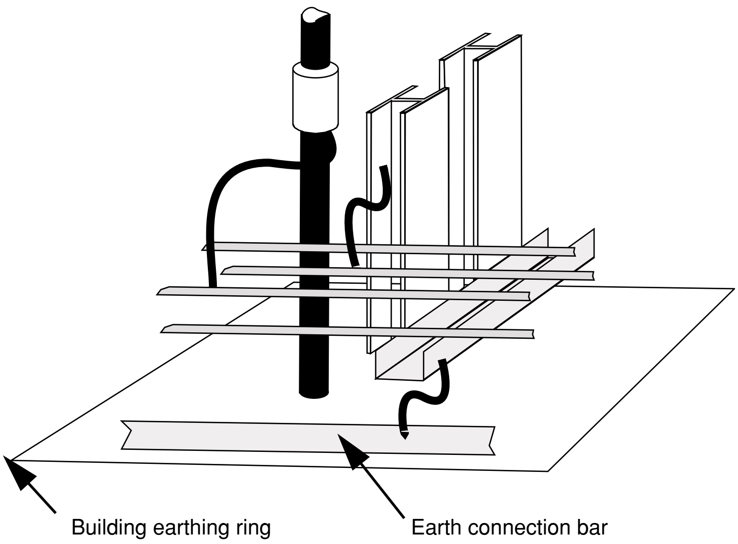

Example of a grounding system for a building

An effective solution is the interconnection of the metal structures with a mesh size of 2 m x 2 m.
The metal frames of cabinets and bays must be connected to the neighbouring metal parts (cableways, machines, frames, etc.).
A standardised immunity test (IEC 61000-4-4) using repeated pulses can quickly check the grounding effectiveness (cableways in particular) near the injection points and the screen termination points of shielded cables.

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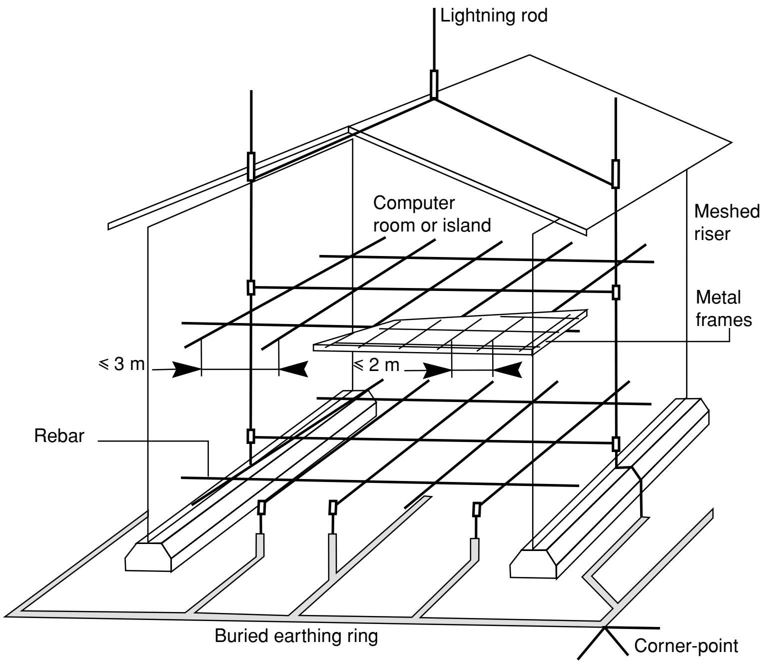


For data links between buildings, fibre optic media are strongly recommended to totally eliminate ground loop problems between buildings.

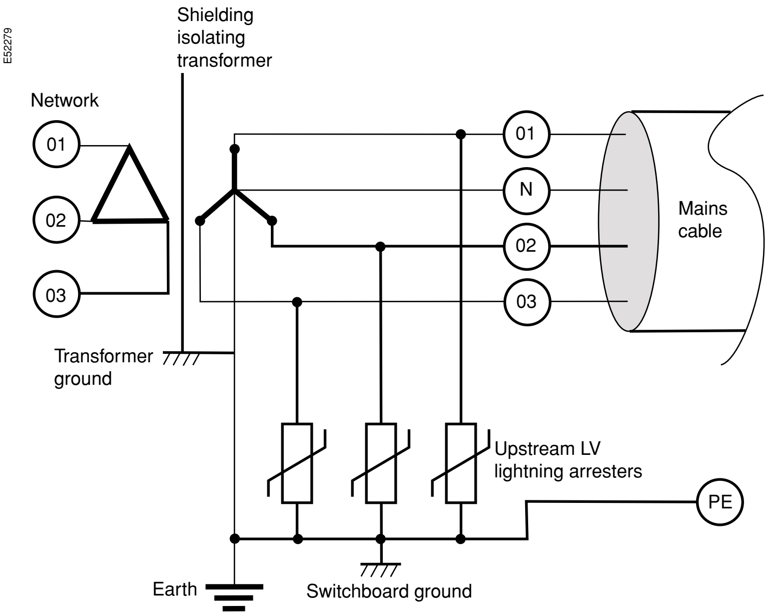
Protection against penetration

Common mode currents coming from the outside must be evacuated by the earthing network at the entrance to the site to limit potential differences between items of equipment.
All conducting conduits (cables, conducting pipes, insulated pipes carrying conducting fluids, etc.) entering a building must be earthed at the entry point by a connection that is as short as possible.

Install lightning arresters at building entry points for:

- *Power cables.*
- *Telecommunications cables.*
- *Signal cables (data, alarms, access control, video surveillance, etc.).*

The effectiveness of such devices depends on how they are installed. Lightning arresters (varistors, spark gaps, etc.) are connected directly to the electrical switchboard ground or to the protected equipment. Connecting a lightning arrester simply to earth, instead of ground, is ineffective.
If possible, install switchboards housing power, telecommunications and signal circuit protection devices near the earth connection bar.

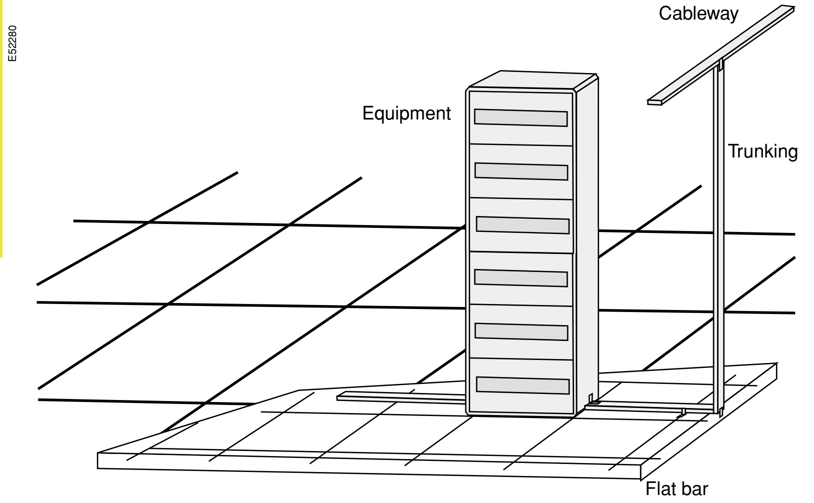


In industrial environments, electronic devices are generally located in specific areas.

This makes it possible to avoid implementation of a ground mesh for the whole building:
■ Islands can be defined for installation of electronic equipment.
■ The cables extending outside the island to sensors and actuators must be carefully shielded.

Example of a grounding system for an island

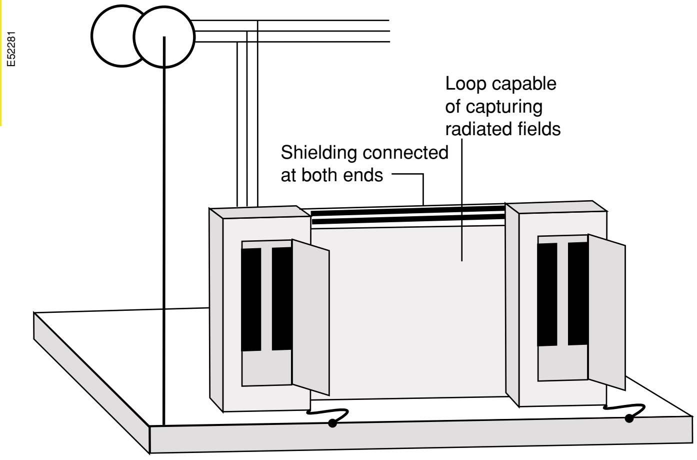
When electronic equipment is grouped together in an area no larger than 10 m^2, implement a grounding system with a 2 m^2 to 3 m^2 19 mesh size by interconnecting the various metal structures and cabinets.



The various power system earthing arrangements are equivalent for the safety of persons and have little effect in relation to EMC.
Certain features of the different arrangements must nevertheless be taken into account.

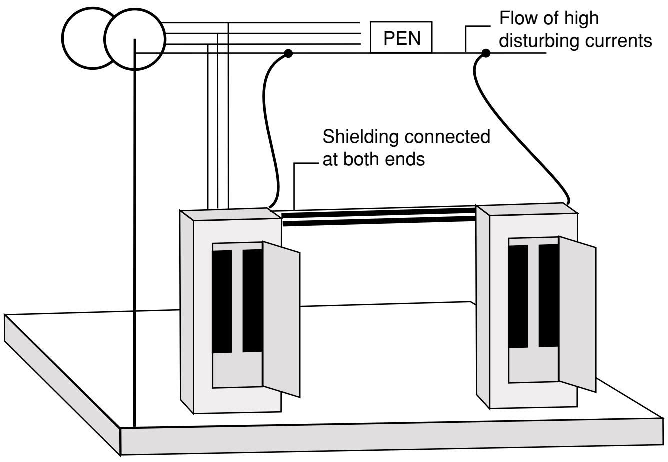
Power system earthing arrangements

TT system



Note that overvoltages may be caused by separate earth electrodes for which the potentials vary differently.

TN-C system



If the distribution system is TN-C, it is highly recommended to adopt a TN-S system right from the building entry point.

Review (continued)

This is the best system from an EMC viewpoint:
- ■ Low risk of ground loop (radiated fields).
- ■ The neutral current is not carried by the protective conductor (conducted disturbances).

Care must taken to ensure equipotentiality

TN-S system

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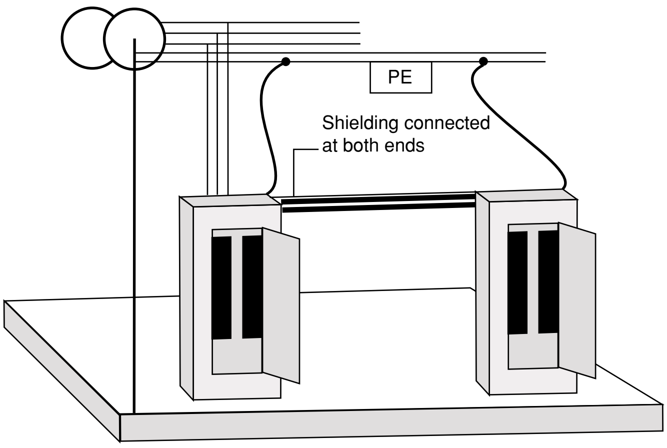

IT system

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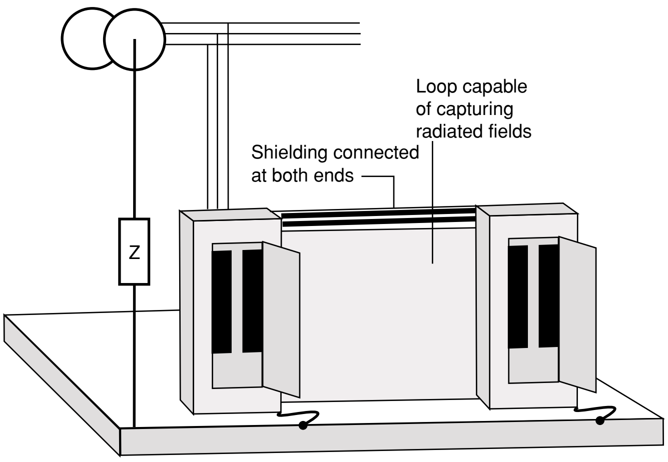

An initial insulation fault can lead to a phase-to-phase voltage between a phase conductor and the equipment ground.
This is unacceptable for electronic devices supplied directly by a phase-to-neutral connection and which cannot withstand the phase-to-phase voltage.

Example: Withstand of RFI filters of (large) variable speed drives.

The main EMC problems are conducted common-mode disturbances.

Common-mode voltages are caused by:
■ Antenna effect coupling.
■ Common impedance coupling.
■ Cable-to-cable coupling, for instance by capacitive crosstalk (for electrical fields) or inductive crosstalk (for magnetic fields).

EMC phenomena

Disturbances and their effects
■ Whether conducted or radiated, their presence generates common-mode currents that flow in the equipment and cause malfunctions.

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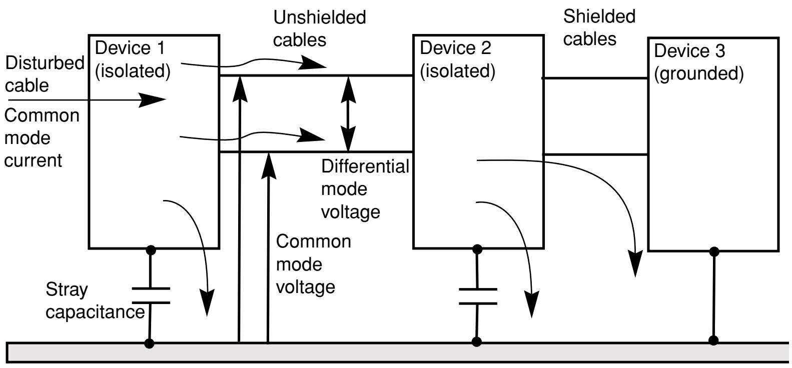

Solutions:
■ Clamp conductors against ground planes to avoid the formation of ground loops.
■ Make sure all exposed conductive parts have the same potential to limit the flow of disturbing currents.
■ Separate conductors by category to reduce the effects of crosstalk.
■ Do not leave any conductors unconnected to prevent antenna effects.

Choice of the Physical Communication Medium

Various Types of Physical Media

Three types of conductors can be used:

■ Metal pairs.

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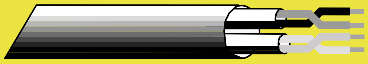

■ Coaxial cable.

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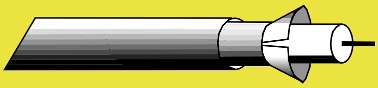

■ Optical fiber.

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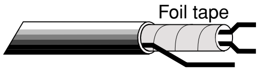
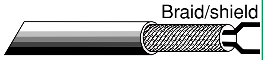
Twisted pairs with braided shielding are recommended for all RS485 communication cables for Schneider Electric products.

Definition: (according to IEC 439-1)
Screening (or shielding) is used to protect conductors or equipment against interference caused in particular by electromagnetic radiation from other conductors or equipment.

Two types of shielding:

Type	Advantages	Disadvantages
Foil shield E52289 	Easy to install.	Fragile. High-frequency protection provided by the metal foil is diminished by cable handling (tension, torsion, etc.)
Single braid E52290 	Excellent protection from electromagnetic interference, particularly at high frequencies. Fairly easy to implement. Sturdy. Compatible with Sub-D and mini-DIN connections.	The effectiveness of a shielded cable depends on the choice of shielding, and above all how it is used.

Note: Shielded cable with a simple braid can increase protection by a factor of up to a 100 from a few MHz up if the shielding is properly connected.

Shielded cable should be chosen when it is necessary to:
■ Limit outside interference that could affect a "sensitive" cable.
■ Keep a "polluting" conductor from interfering with nearby cables or equipment.

Only metal pairs are described below, since they are the most frequently used for data transmission today.
Advantages of metal pairs:
■ *Lowest price of all media (approximately 0.30 euros/meter).*
■ *Easy to implement.*
■ *Simple and inexpensive connections.*
Major disadvantages:
■ *High signal attenuation: signal regeneration circuits are required after approximately 2000 m.*
■ *Signal distortion unacceptable for high transmission speeds (greater than a few Mbits/s).*
■ *Small bandwidth.*
■ *Problem of crosstalk between pairs in the same cable. Use of shielded cable can limit crosstalk.*

Summary table of media:

Medium	Speed	Distance	Notes	Approx. cost
Shielded twisted pair	*Avg: 100 kbits/s* *Max.: 500 kbits/s*	*1 Km*	*Easy installation* *Easy connection* *Low immunity*	*0.30-0.45 euros/m*
Coaxial baseband	*Avg.: 1 Mbits/s* *Max.: 50 Mbits/s*	*2,5 Km*	*Easy connection* *Good immunity* *High performance*	*0.60 to 1.20 euros /m*
Coaxial wideband	*Average: 300 Mbits/s*	*10 to 50 Km*	*Idem*	*0.60 to 1.20 euros /m*
Optical fiber	*1 Gbit/s*	*> 10 Km*	*Perfect immunity* *Low attenuation* *Large bandwidth* *Price still high*	*4.50 to 6.00 euros/m*

Note*: You can also use electromagnetic waves that do not require a physical medium.*

Choice of the Physical Communication Medium (continued)

Equivalent diagram:

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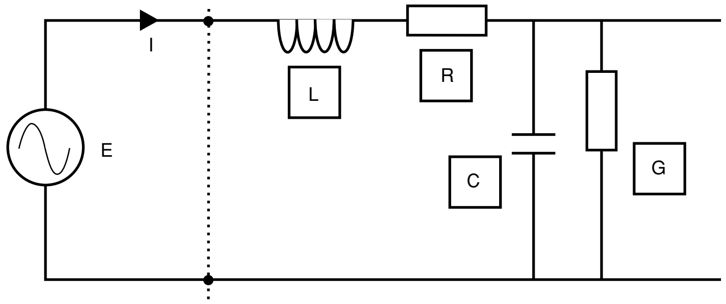

E = Transmitter
L = Series inductance
R = Series resistance
C = Capacitance between wires
G = Conductance (easier to calculate than parallel resistance) – represents loss in insulation

Definition: *The characteristic impedance (Zo) in Ω is the simplified model of the representation of the cable. It is defined for a theoretical length of the infinite cable, so that the termination of this cable need not be taken into account.*
It depends of the physical and electrical characteristics of the conductors and varies with frequency.

$$Zo = \sqrt{\frac{(R+j*2*\Pi*f*L)}{(G+j*2*\Pi*f*C)}}$$

f: frequency
j: symbol of the phase (+90°).
*G is negligible compared to 2*π*f*C for commonly used insulating materials.*
*Likewise, at "low" frequencies (< 1MHz), R prevails over 2*π*f*L.*
Thus the formula becomes:

$$Zo = \sqrt{\frac{R}{(j*2*\Pi*f*C)}}$$

At high frequencies (>1MHz) the formula becomes:

$$Zo = \sqrt{\frac{(j*2*\Pi*f*L)}{(j*2*\Pi*f*C)}} \text{ therefore: } Zo = \sqrt{\frac{L}{C}}$$

