INTERNATIONAL STANDARD

ISO 11898-4

First edition
2004-08-01

Road vehicles — Controller area network (CAN) —

Part 4: **Time-triggered communication**

Véhicules routiers — Gestionnaire de réseau de communication (CAN) —

Partie 4: Déclenchement temporel des communications

Reference number
ISO 11898-4:2004(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11898-4 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

ISO 11898 consists of the following parts, under the general title *Road vehicles — Controller area network (CAN)*:

— *Part 1: Data link layer and physical signalling*

— *Part 2: High-speed medium access unit*

— *Part 3: Low-speed fault-tolerant, medium dependent interface*

— *Part 4: Time-triggered communication*

Introduction

In the classic CAN network, communication is event-triggered; peak loads can occur when the transmission of several messages is requested at the same time. The non-destructive arbitration mechanism of CAN guarantees the sequential transmission of all messages according to their identifier priority. For hard real-time systems, a scheduling analysis of the entire system is done to ensure that all transmission deadlines are met even at peak bus loads.

Some real-time operating systems (RTOS) are based on static cyclic scheduling of all tasks in the application system (control unit). They build a schedule of time slots and place each task in at least one slot. Tasks of high priority appear in more than one slot. All activity in one slot, including interrupt handling, must be completed before the beginning of the next slot.

If such an RTOS is considered for a distributed application system consisting of control units linked by a CAN network, system integration and composability are served when the communication on the CAN network also follows a synchronised schedule.

The time-triggered communication option for CAN-based networks (see ISO 11898-1) gives the prerequisites for the synchronisation of all nodes in the CAN network. When the nodes are synchronised, any message may be transmitted at a specific time slot, without competing with other messages for the bus. Thus the loss of arbitration is avoided; the latency time becomes predictable.

Road vehicles — Controller area network (CAN) —

Part 4: Time-triggered communication

1 Scope

This part of ISO 11898 specifies time-triggered communication in the controller area network (CAN): a serial communication protocol that supports distributed real-time control and multiplexing for use within road vehicles. It is applicable to setting up a time-triggered interchange of digital information between electronic control units (ECU) of road vehicles equipped with CAN, and specifies the frame synchronisation entity that coordinates the operation of both logical link and media access controls in accordance with ISO 11898-1, to provide the time-triggered communication schedule.

NOTE Time-triggered CAN is a higher level protocol layer additional to the CAN protocol itself, which remains unchanged within the time-triggered communication. Time-triggered communication keeps the latency time of each message at a specified value independent of the CAN bus load. Time-triggered CAN is implemented on two levels: Level 1 is restricted to the cyclic message transfer, while Level 2, in addition, supports a global system time. Time-triggered CAN's cyclic, periodical communication is based on reference messages transmitted by a time master. Each period starting with a reference message is called a basic cycle and is subdivided into several time windows. The reference messages are used to synchronise and calibrate the time bases of all nodes to the time master's time base, providing a global time for the network. A mechanism is provided for alternative time masters to substitute for a failing time master.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11898-1, *Road vehicles — Controller area network (CAN) — Part 1: Data link layer and physical signalling*

ISO 11898-2, *Road vehicles — Controller area network (CAN) — Part 2: High-speed medium access unit*

ISO 11898-3, *Road vehicles — Controller area network (CAN) — Part 3: Low-speed fault-tolerant, medium dependant interface*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11898-1, ISO 11898-2 and ISO 11898-3, and the following apply.

NOTE Parameter terms (Cycle_Time, Cycle_Count, etc.) are given as proper nouns, connected by an underscore where the parameter consists of two or more words.

3.1
application watchdog
entity which verifies that the application is operating properly

3.2
arbitrating time window
time window assigned to messages that share the same time window

3.3
basic cycle
row of the system matrix of several consecutive time windows

3.4
Cycle_Time
difference between the local time of an FSE and its Ref_Mark

3.5
Cycle_Count
number of the current basic cycle of the matrix cycle

3.6
Cycle_Count_Max
value of Cycle_Count of the last basic cycle in the given system matrix of the network

3.7
Cycle_Offset
parameter specifying, within a matrix cycle, the first basic cycle for which an Rx_Trigger or Tx_Trigger is valid

3.8
Disc_Bit
part of the reference message signalling a discontinuity in global time caused by an external clock correction by the time master

3.9
error severity
levels of distinguished severity of an error

3.10
exclusive time window
time window assigned to a specific message transmitted periodically without competition for the CAN bus

3.11
Expected_Tx_Trigger
local parameter which specifies, for each FSE, the number of Tx_Triggers the FSE is expected to activate between two starts of a matrix cycle

3.12
Frame_Synchronisation
pulse, generated in each FSE and for each data frame and remote frame in the CAN network at the sample point of start of frame (SOF) bit, synchronous in the whole network, disregarding signal propagation times, and with an optionally added time offset referencing to the sync_segment of the SOF-Bit, to compensate for variations of bit timing configuration in the system

3.13
frame synchronisation entity
FSE
part coordinating the operation of logical link control and media access control

NOTE Each CAN controller in a time-triggered CAN network has its own FSE.

