



Automobiles - Clock Extension Peripheral Interface (CXPI)

-Part 3: Protocol specification

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FOREWORD

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There are following part in the JASO D015.

JASO D015-1 Part1 : General Information and Use Cases Definition

JASO D015-2 Part2 : Transport Protocol and Network Layer Service Specification (to be issued)

JASO D015-3 Part3 : Protocol Specification

JASO D015-4 Part4 : Application Program Interface (API) Specification (to be issued)

JASO D015-5 Part5 : Protocol Conformance Test Specification

Automobiles — Clock Extension Peripheral Interface (CXPI) - Part3: Protocol specification

INTRODUCTION

The objective of this standard "Clock Extension Peripheral Interface" (abbreviation: CXPI) communication protocol is to define a specification which enables the arbitration without destructing even if the protocol sends the PWM (Pulse Width Modulation) waveform which is superimposed the data and clock on communication bus and also the multiple peripherals send the UART (Universal Asynchronous Receiver Transmitter) at the same time.

1 SCOPE

This standard defines the CXPI communication protocol for mainly HMI (Human Machine Interface) of road vehicles electric system.

2 REFERENCES

The following standard s contain sections which, through reference in this text, constitute sections of this standard. For dated references, it shall apply the version but not the revised version (including the supplemental version). For the undated references, the latest edition of the normative document referred to applies(including the supplemental version).

- JIS X 0001:** 1994 Glossary of terms used in information processing - Fundamental terms
- JIS X 0005:** 2002 Glossary of terms used in information processing (Representation of data)
- JIS X 0009:** 1997 Glossary of terms used in information processing (Data communication)
- JIS X 0025:** 1994 Glossary of terms used in information processing (Local area networks)
- JIS X 0026:** 1995 Glossary of terms used in information processing (Open Systems Interconnection)

ISO 11898-1, Road vehicles - Controller area network (CAN) - Part1: Data link layer and physical signalling

3 TERMS AND DEFINITIONS

For the purposes of this standard, the following terms and definitions, other than those given in **JIS X 0001**, **JIS X 0005**, **JIS X 0009**, **JIS X 0025** and **JIS X 0026** apply.

3.1

controller

Portion which contols processing of a data link layer

3.2

IFS

Becoming less crowded of the communication bus among frames.

3.3

master node

Only one node in a system having function of schedule management and a primary clock master.

3.4

clock master

Node that transmits clock to communication bus

3.5

primary clock master

Node that becomes clock master usually

3.6

secondary clock master

Node that has function to transmit clock instead when primary clock master doesn't transmit clock

3.7

slave node

Each node other than master node connected with system

3.8

schedule

Information specifying which frame is transmitted to which timing that becomes the origin of periodic transmission

3.9

sequence

Procedure of transmission and reception of the data among two or more nodes

3.10

idle state

The existence of the frame is not recognized on the communication bus. Only the clock exists, and it is possible to transmit frames.

3.11

PTYPE field

Abbreviation of Protected TYPE field. It includes the parity bit of "1 bit" and the frame TYPE of "7 bit".

3.12

PID field

Abbreviation of Protected ID field. It includes the parity bit of "1 bit" and the frame ID of "7 bit".

3.13

nominal baud rate

The baud rate within the protocol specification range, and target value of baud rate actually used.

3.14

operational state

Supported wakeup/ sleep; in the state of normal mode, Non-supported wakeup/ sleep; in the state of power-on

3.15

Wakeup pulse

A signal which is used for wake other node up. It consists two of dominant level.

4 SYMBOLS AND ABBREVIATED TERMS

4.1 Symbols

kbit/s	Kilobit per second
T_{bit}	Nominal bit time
$T_{\text{bit_ref}}$	Bit time of nominal baud rate
$T_{\text{check_clock}}$	Judgment time for the Clock existence
$T_{\text{clock_start_m}}$	Time that the master node transmits the clock on the CXPI bus at the latest
$T_{\text{clock_stop_m}}$	Time that the master node stops to transmit the clock after master node receives the sleep frame
TH_{dom}	Dominant threshold voltage of the received node
TH_{rec}	Recessive threshold voltage of the received node
$T_{\text{physical_bus_error}}$	Judgment time of the physical bus error
$T_{\text{sleep_s}}$	Time that each Slave node transits to sleep mode after the node receives the sleep frame
$T_{\text{wakeup_m}}$	Minimum time that master node starts the transmission of any PID field or PTYPE field first for the wakeup sequence
$T_{\text{wakeup_recovery_s}}$	Time that slave node starts the transmission of the second wakeup pulse after transmits the first wakeup pulse
$T_{\text{wakeup_s}}$	Maximum time until the slave node wakes up by the wakeup sequence
$T_{\text{wakeup_schedule_m}}$	Maximum time until master node starts the transmission of any PID field or PTYPE field first for the wakeup sequence
V/ μ s	Voltage per microsecond
V_{BUS}	Voltage of communication bus

4.2 Abbreviated Terms

AP	Application Layer
CSMA	Carrier Sense Multiple Access
CD	Collision Detection
CRC	Cyclic Redundancy Check
CT	Counter
DLC	Data Length Code
DLL	Data Link Layer
ECU	Electronic Control Unit
HI	High
IBS	Inter Byte Space
ID	Identifier
IFS	Inter Frame Space
ind	Indicator
LO	Low
LSB	Least Significant Bit
MSB	Most Significant Bit
NRZ	Non Return to Zero

NM	Network Management
OP	Option
OSI	Open Systems Interconnection
PID	Protected ID
PL	Physical Layer
PTYPE	Protected TYPE
PWM	Pulse Width Modulation
RX	Receive (data)
RXD	RXD pin of the Transceiver
TH	Threshold
TX	Transmit (data)
TXD	TXD pin of the Transceiver
UART	Universal Asynchronous Receiver Transmitter

