CiA Draft Standard Proposal 307

CANopen

Framework for Maritime Electronics

This is a draft standard proposal and may be changed without notification.

Version 1.0.1
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HISTORY

Date	Version	Changes
2002-08-21	1.0	Initial revision
2002-11-08	1.0.1	changed values in table physical units from 70_h .. 81_h to $A0_h$ .. $B1_h$

CONTENTS

1 SCOPE

1.1 General

It is the intention of this framework to provide a protocol which facilitates safe inter-operability and support the functionality required by modern maritime systems and equipment. Such requirements is the need of ship owners, operators, manufacturers, yards and regulatory bodies.

Every effort has been made to ensure that the specifications in this standard will support current functions for maritime systems, as well as the increasing demand for integration of systems.

It is stressed that operational safety will ultimately depend upon the correct implementation of this standard - safety is not (and cannot be) intrinsic to the specification. While every measure has been taken to ensure that the specifications are capable of supporting safe implementation, it remains that they will not suit every application. Therefore the user is cautioned to take due consideration of any requirements imposed by the regulatory bodies in this respect

1.2 Rationale for marine-specific standards

There are a number of standardized network interconnection specifications available, such as CANopen with additional device profiles, as well as others. None of them address the particular demands of the maritime field.

One key difference in the use of interconnection standards in the maritime environment is the diversity of applications onboard. A ship is a floating community, intended to sustain both persons and cargo in often hostile conditions. General interconnection standards are not usually developed with such diversity in mind; being fundamentally limited in their scope, and hence their application.

The adoption of proprietary or generalized industrial specifications in the maritime environment can in itself pose risks in implementation. Deviation from a generalized specification to support maritime-specific requirements could potentially lead to the introduction of systematic faults. Furthermore, such specifications may be intended to support functionality not relevant to marine applications, leading to the inefficient use of often limited resources.

It may also be considered that dependability issues such as availability, reliability and maintainability often have safety implications in the maritime environment, e.g. the loss of steering or propulsion.

Also, when the continued effort of IMO and other maritime regulatory bodies lead to new safety regulations and performance standards, a particular maritime standard is easier to adapt to this development, and does not lend itself to be compromised by other potential users.

This framework is designed to offer benefits to the various actors of the maritime community, such as:

- System developers, who will benefit in that economies of scale might be made by reducing application-specific development, facilitating common hardware and software platforms and eliminating the need to individually specify or adapt other specifications.
- Yards, who will benefit in that the installation and testing of disparate systems will be simplified considerably.
- Ship owners and operators, who will benefit from better integrated systems capable of implementing advanced functionality, rather than ad-hoc solutions.
- Regulators, who will benefit from the application of a cohesive and systematic standard, which readily supports verification and validation.

1.3 Motivation for the standard

The main task of system builders is to handle the company-specific data interfaces of subsystems in respect to physical and protocol interfaces. High adapting efforts during the system integration requires a ”manufacturer-independent standard” in the electrical and protocol data interface.

This framework discusses the methods and tools to integrate subsystems from different vendors to a complete monitoring and control system using the field-bus integration platform ”CANopen” and the maritime application framework CiA 307.

Today many engine and propulsion system manufactures offer a CAN field bus system interface. This is a consequence of the wide use of CAN in different application fields.

The large demand for a standard communication protocol was solved with the ”CANopen” protocol which is offered and distributed by the international CAN in Automation users group. ”CANopen” standardizes the physical layer and the higher layer communication protocol. With ”CANopen”, the system integration effort decreases considerably.
But it is not sufficient to use a common physical layer and a protocol standard. The experience of system builder and integrators shows the necessity to tailor the protocol in reference to the application requirements.

2 REFERENCES

/ISO11898/	ISO 11898, Road vehicles – Interchange of digital information – Controller area network (CAN) for high-speed communication, 1993
/CiA301/	CiA DS 301 V 4.02, CANopen application layer and communication profile, February 2002
/CiA302/	CiA DSP 302 V 3.1.1, Framework for programmable CANopen devices, May 2002
/CiA303-1/	CiA DR 303-1 V 1.1.1, CANopen cabling and connector pin assignment, December 2001
/CiA303-2/	CiA DR 303-2 V 1.1, CANopen representation of SI units and prefixes, January 2000
/CiA401/	CiA DS 401 V 2.01, CANopen device profile generic I/O modules, May 2002
/IEC61162-420/	IEC 61161-420, Maritime navigation and radio communication equipment and system – Digital interface – Part 420: Multiple talkers and multiple listeners – Ship systems interconnection – Companion standard requirements and basic companion standards, 2001

3 DEFINITIONS AND ABBREVIATIONS

3.1 Abbreviations

CAN Controller Area Network is an internally standardized serial bus system.

COB Communication Object. A unit of transportation in a CAN network. Data must be sent across a CAN Network inside a COB. There are 2048 different COB's in a CAN network. A COB can contain at most 8 bytes of data.

COB-ID Each COB is uniquely identified in a CAN network by a number called the COB Identifier (COB-ID). The COB-ID determines the priority of that COB for the MAC sub-layer.

ME MPDO Maritime Electronic MPDO

MPDO Multiplexed PDO

NMT Network Management. One of the service elements of the application layer in the CAN Reference Model. The NMT serves to configure, initialise, and handle errors in a CAN network.

Node-ID The Node-ID of the NMT Slave has to be assigned uniquely, or 0. If 0, the protocol addresses all NMT Slaves.

PDO Process Data Object.

RPDO Receive PDO.

SDO Service Data Object.

SYNC Synchronisation Object.

TPDO Transmit PDO.

4 DEFINITIONS

For fulfillment of the classification societies rules, some extensions and precised definitions of the CANopen standard (see /CiA301/) are necessary for security reasons. The CANopen standards /CiA301/ and /CiA302/ should be consulted in parallel to this framework.

4.1 Redundant CANopen network

If monitoring and control functions of the monitoring control system use the same communication network, this shall be designed redundantly. The alarm system will use the redundant CAN-bus concept. All alarms will be send on the active CAN line. This demand is prescribed by the other classification societies in same form.

Therefrom it follows that the CANopen network is to be carried out redundantly for maritime applications.

E.g. a disconnection of the CAN controller of a device or a defective bus cable shall not lead to a functional reduction concerning communication flow.

4.2 Flying NMT master principle

The disconnection of the NMT master device may not cause the disconnection of the overall network communication. The critical functionality concerning CANopen is the NMT master with it network management functionality. An implementation approach is to settle these function in several CANopen devices. Further the disconnection of the NMT master device shall be recognized and the NMT master functionality shall be transferred to an available device. The error recognition and functional incorporation shall occur within shortest time.

Therefrom it follows that the flying NMT master principle shall be fulfilled.

4.3 Heartbeat protocol

The heartbeat protocol shall be used so all modules, which support it, shall be configured for heartbeat protocol.

All modules which participate in the flying NMT master functionality shall be configured for heartbeat protocol. If an NMT slave does not support heartbeat protocol, node guarding will be configured only for this NMT slave. In this case, heartbeat protocol will be configured for those NMT slaves which support it.

4.4 Multiplexed PDOs

In large ship automation systems a huge number of process data has be exchanged via the network. The 512 receive PDOs and 512 transmit PDOs which are specified in CANopen as maximum number of PDOs per device are not enough for such systems. The solution is the use of the multiplexed PDO.

By use of the multiplex PDO, additional address information is transmitted. These address extension allows to distinguish a sufficient number of process data inside the system.

For maritime applications multiplexed PDOs shall be used.

4.5 Timing values

Proposed values for the node guard time are 1 to 1.5 s at 50 nodes. With a node guard time of 500 ms a lifetime factor of 2 or 3 is required for maritime applications.

Proposed values for the heartbeat consumer time are 1 to 1.5 s at 50 nodes. The heartbeat producer time is 500 ms.

4.6 Device to device communication

Reasons for this communication type:

Safety system functionality distributed on two or more CANopen devices. It shall be guaranteed that communication also functions without NMT master.

Higher availability in case of the disconnection of the NMT master functionality in the network.

For direct PDO or SDO communication between two NMT slaves heartbeat protocol is required.

4.7 Physical and electrical definitions

4.7.1 Topology

CAN bus is based on a “line” topology. Bus line is terminated on each end by a 120 Ohms resistor which is the nominal impedance for CAN bus. Every devices connected to the network shall comply with rules established in /CiA301/.

Topologies such as ring, star are not supported. Nether the less, it is possible to use dedicated hubs in a way to share the whole network in several branches. Each branch has a normal line topology and is, physically speaking, an independent bus line. This particular configuration is useful to limit common mode in case of general bus fault. Faulty communication is limited to the faulty branch.