3.14
free time window
time window free of messages scheduled in the system matrix

3.15
global time
node view of the global time of the current time master

3.16
Global_Ref_Mark
parameter saved on successful reception of a reference message

3.17
Global_Sync_Mark
current value of the node view of global time, saved at the pulse of Frame_Synchronisation

3.18
Init_Watch_Trigger
value of the maximum of cycle time

3.19
Initial_Ref_Offset
initialisation value that loads the Ref_Trigger_Offset

3.20
level
level of implementation of time-triggered CAN in accordance with this part of ISO 11898

NOTE There are two levels, Level 1 and Level 2, with Level 2 an extension of Level 1.

3.21
local time
time generated by a cyclic incrementing counter

3.22
Local_Offset
difference between Global_Ref_Mark and Ref_Mark, saved at each successful completion of the reference message

3.23
master state
vector which combines the FSE states referring to error, synchronisation and master-slave relation, i.e. a triplet (error level, sync_mode, master-slave_mode)

3.24
Master_Ref_Mark
MRM
parameter transmitted by the time master in the reference message

3.25
matrix cycle
cycle of all basic cycles in the system matrix, consecutive from the first to the last basic cycle

NOTE The matrix cycle is the same as the basic cycle if the system matrix consists of one basic cycle only.

3.26
merged arbitrating time window
single window into which consecutive arbitrating time windows are merged

3.27
message object
buffer providing storage of an LLC frame together with control and status information

3.28
message status count
MSC
error counter providing means for detecting scheduling errors for messages sent in exclusive time windows

3.29
network time unit
NTU
unit measuring all times and providing a constant of the whole network

3.30
network view
system aspect of network parameter

3.31
node view
local aspect of network parameter

3.32
node view of global time
integer part of the sum of local time of the node and its Local_Offset

3.33
potential time master
frame synchronisation entity that is allowed to send a reference message by system configuration

3.34
Ref_Mark
parameter saved on each successful completion of the reference message

3.35
Ref_Trigger_Offset
parameter used to modify the time mark within a Tx_Ref_Trigger such that it sends a reference message

3.36
reference message
message (data frame) that starts a basic cycle

3.37
Repeat_Factor
parameter specifying the repetition rate of a message within a transmission column, being a part of Tx_Trigger or Rx_Trigger parameters

NOTE The unit of the repetition rate is “rows in the system matrix”.

3.38
Rx_Trigger
parameter that specifies when the successful reception of a message will be verified

3.39
Sync_Mark
current value of the local time saved at the pulse of Frame_Synchronisation

3.40
system matrix
form containing all messages of all nodes in the network, organised as components and consisting of time windows organised in basic cycles (rows of the matrix) and transmission columns (columns of the matrix)

NOTE The system matrix specifies the correlation between messages and time windows (type and time mark). The first basic cycle in the system matrix starts with Cycle_Count 0.

3.41
time gap
time between the end of a basic cycle and the beginning of the next basic cycle, when the beginning of the next basic cycle is synchronised to an event

3.42
time mark
mark within a frame synchronisation entity specifying an instant of Cycle_Time (in NTUs) at which a certain action is expected or planned

3.43
time master
frame synchronisation entity sending the reference message

3.44
time window
amount of time allocated for a specific transmission column in the system matrix

3.45
transmission column
column of the system matrix whose elements correlate to a particular time window repeated in each basic cycle

NOTE Transmission rows are the basic cycles of the system matrix.

3.46
time unit ratio
TUR
ratio between the length of a NTU and the length of the FSE specific basic time unit (e.g. local oscillator period) used for clock synchronisation

NOTE TUR is, in principle, a non-integer number. The node view of a NTU is implemented by the value of TUR.

