



Sleep/Wake-Up Electrical Interface Specification

Sleep/Wake-up Electrical Interface Specification
for Automotive Ethernet

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INTRODUCTION

This specification defines a standard set of service primitive and physical interface provided by the ISO/OSI layer 1 (PHY) and supporting a controlled link shutdown and a fast global wake-up within an Ethernet network. Higher layers like the network management can access those service primitives to realize partial networking, where selected parts of a network are inactive. The coordination of switching off selected nodes of a network is handled by the network management and is not part of this specification. This partial networking concept relying on selective link shutdown and fast global wake-up is especially suited for automotive Ethernet networks.

The IEEE 802.3 specification does not define mechanisms for controlled link shut-down and wake-up. Therefore the new service primitives defined in this specification can be regarded as a supplement to the IEEE 802.3 specification to define the physical interface as well as timing behavior in response to the physical interface.

ABBREVIATION/SYMBOLS

CSMA/CD	Carrier Sense Multiple Access with Collision Detection
DME	Differential Manchester Encoding
DUT	Device Under Test
LPS	Low Power Sleep
MAC	Media Access Control
MDI	Media Dependent Interface
MII	Media Independent Interface
PCS	Physical Coding Sublayer
PHY	Physical Layer
PLCA	Physical Layer Collision Avoidance
PM	Power Management
PMA	Physical Medium Attachment
PMIC	Power Management Integrated Circuit
pt-pt	Point to point
INH	Inhibit
I/O	Input/Output
OTP	One Time Programmable
RS	Reconciliation Sublayer

SMI	Serial Management Interface
SoC	System on Chip
VBAT	Battery Voltage
WUP	Wake-Up Pulse
WUS	Wake-Up Sleep
WUT	Wake-Up Tone
+	May indicate either the arithmetical sum operation or the logical OR function
*	May indicate either the arithmetical multiply operation or the logical AND function

1 SCOPE

The following are the objectives of this Sleep/Wake-up Electrical Interface specification:

- a) Comply with the CSMA/CD MAC
- b) Comply with the specifications for the xMII (MII, RMII, RGMII etc.)
- c) Support global network wake-up
- d) Support wake-up process completely covered in ISO/OSI layer 1
- e) Support controlled link shutdown to deactivate selective parts of network
- f) Comply with AUTOSAR network management
- g) No unwanted wakeup in presence of interference noise
- h) Applicable for device supporting any speed-grade of Single Twisted Pair Ethernet Transceiver

2 TERMS AND DEFINITIONS

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

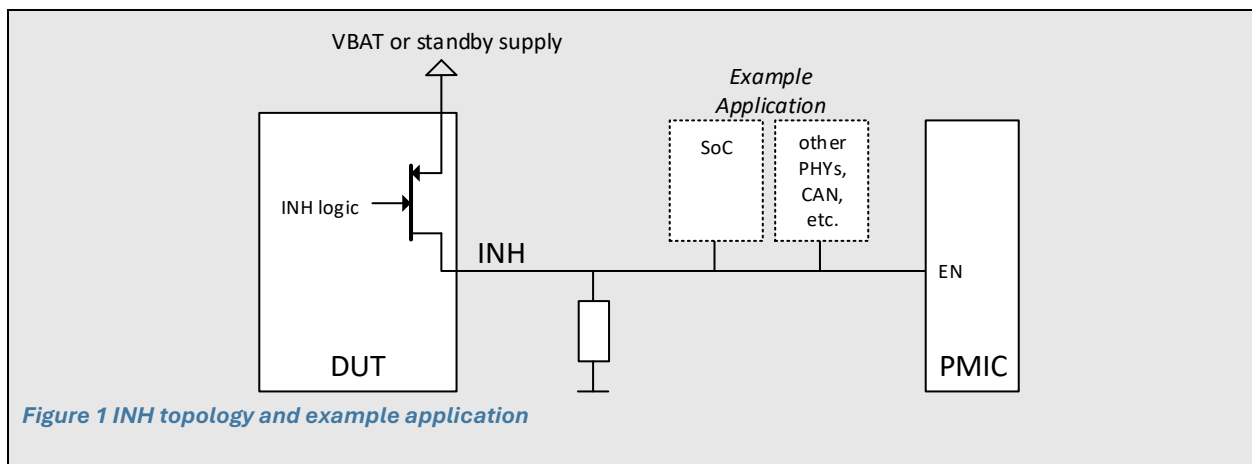
3 WAKEUP/SLEEP ELECTRICAL INTERFACE

PHYs supporting wakeup and sleep signaling over dedicated I/O pins should follow the following guidelines. Sleep/wakeup commands are not part of the xMI interface.