5. PROTOCOL SPECIFICATION

5.1 Features

5.1.1 Overview

This communication has the following features:

- a) Carrier Sense Multiple Access (CSMA) is adopted.
- b) Collision Detection (CD) is adopted.
- c) Operation that combines the master/slave schedule method and CSMA/CD method is done, and in the periodic request and response based on the schedule, the frame corresponding to the event can be transmitted.
- d) The data with clock is transmitted and received on a single communication bus.
- e) The clock master provides the clock to the communication bus, and the slave node communicates with this clock.
- f) Maximum baud rate of 20kbit/s
- g) Two kinds (the method to value the responsivity to the event and the method to value the periodicity of the communication) can be selected. Either is selected at the system design.

5.1.2 Frame Transmission

The frame consists of the PID field and the response field, and the node that corresponds to frame ID described in the PID field can transmit the response field.

5.1.3 Access Method

In this communication protocol, the following two methods can be selected. Only the part where the protocol is different is described dividing into method 1 and method 2. If not otherwise described, method 1 and method 2 share common protocol.

5.1.3.1 Method 1: Event Trigger Method

Each node can freely transmit the frame by finding idle state of the bus.

5.1.3.2 Method 2: Polling Method

The slave node transmits the response only when the master node transmits the request. When the PTYPE field that shows the event request is received from the master node, each node can be transmitted a frame by the nondestructive arbitration method.

5.1.4 Clock Sharing

In this communication, only one clock master exists in the system. The clock master always transmits the clock on the communication bus. The slave node receives the clock from the communication bus and can use it for communication processing. When each slave node in the system uses this clock, the communication clock in the system can be synchronized.

5.1.5 Node Information

In this communication, system information (e.g. node address) is not used to communicate. Instead, the need of data is judged per each node, and either receiving or not receiving of the frame is chosen at each node.

5.1.6 Data Request

In this communication, the node that corresponds to the received frame ID transmits the response. As a result, each node transmits own frame ID when it wants to transmit, and transmits the frame ID of another node when there is a data which it wants another node to transmit.

5.1.7 Error Detection

The method of detecting the error is as follows.

- a) Bit error
- b) CRC error
- c) Parity error
- d) Physical bus error
- e) Data length error
- f) Counter error (OP)
- g) Overrun error
- h) Framing error

5.1.8 Confinement on Errors

The node corresponding to the event transmission prevents a continued destruction of the signal on the communication bus by an error of transmission by stopping the event transmission when an error of transmission continues.

5.1.9 Wakeup/Sleep (OP)

To decrease power consumption of the system, transmitting and receiving the data of each node can be started or stopped. After the master node confirms the sleep prohibition of each slave node, it directs the stop of transmission and reception of the data. The restart of transmitting or receiving of the data is achieved by putting a trigger by each node.

5.2 OSI Layer Structure

This communication is composed of three layers of the OSI model.

- a) Application layer (AP)
- b) Data link layer (DLL)
- c) Physical layer (PL)

The structure and the function of layer are as **Table 1**.

Table 1 - CXPI layer structure

Application layer
Frame transfer management Wakeup/ Sleep Assign frame ID
Data link layer
Management of retransmission Transmission processing Reception processing
Physical layer
Encoding Decoding Switching; selecting processing or non-processing of PWM encoding/ decoding Clock synchronization Clock output

5.3 Application Layer

5.3.1 Overview

Application layer section provides for the following items.

- a) Frame transfer management
- b) Wakeup/ Sleep
- c) Assign frame ID

5.3.2 Frame Transfer Management

In this communication, there are two access methods of the following. Select and perform either one of them according to the requirement for the system.

Method 1: Event trigger method

Method 2: Polling method

In this communication, the frame is composed of the request and the response. The request specifies frame ID of the data that should respond, and the node corresponding to the frame ID that specified by the request transfers the corresponding data. At this time, when the data of own node is transmitted, the frame ID corresponding to the data of own node can be specified, and the response can also be transmitted by the same node.

Figure 1 is a request and response example. The node A, the node B and the node C has the data corresponding to frame ID A, frame ID B and frame ID C, respectively. Node A transmits frame ID B to the communication bus as a request. Corresponding node B transmits response B. Then, node C transmits frame ID C as a request. Node C continuously transmits response C immediately. Thus, the request is enforceable for both another node and own node.