The following curve can thus be traced:

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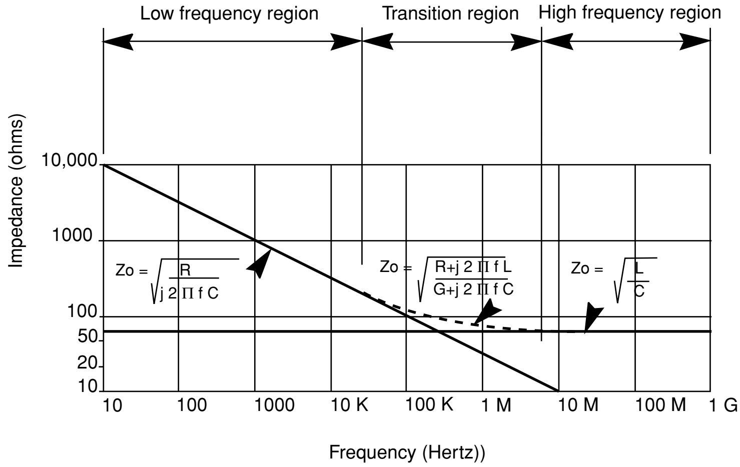


Choice of the Physical Communication Medium (continued)

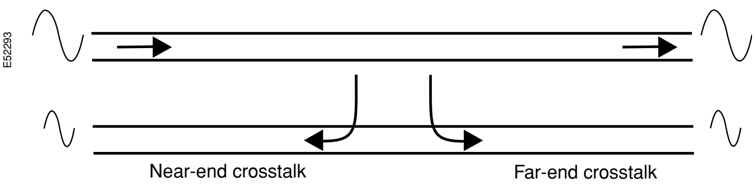
Attenuation in dB/km:
- *This is the loss of signal quality in terms of amplitude.*
- *It depends on cable geometry.*
- *It varies according to frequency and length.*

Resistance per unit length in Ω/m:
- *This is the resistance to the passage of a direct current (or a low frequency).*
- *It depends on the cross-section of the wire and the material from which it is made.*
- *It varies according to length and temperature.*

Capacitance between two conductors in pF/m:
- *This is the capacitance measured between two wires in the same pair.*
- *It depends on the type of insulation used and its thickness.*

Transmission speed in m/s:
- *This is the time it takes the signal to travel from one point to another on the wire.*
- *For low frequencies (for which voltage variations are much slower than signal transmission) transmission speed is considered infinite, i.e., transmission is instantaneous.*
- *This approximation is not valid for high frequencies.*

Crosstalk between pairs in dB:



Temperature of use in °C
- *Temperature of use should take into account:*
  - *ambient temperature,*
  - *how the cable was laid,*
  - *the cable's own heating,*
  - *the proximity of power devices, etc.*

Choice of the Physical Communication Medium (continued)

Example of a choice of medium

■ *Characteristic impedance: 120 Ω.*

■ *Attenuation: a minimum voltage of 0.2 V on the receiver is required for a minimum voltage of 1.5 V at the transmitter output:*
□ *Thus attenuation will be:*
- Att = 20 Log (Vout/Vin); Max. att. = 17 dB over 1200 m.
□ *Calculation of maximum network length:*
- length (in m) = 1000 x [1-(1-α/αc)]
α: 14 dB/km
αc: attenuation of cable used (in dB/km)

■ *Resistance per unit length: the application guide for standard EIA485 (TSB89) stipulates that maximum resistance should in no case exceed 390 Ω (for the conditions defined in this guide and at the given use temperature).*
□ *therefore, length (in m) = 1000 x [1-(1-R/Rl)]:*
R: 0.325 Ω/m
Rl: Resistance per unit length of the cable used (in Ω/m).

■ *Capacitance between conductors:*
□ *rise time or decay time for the signal Tr <0.3 Tui, where Tui (Time unit interval) = 1/Br (Baud rate).*
Transmission times are between 10% and 90% of the total amplitude of the signal Vss (approximately 2τ, where τ =Rl x Cl)
Therefore Cl < 0.3 / (Br x Rl x 2).

■ *Temperature of use: > 70°C (Maximum ambient temperature in the enclosure).*

Application with an RS485 link at 19200 Bds on a 1000 m bus

■ Characteristic impedance: 120 Ω.

■ Cable attenuation = 20 dB/km at 19200 bds:
□ length = 1000 x [1-(1-14/20)],
□ maximum length = 700 m,
□ since this length is incompatible with the specified 1000 m bus, a cable with a maximum attenuation of 14 dB/km is required.

■ Resistance per unit length: 0.213 Ω/m (at the temperature of use):
□ length = 1000 x [1-(1-0.325/O.213)],
□ maximum length = 1525 m.

■ Capacitance between conductors:
□ Cl < 0.3/ (19200 x 213 x 2),
□ Cl < 36.6 nF, i.e. < 36.6 pF/m.

■ Temperature of use: > 70°C.
Example: BELDEN ref 9842 for applications RS232/RS485.

Implementation guidelines

Sensitivity of various types of cable

Type	Cable	Type of signal	EMC behavior
1	*Analogue*	*Power supply and measurement circuits for analogue sensors*	*Sensitive signals*
2	*Digital and telecommunications*	*Digital circuits and data buses*	*These signals are sensitive. They also interfere with family 1*
3	*Relay*	*Dry contact circuits with risk of flashover*	*These signals interfere with families 1 and 2*
4	*Power supply*	*Power supply and power circuits*	*These signals generate interference*

Note*: Shielded cables are not sensitive and do not generate interference.*

■ The manufacturer's instructions should always be followed when installing devices.
■ Cabling configuration must always be adapted to fit the topology of the system. This configuration differs depending on whether the network is a star, ring or bus.
In any case, the following are general guidelines and can be applied whatever the topology or type of signal carried.

Implementation of shielded cable

Where should the shielding be connected?

■ Connect both ends of the external shielding of all digital or power cables to ground at equipment entries.
■ Only low-level, low frequency analogue links may in some cases require grounding at one end only.

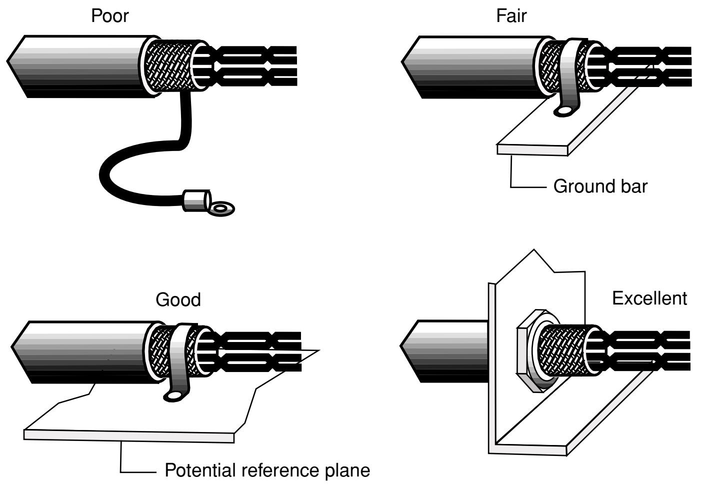
Unlike one-end connections, two-end connections allow low-frequency currents to flow on the shielding (voltage between the two ends or ground loop). This current generates a low voltage or 50 Hz noise on the pair inside.

■ One-end connection of shielding protects against low frequency currents.
■ Two-end connection of shielding protects against the most severe interference, i.e. high frequency common mode.
Thus when the connection is at one end only, the differential signals are protected at low frequency, but at high frequency this type of connection is ineffective.

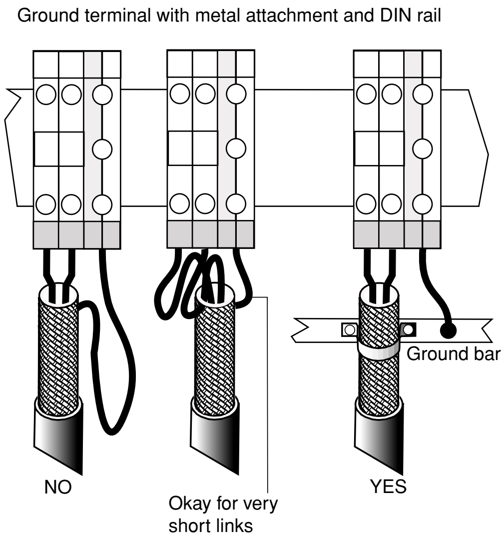
High frequency protection depends directly on how cable shields are connected.
If a "pig-tail" or long wire is used for connection, protection provided by shielding will drop sharply at high frequencies.

How should the shielding be connected?

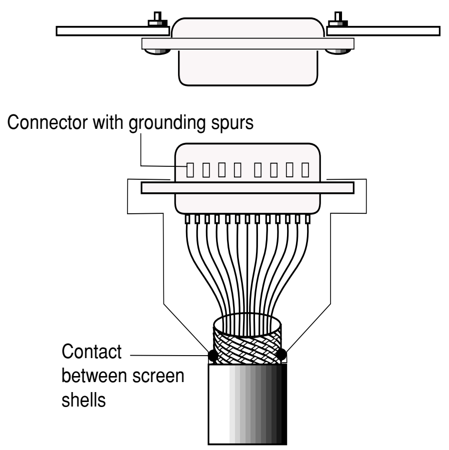
A secure connection of the shielding to a cable gland in the enclosure wall is the best solution, as long as the paint is scratched on the enclosure to guarantee good electrical contact.
A U-shaped clamp can also be used to guarantee at least 180° contact.



If a U-shaped clamp cannot be used to ground the shielding when connecting to a screw-type terminal, the grounding wire should be as short as possible. This type of connection should be avoided.



If a connector is used, it must provide a 360° electrical continuity between the cable shielding and the equipment ground.

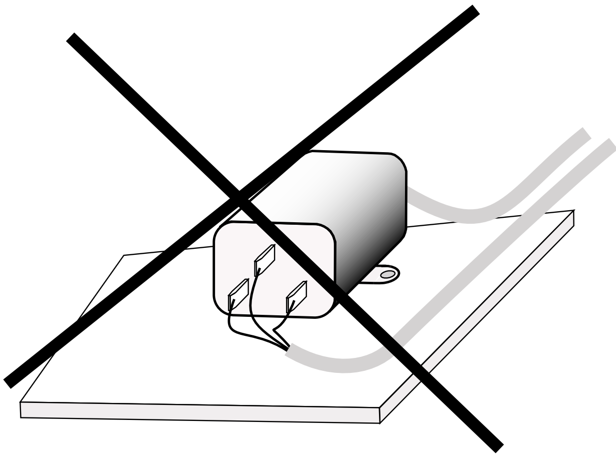


The effectiveness of a mains filter for high frequencies depends on how well it is installed.

Using filters

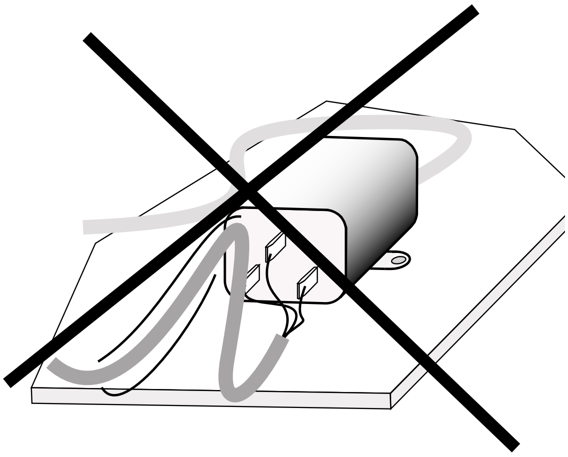
Three rules must be followed when installing a filter:
- Reference the filter sheetmetal to sheetmetal.
- Connect the upstream and downstream cables on each side of the filter to reduce parasitic coupling between the input and the output.
- Clamp the upstream and downstream cables against the sheetmetal to reduce radiation from the input to the output.

E52297



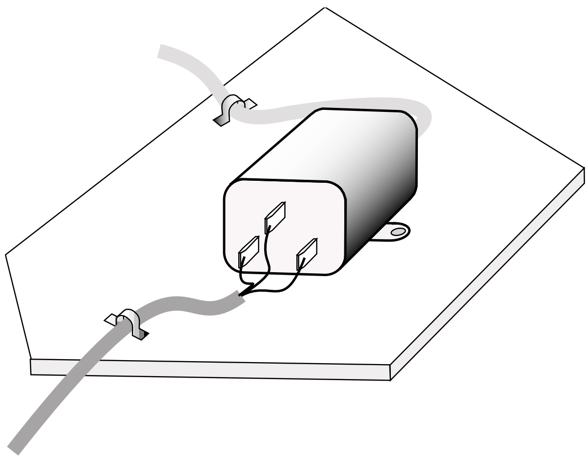
No

E52298



No

E52299



Yes

Principal cabling rules

Rule no. 1:
The outgoing and incoming conductors should always remain together.

■ Work with pairs for digital or analogue signals.

⚠ Inside cabinets, be careful with cabling that uses separate conductors. Identify wires by type of signal and by pair.

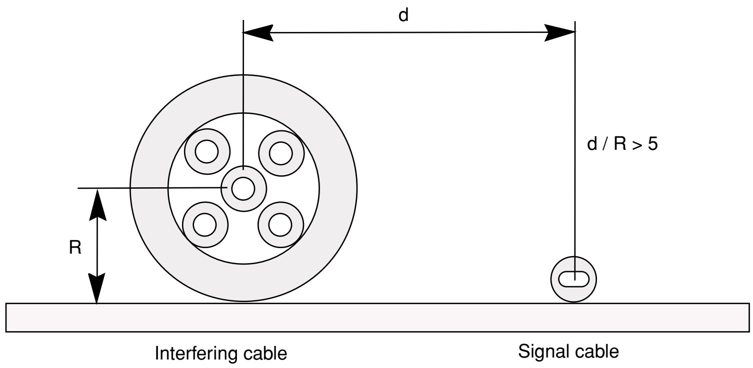
Special case: Emergency Off and alarm connections should never be cabled using point-to-point single wires; always use pairs.

Rule no. 2:
All cables should be clamped against the equipotential bonding structures to provide high frequency protection.

■ Use shielded cables or double-shielded strands.
■ The use of conducting raceways provides a satisfactory level of protection in most cases. Be sure to provide inter- or intra-building connecting cables with at least equipotential bonding (small earthing cable or raceway).
■ Systematically clamp all interconnection cables against the sheetmetal inside cabinets and machines.

For proper protection, the following ratio should be respected:

$$\frac{\textit{Distance between cables}}{\textit{Radius of the largest cable}} > 5$$



Rule no. 3:
Only pairs carrying analogue, digital and telecommunications signals can be run side by side in the same bundle or pulled into the same group.

■ Keep relay, variable speed drive and power circuits separate from analogue, digital and telecommunications pairs.
■ Use a special trunking inside cabinets for power cables.

⚠ Separate power cables from data cables when installing variable speed drives.

Implementation guidelines (continued)

Rule no. 4:
The same connector should not be used for different types of connections (except for relay and power circuits).

Rule no. 5:
All free conductors in a cable should systematically be connected to chassis ground at both ends (except for analogue cables).

Rule no. 6:
Power cables do not need to be shielded if they are filtered.

■ Separate analogue and digital signals with a row of 0 V pins if they use the same connector.

■ Protection with a factor of approximately 5 with high frequencies can be obtained if rule number 5 is followed.

■ Power outputs of variable speed drives must always be shielded or filtered.

Inside partitioning of enclosures increases electromagnetic interference.

Internal cabling of cabinets

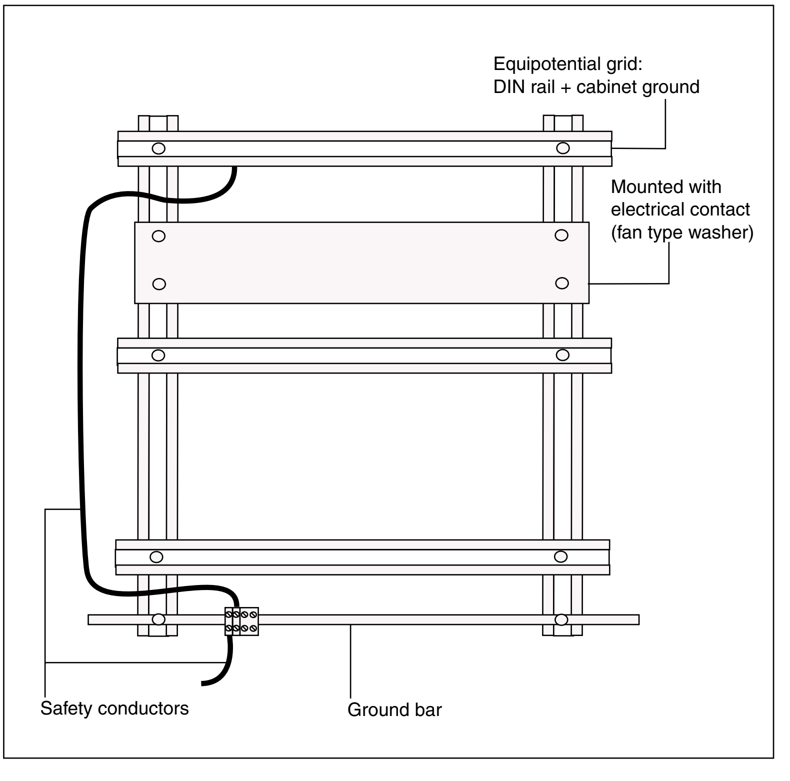
Digital control devices, variable speed drives and PLCs can be placed in the same cabinet if:
■ Variable speed drives are installed with shielded cables.
■ All the above cabling guidelines are followed.

Recommendations:
■ Use the enclosure as a Faraday shield.
■ Limit the number and size of openings in enclosure panels.
■ Avoid inside partitioning of enclosures, which increases electromagnetic interference.
■ Attach devices to plates made of non-insulating materials that act as grounding planes.
■ Place all equipment on a grid at the back of the cabinet.

Definition: A Faraday cage is a conducting envelope with perfectly joined walls.

Note: all attachments should make electrical contact => scratch the paint.