Though CAN bus is not initially a redundant bus, this framework establishes all necessary rules to handle a redundant bus for maritime applications. For the safety requirements of maritime applications a redundant bus may be used.

4.7.2 Baud rate

Maritime applications has to use a default baud rate of 125 kbit/s. This transmission speed allows a bus length of at least 500 meters if specifications for bus cable, cabling and shielding are respected. Other bit rates e.g. 250 kbit/s, 500 kbit/s are optional (see /CiA301/ and /CiA303-1/).

4.7.3 Network cable, shielding and grounding

Although network cable type is not mandatory, it is strongly recommended to respect the following points:

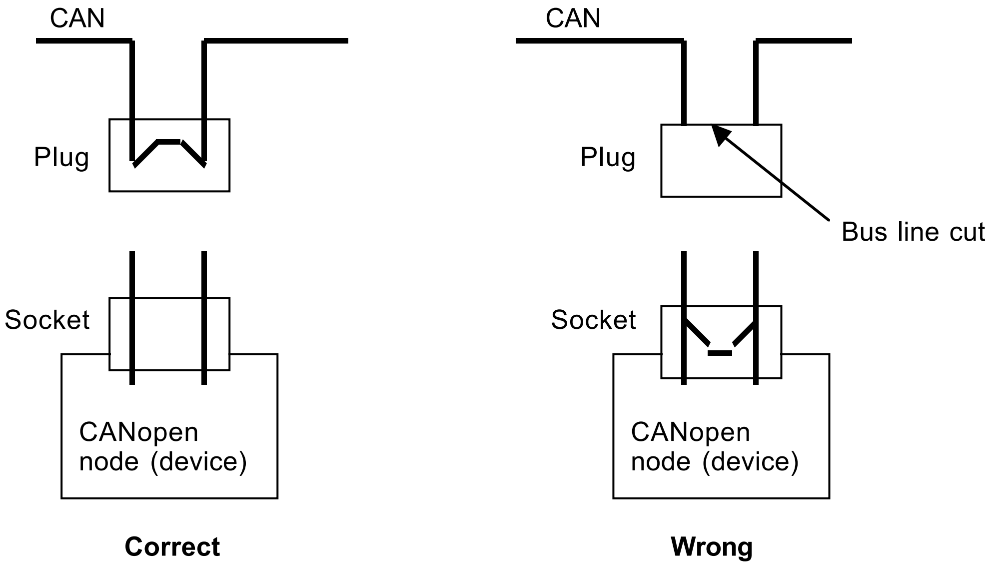
- Individual network cable[1]: means not used for other kind of signals.
- Two separated cables in case of double network to allow geographical segregation.
- Simple twisted shielded pair or twin axial cable (2 wires + shielding)
- Cable section superior or equal to 2 x 0.5 mm^2 and inferior to 2 x 1 mm^2
- Impedance: 120 ± 10 %
- Attenuation: < 14 dB / km at 1 MHz
- The connector shall identify the default and redundant CAN line clear

In other respects, application of these rules does not exempt from respecting other maritime rules. For example, temperature range, mechanical properties, behavior regarding oil or any other chemical products, behavior regarding fire, smoke composition, etc.

4.7.4 Network pin out connections

When a node is physically disconnected, *the bus line shall not be cut.*

[1] Referring to present rules described in /CiA303-1/ same cable is used for both network and power supply. In maritime applications, this is not advised and even often not possible. Indeed, rules emitted by classification societies for EMI perturbations are different for power supply and other signals. They are much more severe for power supply signals and a common cable would force CAN network to support these much harder perturbations. An other major reason is that power supply can come from different sources in a way to supply different nodes without common mode regarding reliability and availability.



Female contacts on cable are preferred to avoid short circuit during manipulations.

Every device has to offer the possibility to connect shielding of bus cables.

4.7.4.1 Terminal blocks

As CAN has a line topology, each node not located at one end is connected by two CAN cables. To avoid two wires per terminal block, it is useful to double each polarity.

Pin	Signal	Description
1 (or n) (1)	CAN_L	CAN_L bus line (dominant high)
2 (or n+1)	CAN_L	CAN_L bus line (dominant high)
3 (or n+2)	CAN_H	CAN_H bus line (dominant low)
4 (or n+4)	CAN_H	CAN_H bus line (dominant low)
5 (or n+5)	Shielding	Mechanical ground
6 (or n+6)	Shielding	Mechanical ground

If a simple connection is used, the following pinning shall be applied:

Pin	Signal	Description
1 (or n) (1)	CAN_L	CAN_L bus line (dominant high)
2 (or n+1)	CAN_H	CAN_H bus line (dominant low)
3 (or n+2)	Shielding	Mechanical ground

If network connection is included in a general terminal block, the same order has to be respected.

4.7.4.2 Circular connectors or other connectors

Same remark can be done as for terminal blocks.

Pin	Signal	Description
1	CAN_L	CAN_L bus line (dominant low)
2	CAN_L	CAN_L bus line (dominant low)
3	CAN_H	CAN_H bus line (dominant high)
4	CAN_H	CAN_H bus line (dominant high)
5	Shielding	Mechanical ground (optional)
6	Shielding	Mechanical ground (optional)

If a simple connection is used, the following pinning shall be applied:

Pin	Signal	Description
1	CAN_L	CAN_L bus line (dominant high)
2	CAN_H	CAN_H bus line (dominant low)
3	Shielding	Mechanical ground

Shielding may is connected to connector body on socket and plug.

4.7.4.3 Circular connectors or other connectors for redundant network

Two separate connectors shall be preferred. If a redundant network is connected on the same connector, network 1 is connected pin 1 to 3 (simple pinning) or 1 to 6 (double pinning) and network 2 is connected pin 4 to 6 (simple pinning) or 7 to 12 (double pinning).

Double pinning

Pin	Signal	Description
1	CAN_L network 1	CAN_L bus line (dominant low)
2	CAN_L network 1	CAN_L bus line (dominant low)
3	CAN_H network 1	CAN_H bus line (dominant high)
4	CAN_H network 1	CAN_H bus line (dominant high)
5	Shielding network 1	Mechanical ground (optional)
6	Shielding network 1	Mechanical ground (optional)
7	CAN_L network 2	CAN_L bus line (dominant low)
8	CAN_L network 2	CAN_L bus line (dominant low)
9	CAN_H network 2	CAN_H bus line (dominant high)
10	CAN_H network 2	CAN_H bus line (dominant high)
11	Shielding network 2	Mechanical ground (optional)
12	Shielding network 2	Mechanical ground (optional)

Simple pinning

Pin	Signal	Description
1	CAN_L network 1	CAN_L bus line (dominant high)
2	CAN_H network 1	CAN_H bus line (dominant low)
3	Shielding network 1	Mechanical ground (optional)
4	CAN_L network 2	CAN_L bus line (dominant high)
5	CAN_H network 2	CAN_H bus line (dominant low)
6	Shielding network 2	Mechanical ground (optional)

4.7.5 Power supply pin out connections

No general rule in the present rules described in /CiA301/. Pin out is different for each kind of connection.

4.7.5.1 Terminal blocks

As power supply is generally distributed according a line topology, each node not located at one end receives two power supply cables. To avoid two wires per terminal block, it is useful to double each polarity.

Double connection

Pin	Signal	Description
1 (or n) (1)	+ V	+V generally +24 VDC
2 (or n+1)	+ V	+V generally +24 VDC
3 (or n+2)	-V (0V)	- V generally 0 VDC
4 (or n+4)	-V (0V)	- V generally 0 VDC
5 (or n+5)	Shielding	Mechanical ground
6 (or n+6)	Shielding	Mechanical ground

Simple connection

Pin	Signal	Description
1 (or n) (1)	+ V	+V generally +24 VDC
2 (or n+1)	-V (0V)	- V generally 0 VDC
3 (or n+2)	Shielding	Mechanical ground

If power supply connection is included in a general terminal block, the same order has to be respected.

4.7.5.2 Circular connectors or other connectors

Same remark can be done as for terminal blocks.

Double pinning

Pin	Signal	Description
1	+ V	+V generally +24 VDC
2	+ V	+V generally +24 VDC
3	-V (0V)	- V generally 0 VDC
4	-V (0V)	- V generally 0 VDC
5	Shielding	Mechanical ground
6	Shielding	Mechanical ground

Simple pinning

Pin	Signal	Description
1	+ V	+V generally +24 VDC
2	-V (0V)	- V generally 0VDC
3	Shielding	Mechanical ground

Shielding can also be connected to connector body on socket and plug.

General remark: On some connectors, pin designation is alphabetic. In that case, begin by first letter and follow alphabetic order.