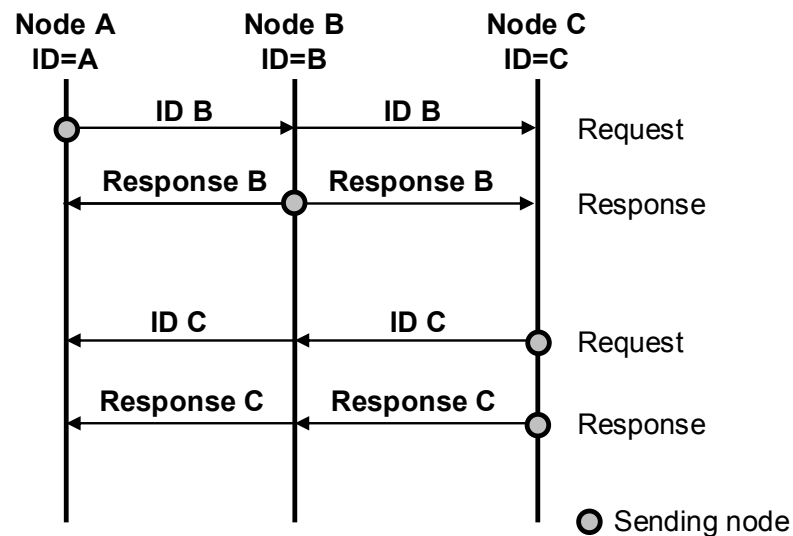


Figure 1 - Example of request and response

5.3.2.1 Method 1: Event Trigger Method

When idle state of the communication bus is detected, each node may transmit PID field. If a number of nodes transmit PID field at the same time and PID field collides on the communication bus, it is arbitrated with nondestructive, and higher-priority PID field is transmitted to the communication bus. Based on the schedule the master node can request each slave node to transmit response. At this time, if PID field that is transmitted by the master node periodically collided with PID field that is transmitted by each node, arbitration is done according to the priority of PID field. Though there is possibility that the periodicity of the communication of method 1 is easier to be impaired compared with the that of method 2 polling method, method 1 may be selected to raise the responsivity to the event.

Figure 2 shows the example of the sequence. The node A transmits the request frame ID B after it detected the communication bus is idle state, then node B corresponding to request frame ID B transmits the response frame B and then an event occurs on node B and node C. Next, the request frame ID B of the node B and the request frame ID C of the node C are transmitted at the same time when the communication bus became idle state, and the collision occurs. The request frame ID C of the node C is transmitted as a result of arbitration, and node C corresponding to the request frame ID C retransmits the response. Node B transmits the request frame ID B according to timing at which the communication bus becomes idle state.

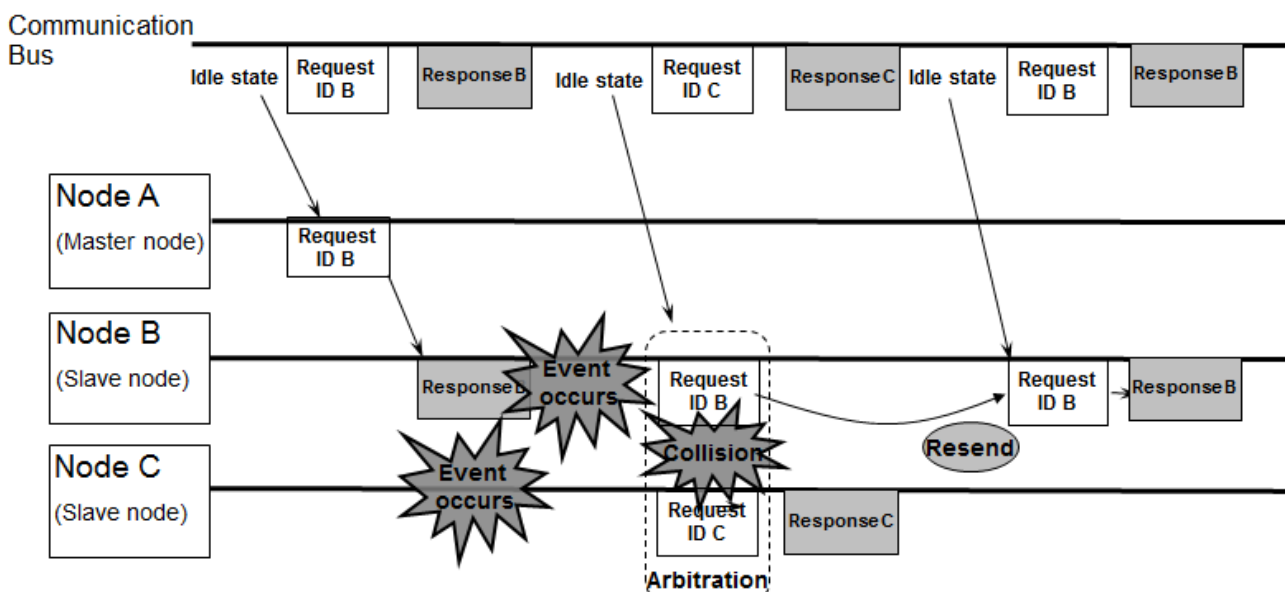


Figure 2 - Sequence of event trigger method

5.3.2.2 Method 2: Polling Method

There are two kinds of requests that the master node transmits about PID field and PTYPE field. When the master node transmits PID field to the communication bus, the node corresponding to frame ID can transmit the response field. When the master node transmits PTYPE field to the communication bus, each node can transmit PID field. At this time, when a number of nodes transmit PID field at the same time and PID field collided on the communication bus, it is nondestructive arbitration and higher-priority PID field is transmitted to the communication bus. The node corresponding to frame ID transmits the response field. If necessary the slave node can respond only when it received PID field or PTYPE field from the master node, and it cannot be transmitted voluntarily even when the communication bus is idle state. Though the responsivity to the event is lower compared with the method 1 event trigger method, method 2 may be adopted to ensure the periodicity of the communication.

Figure 3 shows the example of the sequence. After the node A detected the communication bus is idle state the request frame ID B is transmitted based on the schedule, and node B corresponding to request frame ID B transmits the response frame B and then node B and node C occur the event. Next, the PTYPE field is transmitted by the node A. Then the node B and the node C which have occurred event transmit request frame ID to a communication bus simultaneously. Though the collision occurs, as a result of arbitration, request frame ID C of the node C is transmitted and node C corresponding to request frame ID C transmits the response. Next, the node C transmits the response so that the node A transmits frame ID B or PTYPE field. The node B that the event occurred cannot respond until it receives the request frame ID B or PTYPE field.