E52301



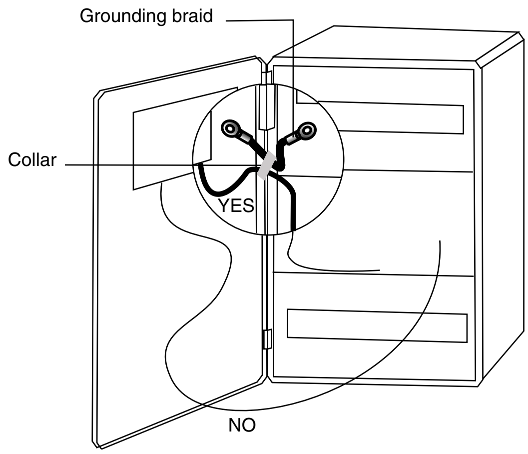
The presence of many equipotentially bonded structures in machines and cabinets provides maximum protection.

Protection inside a cabinet or small machine

- ■ Clamp all cables against equipotential structures.
- ■ Plastic trunking can be used in cabinets if they are installed on:
- □ the back grid,
- □ or the DIN rails connected to the cabinet ground.

Cabinets are made of various parts assembled with screws or hinges, or welded.
The many resulting openings diminish the electrical continuity.
To mask these opening, place cable entries near assembly points, or combine them with an earth braid.

E52302



Most on-site problems are related to conduction.

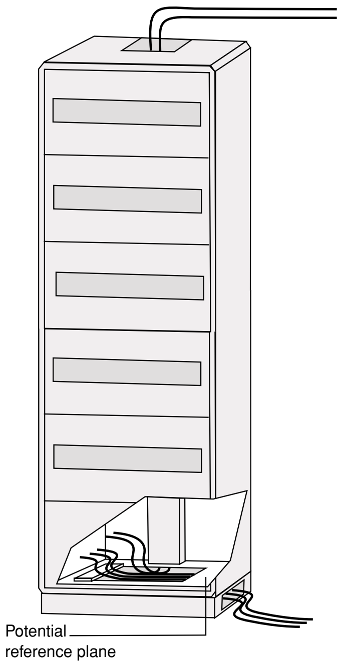
⚠ All wire connections outside the cabinet or machine must be protected. Each cabinet or machine must be equipped with a ground bar or potential reference plane to which are connected all shielded cables and wire protection systems.

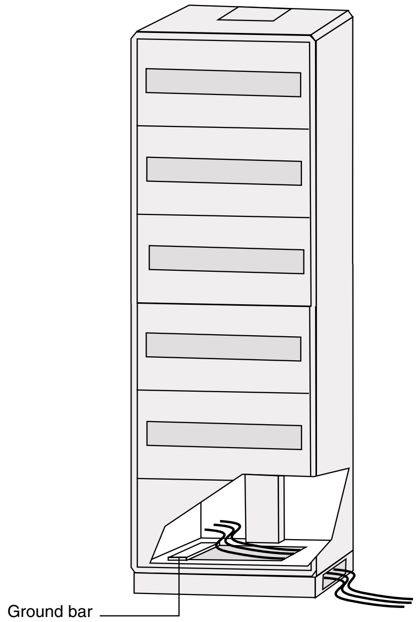
Definition: Potential reference plane.

Cabling between two cabinets

Protection of cabling outside equipment

The potential reference plane can be one of the metal sides of the cabinet or its DIN grid. The potential reference plane is always connected to the equipotential grid of the cabinet or machine as well as to that of the equipotential island.
For plastic cabinets (not recommended) use a DIN rail or ground terminal.





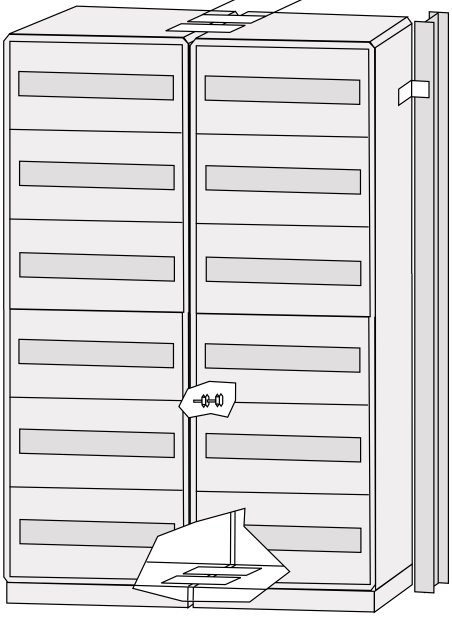
Equipotentiality must be guaranteed for cabinets placed side by side.

Placing cabinets together

When equipment is placed in a number of side-by-side cabinets the following rules must be followed:

- Attach the cabinets to form islands.
- Ensure equipotential bonding of the cabinets with at least two contacts at the top and bottom.
- The bonding should be made up of:
  - copper bars
  - or wide, short leaf metal,
  - or tinned braid.
- Use conducting false floors to provide an effective equipotential grid.
- Scratch paint to provide contact and use fan type washers.

E52305



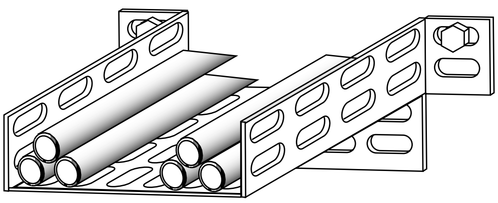
The cross-section of equipotential bonding conductors is unimportant; only their length matters: they must be no longer than 50 cm.

Trunking should be used for equipotential bonding.

Use of trunking

Trunking on the outside of cabinets must be made of metal if they are longer than 3 m.
To guarantee proper continuity, trunking should be connected to the exposed conductive parts of cabinets or machines using splices or leaf metal.

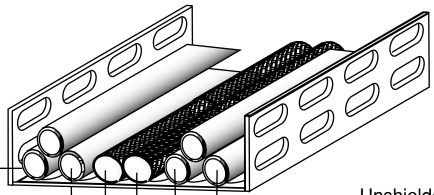
E52306



If a single trunking assembly is used, it must be no longer than 30 m.

■ Attach unshielded cables in corners of chutes.

E52307

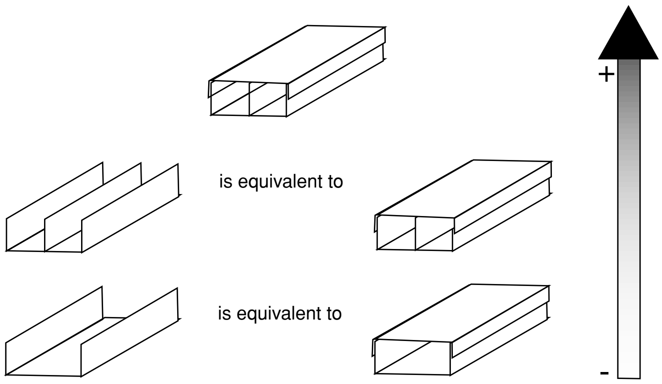


■ Use a vertical separation in the trunking to avoid mixing incompatible cables.
■ Place a metal cover on the signal half of the trunking.

Note: a metal cover over the complete trunking does not improve EMC.

Plan ahead for changes in your installation.

E52308



Definition: *For each communication network, an initial maximum segment length without repeater must be respected. This length depends on network speed and the size of the cable used.*

This maximum length, indicated in product documentation, can be attained only if installation conditions are satisfactory with respect to EMC (cables laid in metal trunking with end-to-end electrical continuity, connected to the equipotential grid and earth).

Definition: *A maximum theoretical length for electromagnetic compatibility (TLC) must also be defined. This second restriction is theoretical because it is usually longer than the first. It is used to optimise installation conditions and should be respected along with the first limit.*

It also applies to a segment with no regenerative repeater.

The theoretical EMC length is 1200 m on average, but can vary according to the type of communications network:
■ *2000 m for FIP at 1 Mbit/s and for Unitelway.*
■ *1000 m for Modbus Plus and for Ethway tri-axial cable at 50 W.*
■ *700 m for Mapway.*
■ *400 m for the BusX system in PREMIUM PLCs.*

Likewise, when single trunking is used for power and signal cables, a coefficient takes into account the absence of a metal separation or metal cover on the portion of the chute used for signal cables.

Whenever one of the three conditions is not completely met, the physical length of the trunking should be associated with a coefficient to respect EMC. Such coefficients reflect the decrease in the protection. The resulting permissible length of the trunking will be less than the TLC.

A raceway increases protection by a factor of approximately 50 between 1 MHz and 100 MHz.

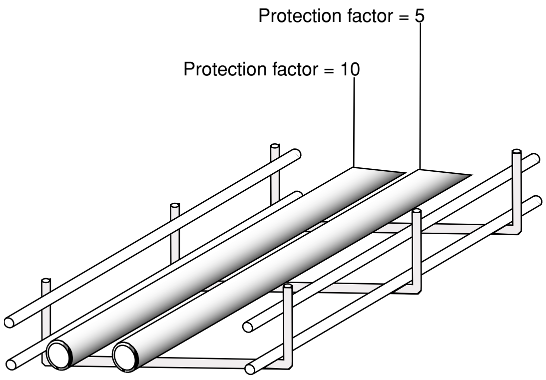
Examples of other interference reduction systems

In cases where sheetmetal trunking cannot be used, other means can be used to provide electrical continuity:

■ *Use of cable trays.*

These cableways, made of welded heavy wire, are less effective and often more costly than sheetmetal trunking.

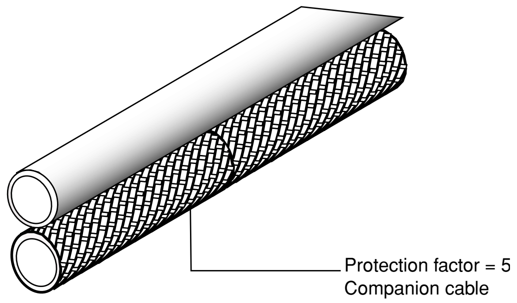
E52309



■ *Use of a companion cable.*

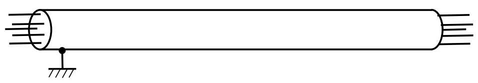
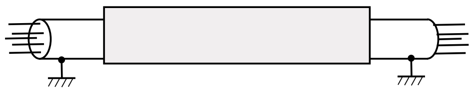
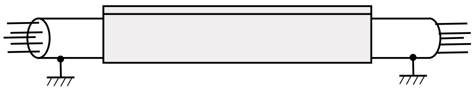
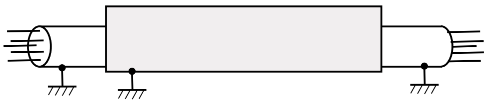
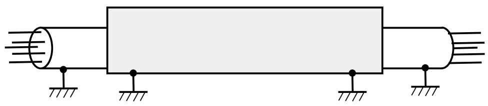
A companion cable can be used when no other solution is possible.

E52310



Error rate for a slow link:

Transmission of 41222 bytes at 4800 Bds. IEC test 1000-4-4. 15-pair shielded cable.

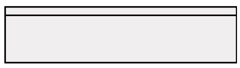
E52311 	Transmission impossible		
	Errors	Stops	Length
E52312 	13	110	1352 s
E52313 	8	86	1225 s
E52314 	0	0	160 s
E52315 	0	0	160 s

Raceway without cover:

E52316

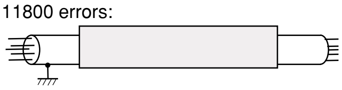
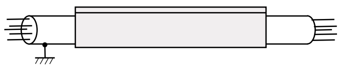
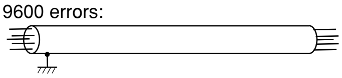
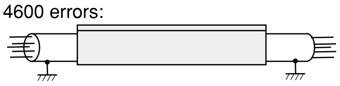
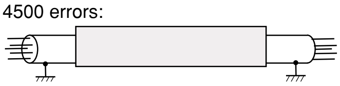
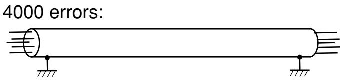
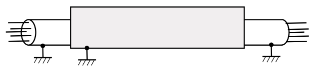
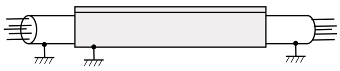
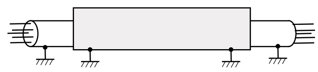
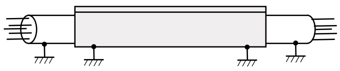
Raceway with cover:

E52317



Error rate for a fast link:

Transmission at 2 Mbits/s. Length of IEC test 1000-4-4: 3 minutes.

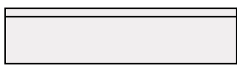
E52318 11800 errors: 	E52319 12000 errors: 
E52311 9600 errors: 	E52313 4600 errors: 
E52312 4500 errors: 	E52320 4000 errors: 
E52314 **0 error:** 	E52321 **0 error:** 
E52315 **0 error:** 	E52322 **0 error:** 

Raceway without cover:

E52316

Raceway with cover:

E52317



Summary

Essential rules

■ Make sure all exposed conductive parts have the same potential..
■ Choose equipment that complies with standards.
■ Follow manufacturers' instructions.
■ Protect your installations from outside disturbances (careful grounding of shielding).
■ Eliminate ground loops.
■ Shield both sensitive and interfering cables.
■ Use enclosures or cubicles as Faraday cages (contact between unpainted, rust-free steel sheets, short and wide earth braids, no unnecessary openings, etc.)
■ Do not use "pigtails" or long grounding wires.
■ Avoid TN-C systems, as common mode interference is the principal problem in EMC.
■ Clamp conductors against ground planes.
■ Separate conductors by category.
■ Do not leave any conductors unconnected.
■ The outgoing and incoming conductors should always remain together.
■ Make use of "natural protections" (cable raceways, etc.)

Lack of regard for rules can lead to:

■ Problems with EMC:
□ operating problems:
- evaluation of the installation,
- re-cabling,
- implementation of software solutions.
□ risk of service interruptions,
□ systems that do not perform their tasks.
■ Loss in production, expertise, need to re-do work, high costs.

Guide to Integration

This chapter describes layer 2 of the OSI model in detail. This layer is composed of two separate parts for data transmission:

■ A "hardware" part (interfaces, addressing, parameters, etc.).
■ A "software" part (medium access control, error management, logical level control, etc.).

Review

Networks

Definition : The purpose of a communications network is to link at least two devices in order to exchange data (ex.: Ethernet network).

A network is defined by its:
- Topology (bus, ring, star, tree, mesh, etc.)
- Physical limits (length, speed, number of subscribers, etc.)
- Type of physical medium used (cable, optical fibre, radio waves, etc.)
- Type of network access (random, master-slave, token ring, with or without error management, etc.)
- Transmission modes (synchronous/asynchronous, in packets, serial/parallel, NRZ/Manchester coding, etc.)
- Protocol (TCP/IP, FIP, MODBUS, etc.).

Systems

Definition : A system brings together a number of different entities that function independently but are connected to each other (in a network) in order to participate in an overall function.

Bauds and bits per second

Definition : A baud corresponds to a number of electrical states per second..

Definition : The throughput or number of data bits transmitted in one second on the network is expressed in bits per second.

Definition : Valence is the ratio between throughput in bits/s and speed in bauds.

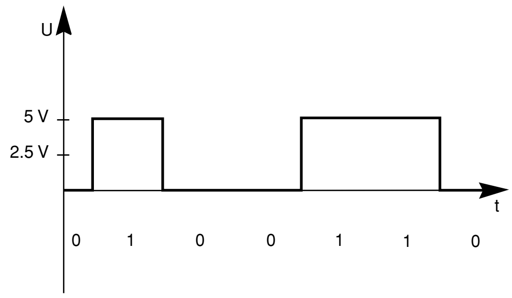
One important parameter to be considered when choosing a cable is bandwidth. Bandwidth is related to modulation speed expressed in Bauds.

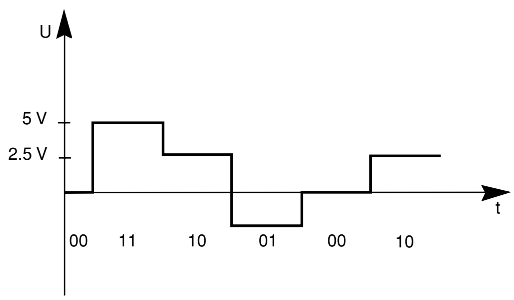
Bauds are often mistakenly expressed in bits per second.

This parameter is of greatest interest to the user. The two are often confused because their valence is generally 1.

A valence of 2 indicates that the throughput is doubled for the same communication speed.

E70510





20 mA CL – RS232 – RS422 – RS485 links

Architectures

Definition: A 20mA current loop is a multi-point link (the number of points depends on the types of transmitters/receivers) via a 4-wire cable.

(Connection on SubD9 recommended, maximum length 3000 m at 1200 Bds, and 300 m at 9600 Bds, bus topology.)

Definition: An RS232 link is a point-to-point link via a cable with at least three wires.

(Connection on a SubD9 or 25 pts, maximum length 15 m at 19200 Bds.)

Definition: An RS422 link is a point-to-point link via a cable with at least four wires for full duplex operation.

(Connection on SubD9 recommended, maximum length 1200 m at 19200 Bds.)

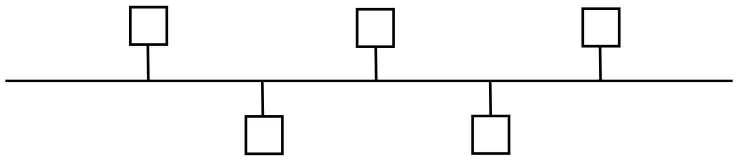
Definition: An RS485 link is a multi-point link (32 points maximum) via a cable with at least 2 wires for half-duplex operation.

(Connection on SubD9 recommended, maximum length 1200 m at 19200 Bds, bus topology.)

Topologies

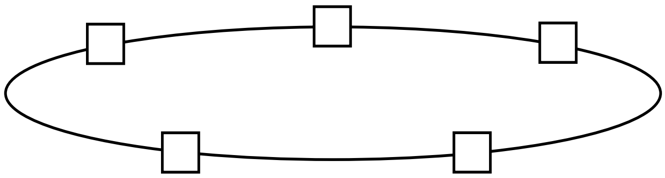
Bus

E52323



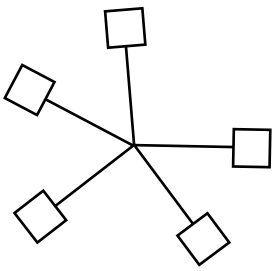
Ring

E52324



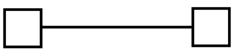
Star

E52325



Point-to-Point

E52437



20 mA CL – RS232 – RS422 – RS485 links (continued)

This transmission mode, used on some equipment, provides better performance than RS232C mode. Although this mode provides good immunity to parasites, it is not always the best solution because the current loop is not standardised.

General characteristics:

■ Maximum number of loads on the bus: depends on the type of transmitters/ receivers.
■ Standard topology: "Multi-point" of the 4-wire bus type.
■ Transmission speed: 300/600/1200 Bds.
■ Electrical levels: 0 mA / 20 mA.
■ Control lines: None.
■ Length of the bus: 3000 m from 300 to 1200 Bds. Depends directly on type of cable and voltage of bus power supply (12 V or 24 V).