5 NODE MONITORING

The purpose of these protocols is to provide a continuous monitoring of the communication status of the nodes of a CANopen network. There two alternative methods specified in /CiA301/ for this:

- Heartbeat messaging
- Node guarding

5.1 Compatibility issues

Principally both protocols may be used simultaneously within the same network. But, a node shall only support one protocol at the very same time. If protocols are supported, it shall be configured via the heartbeat producer time parameter to use the desired protocol.

A CANopen manager shall be able to monitor heartbeat producers. If there are nodes in the network which only support node guarding, the CANopen manager shall also be able to handle the node guarding protocol.

Nodes which participate in the flying NMT master shall be heartbeat producers.

It is not possible that a heartbeat consumer also monitors a NMT slave node which is guarded by the NMT master, since this is restricted by the current specification /CiA301/ (If this may be possible, the heartbeat consumers shall ignore the toggle bit of the node status information).

It is highly recommend to use the heartbeat protocol.

6 REDUNDANT COMMUNICATION

6.1 Overview

According to the rules of the maritime classification societies, single failure tolerance is required if a communication system is used for integrated alarm, monitoring and control systems. In such redundant maritime communication system a CANopen device is always connected to two CAN lines. Therefore the following hardware redundancy is required (Figure 5-1):

- Double cables
- Double CAN transceivers on a CANopen device
- Double CAN controllers on a CANopen device

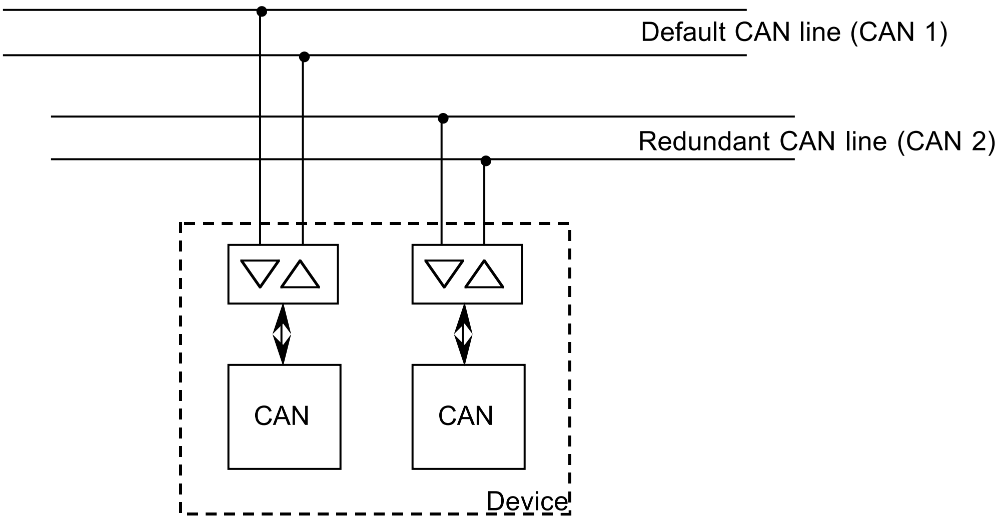


Figure 5-1: Hardware requirements of a redundant communication system

For identification one CAN line is called the “Default CAN line”, the other is called “Redundant CAN line”. From a technical view there is no difference of the two lines. One of the two CAN lines has the status “active” with respect to the way of message processing on the receiver side.

In a maritime system the different CANopen object types are transmitted and processed by one of the following methods (Table 5-1):

Table 5-1: Transmission and processing of CANopen objects in a maritime CANopen communication system

CANopen object type	Method of transmission and processing
PDO, Emergency Object	Simultaneously transmitted on both CAN lines[2]
Time Stamp Object, Synchronization Object	Simultaneously transmitted on both CAN lines. Only objects received on the active CAN line are processed
SDO	SDO request: Transmitted on one of the two CAN lines which provides the connection to the desired SDO server SDO response: Transmitted on that CAN line on which the SDO request was received
NMT Management Objects, NMT Error Control Protocol	Independently transmitted on both CAN lines and independently processed on both CAN lines

[2] Only if both CAN lines are set to “Operational”. Otherwise the PDO is only transmited via the “Operational” one.

6.2 The maritime CANopen device

A maritime CANopen device supporting redundant communication shall be able to operate on two independent CAN lines (CAN channels[3]) simultaneously.

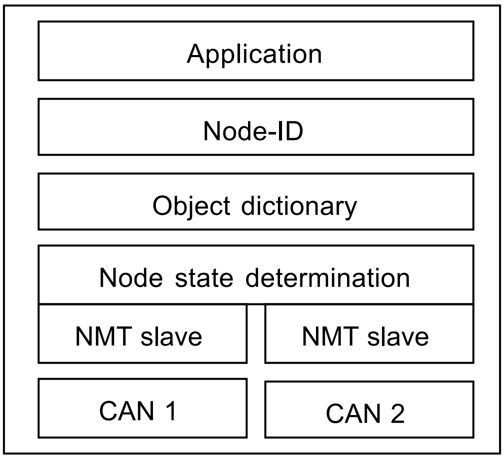


Figure 5-2: Basic software architecture of a maritime CANopen device.

This is a solution for the maritime application in order to fulfill the rules of the maritime classification societies.

The device has

- one application,
- one Node-ID[4],
- one object dictionary, and
- two independent NMT slave state machines based on a node state determination mechanism[5]

6.3 Flying NMT master and redundant communication

In order to apply the flying master principle on a redundant communication system the startup process shown in figure 5-3 has to be followed.

After power-on or reception of NMT “Reset Application” the active CAN line is first determined[6] and then the master negotiation is performed according to /CiA302/ on the active CAN line. When the device got the mastership, it starts the network on the active CAN line. After this done, it transmits the NMT “Reset Communication” command on the other CAN line in order to get a well defined starting point and starts the network on this CAN line.

Note 1: The CAN line selected for performing the master negotiation is used until the master negotiation process is completed.

Note 2: For the detection of multiple active NMT masters the “Forcing New NMT Master Negotiation” protocol according to /CiA302/ is performed on both CAN lines.

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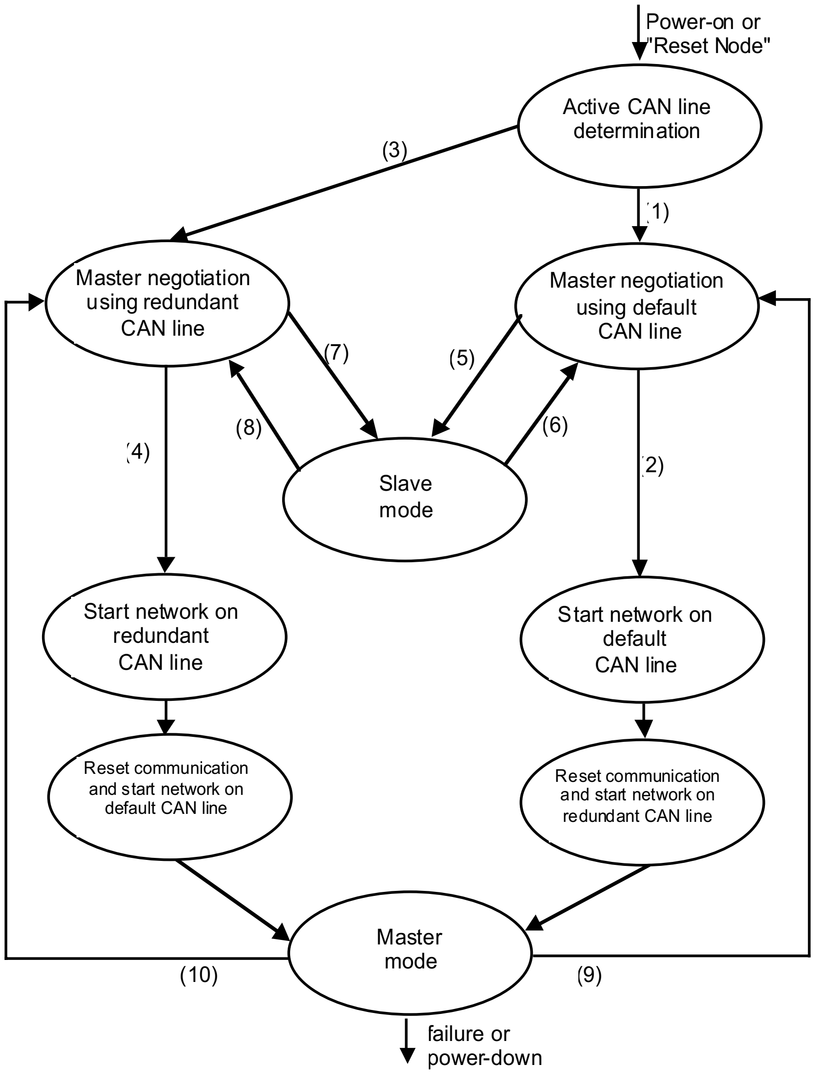
[3] CAN channel = CAN controller, CAN transmitter, CAN line, CAN receiver, CAN controller