Table 1 below shows examples of pins typically associated with wakeup and sleep functionality. Depending on the type of Ethernet device and required functionality, not all pins listed are relevant. When the pin in Table 1 is supported, the functionality and electrical characteristic defined in this section shall be implemented accordingly.

Table 1 Example of wakeup related device pins

Pin name	Direction ¹	Function	Voltage Source
INH	OUT (Wired-OR)	Prevent external regulator from shutdown	VDD_AO
LOCAL_WAKE	IN	Local wake input	VDDIO ² or VDD_AO
WAKE_FWRD	OUT	Wake Output	VDDIO or VDD_AO
WAKE_IN_OUT	IN/OUT (Wired-OR)	Multiplex interface to support wake input and output over the same pin	VDDIO or VDD_AO
VDD_AO	IN	Always-on supply, available during sleep to power wakeup detection functionality	VBAT or other available standby supply



The interface shall support a local-wakeup input and may support an active-high wakeup-forwarding output. For multi PHY designs these pins can be joined. Inhibit pins should be a high-side switch, which is pulling INH high during normal operation and high-Z during low power.

¹ From the perspective of the DUT

² Standard JEDEC voltage level recommended. No specific voltage level given in this spec.

The I/O voltage is left to the implementer. Note that INH is supplied by a standby supply which is available during sleep.

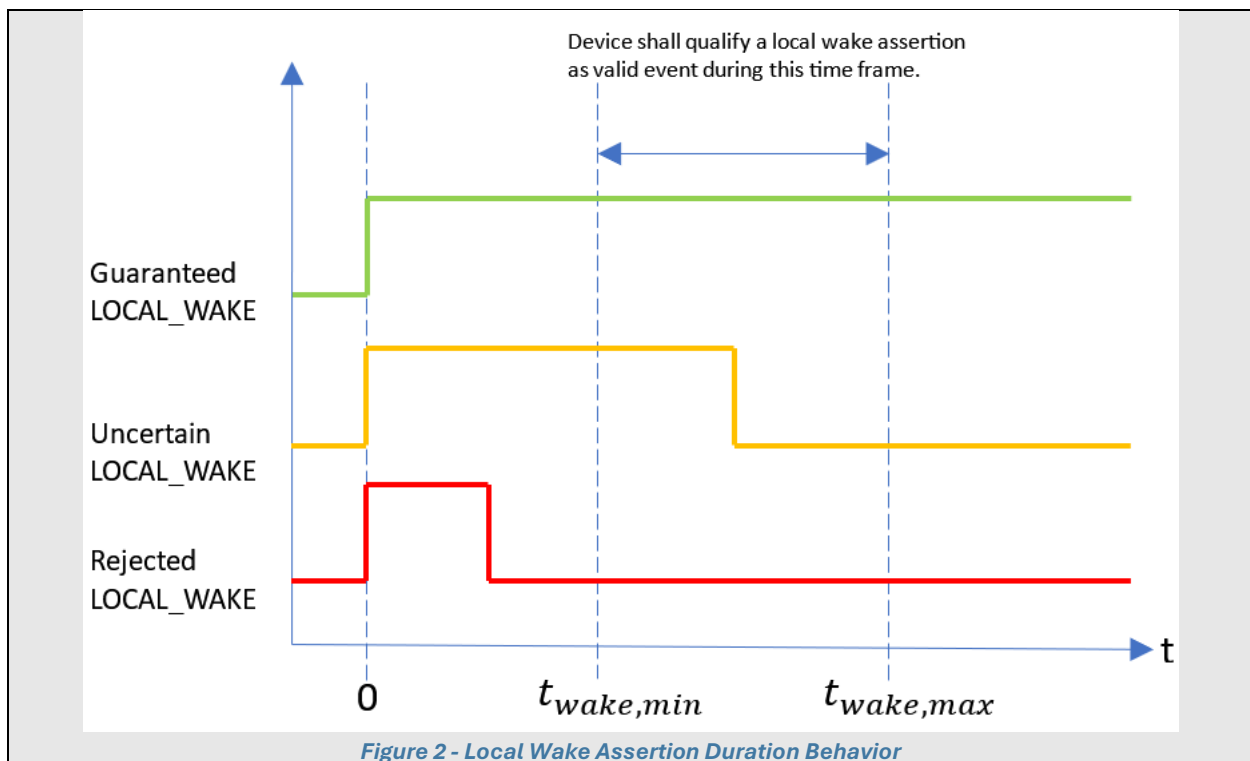
In some automotive use-cases a glitching wakeup source is connected to the LOCAL_WAKE pin. It is required to implement a duration detection threshold to support such applications. Local_Wake assertion (begin with a low to high transition) with a duration less than $t_{wake,min}$ shall not be detected as wakeup event and are to be ignored. Local_Wake assertion with duration more than $t_{wake,max}$ shall be guaranteed to be detected and cause a wakeup. Behavior of Local_Wake assertion with duration between $t_{wake,min}$ and $t_{wake,max}$ is undefined and implementation specific. The specific timing requirement is listed in Table 2 with behavior illustrated in Figure 2.