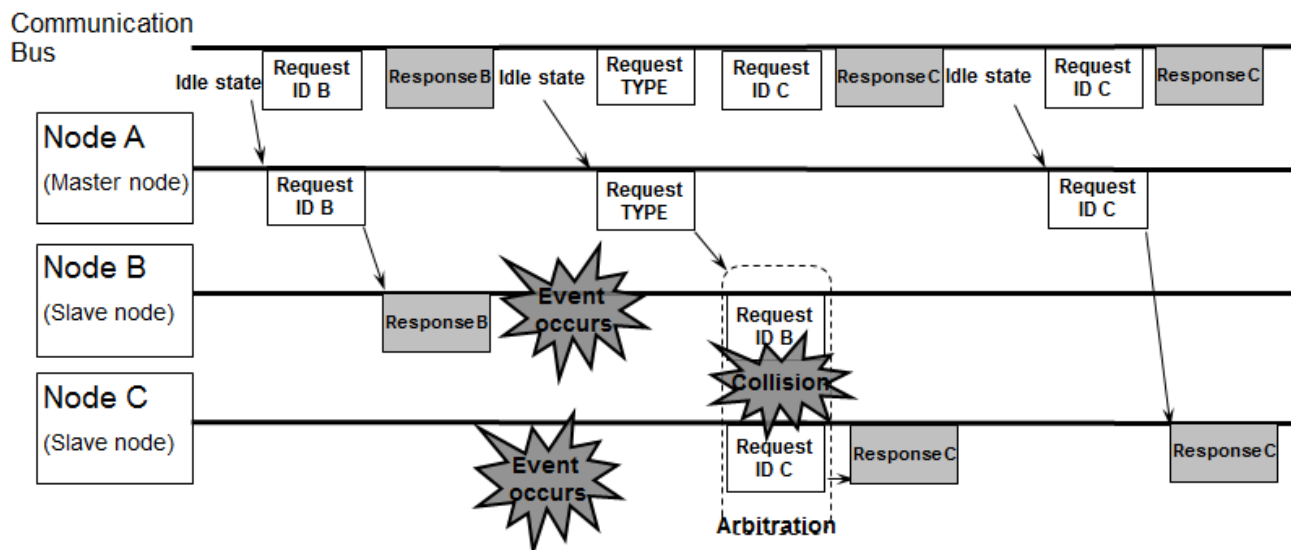


Figure 3 - Sequence of polling method

5.3.3 Wakeup/ Sleep (OP)

This section describes the wakeup/ sleep function that can transit to the sleep mode of power saving to control the power consumption of the node that the power supply is supplied permanently. Whether to use this function to each system can be selected. For instance, in the system to which the power supply is supplied only when necessary, it can choose not to install the wakeup/ sleep function.

5.3.3.1 Mode Management

The mode which manages the state of wakeup/ sleep for each node is shown in **Figure 4**. The state that should be managed has the following three modes.

- Sleep mode
- Standby mode
- Normal mode

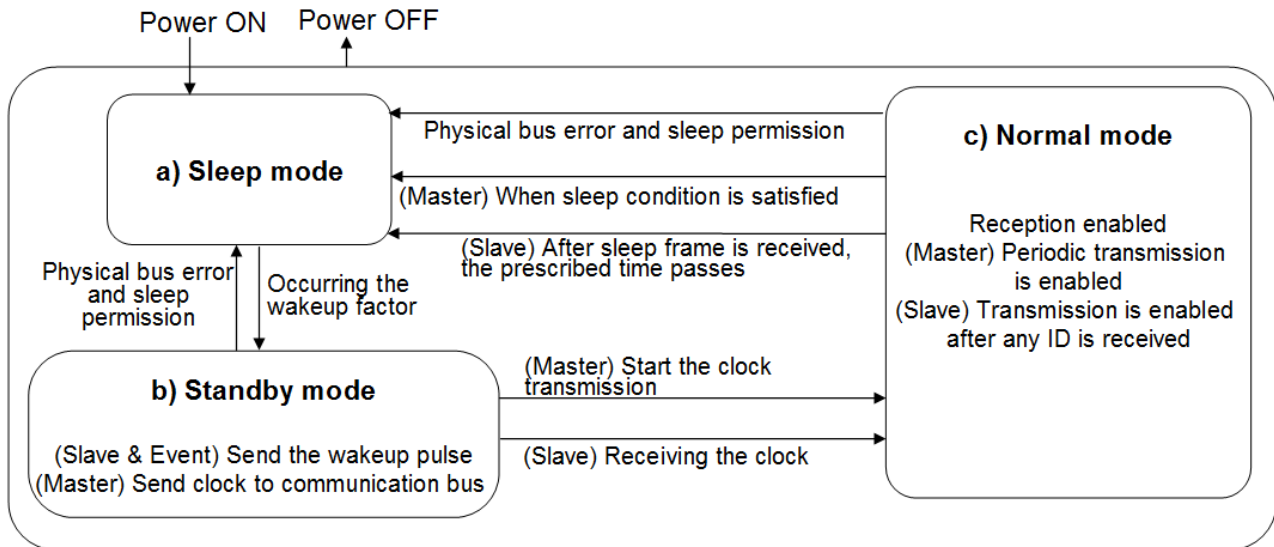


Figure 4 - Mode management

5.3.3.1.1 Sleep mode

The sleep mode denotes the state of the power saving to which each node stopped transmitting and receiving of data. All nodes transit to sleep mode after power-on. Other than immediately after power-on, they also transit to sleep mode after the sleep processing was executed from the normal mode and transit from standby mode or normal mode due to the physical bus error. During the sleep mode, when each node receives the wakeup factor, it transits to the standby mode. The wakeup factor is described per the system and is composed of the internal factor (e.g. detecting that the switch was pushed) and the external factor that receives the wakeup pulse from the communication bus. During the sleep mode, the reception signal is received without decoding.