[4] A device which is connected only to one CAN line occupies the same Node-ID on both CAN lines.
For distinction if a device is connected to both CAN lines or only to the default CAN line or the redundant CAN line, the heartbeat consumer uses the object 1016_h

[5] See 6.4.6 Network management objects

[6] Concerning the flying NMT master the active CAN line is not determined until the reception of the heartbeats of all redundant devices on the default CAN line or the expiration of the “Heartbeat Evaluation Time”



(1)	All devices, which are supporting redundant and default CAN lines function found on the default CAN line, or reception of master negotiation request on the default CAN line, or reception of reset communication command on the default CAN line
(2)	Device received mastership
(3)	Heartbeat evaluation time $1F60_h/02_h$ expired
(4)	Device received mastership
(5)[7]	Device lost master negotiation
(6)	Reception of reset communication on the default CAN line
(7)	Device lost master negotiation
(8)	Reception of reset communication on the redundant CAN line, or failure of master on both CAN lines
(9)	Reception of new master negotiation request on the default CAN line
(10)	Reception of new master negotiation request on the redundant CAN line

Figure 5-3: Flying NMT master principle on a redundant communication system (only valid for devices with default and redundant CAN line capability)

[7] Even when a node with higher priority lost mastership (caused by wrong configured timing parameters) no new master negotiation is triggered in order to avoid a deadlock situation.

6.4 CANopen communication objects and redundant communication

6.4.1 Process data objects (PDO) in redundant networks

6.4.1.1 Redundant PDO transmission[8]

In Figure 5-4 the basic principle and the associated timing parameters for the redundant transmission of PDOs are shown. Each PDO is transmitted on both transmission channels[9] (transmitting CAN controller, transmitter bus driver, CAN line, receiving bus driver, receiving CAN controller). Due to different conditions on the two communication channels, the transmission of the according PDOs will differ in time. It is assumed, that for a well designed system, the transmission of a PDO is possible within a determined time. To secure this the concept of the PDO inhibit time has been introduced in the CANopen standard. The inhibit time secures that all of the important messages can be transmitted within a guaranteed time window. A failure of a communication channel therefore can be detected, when the transmission of a PDO is delayed too long.

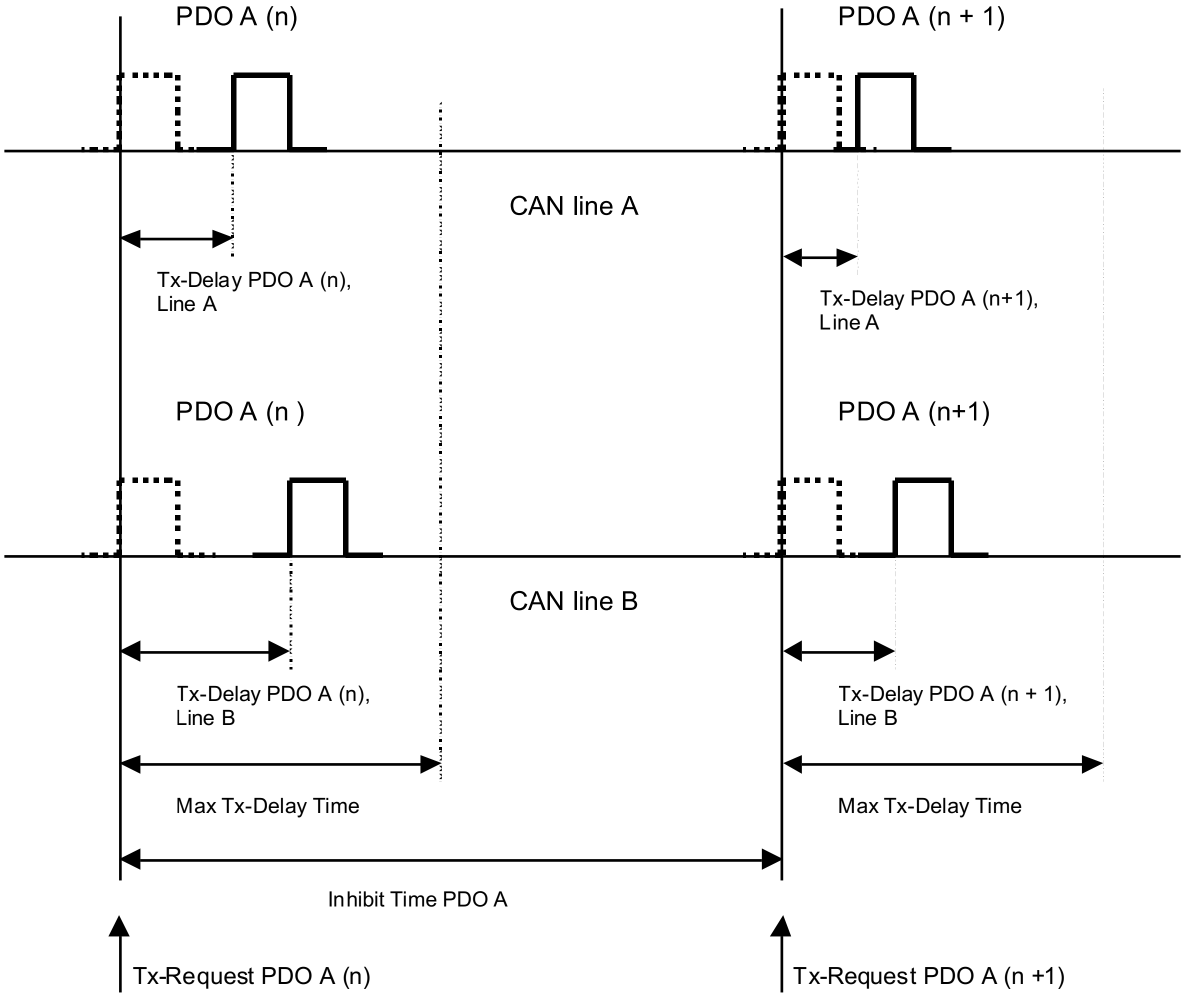


Figure 5-4: Model of redundant PDO transmission

6.4.1.1.1 Rules for redundant PDO transmission

The following rules apply for transmission of PDO in a redundant communication system:

1. For each PDO to be transmitted, transmission is requested on both channels (default and redundant) simultaneously.

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[8] This is also valid for the transmission of MPDOs

[9] Only if both CAN lines are set to “Operational”. Otherwise the PDO is only transmitted via the “Operational” one.

2. Transmission of a PDO is only allowed, if this occurs not later than a maximum delay time after a transmission request[10]. This time is given by the "Maximum Tx-Delay Time". The "Maximum Tx-Delay Time" is a system parameter ($1F60_h/01_h$), valid for any PDO in the system. The transmission delay is measured from the internal transmission request until beginning of the PDO transmission on the bus line. The "Maximum Tx-Delay Time" therefore represents the maximum possible time difference between the transmission of a PDO on both lines[11].
3. The transmission of the next instance of a specific PDO is only allowed after expiration of the PDO-specific "Inhibit Time" as specified in /CiA301/[12].
4. Each time when the transmission of a specific PDO on the **default** channel is not possible, a "Channel Error Counter" is incremented by 4 up to a maximum value defined within object "Failure Counter Threshold" ($1F60_h/04_h$). After each successful transmission of a PDO the counter is decremented by 1, but not further than to 0. If the channel error counter reaches the "Failure Counter Threshold", the node stops to send its heartbeat message on this channel and transmits the "Indicate Active CAN Line" message on the redundant CAN line. If the channel error counter reaches a value of zero again due to successful PDO transmission, this is indicated by transmitting its heartbeat message on this channel again. The channel error counter is only implemented for the default channel.

