802.3ch Sleep/Wake-up Specification

TC10 - OPEN Sleep/Wake-up Specification for Automotive Multi-Gigabit Ethernet

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Introduction

This specification defines new service primitives 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 802.3ch: MultiGBase-T1 specification does not define mechanisms for a controlled link shut-down and wake-up. Therefore the new service primitives defined in this specification can be regarded as a supplement to the 802.3ch: MultiGBase-T1 specification.

The new services primitives make use of LPS, WUR and WUP commands. When not using the new service primitives and commands, implementation of these extensions will not impact the interoperability to a “basic” 802.3ch: MultiGBase-T1 PHY.

1 Scope

The following are the objectives of the Sleep/Wake-up 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 (incl. link start-up time) within less 250ms

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 MultiGBASE-T1

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

[1] Amendment 8: Physical Layer Specification and Management Parameters for 2.5 Gb/s, 5 Gb/s, 10 Gb/s Automotive Electrical Ethernet", IEEE Std 802.3ch

[2] Open Alliance TC10 Sleep/Wake-up Electrical Interface Specification

[3] Open Alliance TC10 Sleep/Wake-up Auto-negotiation Specification

3 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/

4 Wakeup/Sleep electrical interface

Ethernet Product supporting Open Alliance TC10 Sleep/Wake-up specification shall implement Electrical Interface as defined in Section 4 of [2]

5 Power consumption

Ethernet Product supporting Open Alliance TC10 Sleep/Wake-up specification shall follow power consumption guideline as defined in Section 5 of [2]

6 Timing Behavior

Ethernet Product supporting Open Alliance TC10 Sleep/Wake-up specification shall follow timing behavior as defined in Section 6 of [2]. In additional, Ethernet transceiver supporting MultiGBase-T1 Sleep/Wakeup specification shall fulfill the following requirements[1]:

6.1 ACK_timer

The time duration in SLEEP_ACK state shall expire in 8ms.

ACK_timer = 8 ms.

6.2 REQ_timer

The time duration in SLEEP_REQUEST state and SLEEP_SILENT state shall expire in 16ms.

REQ_timer = 16 ms.

6.3 TWU_Link_passive

The wake-up transmission time over a passive link (WUP) shall be less than 2 ms.

TWU_Link_passive < 2 ms.

6.4 TWU_Link_active

Wake-up transmission time over an active link (WUR) shall be less than 2 ms.

TWU_Link_active < 2 ms

7 Service Primitives and Interfaces

Ethernet Product supporting Open Alliance TC10 Sleep/Wake-up specification shall implement service primitives and interface as defined in Section 7 of [2].

8 Command Definitions

This specification defines three commands which are used to request a power down and signal a wakeup over an active as well as a passive link for MultiGBase-T1.

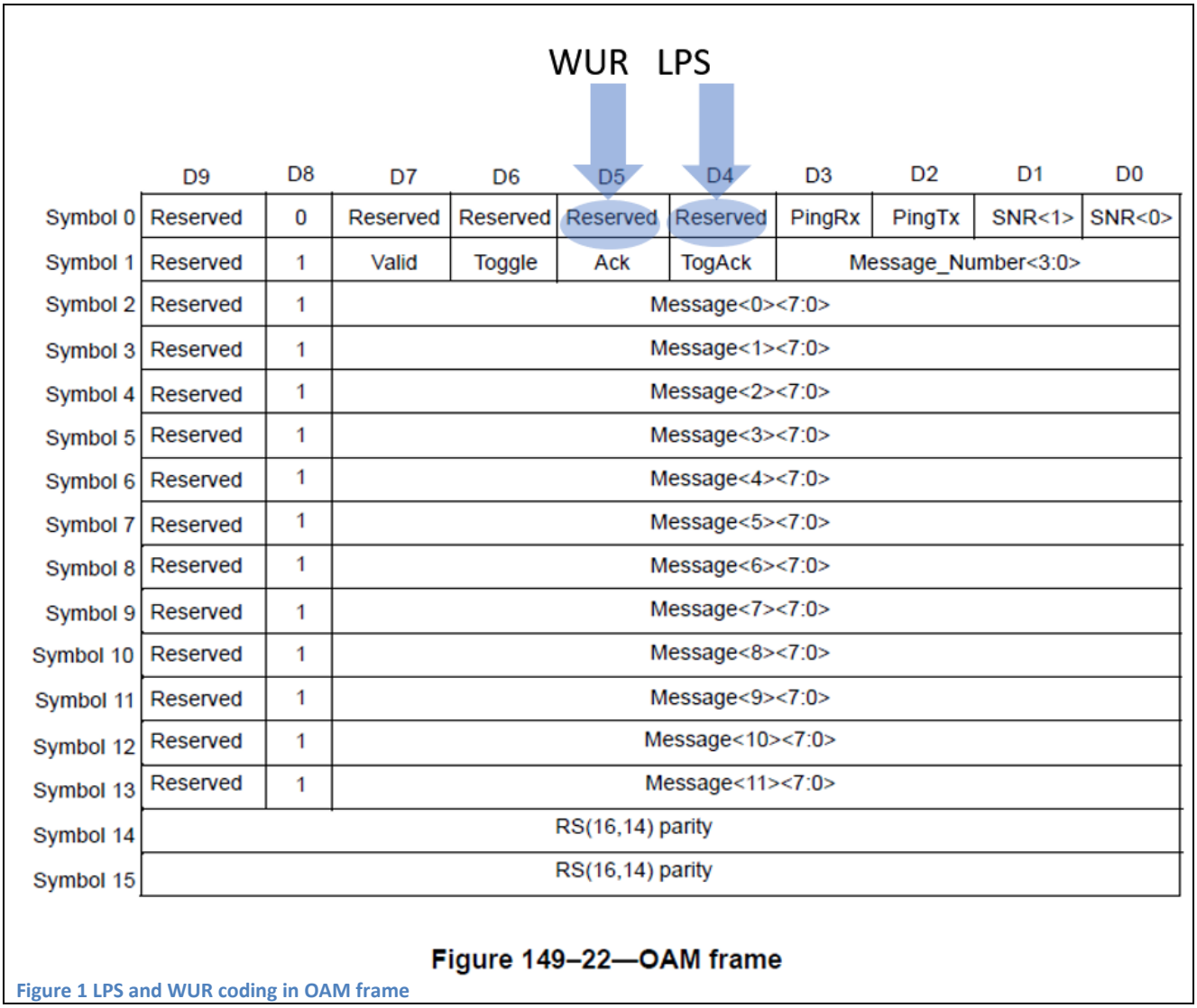
8.1 Low Power Sleep (LPS) and Wake-Up Request (WUR)