5.3.3.1.2 Standby mode

The standby mode denotes the state of standing by the transition to the normal mode. Transition to standby mode can be achieved only from sleep mode. If the master node in the standby mode starts transmitting the clock to the communication bus, it transits to the normal mode. If the slave node in the standby mode and the node to which the event of the internal factor occurred, it transmits the wakeup pulse to the communication bus, and then when it received the clock transmitted by the master node to the communication bus, it transits to the normal mode. If the clock is not received, the slave node can resend wakeup pulse. If the slave node in the standby mode and the node to which the event of the internal factor has not occurred, when it received the clock transmitted by the master node to the communication bus, it transits to the normal mode. During the standby mode, the signal is transmitted to the communication bus without encoding state and the signal is received from the communication bus without decoding.

5.3.3.1.3 Normal mode

5.3.3.1.3.1 Method 1 : Event Trigger Method

The normal mode denotes the state to which the communication is possible. Transition to normal mode can be achieved only from standby mode. After the master node transits to the normal mode, it can begin a periodical transmission. After receiving any PID field that the master node transmits, the slave node can transmit data. **Table 2** shows the condition that the transmission of data becomes possible and executable processing. During the normal mode, the master node transmits the sleep frame to the communication bus after the sleep condition is satisfied, and transits to the sleep mode after stopping the clock transmission. After the slave node received the sleep frame from the master node it transits to the sleep mode after the prescribed time passes. During the normal mode the signal that is transmitted is encoded and the signal that is received is decoded.

Table 2 - Condition that transmission of data of the Slave node becomes possible

Condition	It receives any PID field from the communication bus, and there is no error.	When the communication bus became idle state.
Executable processing	Transmission of response field that corresponds to frame ID.	Transmission of PID field.

5.3.3.1.3.2 Method 2: Polling Method

The normal mode denotes the state to which the communication is possible. Transition to normal mode can be achieved only from standby mode. After the master node transits to the normal mode, it can begin a periodical transmission. After receiving any PID field or PTYPE field that the master node transmits, the slave node can transmit data. **Table 3** shows the condition that the transmission of data becomes possible and executable processing. During the normal mode, the master node transmits the sleep frame to the communication bus after the sleep condition is satisfied, and transits to the sleep mode after stopping the clock transmission. After the slave node received the sleep frame from the master node, it transits to the sleep mode after the prescribed time passes. During the normal mode the signal that is transmitted is encoded and the signal that is received is decoded.

Table 3 - Condition that transmission of data of the Slave node becomes possible

Condition	It receives any PID field from the communication bus, and there is no error.	It receives any PTYPE field from the communication bus, and there is no error.
Executable processing	Transmission of response field that corresponds to frame ID.	Transmission of PID field after the PTYPE field that master node transmitted.

5.3.3.2 Wakeup/ Sleep Sequence

This section describes the sequence of the following wakeup/ sleep respectively. Furthermore the time to appear in each sequence is listed in **Table 4**.

- a) Sleep sequence
- b) Wakeup sequence of master node trigger
- c) Wakeup sequence of slave node trigger
- d) Wakeup pulse retransmission sequence

Table 4 - Wakeup/ Sleep sequence parameter

Signal name	Starting point	Ending point		unit
		min.	max.	
$T_{\text{clock_stop_m}}$	Sleep frame reception ^(e)	0	30	T_{bit}
$T_{\text{sleep_s}}$	Sleep frame reception	25	50	ms
$T_{\text{wakeup_s}}^{(b)}$	Wakeup pulse reception ^(a)	-	50	ms
$T_{\text{wakeup_m}}$	Wakeup pulse reception ^(a)	70	-	ms
$T_{\text{wakeup_schedule_m}}$	Wakeup pulse reception ^(a)	-	100	ms
$T_{\text{clock_start_m}}^{(b)}$	Wakeup pulse reception ^(a)	-	50	ms
$T_{\text{wakeup_recovery_s}}^{(c)}$	Wakeup pulse transmission	60	250	ms
$T_{\text{check_clock}}^{(d)}$	Supported for wakeup/ sleep: at the time of transition from sleep mode Non-support for wakeup/ sleep: at the time of power-on	$2 \cdot T_{\text{wakeup_recovery_s}}$	$T_{\text{physical_bus_error}}$	—
$T_{\text{physical_bus_error}}$	Refer to the section 5.4.9.4			—

Note: The signal name “*_m” is a parameter only for the master node, and “*_s” is a parameter only for the slave node.

^(a) Clock is one of the wakeup pulse too.

^(b) It is less than the time which master node starts the transmission of the first PTYPE field or PID field.
(< $T_{\text{wakeup_m}}$)

^(c) It is longer than the time which master node starts the transmission of clock. (> $T_{\text{clock_start_m}}$)

^(d) It is after the time which primary clock master shall transmit the clock, and before the time which secondary clock master transits to sleep mode due to the physical bus error.

^(e) In case of that master node cannot transmit the sleep frame to the communication bus due to error, starting point is when master node detects error.

5.3.3.2.1 Sleep Sequence

When all the sleep conditions of **Table 5** are satisfied, the master node can transmit the sleep frame. The slave node prepares for sleep when it receives the sleep frame, then transits to the sleep mode when the prescribed time passes. (Refer to **Figure 5**.)

Table 5 - Condition of transmission of Sleep frame of Master node

Sleep condition	- It does not receive the frame of sleep prohibition (sleep.ind=0) from any nodes for a certain period. - Master node corresponds to the sleep condition described by the system requirement.
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After receiving the sleep frame, master node stops the clock at $T_{\text{clock_stop_m}}$ time. When master node cannot transmit the sleep frame to the communication bus due to error, master node stops the clock at $T_{\text{clock_stop_m}}$ time after detecting error. The sleep frame is described at data link layer specification. After receiving the sleep frame, the slave node transits to the sleep mode at $T_{\text{sleep_s}}$ time.