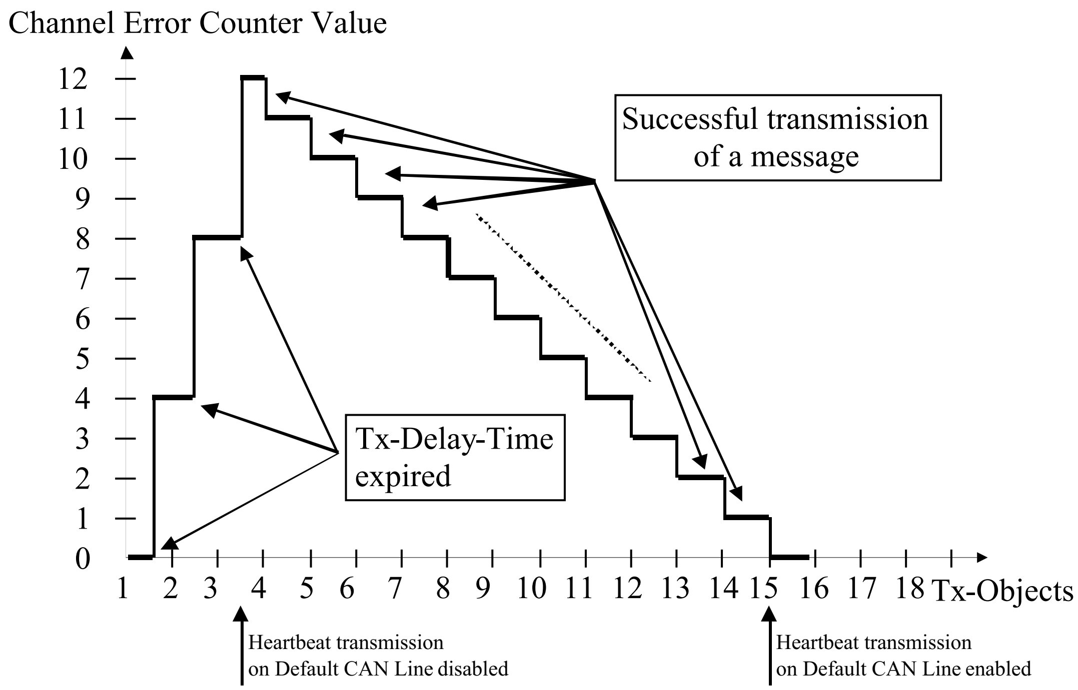

Figure 5-5: Principle of the channel error counter

5. Messages, which are crucial for the system operation have to be confirmed on the application level[13].

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[10] The allowance of a certain transmission delay time considers temporarily different transmission conditions on the two transmission channels. On the other hand, the limitation of the time delay provides a limit for the "age" of a message.

[11] This time can be monitored respectively verified on the bus lines

[12] Applying the inhibit time attribute for PDO transmission secures that no PDO transmission can monopolize the bus. Rule 2 secures that always the same instance of a specific PDO is sent within a transmission window, given by the inhibit time of this PDO. Applying an inhibit time has no influence on the reaction time for messaging of event-oriented messages. For periodically transmitted messages the inhibit time determines the "sampling rate". The value of "Max Tx Delay Time" must be smaller than the shortest inhibit time in the system. The inhibit time can be monitored respectively verified on the bus lines.

[13] For the case that both transmission channels suffer on a temporarily distortion longer than the maximum transmission delay time it is possible, that a PDO is not sent on both channels.

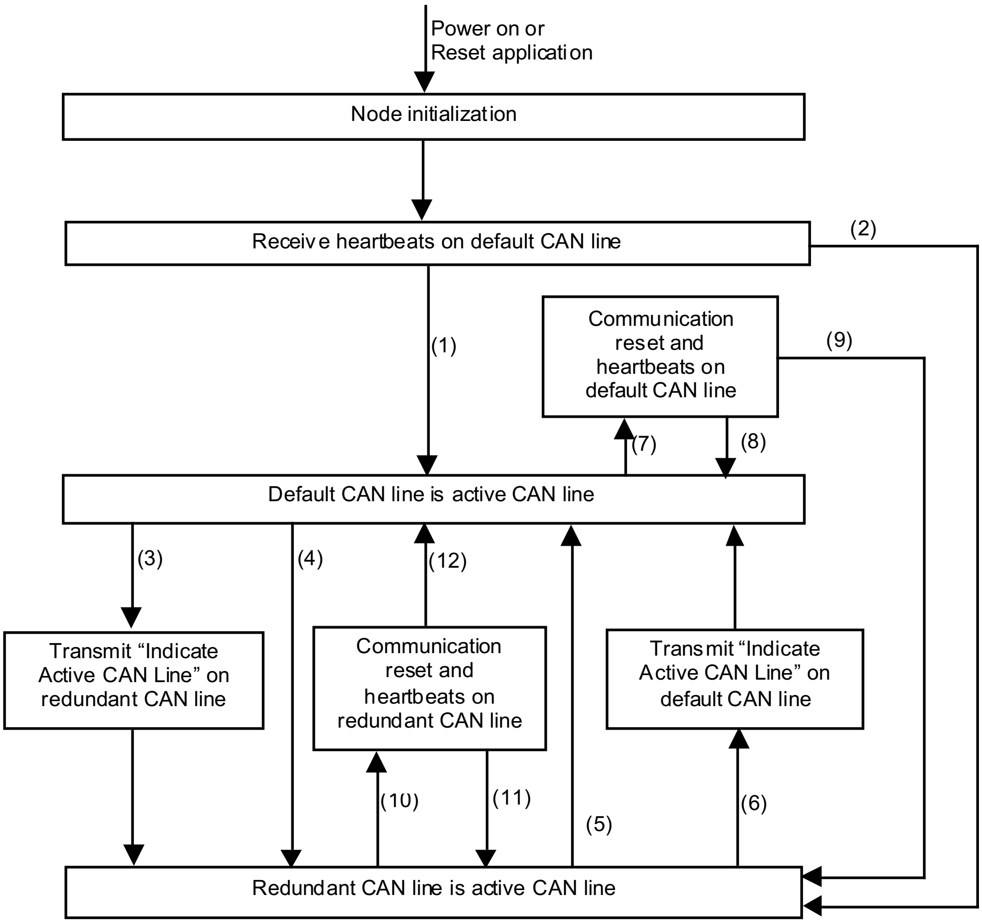
6.4.1.2 Redundant PDO reception[14]

PDOs are received via two transmission channels (default and redundant channel). It is up to the receiving node (application), how to further use the redundantly received PDOs.

6.4.1.3 Determination and indication of the active CAN Line

If a redundant device detects a missing heartbeat[15] of any other redundant device[16] on the default CAN line and the default CAN line is currently the active CAN line, it transmits the "Indicate Active CAN Line" message on the redundant CAN line. After power-on or reception of the NMT message "Reset Node" or the NMT message "Reset Communication" the node waits until the reception of the heartbeat messages of all redundant devices or until the "Heartbeat Evaluation Time after Power On or Reset Application" ($1F60_h/02_h$) respectively "Heartbeat Evaluation Time after Reset Communication" ($1F60_h/02_h$) has elapsed before it applies this mechanism.

A receiving device transmits the "Indicate Active CAN Line" message on the default CAN line after it has received at least 3 heartbeat messages of all redundant nodes on the default CAN line.



(1)	Heartbeats of all redundant devices on the default CAN line received
(2)	Heartbeat evaluation time after power-on ($1F60_h/02_h$) expired
(3)	Heartbeat of one redundant node missing on the default CAN line
(4)	Reception of "Indicate Active CAN Line" on the redundant CAN line

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[14] This is also valid for the reception of MPDOs

[15] Depending on the configured heartbeat producer and consumer time it is also possible to configure that more than one heartbeat must be missing before a heartbeat event occurs.

[16] Therefore any redundant node must be configured as a consumer of the heartbeat message of any other redundant node in the system.

(5)	Reception of "Indicate Active CAN Line" on the default CAN line
(6)	Heartbeat of all redundant nodes at least 3 times received on the default CAN line
(7)	Reception of reset communication command
(8)	Heartbeat evaluation time after reset communication $1F60_h/03_h$ expired, or Reception of all redundant devices on the default CAN line, or Reception of "Indicate Active CAN Line" on the default CAN line
(9)	Reception of "Indicate Active CAN Line" on the redundant CAN line
(10)	Reception of reset communication command
(11)	Heartbeat evaluation time after reset communication $1F60_h/03_h$ expired, or Reception of "Indicate Active CAN Line" on the redundant CAN line
(12)	Reception of "Indicate Active CAN Line" on the default CAN line

Figure 5-6: State chart of receiving node

6.4.2 Emergency messages in redundant networks

An emergency message shall be transmitted over both CAN lines in the same way as defined for redundant PDO transmission. This implies that the object "Inhibit Time EMCY" (1015_h) shall be implemented.

6.4.3 Time stamp object in redundant networks

The CANopen device processes received time stamp objects from the active CAN line. In case of a change of the active CAN line a time jitter may occur.

6.4.4 Synchronization object in redundant networks

The CANopen device processes received synchronization objects only from the active CAN line. In case of a change of the active CAN line a jitter may occur.

6.4.5 Service data objects (SDO) in redundant networks

6.4.5.1 Client SDO

A client SDO shall be transmitted only on one CAN line. The device has to decide on which CAN line the SDO request is transmitted. When more than one client SDO channels are available the selection of the CAN line can be made individually for each SDO channel.