From this follows that a local wakeup output pulse (originating from WAKE_IN_OUT, WAKE_FWRD or another source) shall have a duration of at least $t_{wake,max}$ to be reliably detected.

In case LOCAL_WAKE is fed through the wiring harness (support for slow legacy wake-up line) it is recommended to have configurable option to increase the rejection window $t_{wake,min}$ (e.g. minimum of 10 ms).

Table 2 - Local Wake Assertion Timing Requirement

Variable	Description	Mandatory Support	Min	Max	Unit
t_{wake}	Valid Local_Wake assertion qualification time	Mandatory	10	40	us
		Optional	Implementation Specific		



3.1 Ethernet Transceiver electrical interface type

Table 3 below indicate the different device type and the availability of different pins. While type IV and type V implementation is recommended for maximal application flexibility, the specific choice of electrical interface type is vendor specific based on target application and cost.

Table 3 Ethernet Transceiver electrical interface type

Device Type	INH	LOCAL_WAKE	WAKE_FWRD	WAKE_IN_OUT	VDD_AO
I-a	Yes	No	No	No	Yes
I-b	No				
II-a	Yes	No	Yes	No	Yes
II-b	No				
III-a	Yes	Yes	No	No	Yes
III-b	No				
IV-a	Yes	Yes	Yes	No	Yes
IV-b	No				
V-a	Yes	No	No	Yes	Yes
V-b	No				

3.1.1 Ethernet Transceiver electrical interface type I

Type I Ethernet device has only VDD_AO and optionally physical INH pin. Example application that may utilize Ethernet transceiver belong to this category are ECU with Ethernet Transceiver where only wake up over MDI is required.

3.1.2 Ethernet Transceiver electrical interface type II

Type II Ethernet device has VDD_AO and WAKE_FWRD and optionally physical INH pin. Example application that may utilize Ethernet transceiver belong to this category are ECU requiring an Ethernet Transceiver to support wake up over MDI with capability to forward the wake event to device on the same ECU.

3.1.3 Ethernet Transceiver electrical interface type III

Type III Ethernet device has VDD_AO and LOCAL_WAKE and optionally physical INH pin. Example application that may utilize Ethernet transceiver belong to this category are ECU requiring an Ethernet Transceiver to support wake up over MDI with capability to forward wake request from a device on same ECU to a device on different ECU through the MDI.

3.1.4 Ethernet Transceiver electrical interface type IV

Type IV Ethernet device has VDD_AO, LOCAL_WAKE, WAKE_FWRD, and optionally physical INH pin. Along with type V this type of device is the most generic and feature rich and can be used to support any application. The difference between type IV and type V device is type V device has the LOCAL_WAKE and WAKE_FWRD merged into a single pin while type IV utilize separate pin.

3.1.5 Ethernet Transceiver electrical interface type V

Type V Ethernet device has VDD_AO and WAKE_IN_OUT and optionally physical INH pin. Along with type IV this type of device is the most generic and feature rich and can be used to support any application. The difference between type IV and type V device is type V device has the LOCAL_WAKE and WAKE_FWRD merged into a single pin while type IV utilize separate pin.

4 POWER CONSUMPTION

The following guidelines on the device power consumption in sleep mode target typical Ethernet products such as single and multiport PHYs and switches.