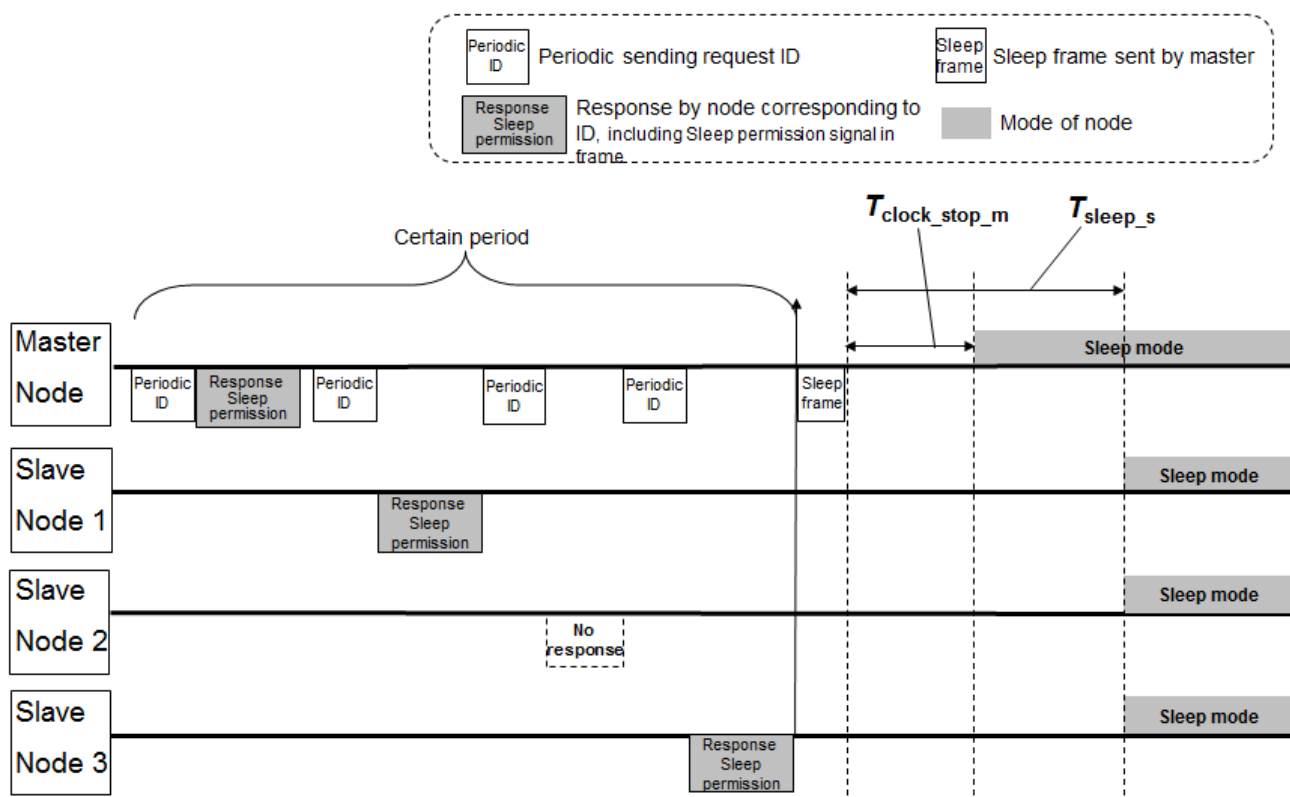


Figure 5 - Sleep sequence

5.3.3.2.2.1 Method 1: Event Trigger Method

This section describes processing of wakeup a

Figure 6.) After detecting the event of an internal factor at sleep mode, the master node transmits the clock to the communication bus. The slave node transits to standby mode within $T_{\text{wakeup_s}}$ time by putting a trigger the clock which the master node transmitted, then receives the clock and transits to normal mode. The master node starts transmitting any PID field which $T_{\text{wakeup_m}}$ time or more to $T_{\text{wakeup_schedule_m}}$ time or less, and the slave node can transmit to the communication bus at timing of confirmation of the receiving of the first PID field that the periodical master node transmits.