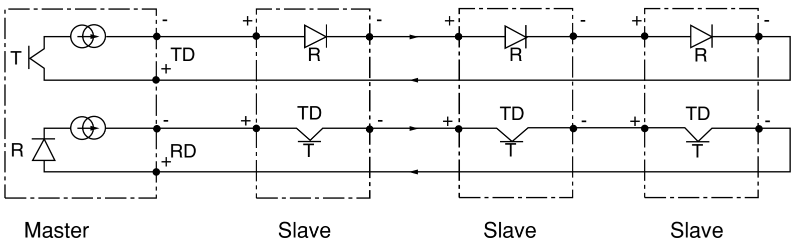
Notes:
■ The sign "+" is used for incoming current and "-" for outgoing current.
■ In the figure, T = transmitter, R = receiver .

The 20 mA current loop

A 20 mA current obtained from the power supply voltage (12 V or 24 V) flows through the loop.
For normal lines (20 mA: resting state on the line) approximately 1.5 V is lost for each station connected.

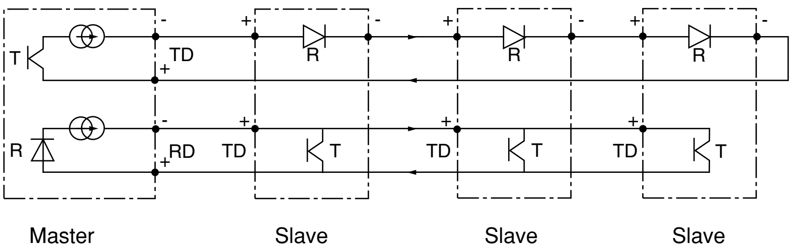
■ Transmitters for slave stations are usually connected in series with the receivers of the master station (normal line, 20 mA at rest):

E52338



■ Transmitters for slave stations can be connected in parallel with the receivers of the master station. In this case the resting state of the line is 0 mA:

E52339

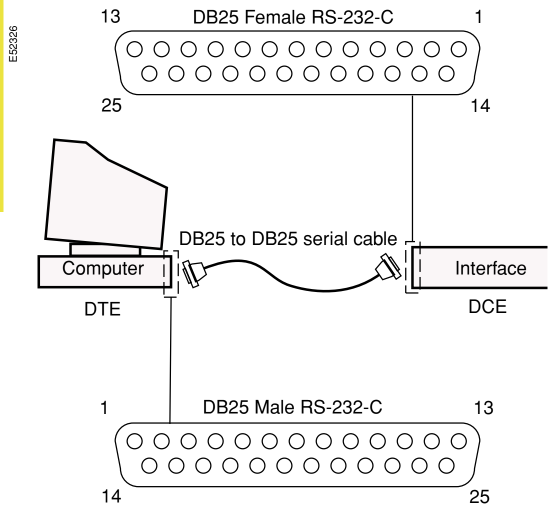


20 mA CL – RS232 – RS422 – RS485 links (continued)

General characteristics:
- ■ Electrical levels ± 15 V.
- ■ Control lines: possible (RTS, CTS, DCD, etc.) but not systematic depending on the software and/or interface.
- ■ Charge and polarisation of the line: no.
- ■ Minimum connection (in DB9):
  - □ pin 2 (Transmitted Data),
  - □ pin 3 (Received Data),
  - □ pin 7 (Signal Ground).

The RS232 link

The physical DB25-DB25 connection



Definition: DTE (Data Terminal Equipment) represents the terminal or computer.

Definition: DCE (Data Communication Equipment) represents the modem (or printer).

- ■ Link two devices of different types (DTE-DCE) with a direct PIN-to-PIN cable.
- ■ Link two devices of similar type with a special cable:
  - □ DTE-DTE, use a nul-modem cable,
  - □ DCE-DCE, use a nul-terminal cable.

On computers the serial port is usually a DB9 or DB25 male. The parallel port is a DB25 female.

***Note**: The terms "DCE" and "DTE" are not related to the type or gender of the connector.*
Standard RS-232-C does not clearly define whether the connector is male or female. Its purpose is rather to standardise the function and utility of connector pins and the voltage applied.

***Definition:** Parallel communication is the simultaneous transmission of 8 binary elements (a byte). The 8 bits in the byte are sent onto the communications media simultaneously.*

Printers are often connected to computers with a parallel cable with DB25 connectors.
The maximum length of a parallel cable is 30 meters. A parallel cable that is too long could falsify the transmitted data because of electrical noise and the deformation of squared waves (bits at 1 and 0).

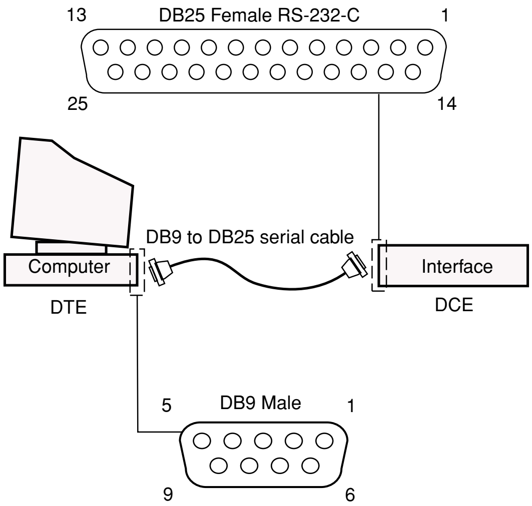
***Definition:** Serial communication is the transmission of bits one after another.*

This method is used when the distance between the two machines is too great to link them with a parallel connection. Note that computers and modems are connected via a serial connection. Manufacturers usually comply with connection standard RS-232-C.
The maximum recommended length for a serial cable is 30 meters, but longer cable can be used if certain electrical characteristics specified in standard RS-232-C are respected.

20 mA CL – RS232 – RS422 – RS485 links (continued)

The DB9-DB25 physical connection

E70511



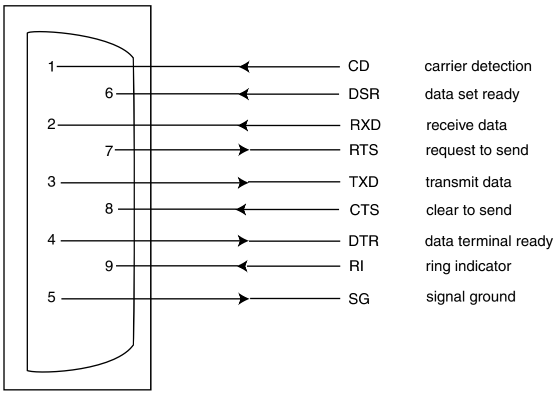
Some terminals and computers may have a DB9 type RS-232-C serial connector. In the figure above, the RS-232-C serial connection uses a DB9 to DB25 cable.

Correspondence between a DB9 and a DB25 connector.

DB25 (PIN)	DB9 (PIN)
1	n/a
2	3
3	2
4	7
5	8
6	6
7	5
8	1
12	N/a
20	4
22	9

DB9 pinout diagram

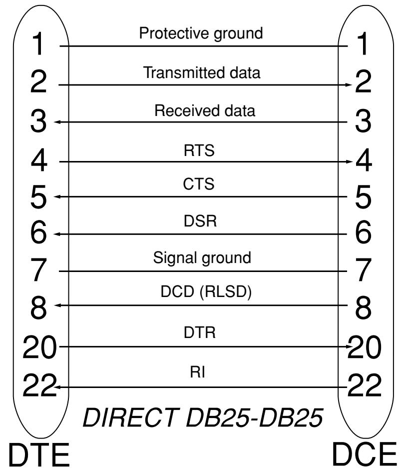
E52487



20 mA CL – RS232 – RS422 – RS485 links (continued)

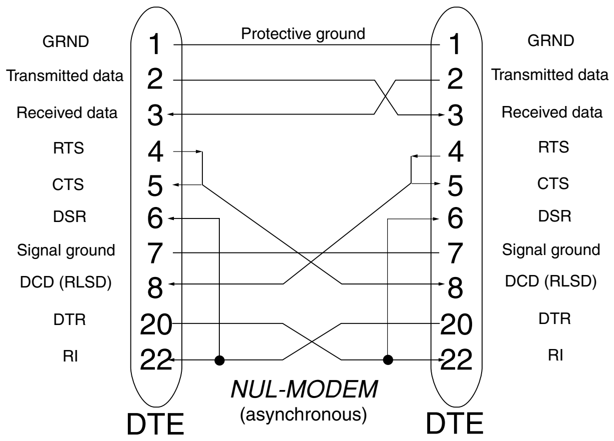
Standard cabling

E52329



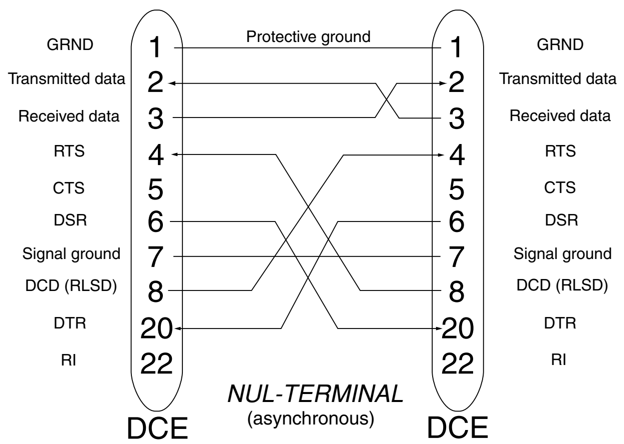
Nul-modem cable

E52330



Nul-terminal cable

E52331



20 mA CL – RS232 – RS422 – RS485 links (continued)

Definition : Flow control allows the receiver to order the terminal to stop transmission when its buffer memory has reached 90% of its capacity. There are two types of control: hardware and software.

Regardless of the method used, flow control makes it possible to increase the transmission speed of the terminal (DTE) to a speed greater than that of modem throughput on the line.

RTS/CTS or XON/XOFF flow control

The hardware method is recommended: it uses signals from the RTS/CTS pins in the RS-232 serial interface to order the DTE to stop transmitting. This method is the most secure and most widely used.
The software method requires that the modem send two different ASCII codes to the terminal to order it to stop (Xoff) or continue (Xon) to transmit:
- *XON Ctrl-Q ASCII 11 Hex.*
- *XOFF Ctrl-S ASCII 13 Hex.*

All IBM PCs and compatible computers permit flow control by RTS/CTS, but some Apple computers do not.

If its buffers are full, the modem can signal the DTE at any time to wait for a certain period before transmitting (and vice-versa).

20 mA CL – RS232 – RS422 – RS485 links (continued)

An RS485 link has the following general characteristics:

- ■ Maximum number of loads on the bus: 32 (for Zc = 120 W and Ucm = -7 V to 12 V).
- ■ Standard topology: chaining of connection points.
- ■ Possible topologies:
  - □ point-to-point,
  - □ Bus type multipoints (2 or 4 wires),
  - □ Multidrop (1 transmitter and several receivers),
  - □ 1 receiver and several transmitters.
- ■ Topology not recommended: star.
- ■ Minimum distance between 2 points: 27 cm.
- ■ Maximum length of a tap: 1 m (in accordance with ISO/IEC 8482).
- ■ Transmission speed: 4800/9600/19200 Bds.
- ■ Type of protocol: Modbus/Jbus in our case.
- ■ Security required: more detailed study of the network to adjust the various parameters.
- ■ Throughput required for use: optimisation of links according to requirements, 10 Mbits/s max.
- ■ Control lines: no.

RS485 link

Type of connector:

- ■ A "SubD 9 points" connector is recommended for Schneider products, in which case connection is as follows:
  - □ pin 9 (Transmitted Data +) = A,
  - □ pin 5 (Transmitted Data -) = B
  - □ pin 8 (Received Data +) = A',
  - □ pin 4 (Received Data -) = B'
  - □ pin 1 (Signal Ground) = C/C'.

Environment:

- ■ Ambient and storage temperature: respect characteristics of products and cables.
- ■ Electromagnetic compatibility:
  - □ respect rules for implementation,
  - □ products should comply with "CE" directives.

Electrical characteristics:

- ■ *Electrical levels: ± 5 V (in differential).*
- ■ *Transmitter: minimum output voltage: 1.5 V / 54 Ω.*
- ■ *Receiver: minimum sensitivity ± 0.2 V.*
- ■ *Type of medium: shielded twisted pair.*
- ■ *Characteristic impedance of the medium: Zc = 120 Ω.*
- ■ *Maximum voltage in common mode: -7 V to 12 V (for Zc = 120 Ω).*
- ■ *Maximum current for transmitter output: 250 mA.*
- ■ *Load and line polarisation: yes.*
- ■ *Load resistance = 120 Ω.*
- ■ *Polarisation resistance = 470 Ω.*

***Note**: If a compromise is made on the maximum variation of common mode voltage, it is possible to:*

- ■ *Use a cable with a lower characteristic impedance.*
- ■ *Connect more loads to the bus (example: for 50 connection points, Umc = -1 to 5 V).*

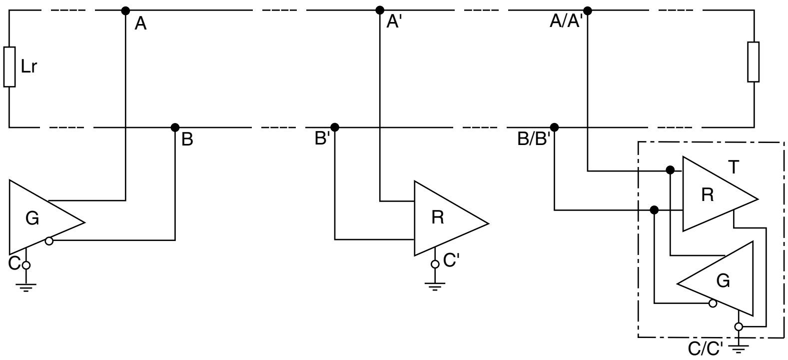
The TSB89 bulletin specifies that if the transition time of the fastest transmitter on the line is greater than twice the propagation time on the same line (in one direction), the connection is not a transmission (SIC). Load resistance is unnecessary.

20 mA CL – RS232 – RS422 – RS485 links (continued)

Standards EIA 485A (March 98 update) and TSB89 (application guidelines for TIA/ EIA-485-A)

Connection and identification:

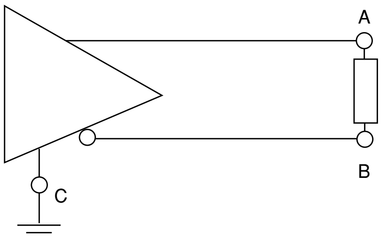
E52332



Key:
- *G = Generator*
- *A & B = Generator connection points*
- *C = Common point for the generator*
- *R = Receiver*
- *A' & B' = Receiver connection points*
- *C' = Common point for the receiver*
- *T = Transmitter*
- *A/A' & B/B' = Transmitter connection points*
- *C/C' = Common point for the transmitter*
- *RL = Load resistance.*

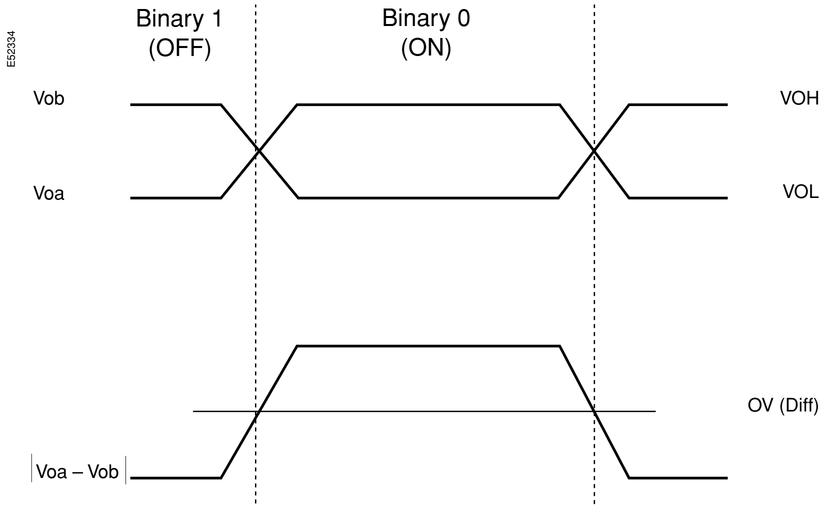
Electrical states:

E52333

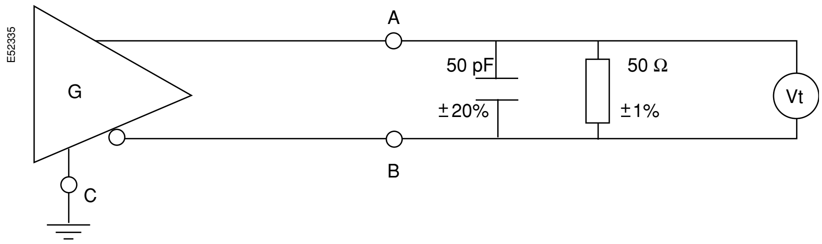


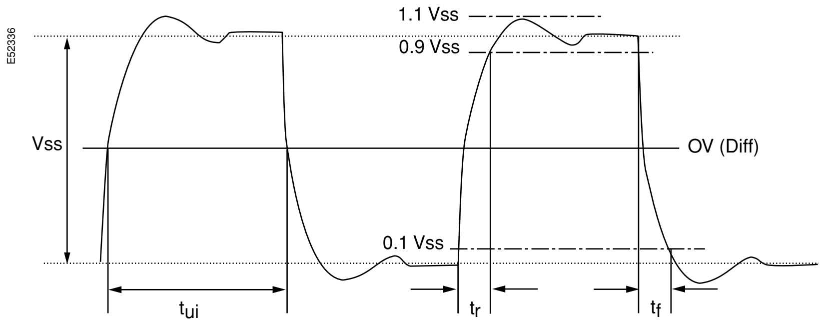
Line "A" on the transmitter is negative with respect to line "B" for a binary "1" (OFF).
Line "A" on the transmitter is positive with respect to line "B" for a binary "0" (ON).

20 mA CL – RS232 – RS422 – RS485 links (continued)



Signal transition time:





Vss = | Vt - Vt |*

Constraints concerning signal form:
- *tr & tf < 0.3 x tui.*
- *Between two transitions (after tr and before tf) the value of Vt or Vt* should not exceed Vss + 10%.*
- *Vt and Vt* should never exceed 5 V.*

All personal computers used in offices are equipped with at least one serial port (COM1) that is specified by standard RS232C. An adapter (interface RS232/ RS485) for electrical levels is required. In some cases, such as for "industrial" PCs, an adapter is not required if a card supporting standard RS485 can be installed.