6.4.5.2 Server SDO

The CAN node shall process a read or write access received via its server SDO channel(s) on both CAN lines. The access via one SDO channel is limited to one CAN line at the very same time. The response to a request is answered on the very same CAN line on which the request was received.

6.4.6 Network management objects in redundant networks

With reference to network management, it shall be possible to control the NMT slave node separately on each CAN line. There shall be a separate NMT slave state machine for each CAN line.

An NMT service executed on one CAN line changes only the state of the NMT slave on this line[17], the state of the NMT slave on the other CAN line remains unchanged except for the NMT service "Reset Node" which resets the complete device. After execution of this service the states of both NMT slaves of the CAN node are reset.

---

[17] As a reset communication command also resets the configured data in the object dictionary (which are identical for both CAN lines), it is necessary to store the configured data of the object dictionary in order not to affect the other CAN line when performing the reset.

As there are some mechanisms within CANopen which uses the node state of a device, Table 5-2 determines the valid NMT state for the application.

Table 5-2: Priority table of NMT node states

		State of redundant CAN line			
		Initialisation	**Pre-Operational**	**Operational**	**Stopped**
State of default CAN line	**Initialisation**	Initialisation	Pre-Operational	Operational	Stopped
	Pre-Operational	Pre-Operational	Pre-Operational	Operational	Stopped
	Operational	Operational	Operational	Operational	Stopped
	Stopped	Stopped	Stopped	Stopped	Stopped

Life guarding protocol reports the state according to the channel related NMT slave.

6.5 Indicate active CAN line protocol

This protocol (Figure 5-7) is used for indication of the new active CAN line. The indication message is send on the new active CAN line. The protocol shall be supported (transmission and reception) by all redundant devices.

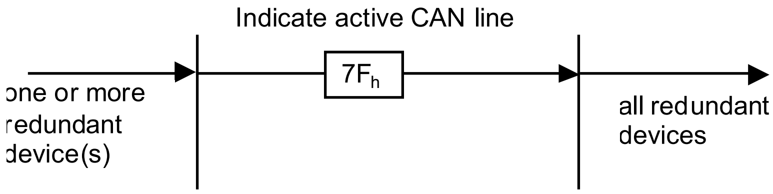

Figure 5-7: Indicate active CAN line protocol

7 SELF STARTING DEVICES

7.1 CANopen starting mechanism

The CANopen starting mechanism is defined in /CiA301/. This procedure requires one device with master capability. A system with one master is very crucial, if the master device damages.

For maritime applications there is a extension of this defined. The extension defines the usage of multiple masters with a mechanism to determine which device will become the master. This is defined in chapter 4.2.

7.1.1 Self starting devices[18]

In safety relevant devices it could be essential to have self starting devices. This is relevant for systems. The intention of this chapter is to define the procedure to start a device by its self.

Conditions:

- Use of predefined connection set or stored configuration
- Internal emulation of master functionality

Function:

It is assumed that a master is going out or is not integrated in the system.

- Start-up of the device
- Monitoring of all devices in the system
- Handling of network failures in the devices application

[18] according to /CiA302/

8 MARITIME ELECTRONICS MPDO

8.1 Introduction

Connecting intelligent maritime electronic devices to the same network induces the request to interchange configuration data (object dictionary entries). Since these devices normally are considered as NMT slaves (one default SDO server), the only SDO access to dictionary entries from different devices possible is by use of dynamic establishment of SDO connections. This mechanism is described in /CiA302/, but regarded as optional for maritime devices. Instead, the MPDO protocol (see /CiA301/) in destination address mode will be used. To meet special maritime requirements, additional agreements were made, which lead to a maritime electronics multiplexed PDO (ME MPDO). These enhancements of the generic multiplexed PDO specification are given below and have to be seen from the producers point of view.

8.1.1 ME MPDO source addressing

The maritime electronics MPDO in source address mode (SAM) is based on the mechanism described in /CiA301/ with the following enhancements:

- This kind of MPDO is mainly used to report values.
- Every device supports a maximum of 1024 channels, analogue or digital inputs or calculated variables.
- The default COB identifier corresponds to the RPDO3 of the CANopen pre-defined connection set. The binary function code is 1000 resulting in COB-IDs from 1025 (401_h) to 1151 ($47F_h$).
- The ME MPDO is event-driven (asynchronous transmission type). The event is defined as content change of the corresponding object in the object scanner list. If an event timer exists for this MPDO, the elapsed timer is considered to be an event, too.
- Objects which are mapped to this MPDO shall suffice the object dictionary entry structure shown in chapter 6.2.

8.1.2 ME MPDO destination addressing

The maritime electronics MPDO in destination address mode (DAM) is based on the mechanism described in /CiA301/ with the following enhancements:

- This kind of MPDO is mainly used to send commands.
- Every device supports a maximum of 1024 channels, analogue or digital outputs, calculated variables or programmable blocks.
- The default COB identifier corresponds to the TPDO3 of the CANopen pre-defined connection set. The binary function code is 0111 resulting in COB-IDs from 897 (381_h) to 1023 ($3FF_h$).
- The ME MPDO is event-driven (asynchronous transmission type). The event is defined by the application as well as the actual content.
- Objects which are mapped to this MPDO shall suffice the object dictionary entry structure shown in chapter 6.2.

9 APPLICATION DEFINITIONS

9.1 Data types and encoding rules

9.1.1 Data type description

The Data types used here are defined in detail in /CiA301/. For reference only, Table 1 list the data types used.

Table 1: Data types used

Name	Name	Name
NIL	INTEGER64	REAL64
BOOLEAN	UNSIGNED8	VISIBLE_STRING
VOID	UNSIGNED16	OCTET_STRING
INTEGER8	UNSIGNED32	DATE
INTEGER16	UNSIGNED64	TIME_OF_DAY
INTEGER32	REAL32	TIME_DIFFERENCE

.

9.1.2 Channel parameter record specification (Index 0080_h)

Functional data type	Sub	Name	Data type	M/O/C	Access by	Acc.	Description
Normative	0	Maximum supported sub index	UNSIGNED8	M	SDO	ro	
	1	Function code (ISA)	VISIBLE_STRING		SDO	ro	Refer to chapter 8.2.3 for details
	2-10	reserved					for possible further measurement classification
Real time data	11	Condensed value	UNSIGNED32	M	MPDO	ro	Refer to chapter 8.2.4 for details
	12	Scaled value	REAL32	M	MPDO	ro	not used if "Condensed value" is used
	13	reserved for 'Scaled value' if REAL64 is used		O	MPDO		(*)
	14	Status	UNSIGNED32	M	MPDO	ro	Refer to chapter 8.2.5
	15-16	Channel default time stamp	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	17-18	Absolute time of sampling	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	19-20	Alarm time stamp for LL alarm	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	21-22	Alarm time stamp for L alarm	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	23-24	Alarm time stamp for H alarm	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	25-26	Alarm time stamp for HH alarm	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	27-28	Alarm time stamp for GR alarm	TIME_OF_DAY	O	MPDO	ro	28 bit for ms, 4 bit reserved, 16 bit for day
	29	Locking command for time stamp request	UNSIGNED16	O	MPDO	ro	Refer to chapter 8.2.6
	30-40	reserved					for possible new real time data

Functional data type	Sub	Name	Data type	M/O/C	Access by	Acc.	Description
Static data	41	Engineering unit	UNSIGNED8	M/O	SDO MPDO	rw ro	Refer to chapter 8.2.2 for details
	42-53	Tag description	VISIBLE_STRING48	M	SDO	rw	48 ASCII characters
	54-59	Tag name	VISIBLE_STRING24	M	SDO	rw	Refer to chapter 8.2.3 for details
	60	Resolution	REAL32	O	SDO	rw	In "Scaled value" unit
	61	Input conversion scaling (gain)	REAL32	M	SDO	rw	Value = raw value * Scaling + Offset (see /CiA401/)
	62	Input conversion scaling (offset)	REAL32	M	SDO	rw	
	63-70	reserved					for possible new static data
Configuration data	83	State generating alarm for binary channel	BOOLEAN	O	SDO	rw	0 if 0 generates alarm, 1 if 1 generates alarm
	84	Appearance limit for LL alarm	REAL32	O	SDO	rw	In "value" unit different values for appearance and disappearance allow to create any value of hysteresis without any ambiguity.
	85	Appearance limit for L alarm	REAL32	O	SDO	rw	
	86	Appearance limit for H alarm	REAL32	O	SDO	rw	
	87	Appearance limit for HH alarm	REAL32	O	SDO	rw	
	88	Appearance limit for Gr alarm	REAL32	O	SDO	rw	in "Scaled value" unit per second
	89	Disappearance limit for LL alarm	REAL32	O	SDO	rw	If not existing or not transmitted, equipment will use the same value as for appearance (no hysteresis)
	90	Disappearance limit for L alarm	REAL32	O	SDO	rw	
	91	Disappearance limit for H alarm	REAL32	O	SDO	rw	
	92	Disappearance limit for HH alarm	REAL32	O	SDO	rw	
	93	Disappearance limit for GR alarm	REAL32	O	SDO	rw	