3.47
Tx_Count
counter that is reset at each start of a matrix cycle, i.e. after identification of the corresponding reference message with Cycle_Count equal to zero

3.48
Tx_Enable
time period within which the transmission of a message may be started

3.49
Tx_Overflow
status flag set when more Tx_Triggers occur than specified by Expected_Tx_Trigger

3.50
Tx_Ref_Trigger
special Tx_Trigger parameter referring only to the triggering of reference messages

3.51
Tx_Trigger
parameter specifying when a certain message will be transmitted and which consists of a time mark, the position within the transmission column in respect of the first sending (Cycle_Offset) and the repetition rate (Repeat_Factor) within that transmission column, and a reference to a message object for which the Tx_Trigger is valid

NOTE The Tx_Trigger also contains information about the window type (exclusive, arbitrating, merged).

3.52
Tx_Underflow
status flag set when less Tx_Triggers occur than specified by Expected_Tx_Trigger

3.53
Watch_Trigger
time mark used to check whether the time since the last valid reference message has been too long

4 Abbreviated terms

CAN	controller area network
FSE	frame synchronisation entity
LLC	logical link control
LSB	least significant bit
MAC	medium access control
MSB	most significant bit
SOF	start of frame

5 Basic concepts of time-triggered CAN

5.1 General conventions

For the purposes of this part of ISO 11898, the following conventions apply.

Application watchdog: regularly served by the Host_Alive_Sign parameter.

Arbitrating time window conflicts are resolved by the identifier arbitration of CAN and a CAN node may not start transmission if the bus is not idle. Several CAN nodes in the network may start a transmission within the Tx_Enable window of an arbitrating time window. The immediate automatic retransmission is disabled. Exception: merging of time windows.

Basic cycle elements are several consecutive time windows. The number and length of the different time windows is specified off-line and is the same for the whole network. Each basic cycle of the system matrix consists of the same sequence of time windows, starting with the time window for the reference message.

Cycle_Time is truncated to the most significant 16 bits of the difference between the local time of a FSE and its Ref_Mark, Cycle_Time = most significant 16 bits of (Local_Time – Ref_Mark).

Cycle_Count starts counting at zero.

Cycle_Offset is part of a Tx_Trigger or Rx_Trigger parameter.

Error severity: no error (S0), warning (S1), error (S2), and severe error (S3).

Expected_Tx_Trigger: when Tx_Count reaches Expected_Tx_Trigger, all further Tx_Triggers of this FSE in the current matrix cycle are disabled.

FSE handles the transmission or reception of the time reference messages and provides a status and control interface to the application layer.

Free time windows are reserved for future extensions of the network.

Global_Sync_Mark (Level 2 only) is saved at the pulse of Frame_Synchronisation. This value contains the 16-bit integer part as well as the fractional part of the sum (local time + local offset).

Init_Watch_Trigger has the value of 2^{16}–1, the maximum of cycle time.

Local time is generated with a width of 16 bit in Level 1 and at least 19 bit in Level 2. All but the 16 most significant bits in Level 2 give fractional parts of a NTU. The incrementation procedure of local time shall guarantee that the non-fractional part is incremented once each local equivalent of NTU.

EXAMPLE If the fractional part uses 3 bits, local time is incremented eight times in Level 2, each increment being the local equivalent of NTU/8.

Inside a **merged arbitrating time window**, the retransmission for frames that lost arbitration or were disturbed by an error is enabled.

NTU is a constant of the whole network:

— in Level 1, NTU is the nominal CAN bit time;

— in Level 2, NTU is a fraction of the physical second.

Node view of global time is the integer part of the sum of local time of the node and its Local_Offset. The fractional part is used for clock synchronisation only. Hence the node view of the global time is the local image of the global time in (local) NTUs. It shall be possible to provide the node view of the global time as a continuous monotonic value to the application.

Ref_Mark: at each successful completion of the reference message, the current Sync_Mark becomes Ref_Mark.

Rx_Trigger: the necessary information for an Rx_Trigger consists of a time mark (point of time after which the reception of the corresponding message is expected to be completed), the position within the transmission column in respect to the first reception (Cycle_Offset) and the repetition rate (Repeat_Factor) within that transmission column, and, of course, a reference to a message object for which the Rx_Trigger is valid. Several Rx_Triggers may be specified for the same message. Rx_Triggers are intended for messages sent in exclusive time windows only.

Time window: the three types of time window are *exclusive*, *arbitrating* and *free*.

TUR (Level 2 only) is used for clock synchronisation.

Tx_Count: each time a Tx_Trigger becomes active, Tx_Count is incremented. Tx_Count is not incremented beyond Expected_Tx_Trigger.

Tx_Enable is opened with Tx_Trigger and closed after a predefined number of nominal CAN bit times specified by the system configuration.

Watch_Trigger parameter value depends on the mode of operation (event synchronised or time-triggered) of Time-triggered CAN.