RS232/RS485

Definition of an RS232/RS485 interface:
■ RS232:
□ conformity with the EIA standard,
□ PC connection cable < 20 m,
□ transmission speed compatible with PC port,
□ management of flow / presence control signals:
- RTS (Request To Send); DTE ÆDCE,
- CTS (Clear To Send); DCE ÆDTE,
- DCD (Data Carrier Detect),
- DSR (Data Set Ready)
- DTR (Data Terminal Ready) DCE Æ DTE.

□ if it is possible to choose the type of interface (DTE/DCE), choose DCE.
■ RS485:
□ conformity with the EIA standard,
□ connection cable < 1200 m,
□ transmission speed compatible with equipment,
□ possibility of line polarization (Rp),
□ possibility of line load (Rp),
□ 2 wire or 4 wire management,
□ conformity of data format (start, stop, parity, etc.)
□ possibility of 32 modules (at least) on its line.

For long-distance communication, the easiest solution is to use the existing telephone network. This requires a MODEM.

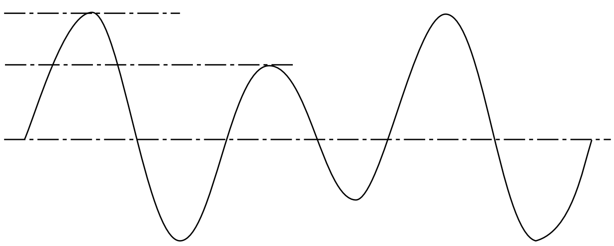
Modems

Bits cannot be transmitted directly over a telephone line (except for an ISDN line). A telephone conversation between two people is analogue because it varies in amplitude and phase over time.
Transmission of the bits 1 and 0 corresponds to variations in continuous voltage and thus cannot be placed directly on the telephone line. Modems are used to "MOdulate and DEModulate" these bits into analogue signals.
There are four types of modulation:

Definition: a modem, or MOdulator DEModulator is a device used to change digital signals into analogue signals and vice-versa.

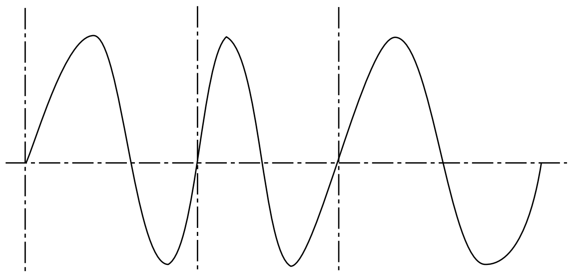
■ Amplitude modulation

E52341



■ Frequency modulation

E52342



■ Phase modulation (synchronisation)

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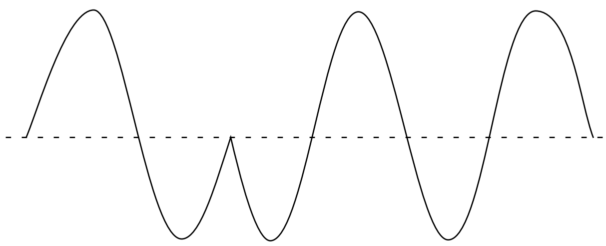
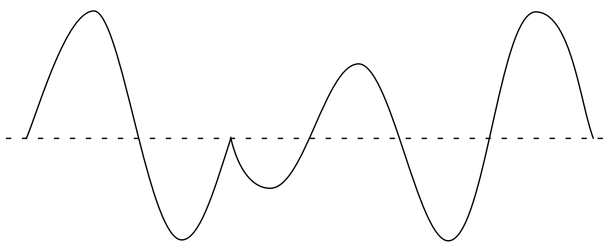


■ Combined modulation (ex.: of amplitude and phase)

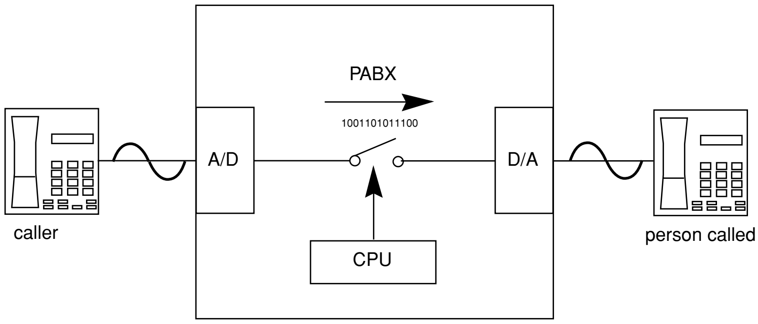
E52488



Interfaces (continued)

Telephone companies dispatch pairs of cables to their clients; each pair represents a different telephone number. Each of these telephone lines is linked to a special computer called a "switching exchange or PABX" at the central telephone station. The purpose of this computer is to set up the communications link between the caller and the number being called.
Computers only process information in binary form, i.e., 1 or 0.
For telephone exchanges they must:
- Decode the numbers dialed.
- Establish the communications link between the two subscribers.
- Convert analogue conversations to digital form (1 and 0).
- Process the digital data.
- Re-modulate the digital data to obtain analogue signals.

E52340



Definition:
- PABX: Public Automatic Branch eXchange
- A/D: Analogue to Digital converter
- D/A: Digital to Analogue converter
- CPU: Central Processing Unit
- Caller: User who dials the telephone number
- Person called: User who receives the telephone call

Dedicated lines and modems
A connection made on a telephone line through an electronic exchange (PABX) is called "temporary" because it represents a simple telephone call that anyone can make at any time. When the communication is terminated, the line is freed. Specific software is required to set parameters for the module, open communications on the telephone line, manage the line, etc.

A dedicated line provides point-to-point connection. This connection is not through a telephone exchange. It is permanent and requires components other than a telephone to operate. Such a connection is in service 24 hours a day, 365 days a year. A dedicated line with a bandwidth of 3 kHZ can carry 19.2 kBps (28.8 kBps V.FC and V.34 for 3600 Hz).

Local modem links
This type of link is used inside buildings, in private areas, for transmissions over long distances or in some case in disturbed environments.

ISDN connections

***Definition:** ISDN (Integrated Services Digital Network) is a telephone network that uses digital signals up to the user level. Its characteristics make it useful for transmitting moderate volumes of digital data, over medium distances, between companies.*

In this application, ISDN will progressively replace analogue telephone service. (The future competitors of ISDN will be DSL technologies and cable.) This type of digital connection does not use modems; it requires a Terminal Adapter or other specialised card. The configuration of these devices is often similar to that of modems, but they have additional and different characteristics that vary according to the model used.

Interfaces (continued)

General characteristics:
■ Industrial or office modem (depending on use).
■ Analogue/Digital (depending on connection to the telephone network).
■ Adaptable transmission speed (on the telephone network).
■ AT commands accepted for use and parameter setting.
■ RS232 input available (speed compatible with MODBUS).
■ Dry contact input available to initiate a call.
■ Conformity with EMC directives.

Definition: The modulation speed of the modem must not be confused with the speed of the COM port on the computer. Modem speed represents the rate of transfer of DCE, while COM port speed represents the transfer rate of DTE. Modem communication speed can be changed during an exchange according to load on the telephone network. For high speeds, use of RTS/CTS "hardware" flow control is recommended.

Installation recommendations

Hardware:
■ Modems are normally delivered with a telephone connection cable and a serial connection cable for connecting to the PC/Mac/terminal.
■ Refer to supplier instructions when installing a PCMCIA modem.
■ Connect the telephone cable to the LINE outlet (and not the PHONE outlet) on the modem. (Other terms are sometimes used.)
■ Connect the serial cable to the RS232 outlet on the modem and the PC/Mac/terminal.
■ Connect the outside power supply first to the 220 V line and then to the modem. (First make sure the modem is set to the OFF position.)

Software:
■ The software provided with the modem cannot generally be used to perform tests. Thus we recommend that a terminal emulator be used to perform the first operating tests.
■ A driver and installation instructions are provided with PCMCIA modems. Refer also to drivers installed on the PC operating system.

The most frequently encountered problems with serial connections are poorly suited speed and cables that cannot support hardware flow-control.

Serial connection with the modem:
■ Once the modem has been turned on:
□ verify that the modem has passed tests successfully and is in READY mode (ready to operate according to its LEDs),
□ configure the terminal emulator (or the terminal) with the maximum baud rate supported by the modem or the PC/Mac/terminal.
- choose 9600, 19,200, 38,400, 57,600 or 115,200,
- choose 8 data bits, 1 stop bit and parity none (8, 1, N or 8N1).
□ type the command AT [ENTER] and verify that the modem responds OK. If this is the case, the PC/Mac/terminal and modem link are already operating (but without any real flow-control test).

The most common problems with telephone connections are:
■ Unsuitable telephone cables (not adapted to the Swiss standard, for example).
■ Wall jack incorrectly cabled.
■ The telephone is connected:
□ to a double jack with 2 telephones,
□ to a special fax / telephone line,
□ to a private exchange.

Connection with the telephone line:
■ Now that your emulator is communicating with the modem:
□ type the command ATDP161 [ENTER],
□ the modem will dial the number; you should hear the talking clock in the modem's speaker.
□ the modem <-> telephone line link is in order.
□ you can then use a CARPE number (or the number of another service provider) to test the connection with data.
□ at this point, if everything is operating properly, part of your installation has been completed.

Billing pulses will disturb the modem if they are not filtered (in the modem, with an external filter or by your telecommunications service), particularly if there is no error correction.

Interfaces (continued)

For some applications it is useful to know the modem parameters and how to set them.
Commands beginning with AT (Hayes compatible) differ according to the modem. Modems that use Rockwell chips all have the same commands. Thus it is best to describe functions rather than specific commands.

Modem parameters are:
- Error correction,
- Data compression,
- Flow control.

Modem parameters:

■ Error correction can be used to eliminate a number of transmission errors on the often disturbed telephone network. ITU standard V.42 is faster and better than the MNP-4 (from Microcom).

■ Data compression can be used to accelerate the transfer of data that has not yet been compressed. With ITU standard V.42bis, the data compression rate can be as high as 4:1, and compressed data is recognized. MNP-5 (from Microcom) provides a compression rate of only 2:1.

■ Flow control: slow modems may have only software flow control, known as XON/XOFF in manuals, but faster modems must use hardware flow control, with RTS/CTS control lines. Use of both modes, possible with some modems, is not recommended.

Common AT commands:

ATD	*To dial a number, followed by a T for frequency selection (DTMF) or, more rarely, D for pulses (for older telephone switching stations). Example: ATDT 6939332 [ENTER] +++ can be used to return to the control mode and, for example, hang up with ATH. Remember to pause for one second before and after the command.*
AT&W	*Records the profile currently in memory. This is the profile that will be activated when the modem is turned on or with the ATZ command. Note that several profiles can be recorded on some models.*
AT&V	*Used to view active modem parameters.*
AT&F	*Resets all modem parameters to their original factory settings.*
ATLn	*Changes speaker volume. (ATMn selects speaker operating mode.)*
ATSr=n	*Places value n in register r. The command ATSr can be used to view the contents of the register.*
ATS0=n	*Sets the number of rings before the modem answers. If the value is 0 the modem will not respond. In Switzerland there must be at least two rings before the modem answers (according to OFCOM).*
ATS7=n	*Used to define the time the modem waits for a carrier before hanging up and indicating NO CARRIER. This value is usually between 45 and 60 seconds.*

***Note**: The modem reference manual is the most reliable source of information. Examples given here may differ.*

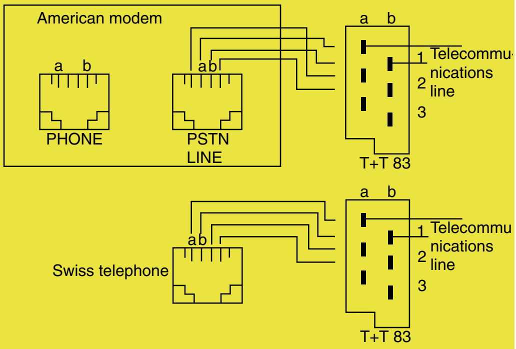
Messages:

OK	*The command has been understood.*
ERROR	*All or part of the command is erroneous.*
CONNECT	*The link is established. This message is often accompanied by other information on speed and protocol (error correction and/or compression).*
NO DIALTONE	*The modem cannot dial the number because there is no dial tone.*
NO CARRIER	*The carrier has been lost, or the remote modem has hung up, or our modem did not receive a carrier when calling (for example, when someone picks up the phone and says "hello!").*
NO ANSWER	*No one is answering, the number is wrong, or the equipment at the other end has broken down. (This does actually occur.*
BUSY	*All lines are occupied; the modem must try again later or use another number.*

Interfaces (continued)

Most cables linking the modem to the telephone jack comply with the international connection standard. This standard is not the same as the standard used in Switzerland.

E52344



The right cable

The serial link cable between the modem and the PC/Mac/terminal (DTE) should include all the necessary signals.

■ DB-25 and DB-25:

Note: General example used in most applications.

DTE (DB-25)		MODEM (DB-25)
1	Protective Ground	1
2	Transmitted Data (TD)	2
3	Received Data (RD)	3
4	Request to Send (RTS)	4
5	Clear to Send (CTS)	5
6	Data Set Ready (DSR)	6
7	Signal Ground	7
8	Data Carrier Detect (DCD)	8
9	Data Terminal Ready (DTR)	20
22	Ring Indicator (RI)	22

■ DB-9 and DB-25:

Note: The DB-9 connector is often used on PCs.

DTE (DB-9)		MODEM (DB-25)
1	Data Carrier Detect (DCD)	8
2	Received Data (RD)	3
3	Transmitted Data (TD)	2
4	Data Terminal Ready (DTR)	20
5	Signal Ground	7
6	Data Set Ready (DSR)	6
7	Request to Send (RTS)	4
8	Clear to Send (CTS)	5
9	Ring Indicator (RI)	22

■ Mini-DIN and DB-25:

Note: The Mini-DIN 8 connector is used on Macintosh computers (DTE).

DTE (Mini-DIN8)		MODEM (DB-25)
1 DTR	(RTS & DTR)	4 & 20
2 DSR	(CTS)	5
3 TD	Transmitted Data (TD)	2
4 & 8	(Ground)	7
5 RD	Received Data	3
7 DCD	(DCD)	8
SHIELD		1

Definition : ASCII, American Standard Code for Information Interchange.

Definition : RTU, Remote Terminal Unit.

Both of these frame formats can be used in the Modbus protocol, but they are incompatible with each other. About 95% of modules that communicate over Modbus use RTU frames.

Difference between ASCII and RTU frames

Some devices can use either of the two formats:
- With the RTU format the user can obtain higher data throughput with the same transmission speed.
- The ASCII format provides greater flexibility on inter-byte timing (up to 1 second) and provides truly asynchronous transmission.

Definition : The Modbus protocol uses frames with standard beginnings and ends. The address is placed at the beginning of the frame.

Definition : The Modbus+ protocol uses frames with start and end delimiters that are specific to the network. The destination address is integrated in the protocol.

Differences between Modbus and Modbus+ protocols

- In the Modbus protocol, the receivers read the address and thus identify the module to which the message is addressed. The receivers also determine the length of the message and can thus detect truncated messages.
- In Modbus+ the transmitter converts the Modbus address to an address with the node and access path on the network.

The Jbus protocol uses part of the Modbus protocol.
Note: Products (modules) may contain only part of the Modbus functions (see product documentation).

Note: @ Modbus begin at "1", while @ JBus begin at "0".

Modbus / Jbus

Frame structure	***Jbus***	***Modbus***
Slave no.	*1 to 255*	*1 to 247*
Function code	*1 to 16 (except 9 & 10)*	*1 to 24*
Frame length	*Maximum 255 bytes*	*Maximum 261 bytes*
CRC	*CRC16*	*CRC16*
*Frame detection**	*silence > 3 characters*	*silence > 1.5 or > 3.5 characters*
** This difference is unimportant at throughputs greater than 1200 bits/s because the times are shorter than device processing time (turnaround time).*		
Standard functions		
F1	*Read n bits at @ 0 to FFFF (1 < n < 2000)*	*Read n bits at @ 1 to 9999*
F2	*Read n bits at @ 0 to FFFF (1 < n < 2000)*	*Read n bits at @ 10001 to 19999*
F3	*Read n words at @ 0 to FFFF (1 < n < 125)*	*Read n words at @ 40001 to 49999*
F4	*Read n words at @ 0 to FFFF (1 < n < 125)*	*Read n words at @ 30001 to 39999*
F5	*Write 1 bit at @ 0 to FFFF*	*Write 1 bit at @ 1 to 9999*
F6	*Write 1 word at @ 0 to FFFF*	*Write 1 word at @ 40001 to 4999*
F7	*Fast read 8 user bits*	*Read exception status (8 bits). Signal errors in the equipment*
F15	*Write n bits at @ 0 to FFFF*	*Write n bits at @ 1 to 9999*
F16	*Write n words at @ 0 to FFFF*	*Write n words at @ 40001 to 49999*

The Modbus Protocol (continued)

The Modbus protocol can be used to read or write one or more bits, one or more words, the contents of the event counter or the contents of the diagnostic counters.

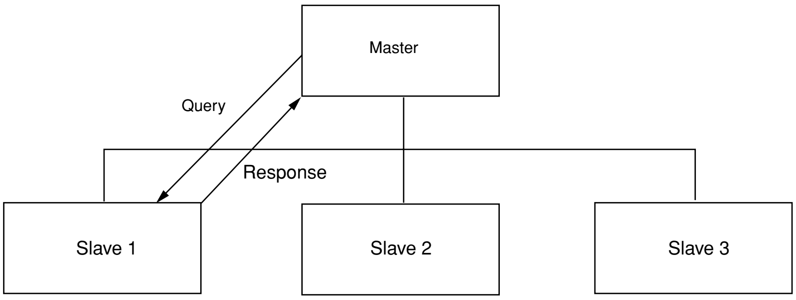
Frame structure	*Jbus*	*Modbus*
Diagnostic functions (sub-functions)		
F8	*Read diagnostic counters*	*Read diagnostic counters*
(01)	*Data = 0000 => no response transmitted* *data = FF00 resets counters*	*Response* *no counter reset*
(02-03-04-0A)	*Identical*	*Identical*
(0B)	*Count frames with no CRC error*	*Count all frames*
(0C-0D)	*Identical*	*Identical*
(0E)	*Not incremented upon broadcast*	*Incremented upon broadcast*
(0F)	*Count number of broadcasts received*	*Count number of no-responses from the slave*
(10-11)	*Identical*	*Identical*
(12)	*Count character errors (format, parity, etc.)*	*Count overruns*
F11	*Event counter.* *Increments upon broadcast. In the response the first word is always at 0.*	*Event counter.* *Not incremented upon broadcast.* *In the response the first word is at 0 or FFFF (status)*
F12	*History of the last 64 exchanges.* *In the response the first word is always at 0..*	*History of the last 64 exchanges.* *In the response the first word is at 0 or FFFF (status).*
Exception codes		
(01-02-03-05-07-08)	*Identical*	*Identical*
(04)	*Device not ready*	*Error during processing of the query*
(09)	*Overlapping of memory*	*Not implemented*
Extended functions (sub-functions)		
F13	*Program commands*	*Program commands*
(01 - 02)	*Identical*	*Identical*
(03 - 04)	*Address on 24 bits*	*Address on 16 bits + 8 bits for page number*
Address extension (25) (26) F14	 *Identical* *Data byte = 00 or 80h* *Identical*	 *Identical* *Data byte = 06h* *Identical*

Note*: Function 13 has 43 sub-functions; Jbus uses only 6..*

Description of exchanges

Exchanges take place at the initiative of the master. They include a query from the master and a response from the slave.