Functional data type	Sub	Name	Data type	M/O/C	Access by	Acc.	Description
Configuration data	94	Time delay at appearance and disappearance for alarm on binary channel	UNSIGNED32	O	SDO	rw	The two less significant bytes for Time delay at appearance in milliseconds (0 to 65.535), the two most significant bytes for time delay at disappearance in milliseconds (0 to 65.535).
	95	Time delay at appearance and disappearance for alarm LL	UNSIGNED32	O	SDO	rw	
	96	Time delay at appearance and disappearance for alarm L	UNSIGNED32	O	SDO	rw	
	97	Time delay at appearance and disappearance for alarm H	UNSIGNED32	O	SDO	rw	
	98	Time delay at appearance and disappearance for alarm HH	UNSIGNED32	O	SDO	rw	
	99	Time delay at appearance and disappearance for alarm GR	UNSIGNED32	O	SDO	rw	
	100-110	reserved					for possible new configuration data
	111-127	reserved					
	128-254	manufacturer specific					
Normative	255	Description of the structure of this entry	UNSIGNED32	O	SDO	ro	see /CiA301/

9.1.3 Physical unit representation

The representation of physical units shall to follow the recommendations of /CiA303-2/.

For marine purposes, some additional definitions are made. They are defined with notation indexes in the area $A0_h$ - FF_h, which is reserved for specific profiles according to the above recommendations.

Table 2 Code table for marine units

Name of unit	International symbol	Notation index
Count	-	$A0_h$
Ratio	-	$A1_h$
Text	No unit - text string	$A2_h$
Navigational distance (nautical miles - 1852 m)	nm	$A3_h$
Navigational direction (positive clockwise, north is zero)	°	$A5_h$
Latitude (-180 to +180)	°	$A6_h$
Longitude (-90 to +90)	°	$A8_h$
Linear velocity	m/s	$A9_h$
Navigational velocity (knots)	nm/h	AA_h
Angular velocity	rad/s	AB_h
Angular acceleration	rad/s^2	AC_h
Density	kg/m^3	AD_h
Mass flow	kg/s	AE_h
Heat flow	J/m^2	AF_h
Dynamic viscosity	N/m^s	$B0_h$
Kinematical viscosity	m^2/s	$B1_h$

9.1.4 Maritime function codes

These codes consist of upper case letters specifying what kind of information item this is. The code is based on a simplified version of general process equipment coding rules, according to ISA. Up to 5 letters is known to be used for such codes, but this is not according to the ISA standard.

Table 3 – Function codes

Letter	First position meaning	EU	Second position meaning
A	Angle	rad	Alarm (no indication - "binary")
B			
C	Conductivity (electrical)	Ohm or S	Control (output)
D	Density / specific gravity	kg/m^3	Documentation (data models, text: in)
E	Voltage	V	
F	Flow	m^3/s	
G	Dimensions	m	
H			
I	Current (electrical)	A	Indication (input)

Letter	First position meaning	EU	Second position meaning
J	Power	kW	
K	Time	s	
L	Level	m	HMI related data (input)
M	Moisture or humidity	%	Maintenance / calibration data / history (in)
N			
O			
P	Pressure	Bar	Parameter (filter, trend: in or out)
Q	Quantity, event or counter		
R			Record / trend (input)
S	Speed or frequency	Hz, m/s, knots, RPM	System status codes (in or out)
T	Temperature	°C	
U	Function block (composite)		Multifunction (in or out)
V	Viscosity		Version / revision codes (input)
W	Weight or force	kg or N	
X	Any meaning		Any meaning
Y	System level		
Z	Position	m or nm	

The first character defines the type of data entity pointed to by the tag. Of special interest are:

- **U**: This code is used for composite data entities (function blocks).
- **X**: This code is used for entities not otherwise defined.
- **Y**: This code is used for entities relating to monitoring and alarm device itself.

The second character specifies if the entity is an output or input and if it is related directly to a physical state (alarm, indication or control) or if it is related to more system oriented information (HMI, documentation, version codes etc.).

A complex function block with several inputs and/or outputs would normally be coded as '**UX**'.

9.1.5 TAG names

In maritime automation, channels are assigned a tag name. Ship yards have proprietary rules for assigning such names, and maintain systems to ensure unique tag-names to channels of the complete ship. This is done as a kind of interface specification towards all parties engaged in building, maintenance, servicing and operation of the ship, and is highly necessary and useful.

Likewise, for an Integrated ship-wide alarm, monitoring and Control System (ICS), unified channel tag-name definitions are most beneficial, for much the same reasons; interface between all the vendors delivering parts of such systems and/or being connected together by data lines, CAN or others.

The state of the art in this field is that each vendor has his own proprietary tag name system, identical from delivery to delivery. For integration of these systems into an ICS on a particular vessel, several comprehensive ad-hoc cross references has to be made in order to achieve seamless data communication.

The standard /IEC61162-420/ set rules for such tag-name definitions, and these definitions is recommended for use, but are not mandatory. A closer description of this can be found in chapter 10. As more and more vendors take this naming system into use, work related to connectivity between on-board-systems will be reduced, for all parties engaged.

The alternative is to use vendor proprietary tag names for all systems.

9.2 Object dictionary

9.2.1 Object 1016_h: Extension to consumer heartbeat time

In order to distinguish as a heartbeat consumer, if a heartbeat producing device is a single CAN line device and connected to the default or redundant CAN line or if the heartbeat producing device is a redundant device which is connected to both CAN lines the following flags are added within object 1016_h, bit position 24 and 25.

31 26	25 24	23 16	15 0
reserved	see below	Node-ID (see /CiA301/)	Heartbeat time (see /CiA301/)
MSB			LSB

Bit 25	Bit 24	Heartbeat producer connected to	
		Redundant CAN line	**Default CAN line**
0	0	NO	YES
0	1	YES	NO
1	0	YES	YES
1	1	reserved	reserved

9.2.2 Object $1F60_h$: Redundancy configuration parameters

OBJECT DESCRIPTION

INDEX	$1F60_h$
Name	Redundancy configuration parameters
Object code	ARRAY
Data type	UNSIGNED8
Category	Conditional; Mandatory for redundant devices

ENTRY DESCRIPTION

Sub index	0_h
Description	Number of entries
Entry category	Mandatory
Access	ro
PDO mapping	No
Value range	4
Default Value	4

Sub index	1_h
Description	Maximum Tx delay time
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED8
Default value	20 (ms)

Sub index	2_h
Description	Heartbeat evaluation time after power-on or reset application
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED8
Default value	60 (seconds)

Sub index	3_h
Description	Heartbeat evaluation time after reset communication
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED8
Default value	10 (seconds)

Sub index	4h
Description	Channel error counter threshold
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED8
Default value	12

Sub index	5h
Description	Channel error counter value
Entry category	Mandatory
Access	ro
PDO mapping	No
Value range	UNSIGNED8
Default value	No

9.2.3 Object 1F90$_h$: Flying master timing parameters

OBJECT DESCRIPTION

INDEX	1F90$_h$
Name	Flying master timing parameters
Object code	ARRAY
Data type	UNSIGNED16
Category	Conditional; Mandatory for devices supporting the flying master mechanism

ENTRY DESCRIPTION

Sub-index	0$_h$
Description	Number of entries
Entry category	Mandatory
Access	ro
PDO mapping	No
Value range	6
Default value	6

Sub-index	1$_h$
Description	Timeout for detection of an active NMT master
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	100 (ms)

Sub-index	2_h
Description	NMT master negotiation time delay
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	500 (ms)

Sub-index	3_h
Description	Master priority level
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	0h-2h
Default value	No

Sub-index	4_h
Description	Priority time slot
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	1500 (ms)

Sub-index	5_h
Description	Node time slot
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	10 (ms)

Sub-index	6_h
Description	Multiple master detect cycle time
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	4000 + Node-ID * 10 (ms)

9.2.4 Object 1F91$_h$: Start-up capable device timing parameters

OBJECT DESCRIPTION

INDEX	1F91$_h$
Name	Start-up capable device timing parameters
Object code	ARRAY
Data type	UNSIGNED16
Category	Conditional; Mandatory for start-up capable devices

ENTRY DESCRIPTION

Sub-index	0$_h$
Description	Number of entries
Entry category	Mandatory
Access	ro
PDO mapping	No
Value range	3
Default value	3

Sub-index	1$_h$
Description	Timeout for detection of an NMT master capable device
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	100 (ms)

Sub-index	2$_h$
Description	Delay time for an NMT master capable device request
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	500 (ms)

Sub-index	3_h
Description	Node time slot
Entry category	Mandatory
Access	rw
PDO mapping	No
Value range	UNSIGNED16
Default value	15 (ms)

Application note: The timing values are calculated for a system running at 125 kbit/s. For other baud rates the devices have to be configured with appropriate time values.