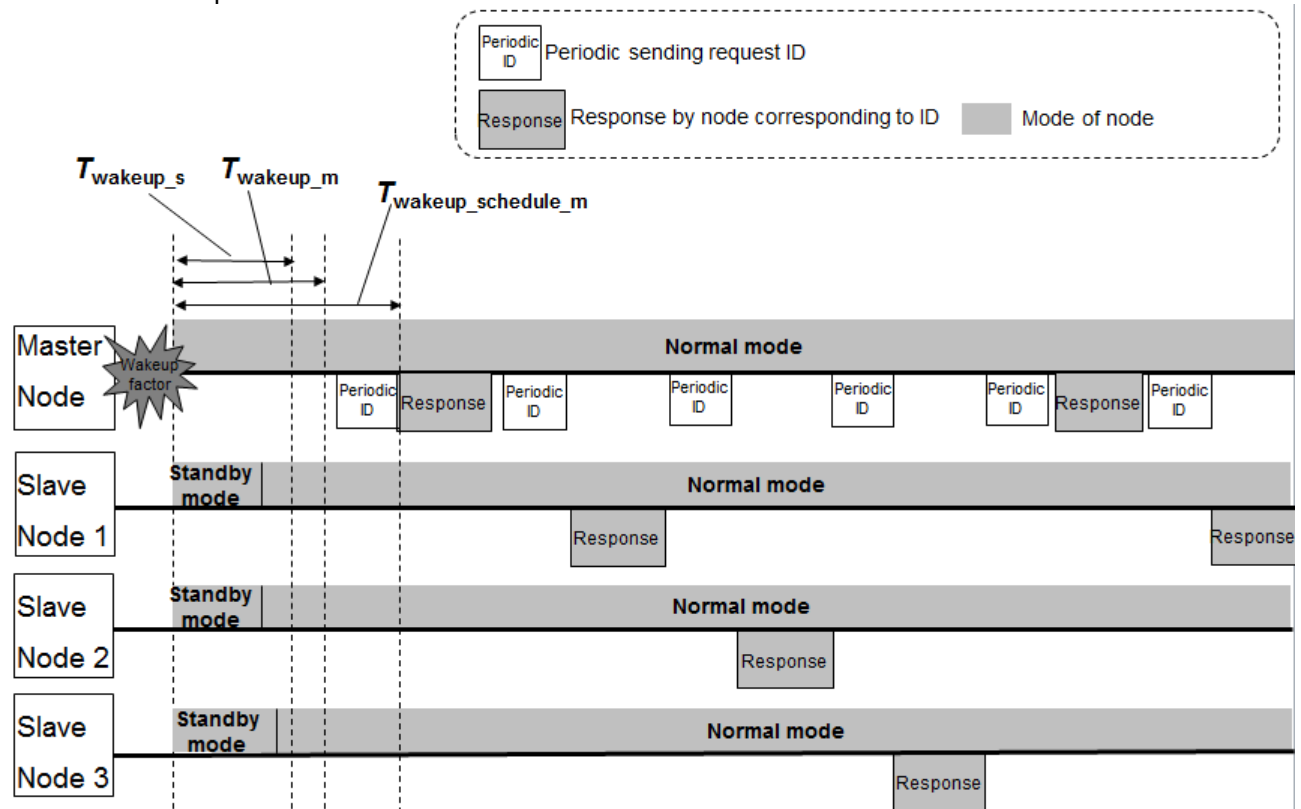
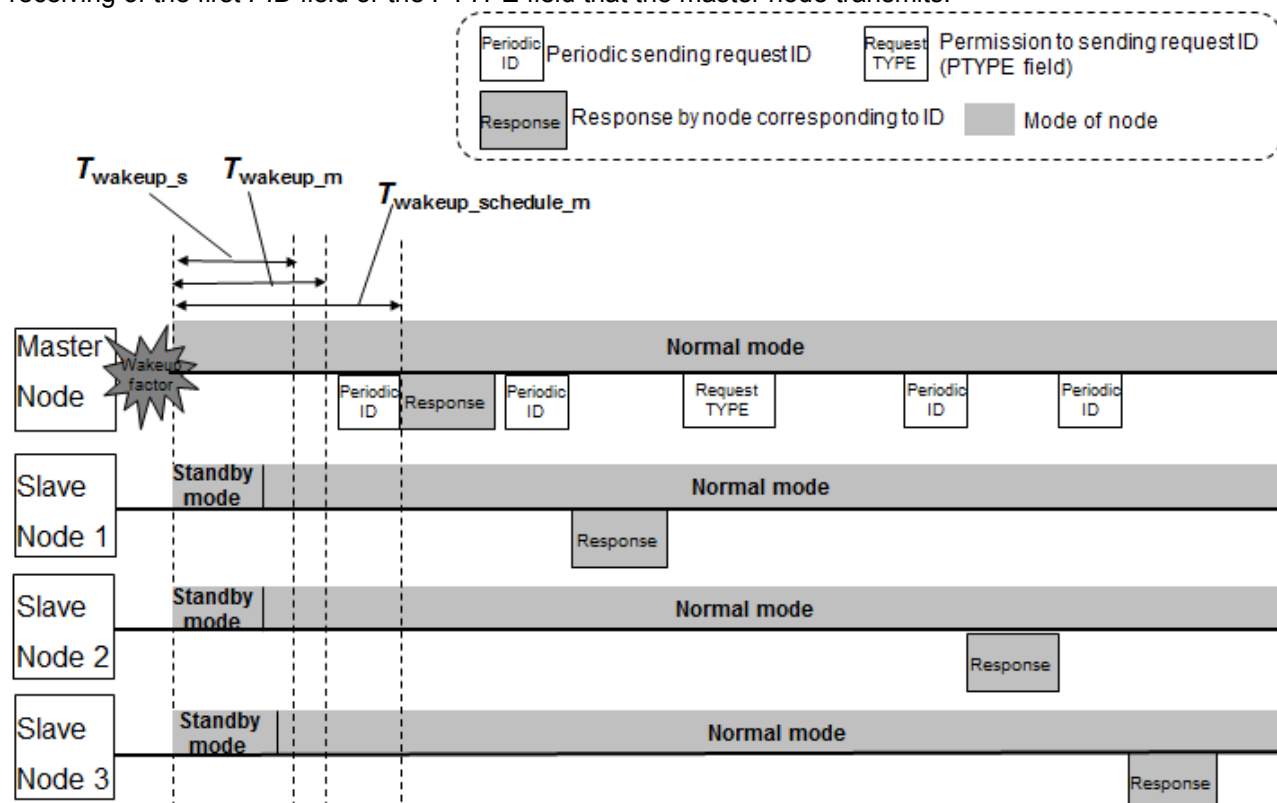


Figure 6 - Wakeup sequence of Master node trigger

5.3.3.2.2 Method 2: Polling Method

This section describes processing of wakeup according to an internal factor of the master node. (Refer to **Figure 7**.) After detecting the event of an internal factor at sleep mode, the master node transmits the clock to the communication bus. The slave node transits to standby mode within T_{wakeup_s} time by putting a trigger the clock which the master node transmitted, then receives the clock and transits to normal mode. The master node starts transmitting any PID field or PTYPE field which T_{wakeup_m} time or more to $T_{wakeup_schedule_m}$ time or less, and the slave node can transmit to the communication bus at timing of confirmation of the receiving of the first PID field or the PTYPE field that the master node transmits.