E52348



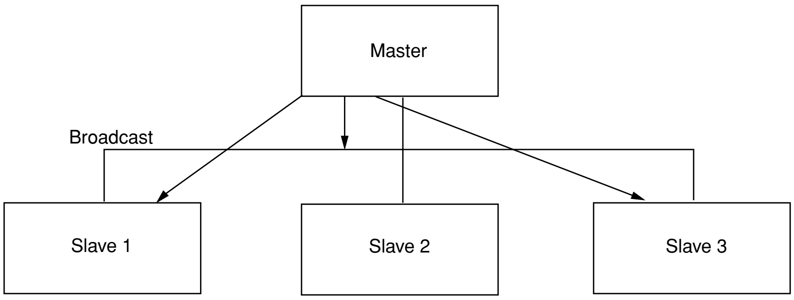
Broadcast commands are always write commands. Slaves do not answer such commands.

All frames exchanged have the same structure.

E52349

Queries from the master are addressed either:
■ To a specific slave (identified by its number in the first byte of the query frame.
■ To all slaves (broadcasting).

E52350



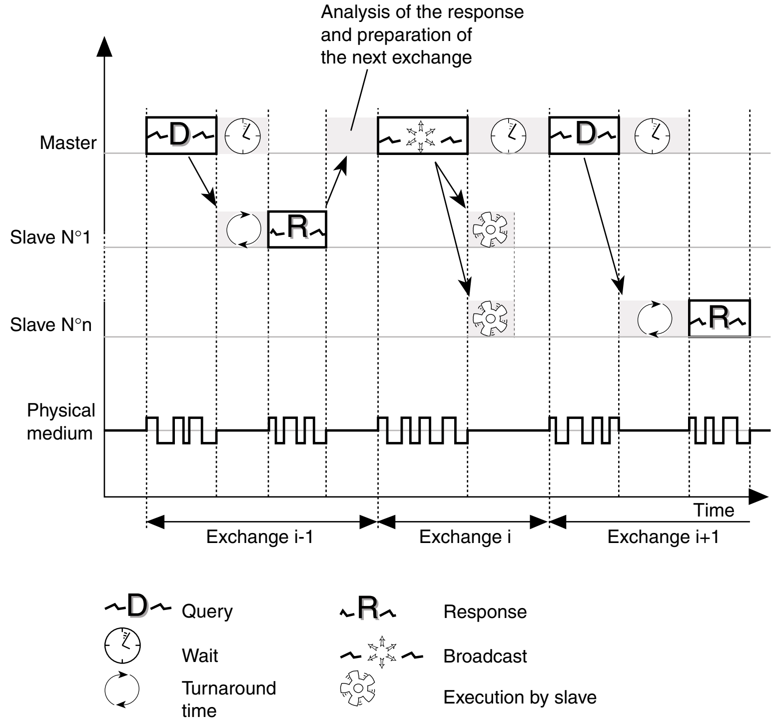
The Modbus Protocol (continued)

All exchanges except broadcasting include two frames: a query from the master and a response from the slave.
Broadcast exchanges (write only) consist of only one frame from the master.

Each frame includes four types of information:
- Slave number (1 byte):
  - the slave number specifies the destination slave (1 to 255). If this number is zero, the query is addressed to all slaves and there is no response message.
- Function code (1 byte):
  - can be used to select a command (read, write, bit, word) and to verify if the response is correct.
- Information field (n bytes):
  - contains the parameters associated with the function: bit address, word address, bit value, word value, number of bits, number of words.
- Control word (2 bytes):
  - is used to detect transmission errors.

Diagram showing how the transmission medium is filled

E52351



***Note**: The lengths of QUERY, RESPONSE, BROADCAST, WAIT and PROCESSING depend on the function performed.*

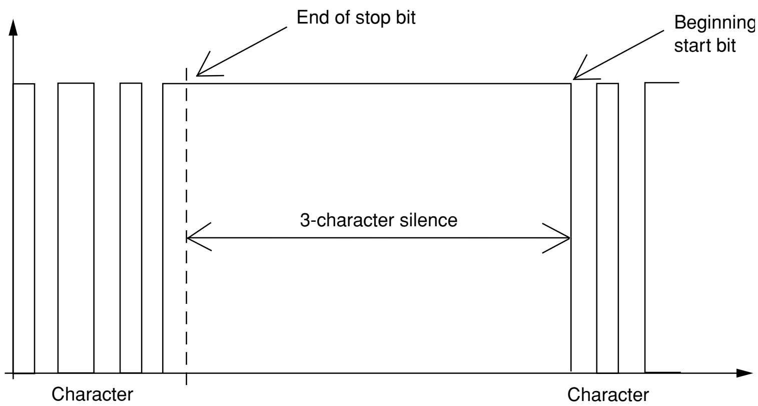
The Modbus Protocol (continued)

Principles used

Synchronisation of exchanges

Any character received after a silence of more than 3 characters is considered the beginning of a frame.

E52352



Note: Be sure to leave a silence of at least three character between frames.

Presentation of frames

The contents of the following frames is given in hexadecimal.

Presentation of query and response frames

■ Query

E52353

Slave no. (1 to FF)	Function code	Information	Control word
1 byte	1 byte	n bytes	2 bytes

Function code: This code is used to select the commands available.

Information: Information required for the query: address bits, bit value words, number of bits words, number of words.

Control word: The slave receives the message, reads the control word and accepts or refuses the message.

■ Response

Slave no. (1 to FF)	Function code	Information	Control word
1 byte	1 byte	n bytes	2 bytes

Information: Value of bits or words read, value of bits or words written, number of words or number of bits, diagnostic.

The Modbus Protocol (continued)

Each module has a single address on the network. This address is between 1 and 255 (1 and FF in hexadecimal).
The value of this address is coded in one byte. The value "0" is prohibited because it is used only for broadcasting.

Addressing

The addressing mode differs according to the module:
■ With a code wheel:
□ wheel no. 1 gives the most significant bit in addresses,
□ wheel no. 2 gives the least significant bit.
■ With a keyboard. The principal is the same, but the method may differ:
□ parameter setting in a single operation,
□ parameter setting in two operations (most significant / least significant).

In any case, always consult module implementation instructions.

The Jbus protocol has 14 functions. Query and response frames have a maximum of 255 bytes.

Functions

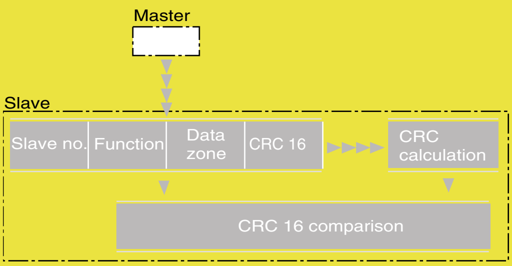
Jbus functions:
■ Function 1: Read n output or internal bits.
■ Function 2: Read n input bits.
■ Function 3: Read n output or internal words.
■ Function 4: Read n input words.
■ Function 5: Write 1 bit.
■ Function 6: Write 1 word.
■ Function 7: Fast read 8 bits.
■ Function 8: Diagnostic of exchanges.
■ Function 11: Read event counter.
■ Function 12: Read trace buffer.
■ Function 13: Read/write address > FFFFh or program command (downloading, etc.).
■ Function 14: Diagnostic associated with program commands.
■ Function 15: Write n bits.
■ Function 16: Write n words.

The master transmits a query indicating:
- Slave number.
- Function code.
- Parameters of the function.

It calculates and transmits the contents of the control word (CRC 16).
When the slave receives the query message, it stores the message in memory, calculates the CRC and compares it with the CRC 16 received.

- If the message received is incorrect (CRC 16 frames not equal) the slave does not respond.
- If the message received is correct but the slave cannot process it (bad address, incorrect data, etc.) it sends an exception response.

E52356

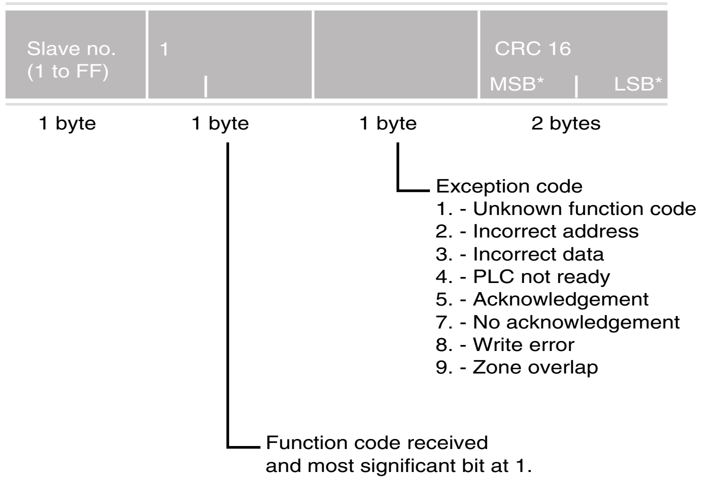


Important: the least significant byte (LSB) of CRC 16 is transmitted first.

Control of messages received by the slave

Contents of an exception response

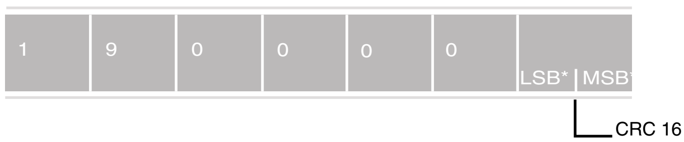
E52357



Example:

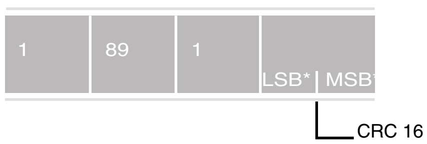
- *Query.*

E52358



- *Response.*

E52359



***Note**: Exception responses 5 and 7 are related to Jbus functions 13 and 14.*

Definition: A bit is a basic unit of information that can only equal 1 or 0. Bits are the "language" used by computers. They correspond to the following levels of electricity in computers:
- "bit 0" = 0 Volt
- "bit 1" = 5 Volts

Important:
When bits are transmitted through a serial port, they correspond to the following levels of electricity:
- bit 0 = +3V to +15V
- bit 1 = -3 to -15V

Definition: A byte is a group of eight (8) binary elements. A byte is thus eight (8) bits that represent a binary "word".

Note: MSB = Most Significant Bit and LSB = Least Significant Bit.

- Function 1: read N output or internal bits.
- Function 2: read N input bits.
- The number of bits to read should be ⩽ 2000.

Read n bits: function 1 or 2

- Query.

E52360

Slave no.	1 or 2	Address of the 1st bit to read: MSB* | LSB*	Number of bits to read: 1 ≤ n ≤ 2000	CRC 16 LSB* | MSB*
1 byte		2 bytes	2 bytes	2 bytes

- Response.

E52361

Slave no.	1 or 2	Number of bytes read	First byte read	Last byte read	CRC 16 LSB* | MSB*
1 byte	1 byte	1 byte	n bytes		2 bytes

Byte in detail:

E52355

Last bit transmitted							First bit transmitted

Note: Unused bits in the byte are reset to zero.

Example:
Read bits 204 to 211 of slave no. 1.

- *Query.*

E52362

01	01	02 04	010E	CRC 16

- *In hexadecimal, the number of bits to read from 204 to 211 are as follows:*
  - *0204, 0205, 0206, 0207, 0208, 0209, 020A, 020B, 020C, 020D, 020E, 020F, 0210, 0211,*
  - *a total of 14 values, or 0E in hexadecimal.*

- *Response.*

E52363

01	01	02	10101001	00101110	CRC 16
			20B ← 204	211 ← 20C	

The Modbus Protocol (continued)

■ Function 3: read output words or internal bits.
■ Function 4: read input words.
■ The number of words to read should be ⩽ 125.

Note: In this case the "word" represents 2 bytes or 16 bits..

Read n words: function 3 or 4

■ Query.

E52364

Slave no.	3 or 4	Address of the first word to read: MSB* | LSB*	Number of words to read: n ⩽ 125 : MSB* | LSB*	CRC 16 LSB* | MSB*
1 byte	1 byte	2 bytes	2 bytes	2 bytes

■ Response.

E52365

Slave no.	3 or 4	Number of bytes read	Value of first word MSB* | LSB*	…	Value of last word MSB* | LSB*	CRC 16 LSB* | MSB*
1 byte	1 byte	1 byte	2 bytes		2 bytes	2 bytes

Example:
Read words 805 to 80A of slave no. 2.

■ *Query.*

E52366

02	03	0805	0006	

CRC 16

■ *Response.*

E52367

02	03	OC	XXXX	…	YYYY	

CRC 16
Value of word 80A
Value of word 805

The Modbus Protocol (continued)

Write a bit: function 5

The response frame is identical to the query frame.

■ Query.

E52368

Slave no.	5	Address of the bit MSB* | LSB*	Value of the bit	0	CRC 16 LSB* | MSB*
1 byte	1 byte	2 bytes	1 byte	1 byte	2 bytes

bit forced to 0_ write 0
bit forced to 1_ write FF

■ Response.

E52368

Slave no.	5	Address of the bit MSB* | LSB*	Value of the bit	0	CRC 16 LSB* | MSB*

Note: If the slave number is 00, all slaves force the values and do not transmit a response.

Example:
Force bit 210 of slave no. 2 to 1.

E52369

02	05	02 10	FF	00	

CRC 16

Write a word: function 6

The response frame is identical to the query frame.

■ Query.

E52370

Slave no.	6	Address of the word MSB* | LSB*	Value of the word MSB* | LSB*	CRC 16 LSB* | MSB
1 byte	1 byte	2 bytes	2 bytes	2 bytes

■ Response.

E52370

Slave no.	6	Address of the word MSB* | LSB*	Value of the word MSB* | LSB*	CRC 16 LSB* | MSB

Note: If the slave number is 00, all slaves force the values and do not transmit a response.

Example:

Write the value 1000 in address word 810 of slave no. 1.

E52371

01	06	810	1000	

CRC 16

The Modbus Protocol (continued)

The addresses of the 8 bits are set by the slave.

Fast read 8 bits: function 7

■ Query.

E52372

Slave no.	7	CRC 16 LSB* | MSB*
1 byte	1 byte	2 bytes

■ Response.

E52373

Slave no.	7	XXXXXXXX	CRC 16
1 byte	1 byte	1 byte	2 bytes

Each slave has a number of event counters (or diagnostic counters):

- There are a total of 9 counters per slave.
- These counters are 16-bit words.

Read diagnostic counters: function 8

- Query/response.

E52489

Slave No.	8	Sub-function code	Data	CRC 16
1 byte	1 byte	1 byte	2 bytes	2 bytes

Function	***Sub-function code***	***Data***	***Notes:***
The slave should echo the query (transmission control).	*00*	*XYZT*	*X, Y, Z, T set by the user*
Reset diagnostic counters to zero, cancel disconnected mode and reconfigure coupler. No response transmitted.	*01*	*0000*	
Diagnostic counters and trace buffer reset to zero.	*01*	*FF00*	
Read diagnostic register of slave.	*02*	*XXXX*	*For the query XXXX equals 0000.* *For the response XXXX is the contents of the diagnostic register (set by the user).*
Change character that serves as a frame end delimiter (in ASCII mode). This character is LF (OA) by default.	*03*	*XY00*	*XY set by the user: ASCII code of the end-of-frame character.*
Disconnected mode – the slave can no longer respond. (Use sub-function 1 to activate slave.)	*04*	*0000*	
Reset diagnostic counters to zero	*0A*	*0000*	
Read total number of:			
□ frames received without CRC error (CPT 1)	*0B*	*XXXX(1)*	
□ frames received with CRC error (CPT 2)	*0C*	*XXXX(1)*	
□ number of exception responses (CPT 3)	*0D*	*XXXX(1)*	
□ frames addressed to the station (CPT 4) (except broadcast)	*0E*	*XXXX(1)*	
□ broadcast queries received (CPT 5)	*0F*	*XXXX(1)*	
□ nacknowledged responses (CPT 6)	*10*	*XXXX(1)*	
□ not ready responses from the slave (CPT 7)	*11*	*XXXX(1)*	
□ unprocessed characters (CPT 8)	*12*	*XXXX(1)*	

(1) For the query XXXX equals 00 00.
For the response, xxxx is the contents of the counter.

This counter tells the master:
■ If the slave has correctly interpreted the command (event counter incremented).
■ If the slave has not interpreted the command (counter not incremented).

Read event counters: function 11

Each slave has an event counter. The master also has an event counter. This counter is incremented by one for each frame correctly received and interpreted by the slave (except for the specific command for reading this counter, i.e., function 11). The counter is also incremented for a correct broadcast command. If the slave transmits an exception response, however, the counter is not incremented.

A diagnostic of exchanges between the master and the slave can be obtained by reading the various counters.

If the master's counter is equal to the slave's counter, the command sent by the master has indeed been executed. If the master's counter is equal to the slave's counter + 1, the command sent by the master has not been executed.

■ Query.

E52374

Slave No.	OB	CRC 16 LSB* | MSB*
	1 byte	2 bytes

■ Response.

E52375

Slave No.	OB	00 00	Contents of slave's counter	CRC 16 LSB* | MSB*
1 byte	1 byte	2 bytes	2 bytes	2 bytes

The user can access a 64-byte memory containing the history of the last 64 transactions.

Read trace buffer: function 12

Note: Functions 12, 13 and 14 are not implemented in all Modicon controllers and are given only for information because they are on the list of Jbus functions.

The master can request a read operation on this memory. The slave responds, and sends the contents of the event counters and message counter as well.

■ Query.

E52376

Slave No.	0C	CRC 16
1 byte	1 byte	2 bytes

■ Response.

E52377

Slave No.	OC	46	00 00	Status of event counter	Status of message counter	64 bytes	CRC
1 byte	1 byte	1 byte	2 bytes	2 bytes	2 bytes		

Report on most recent event	Report on event immediately preceding		Report on event N		Report on event -64

■ In reception.

E52378

1	= 1 if broadcast	= 1 if disconnected mode	1 if erroneous character	0	0	= 1 if CRC error	0

■ In transmission, error number if any.