A single-port PHY product should have a quiescence current of 35μA. A multi-port PHY or switch product should have a quiescence current of 25μA plus 10μA for each port. More complex SoC products with other wakeup-capable interfaces may exceed these numbers, while still meeting this specification.

5 TIMING BEHAVIOR

The sleep and wake up process in a PHY shall fulfil the following requirements³:

Symbol	Max	Units
TWU_Forwarding	1	ms
T_PowerSupply_Stable + T_Initialization ⁴	15	ms
TWU_WakeIO	1	ms

5.1 TWU_Forwarding

For multiport devices it is possible to forward a wakeup from one physical port to another physical port. The Wake-up forwarding time (TWU_Forwarding) is the time from receiving a wakeup WakeupForward.Indication on one physical port until a WakeupForward.Request is generated on another physical port.

5.2 T_PowerSupply_Stable and T_Initialization

When a valid wake source (WUP on MDI pin, or assertion on LOCAL_WAKE/WAKE_IN_OUT) is presented to a passive device, the device will require power up and initialization prior to indicating and servicing Wakeup.indication, for example, generating subsequent wakeup.request to propagate the wake event. The overall time from a valid wake source presented to the passive device to the Wakeup.indication is generated and serviceable, is govern by the following:

For wake source originate from MDI (WUP):

$$T_PowerSupply_Stable + T_Initialization + \max(\text{WUP Detection Time of particular Speed Grade})$$

For wake source originate from LOCAL_WAKE/WAKE_IN_OUT:

$$T_PowerSupply_Stable + T_Initialization + TWU_WakeIO$$

, where

T_Powersupply_Stable is the time from the passive device request power (INH assert high) until power supply is stable

³ For the mentioned timer values a 10 % tolerance is expected.

⁴ T_Initialization should be included in documentation to choose appropriate PMIC.

T Initialization is the time from power supply reached stable voltage until wakeup.indication is generated and serviceable for the two different wake source:

- a) when wake source originated from WUP appeared on its MDI pin, or
- b) when wake source originated from valid LOCAL_WAKE assertion

5.3 TWU_WakeIO

The time TWU_WakeIO is defined from the valid wake pulse presented on the LOCAL_WAKE/WAKE_IN_OUT pin of a receiving device, to the time when the device qualify and accept the wake pulse as valid wake event for that particular device.

6 SERVICE PRIMITIVES AND INTERFACES

Beside the service primitives and interfaces, specified in IEEE802.3, new service primitives are provided by the 802.3 physical layer to the upper management layer. These services are needed to realize the sleep and wake-up behavior.

The wakeup and sleep control information are transferred between the PMA, PCS and SMI and physical device pins. This document does not specify an SMI address layout.

6.1 Sleep.request

The purpose of the *Sleep.request* service primitive is to shut down a link in a controlled manner, without generating unwanted link failure interrupts.

6.2 SleepForce.request

The purpose of SleepForce.request is to force the device into Sleep state bypassing the sleep handshake.

6.3 Sleep.indication

The purpose of the Sleep.indication service primitive is to indicate a received sleep request.

6.4 SleepFail.indication

The purpose of the optional SleepFail.indication service primitive is to indicate an aborted or unsuccessful sleep handshake.

6.5 SleepAbort.request

The purpose of the *SleepAbort.request* service primitive is to abort a received sleep request.

6.6 Wakeup.request

The purpose of the Wakeup.request service primitive is to generate a WUP or WUR command leading to a global wake-up within the Ethernet network.

6.7 Wakeup.indication

The purpose of the *Wakeup.indication* service primitive is to indicate a detected wake-up event. This includes a wakeup over a passive link, a wakeup over an active link as well as over a local wakeup pin. A *Wakeup.indication* can originate from MDI side (as WUP or WUR), from SMI side (over wakeup register) or over a physical pin (LOCAL_WAKE, WAKE_IN_OUT).

6.8 Inhibit.indication

Signals the state of an optional power supply inhibit interface.

6.9 WakeupForward.indication

(optional)

This service primitive signals that a Wakeup forwarding event has been received over wake I/O functionality or MDI.

6.10 WakeupForward.request

(optional)

This service primitive signals that a wakeup event has been forwarded to this port as a consequence of a WakeupForward.indication on another port or through the wake I/O functionality.