5.3.3.2.3 Wakeup Sequence of Slave Node Trigger

5.3.3.2.3.1 Method 1: Event Trigger Method

This section describes processing of wakeup according to an internal factor of the slave node. (Refer to **Figure 8**.) After detecting the wakeup event of an internal factor, the slave node transmits the wakeup pulse to the communication bus. After receiving the wakeup pulse, the master node transmits the clock to the communication bus within $T_{\text{clock_start_m}}$ time. After receiving the wakeup pulse, each slave node transits to standby mode within $T_{\text{wakeup_s}}$ time, then receives the clock and transits to normal mode. The master node starts transmitting any PID field during which $T_{\text{wakeup_m}}$ time or more to $T_{\text{wakeup_schedule_m}}$ time or less, and the slave node can transmit to the communication bus at timing of confirmation of the receiving of the first PID field that the master node transmits. The wakeup pulse is described at the physical layer section.

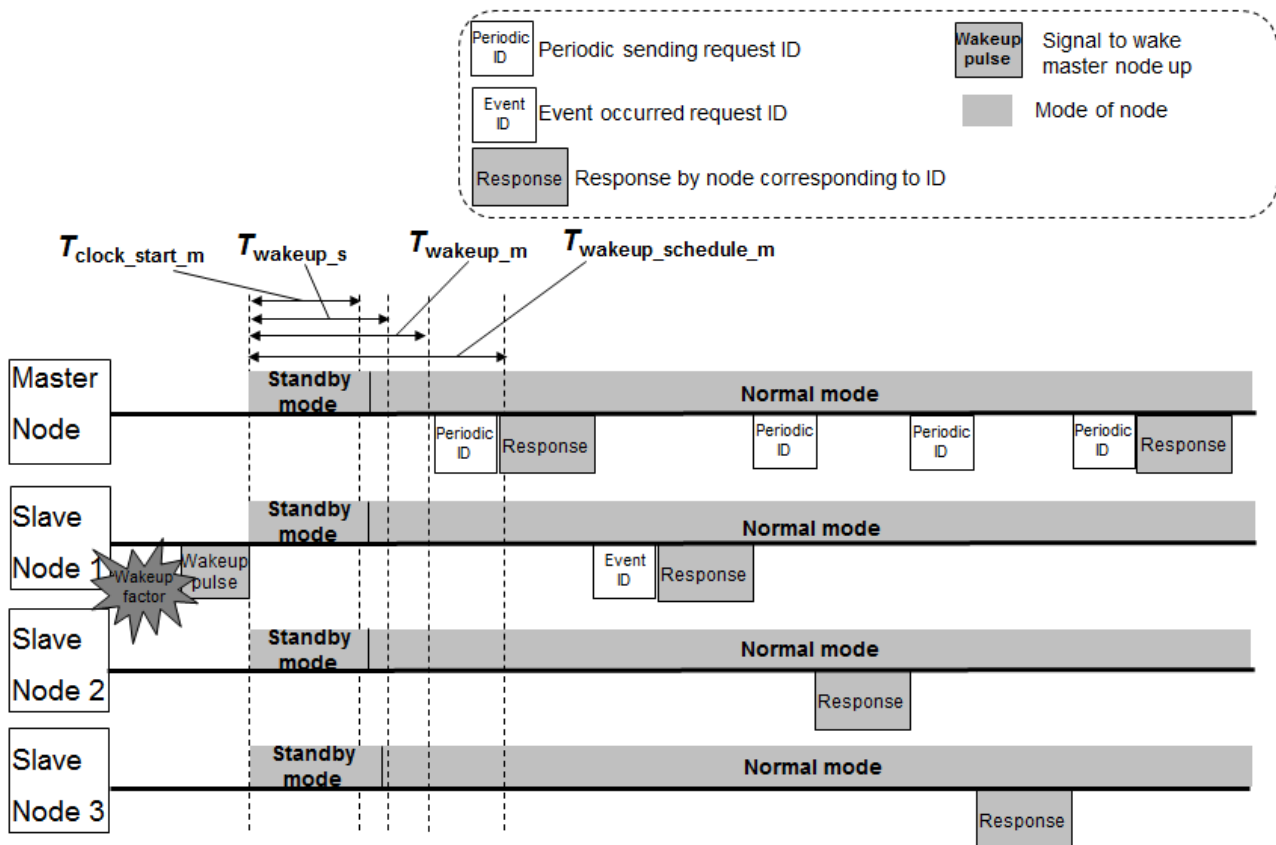


Figure 8 - Wakeup sequence of Slave node trigger

5.3.3.2.3.2 Method 2: Polling Method

This section describes processing of wakeup according to an internal factor of the slave node. (Refer to **Figure 9**.) After detecting the wakeup event of an internal factor, the slave node transmits the wakeup pulse to the communication bus. After receiving the wakeup pulse, the master node transmits the clock to the communication bus within $T_{\text{clock_start_m}}$ time. After receiving the wakeup pulse, each slave node transits to standby mode within $T_{\text{wakeup_s}}$ time, then receives the clock and transits to normal mode. The master node starts transmitting any PID field or PTYPE field during which $T_{\text{wakeup_m}}$ time or more to $T_{\text{wakeup_schedule_m}}$ time or less, and the slave node can transmit to the communication bus at timing of confirmation of the receiving of the first PID field or the PTYPE field that the master node transmits. The wakeup pulse is described at the physical layer section.