E52379

1	1	= 1 if disconnected mode	0				

■ In disconnected mode (1).

E52380

0	0	1	0	0	0	0	0

■ Diagnostic counters reset to zero (command 8, sub-command 01).

E52381

0	0	0	0	0	0	0	0

(1) Disconnected mode is used to analyse certain problems. In this mode, the coupler monitors the line and increments counters and updates the trace table. However there are no transfers to the slave's memory and no responses are transmitted on the line. This mode is piloted by command 8 (sub-functions 01 and 04).

Program commands: Function 13

Program commands can be used to perform the following functions:
- Connect to slave memory.
- Disconnect from slave memory.
- Stop slave (STOP).
- Run slave (RUN).
- Unload program from slave (read contents of the memory).
- Load program in slave (write memory).

The functions used to load and unload the memory can also be used to read and write the data memory in excess of the 16-bit addressing limit.
The memory load and unload commands are accessible at all times. Program commands must be organised within a session composed of:
- *Connection.*
- *Commands.*
- *Disconnection.*

***Note:** Read and write commands cannot be mixed within a single session.*

If the response is a "no acknowledgement" (exception response 7) the diagnostic associated with these functions is obtained with function 14 (see the following section).

Only one coupler at a time can access the slave's memory and/or give orders to the slave's central processing unit.

This mutual exclusion is respected by organising program commands in sessions:
- *Program commands themselves (stop, run, unload, load, etc.).*
- *Memory disconnection.*

Notes:
- *The data memory is always accessible regardless of the status of the coupler (connected or not). Thus the principle of mutual exclusion is respected.*
- *An automatic disconnection procedure (time out, etc.) on the slave should be provided in case the disconnection command does not arrive at its destination (line out of operation, character error, etc.).*

Diagnostic of program commands: Function 14

This command is used to indicate the diagnostic associated with exception response 7 (no acknowledgement) received when a program command is executed (function 13). It provides the diagnostic of the last program command executed.

Command not authorised for broadcast.

Syntax:

- Query.

E52382

Slave no.	OE	CRC 16
1 byte	1 byte	2 bytes

- Response.

E52383

Slave no.	Function code	Frame length	Sub-function code	Type of error	CRC 16
1 byte	1 byte	1 byte	1 byte	1 byte	2 bytes

The sub-function code returned is the sub-function code of the last program command executed, with the most significant bit forced to 1 if an error was detected during execution.

Example: 82 for a run query (sub-function 2). The type of error is coded as follows:

N°	***Name***	***Type of command that could cause this error***
00	*No error*	
01	*Command unknown, not authorised or poorly executed (CPU dialogue error, for example).*	*Any command.*
02	*Invalid virtual address (exceeds maximum authorised address field).*	*Read or write in memory.*
03	*Memory protected. The user is trying to read or write a memory that is already occupied by another coupler (mutual exclusion principle).*	*Read or write in memory.*
04	*Read or write at addresses that do not physically exist (outside the address field of the slave under consideration).*	*Read or write in memory.*
08	*Invalid number of words.*	*Read or write in memory.*
09	*Command not authorised. Slave running.*	*Write in memory.*
10	*Command not authorised. Slave not connected.*	*Run, stop, read or write.*

If the slave number is 0, all slaves perform the write operation but do not return a response.

Write n consecutive bits: function 15

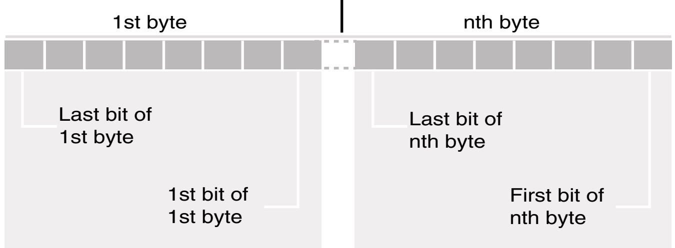
■ Query.

E52384

Slave no.	OF	Address of the 1st bit to force	No. of bits to force	No. of bytes to force	Value of bits to force	CRC 16
1 byte	1 byte	2 bytes	2 bytes	1 byte	n bytes	2 bytes

1 ⩽ X ⩽ 1968

1 ⩽ n ⩽ 246



■ Response.

E52385

Slave no.	OF	Address of the 1st bit forced	No. of bits forced	CRC 16
1 byte	1 byte	2 bytes	2 bytes	2 bytes

Example:
Force bits 200 and 201 of slave 3 to 1.

■ *Query.*

E52386

3	OF	200	0002	01	03	

CRC 16

■ *Response.*

E52387

3	OF	200	0002	

CRC 16

If the slave number is 0, all slaves perform the write operation but do not return a response.

Write n consecutive words: function 16

■ Query.

E52388

Slave no.	10	Address of the 1st word to force	No. of words to force	No. of bytes to force	Value of words to force	CRC 16
1 byte	1 byte	2 bytes	2 bytes	1 byte	n bytes	2 bytes

1 ⩽ X ⩽ 123

1 ⩽ N ⩽ 246

1st word forced — Last word to force

MSB*	LSB*	MSB*	LSB*		LSB*	MSB*

■ Response.

E52389

Slave no.	10	Address of the 1st word forced	No. of words forced	CRC 16
1 byte	1 byte	2 bytes	2 bytes	2 octets

Example:
Force words 0800 to 0803 of slave no. 1.
(0800) = 0001
(0801) = 0010
(0802) = 0100
(0803) = 1000

■ *Query.*

E52390

01	10	0800	0004	08	0001 0010 0100 1000	CRC 16

■ *Response.*

01	10	0800	0004	CRC 16

The Modbus Protocol (continued)

Returns the description of the type of controller at this address, the status of the "run indicator" and information specific to each type of slave. Broadcast not supported.

Identification of a slave: function 17 (specific to PM 6xx/ CM2xxx).

■ Query.

E52392

Slave no.	11	CRC 16
1 byte	1 byte	2 bytes

■ Response.

E52393

Slave no.	11	Number of bytes	Slave ID	ON/OFF indicator	MSB of data	LSB of data	CRC
1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	1 byte	2 bytes

Note: The number of bytes, slave ID and data available depend on the type of slave. For the ON/OFF indicator: FF = ON & 00 = OFF.

Example: Read the data of a PM600 N°17:

■ *Query.*

E52394

01	11	CRC 16
1 octet	1 octet	2 octets

■ *Response.*

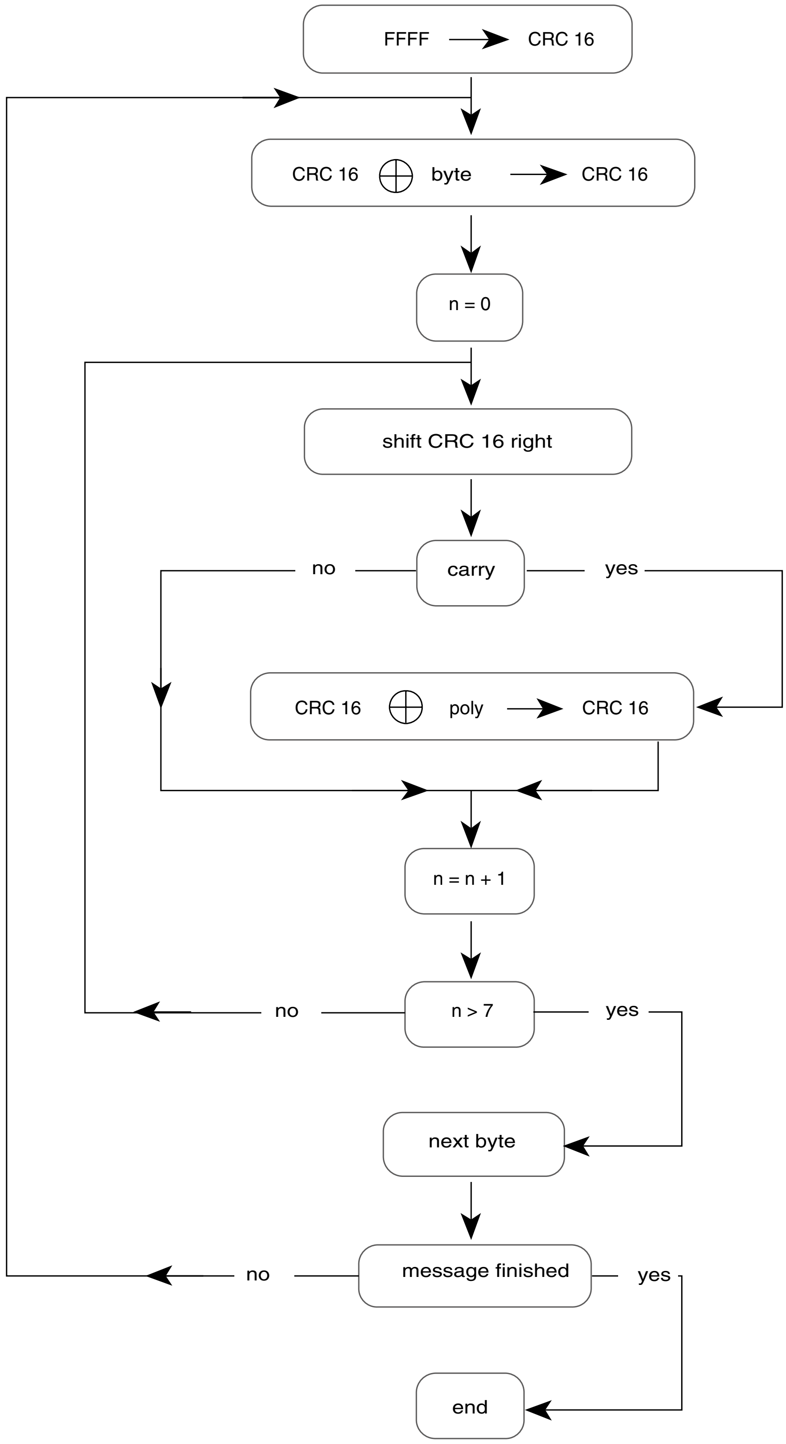
E52395

01	11	04	64	FF	01	E1	CRC 16

64 = specific to Powerlogic modules.
01 E1 = Powerlogic addresses.

Algorithm for generating CRC16

E52396



+ exclusive OR
n = number of data bits
POLY = polynomial for generating CRC 16 = 1010 0000 0000 0001
(generating polynomial = $1 + x_2 + x_{15} + x_{16}$)
In CRC 16, the LSB is transmitted first.

The Modbus Protocol (continued)

Example of CRC calculation: frame 020B = read event counter (function 11) of the slave at 02h.

Initialisation of the CRC		**CRC =**	**1111**	**1111**	**1111**	**1111**
⊕1st byte (02)		**CRC =**	**0000**	**0000**	**0000**	**0010**
n = 0	 *⊕polynomial*	*CRC =* *Shift N°1*	*1111* *0111* *1010*	*1111* *1111* *0000*	*1111* *1111* *0000*	*1101* *1110_ 1* *0001*
n = 1	 *⊕polynomial*	*CRC =* *Shift N°2*	*1101* *0110* *1010*	*1111* *1111* *0000*	*1111* *1111* *0000*	*111* *1111_ 1* *0001*
n = 2 *n = 3*	 *⊕polynomial*	*CRC =* *Shift N°3* *Shift N°4*	*1100* *0110* *0011* *1010*	*1111* *0111* *0011* *0000*	*1111* *1111* *1111* *0000*	*1110* *1110_ 0* *1111_ 1* *0001*
n = 4 *n = 5*	 *⊕polynomial*	*CRC =* *Shift N°5* *Shift N°6*	*1001* *0100* *0010* *1010*	*0011* *1001* *0100* *0000*	*1111* *1111* *1111* *0000*	*1110* *1111_ 0* *1111_ 1* *0001*
n = 6 *n = 7* *n > 7* *⇨ CRC = ⊕ 2nd byte (ϕB)*	 *⊕polynomial*	*CRC =* *Shift N°7* *Shift N°8* *CRC =*	*1000* *0100* *0010* *1010* *1000* *0000*	*0100* *0010* *0001* *0000* *0001* *0000*	*1111* *0111* *0011* *0000* *0011* *0000*	*1110* *1111_ 0* *1111_ 1* *0001* *1110* *1011*
n = 0	 *⊕polynomial*	*CRC =* *Shift N°1*	*1000* *0100* *1010*	*0001* *0000* *0000*	*0011* *1001* *0000*	*0101* *1010_ 1* *0001*
n = 1	 *⊕polynomial*	*CRC =* *Shift N°2*	*1110* *0111* *1010*	*0000* *0000* *0000*	*1001* *0100* *0000*	*1011* *1101_ 1* *0001*
n = 2 *n = 3* *n = 4*	 *⊕polynomial*	*CRC =* *Shift N°3* *Shift N°4* *Shift N°5*	*1101* *0110* *0011* *0001* *1010*	*0000* *1000* *0100* *1010* *0000*	*0100* *0010* *0001* *0000* *0000*	*1100* *0110_ 0* *0011_ 0* *1001_ 1* *0001*
n = 5 *n = 6* *n = 7*		*CRC =* *Shift N°6* *Shift N°7* *Shift N°8* *Final CRC*	*1011* *0101* *0010* **0001** **1** *MSB*	*1010* *1101* *1110* **0111** **7**	*0000* *0000* *1000* **0100** **4** *LSB*	*1000* *0100_ 0* *0010_ 0* **0001_ 0** **1**

Thus the CRC for this frame is: 4117 hex.
MSB = Most Significant Bytes.
LSB = Least Significant Bytes.

Electrical interpretation of the CRC on a RS485 network:

- *In our example, the query from the master is:*

E52397

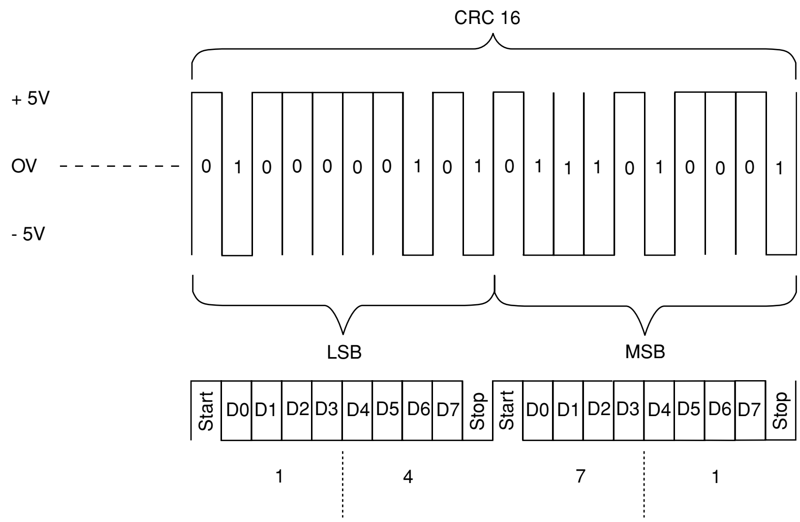
02	0B	41 17

- *In this case, the response would be:*

E52398

02	0B	00 00	counter contents (00 00 in this case)".	A4 38

E52399



Thus the signal is interpreted as: $ 41 17
(as expected).

The Modbus Protocol (continued)

"Physical" example of a frame:

- *"Master" frames are transmitted by a specific software program.*
- *"Slave" frames are transmitted by a module of the Digipact range.*
- *2-wire cabling with load and polarisation is used for the RS485.*
- *Measurements are made with an oscilloscope across terminals 8/9 (hot point on the probe) and terminals 4/5 (cold point) on the module's 9-pin subD.*

The Modbus function 11 "read event counter" is used. All modules have this function (see description of functions).

- *Query.*

E52397

02	0B	41 17

- *Response.*

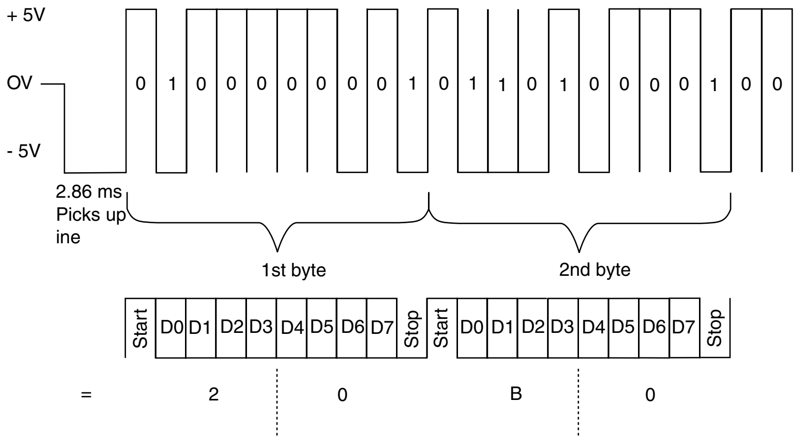
E52398

02	0B	00 00	counter contents (00 00 in this case)".	A4 38

- *Note: since transmission speed is 19200 baud:*
  - □ *1 bit = 52 µs,*
  - □ *1 byte (1start + 8bits + 1stop) = 520 µs,*
  - □ *thus the theoretical length of the response = 4.16 ms (4.14 ms measured).*

- Form of the signal measured (start of frame):

E52400



Thus we have the address of the slave (02 hex) and the function code (0B hex).

Schneider Specifications

Overview

Minimum configuration required:
■ Functions on bits (read/write): 1 and 2; 5 and 15 or/and functions on words (read/write): 3 and 4; 6 and 16.
■ Diagnostic functions: 8 (sub-codes 10 to 18), 11.

In addition, all devices must accept broadcast frames for write functions.

.

The transmission format must include the following data:
■ 1 start bit.
■ 8 data bits.
■ 1 stop bit.
■ No parity.

The transmission speed must integrate 9600 bds.

Choice of a physical interface (RS232C, RS422A, RS485, 20 mA CL) depends on the environment and on the performance levels required.

For the physical interface, use a RS485 connector with a 4-wire topology. (This is the only standard defined for multi-point use.) The equipment must also manage a 2-wire topology.