10 RECOMMENDED TAG NAMES

10.1 General

This chapter is related to the upcoming standard /IEC61162-420/, concerned with communication protocols for ship-wide integration of systems. This protocol is not foreseen to be used for „field-bus“-type applications, like the CANopen for maritime applications.

The IEC standard contain however definitions for standardization of tag names. This enable different vendors on a common CAN line to communicate easier, reducing work of integration..

The standard tag names are recommended for use in this CIA standard, however not mandatory.

The text in chapter 10.2 below is based on /IEC 61162-420/, and is included here for reference only. Whenever this standard is used, the latest version of the finished standard /IEC61162-420/ may be used. The IEC standard contain references to and description of more types of tag names, denominated p-, y-, s- and i-tags, for different purposes. The tag structures referenced below is the p-type, tags conformant with the Pisces Companion Standard (PCS) as described in /IEC61162-420/. This „p“ is used as a prefix to the tag name in /IEC61162-420/, which is omitted in this standard.

The text in chapter 10.2.9 regarding codes of other sub-group is solely on behalf of CiA.

10.2 Tag names according to /IEC61162-420/

10.2.1 Internal and external representation

Note that the tag name has to be encoded in a fixed number of characters and, due to protocol requirements, adhere to a fixed structure. These rules apply only to the protocol and internal representation may use other formats, e.g., more compact to save storage or search times. It may also be useful to format the tag name differently for presentation to humans, although this may cause problems with recognition of the same tag name on different systems.

10.2.2 Tag name length

The tag name is limited to 23 characters maximum. Shorter tag names shall be null terminated.

10.2.3 Character set

All standard tag names shall only use upper case letters (‘A’ to ‘Z’ inclusive), lower case letters (‘a’ to ‘z’ inclusive) or decimal numbers (‘0’ to ‘9’ inclusive). In addition, the special character dash (‘-‘), under score (‘_’) or period (‘.’) can be used.

Character in this context is the type char8_m.

10.2.4 General tag name structure

All tag names shall have a structure as described below:

10.2.4.1 Introduction

The tag name is structured according to the rules presented in this clause. The name body will be divided into groups, each consisting of a defined number of upper case characters followed by from zero to any number of decimal numbers. The name is structured so that it can be parsed by a regular expression.

10.2.4.2 General structural rules

10.2.4.2.1 Outline structure

MGnn.SGnn.TC.nn

MG	- Main group (two letters)
nn	- Optional main group instance number
SG	- Sub group (two letters)
nn	- Optional sub group instance number
TC	- Data type code (two letters)
nn	- Unique serial number

Each group of the tag is delimited by a period (full stop). The main group and the sub group may have an instance number immediately following.

10.2.4.3 Tag name length and encoding

The maximum length of 23 characters allows group and sub-groups of up to three digits and a serial number of up to eight digits. It is possible to compress this in an internal representation by omitting dots.

Special coding with more than three digits group numbers can be used for certain tag types, e.g., container or other modular cargo. However, the total length shall not exceed maximum name length.

10.2.4.4 Group and sub-group number structure

The group and sub group number shall be a decimal number, without leading zeros. In cases where there are only one instance of the indicated group on board (e.g., only one main engine), the instance number shall be omitted.

10.2.4.5 Serial number structure

The serial number will normally be a manufacturer dependent serial number intended to distinguish between otherwise identical tag names. For some types of tags (e.g., contain related identifiers), the serial number may contain structural information.

10.2.4.6 Uniqueness of name

The tag name shall be unique over the ship, although this is more difficult to ensure.

The main group codes shall be unique. The general sub-group codes are unique among sub-groups (achieved by assigning special first letters to these groups).

Other sub-group codes shall be unique among the main groups in which it is used.

10.2.5 Main group codes

The main group code consists of two upper case letters optionally followed by a decimal number. The below table lists the currently defined codes.

Table 4 - Main group codes

Main group	Number	Description
MP	Engine	Propulsion engines
MG	Engine	Generator and auxiliary engines
ML		Lubrication oil systems
MC		Cooling systems, fresh and / or salt water

Main group	Number	Description
MB		Boiler
MD	Shaft	Drive train, i.e, shafts, gears, clutches, propellers
MF		Fuel oil systems
MM		Miscellaneous machinery
CB	Tank	Ballast system
CL	Tank	Liquid cargo tanks
CH	Hold	Bulk cargo
CR		Reefer related entities, cooling (except CH groups)
CM	Deck	Modular cargo on decks (e.g., RO-RO)
CC	Hold	Container cargo
CO		Other/general cargo
SH		Ship data (name, captain, yard)
HU		Hull related data
HF		HVAC, climate control, provisions, waste, sanitary
NA		Navigation (position, speed, ARPA, ECDIS etc.)
EV		Environment (wind, waves, weather)
FA	Central	Fire and gas alarm
SY		System / sub-system (monitoring and alarm system itself)
OT		Other / miscellaneous

The number column specifies what the number code, if used, shall indicate. The number field shall not be used if there is only one instance of the device (e.g., main machinery) on board.

Note that machinery and cargo and ballast main-groups form two super-groups. These super-groups use the same first character ('M' and 'C' respectively).

10.2.6 Sub-groups

The second group consists of two upper case letters that defines a sub-group for the main group. The sub-groups are divided into three classes dependent on whether they are used anywhere on the ship (general sub-groups), whether they are used within one super-group (e.g., machinery or cargo) or if they are specific to one single main group. The sub-group code can be followed by a number as for the main code.

10.2.7 General sub-groups

The following table contains the currently defined sub-groups that are in general use over more than one main group. All codes use 'X', 'Y' or 'Z' as first character. These characters are reserved for these groups.

Table 5 - General sub-groups

Sub-group	Number	Description
ZZ		No specific sub-group
XP		Pump
XV		Valve

Sub-group	Number	Description
XE		Electrical motor
XT		Tank
XM		Manifold
XL		Pipe-line, tube
XC		Compressor
XS		System / Sub-system (network, monitoring system itself)
XH		Heat exchanger

Numbering will normally be dependent on the main group in use.

10.2.8 Navigation sub-groups

The following table identifies navigation related sub-groups.

Table 6 - Navigation sub-groups

Sub-group	Number	Description	Main process codes
GP		GNS receiver	NA
LC		Loran C/Chaicka receiver	NA
AR		ARPA Radar	NA
EC		ECDIS/ECS	NA

10.2.9 Other sub-groups

The /IEC61162-420/ is limited to navigational definitions. Thus its does not cover general automation This chapter provide definitions of machinery automation, and is solely on behalf of CiA.

10.2.9.1 Machinery automation sub-group

Table 7 identifies machinery automation related sub-groups. It contains the currently defined sub-groups This encompass all systems serving the prime mover, inclusive of electric power generation.

Table 7 Machinery automation sub-groups

Sub-group	Number	Description
EX		Exhaust gas cylinders
EG		Exhaust gas system
SS		Scavenging air system
TC		Turbocharger System
MI		Mean cylinder pressure
PC		Piston cooling
CL		Cylinder lubrication
CB		Crankshaft bearings
TB		Thrust bearings
FI		Fuel oil injection system

Sub-group	Number	Description
FS		Fuel oil system
FT		Fuel oil transfer system
FO		Fuel oil treatment system
LS		Lubrication oil system
LT		Lubrication oil transfer system
LO		Lubrication oil treatment system
SW		Sea water cooling system
FC		Fresh water cooling
FW		Fresh water system
SA		Start air system
HA		High pressure air system
CA		Compressed air system
BS		Boiler steam system
BC		Boiler condensate system
BO		Boiler system
ES		Evaporator system
PB		Propeller shaft bearing
PT		Propeller Shaft Thrust bearing
PS		Propeller system
SG		Steering gear system
RB		Reduction gear bearing
RS		Reduction gear system
CS		Clutch system
GE		Electricity generators
SB		Switch board

10.2.10 Data type indication group

The third group is two upper case letters specifying what kind of information item this is. The code is based on a simplified version of general process equipment coding rules, and is further described in chapter 9.1.4.