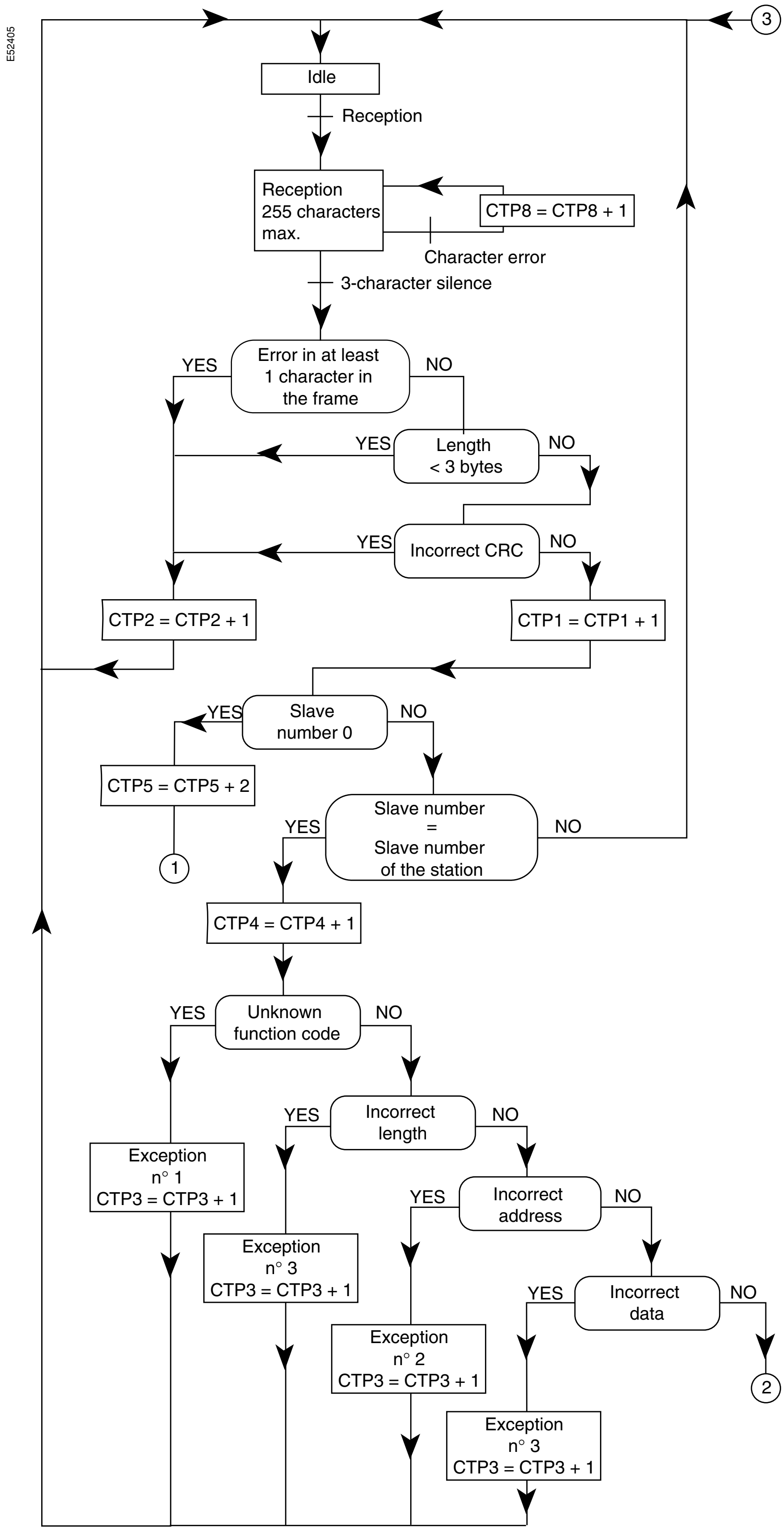
Principles to follow:
■ Respect the frame format.
■ Respect function numbers.
■ Respect limits given by the protocol:
■ Read 2000 bits or 125 words maximum,
■ Write 1968 bits or 123 words maximum.
■ Use slave numbers that can be set with parameters.
■ Detect ends of frames with a 3-character silence.
■ Increment diagnostic counters in strict accordance with specifications.
■ React properly to unexpected events:
■ Upon reception of an invalid master frame with correct CRC 16 (Cyclical Redundancy Check) and slave number, return an exception message.
■ No response to a frame with a CRC 16 error.
■ Reject frames that are incomplete or too long.

Schneider Specifications (continued)

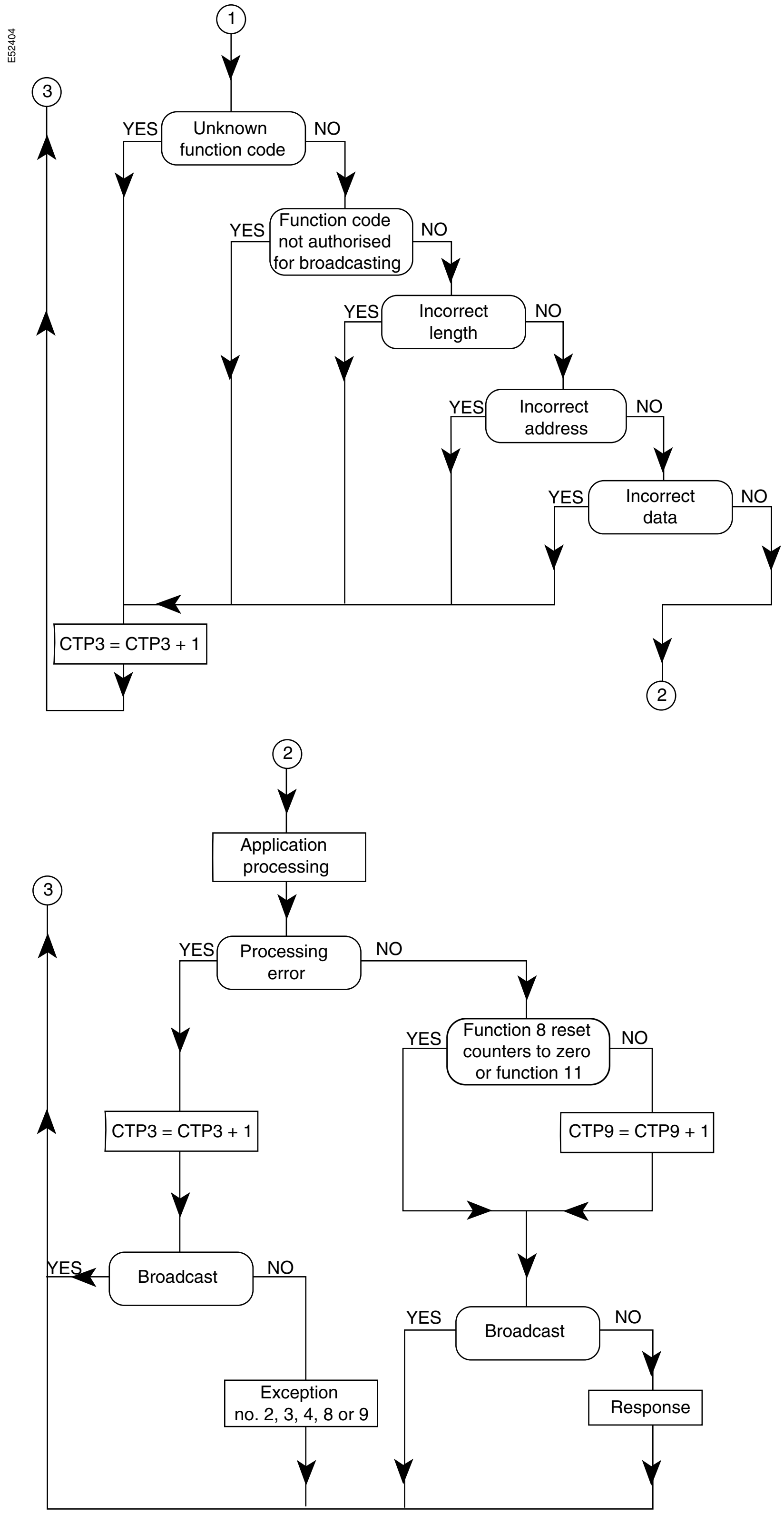
■ *The time between two characters in a frame must always be less than three characters (1 character = start bit, data bits, parity and stop bits).*
■ *The time between two frames (master or slave) must always be greater than or equal to three characters.*
■ *If the device is programmed with parity, verify the parity of all bytes in a frame received.*
■ *If the device is programmed with no parity, refuse frames that have bytes with parity.*
■ *The following controls should be performed on a master or slave frame:*
□ *CRC 16 correct,*
- correct slave number;
- correct function code and sub-codes (if any),
- correct field length (limits authorised by the protocol),
- actual length correct (length field = number of bytes received),
□ *a master should:*
- signal errors (error message, screen, LED, etc.) from slave responses,
- always be able to communicate after an incorrect response from a slave,
- refuse a slave response than arrives during transmission of a master frame (full duplex not authorised by Jbus),
- verify that the structure of a frame transmitted conforms to the protocol (number of variables, number of bytes £ 255, etc.).

Notes:
■ *A character error indicates an error in the format (framing), framing, parity or overrun.*
■ *An incorrect frame length is detected by verifying the "number of data" field (if any), the "number of bytes" field (if any) and the actual length of the frame.*
■ *For a frame longer than 255 bytes, the slave must wait for the end of the frame (detection of a 3-character silence). The frame is not processed and counter 2 (frame with CRC error) is incremented only once.*
■ *There is now a new diagnostic counter 6 for function 13 (program download). The old counter 6 "PLC not ready" is now counter 7. The new counter 6 is incremented each time a "no acknowledgement" exception response is transmitted (including broadcast). In remote download mode all exception codes (1, 2, 3, 4, 8 and 9) are replaced by the "no acknowledgement" code (7). This is the case whenever function code 13 has been recognised (see the <function code unknown> -- no algorithm). Function 14 can be used to obtain more detailed information on errors.*

Counter management algorithm



Counter management algorithm (continued)

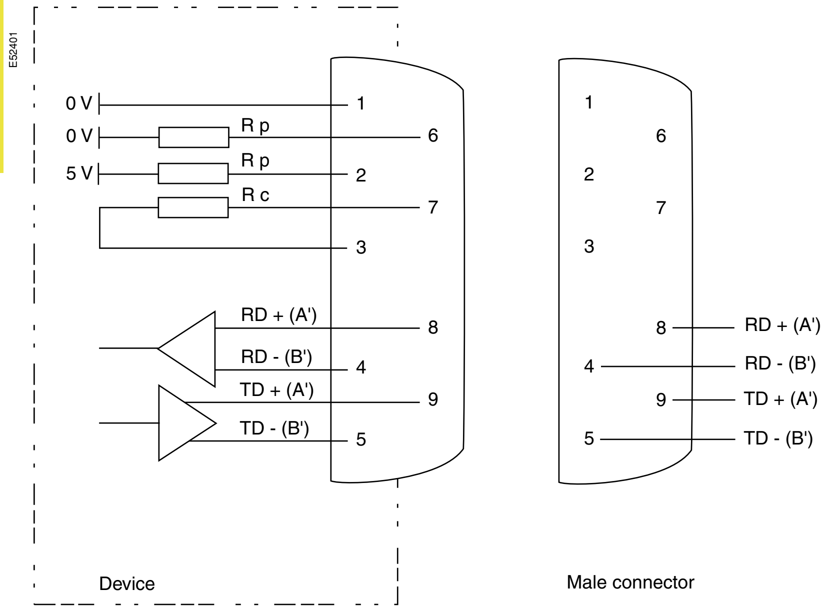


Note: New Schneider EMC recommendations (equipotential grids) indicate that shielding should be grounded at both ends. The means used to connect to ground should limit leakage inductance.

Use a subD 9-pin female connector for connection.

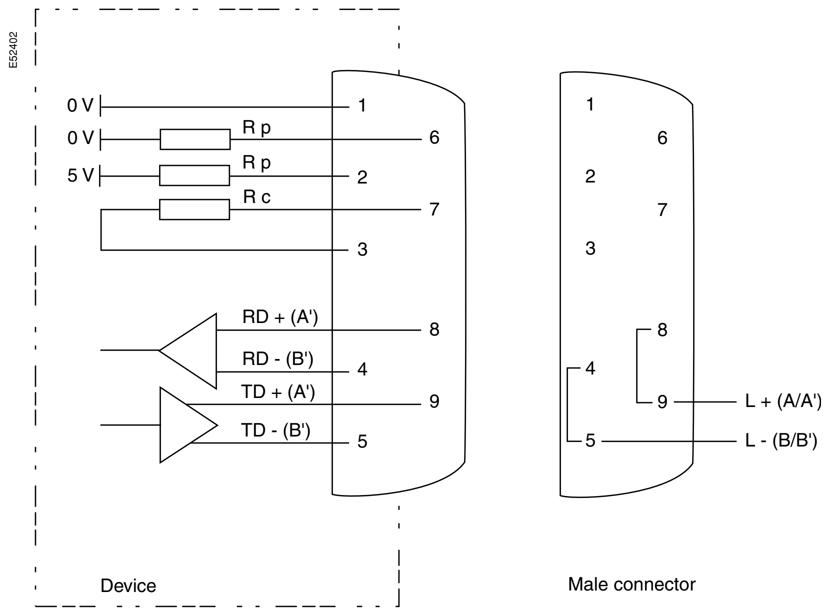
Connection

4-wire slave without polarisation or adaptation



Rp = 470Ω
Rc = 150Ω

Slave without polarisation or adaptation configured for a 2-wire topology.



See PCR implementation document.

Components available

See reference document:
- In French: PCRED 399074FR, art 28992.
- In English: PCRED 3990774EN, art 28993.

Internet link: http://139.160.28.99/sitemt/sep1000.nsf.

Summary

RS232C:

■ Limit length to 15 m.

■ Take into account the specific requirements of each interface and software program with regards to management of control lines (RTS/CTS) when connecting the line.

RS232/RS485 interface:

■ Use converters recommended by Schneider Electric whenever possible; they have been tested and validated for proper operation regardless of the configuration of the installation.

RS485 link:

■ Choose a 2-wire connection over a 4-wire link whenever possible.

■ Use shielded twisted pairs with a characteristic impedance of 120 W.

■ Link earths carefully.

■ Make sure there are load resistors (120 W) on each side of the communication line, as well as polarisation resistors, preferably on the "Master" side.

■ Limit slaves to 32.

Modules:

■ Each module has its own address. Make sure communication speeds and formats used (data, parities, stop) are the same.

Modbus protocol:

■ Do not mix Modbus ASCII and Modbus RTU products.

■ Verify conformity between functions implemented in the modules connected and functions used by the supervisor.

■ Respect the various time constraints in the protocol.

Specific Characteristics of Products

Product	Functions supported	Time stamping	Frame format / speed	Connection	Electrical interface
DC 150	1, 2, 3, 4, 5, 6, 8, 11, 15, 16.	Yes	8 data bits, no parity, 1 stop bit. 9600 & 19200 baud	SubD 9-pin female	RS485 – 2 or 4 wires, with load and polarisation possible
PM 300	1, 2, 3, 4, 5, 6, 8, 11, 15, 16.	No	8 data bits, no parity, 1 stop bit. 9600 & 19200 baud	Phoenix 5-pin male/female with screw	RS485 – 2 or 4 wires + 115V/ 500V AC power supply with load possible
ET 44	1, 2, 3, 4, 5, 8, 11.	No	8 data bits, no parity, 1 stop bit. 9600 baud	SubD 9-pin female	RS485 – 2 or 4 wires, without load or polarisation
XLI/XTU 300	1, 2, 3, 4, 5, 6, 7, 8, 11, 15, 16.	Yes	8 data bits, no parity, 1 stop bit. 300 to 19200 baud	SubD 9-pin female	RS485 – 2 or 4 wires, load and polarisation possible
Digibloc D200	1, 2, 3, 4, 5, 8, 11.	Yes	7/8 data bits, with or without parity, 1 / 2 stop bit. 1200 to 9600 baud	SubD 9-pin female	RS485 – 2 or 4 wires, load possible + RS422 and RS232
Micrologic	3, 4, 6, 8, 11, 16, 17.	Yes	8 data bits, no parity or even/ odd parity, 1 stop bit. 4800 to 19200 baud	6-pin terminal or kit (cable + SubD 9-pin female)	RS485 – 2 or 4 wires + 24V DC power supply without load or polarisation
SEPAM 1000+	1, 2, 3, 4, 5, 6, 7, 8, 11, 15, 16.	Yes	8 data bits, no parity or even/ odd parity, 1 stop bit. 4800 to 38400 baud	4-pin terminal with screw (with specific interface)	RS485 – 2 wires + 12V DC power supply, load and polarisation possible (with specific interface)
SEPAM 2000	1, 2, 3, 4, 5, 6, 7, 8, 11, 15, 16.	Yes	8 data bits, no parity or even/ odd parity, 1 stop bit. 300 to 38400 baud	SubD 9-pin female	RS485 – 2 or 4 wires, load and polarisation possible
CM 2XXX	3, 4, 6, 8, 11, 16, 17.	Yes	8 data bits, no parity, 1 stop bit. 1200 to 19200 baud	5-pin terminal with screw	RS485 only 4 wires, without load or polarisation
CM 4000	3, 4, 6, 8, 11, 16, 17.	Yes	8 data bits, no parity or even parity, 1 stop bit. 1200 to 38400 baud	Phœnix 5 - pin with screw	RS485 - 2 or 4 wires, without load or polarisation RS232
PM 600/ 650	3, 4, 6, 8, 11, 16, 17.	Yes	8 data bits, no parity, 1 stop bit. 1200 to 19200 baud	5-pin terminal with screw	RS485- 2 or 4 wires, without load or polarisation

Implementation in Products

List of diagnostic tests

Control:

■ Are the frames received/sent compatible with the functions supported by the control system / products?
■ Is the frame format the same for all the products connected?
■ Is the maximum number of slaves respected?
■ Does each product have a single and correct address?
■ etc.

Serial link (RS232):

■ Does the software manage the control signals (RTS/CTS)?
■ Is the link "crossed" (2 and 3 on RS232)?
■ Is the communication speed compatible?
■ Are there parameters to be set for the interface (speed, frame format, DTE/DCE, etc.)?
■ Are the Rx and/or Tx LEDs on the interface blinking?
■ etc.

Asynchronous link (RS485):

■ Is the 2 wire / 4 wire configuration taken into account correctly?
■ Are the L+ and L- connections inverted?
■ Is the line polarised at the interface (or elsewhere, but not at 2 points)?
■ Does the line have polarisation resistance at both ends?
■ Is maximum network length respected (with EMC taken into account)?
■ etc.

Products connected:

■ Are the frames received/sent compatible with the functions supported by products and/or by the control system?
■ Is the correct format used (number of data bits, stop, parity bits, etc.).
■ Are parameters set correctly (speed, address, 2 wires / 4 wires, etc.)?
■ etc.

Note:

■ Connect modules one by one in order to identify any "problem" modules.
■ Use communication LEDs as an initial indicator.
■ etc.

Bibliography

- UTE – C 15-900: "Mise en œuvre et cohabitation des réseaux de puissance et des réseaux de communication dans les installations des locaux d'habitation, du tertiaire et analogues".
- IEC 439.1 : Low-voltage switchgear and controlgear assemblies.
- Schneider Electric CT publication no. 149: "EMC: electromagnetic compatibility".
- Schneider Electric CT publication no. 187: Cohabitation of high and low currents".
- Documentation concerning installation of the PCR surge arrester.

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