The Low Power Sleep (LPS) is a command to indicate a sleep request to the link partner. The LPS command is sent by a node requesting a transition to SLEEP, while the link is up.

[1] For the mentioned timer values a 10 % tolerance is expected.

The Wake-Up Request (WUR) is a command to indicate a wake-up request to the link partner. It can be sent by a node PHY or switch PHY to distribute the wake-up request over a link, which is already active.

The LPS and WUR are encoded in MultiGBASE-T1 PCS level Operations, Administration, and Maintenance (OAM). The OAM Frame is shown as follows:



	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Symbol 0	Reserved	0	Reserved	Reserved	Reserved	Reserved	PingRx	PingTx	SNR<1>	SNR<0>
Symbol 1	Reserved	1	Valid	Toggle	Ack	TogAck	Message_Number<3:0>			
Symbol 2	Reserved	1	Message<0><7:0>							
Symbol 3	Reserved	1	Message<1><7:0>							
Symbol 4	Reserved	1	Message<2><7:0>							
Symbol 5	Reserved	1	Message<3><7:0>							
Symbol 6	Reserved	1	Message<4><7:0>							
Symbol 7	Reserved	1	Message<5><7:0>							
Symbol 8	Reserved	1	Message<6><7:0>							
Symbol 9	Reserved	1	Message<7><7:0>							
Symbol 10	Reserved	1	Message<8><7:0>							
Symbol 11	Reserved	1	Message<9><7:0>							
Symbol 12	Reserved	1	Message<10><7:0>							
Symbol 13	Reserved	1	Message<11><7:0>							
Symbol 14	RS(16,14) parity									
Symbol 15	RS(16,14) parity									

Figure 149–22—OAM frame

Figure 1 LPS and WUR coding in OAM frame

The bits LPS and WUR are defined as follows:

$$LPS = (\text{tx\_lps} = \text{TRUE})\ \&\ (\text{loc\_wake\_req} = \text{FALSE})\ \&\ (\text{link\_status} = \text{OK})\ \&\ !\text{tx\_lps\_done}$$

$$WUR = (\text{tx\_lps} = \text{FALSE})\ \&\ (\text{loc\_wake\_req} = \text{TRUE})\ \&\ (\text{link\_status} = \text{OK})$$

An LPS and WUR command is transmitted through transmitting a single OAM frame with the respective bit set. Transmission of LPS and WUR does not utilize the OAM handshaking signals (Valid, Toggle, Ack, TogAck) and thus reception of the command is not acknowledged through the OAM handshaking mechanism[2].

Bits D5 and D4 of Symbol 0 shall remain reserved (value always 0) at MDIO level. Register reads and writes as part of the MultiGBASE-T1 OAM message transmit and receive registers with respective bits set shall have no effect on WUR/LPS.

8.2 Wake-Up Pulse (WUP)

The Wake-up pulses (WUP) is a command to indicate a wake-up request to the link partner. The wake-up pulse is transmitted if tx_mode is set to SEND_WUP as indicated in modified PHY Control State Diagram.

The pattern which is transmitted shall be generated from the side stream scrambler Sn based on IEEE802.3ch Equation 149-5, or Equation 149–10, with transmitted symbol encoded as

$$T_n = \begin{cases} +1 & ,Sn = 0 \\ -1 & ,Sn = 1 \end{cases}$$

The symbol rate shall be 62.5MBaud +/- 1.5MBaud. The differential output voltage over an 100 ohms differential load shall be between 0.85Vp to 1.3Vpp peak to peak (with maximum limited per IEEE 149.5.2.5).

The duration of wake-up pulse duration is 1ms +/- 0.3ms to allow reliable detection. The energy detection of a WUP command is left to the implementer.

PHYs with multi-speed capabilities shall use the specified WUP pattern corresponding to the speed the PHY is configured to operate in. The speed configuration process depends on the application and can be through means of pin-strapping, Auto-Negotiation result, register configuration, OTP fuses or similar.

If WUP is sent prior to Auto-Negotiation results are available, then WUP should be the minimum speed advertised by the Auto-Negotiation.

Note, it is only guaranteed that a WUP can be detected reliably if the responder PHY devices supports and operates in the WUP associated speed mode.[3]

[2] Acknowledgement happens on wakeup-sleep handshake-level by responding with a LPS command.
[3] For example, a WUP transmitted by a PHY operating in 100BASE-T1 mode is not guaranteed to be detected by a 1000BASE-T1 device and vise-versa.

9 Modified PMA and PCS IEEE802.3ch

This section describes the modification of the Physical Media Attachment and Physical Coding Sublayer of IEEE802.3ch [1] to support Sleep/Wake-up capability.

9.1 PHY power modes

The following state diagram shows the power state machine which implements the two-way handshake protocol.

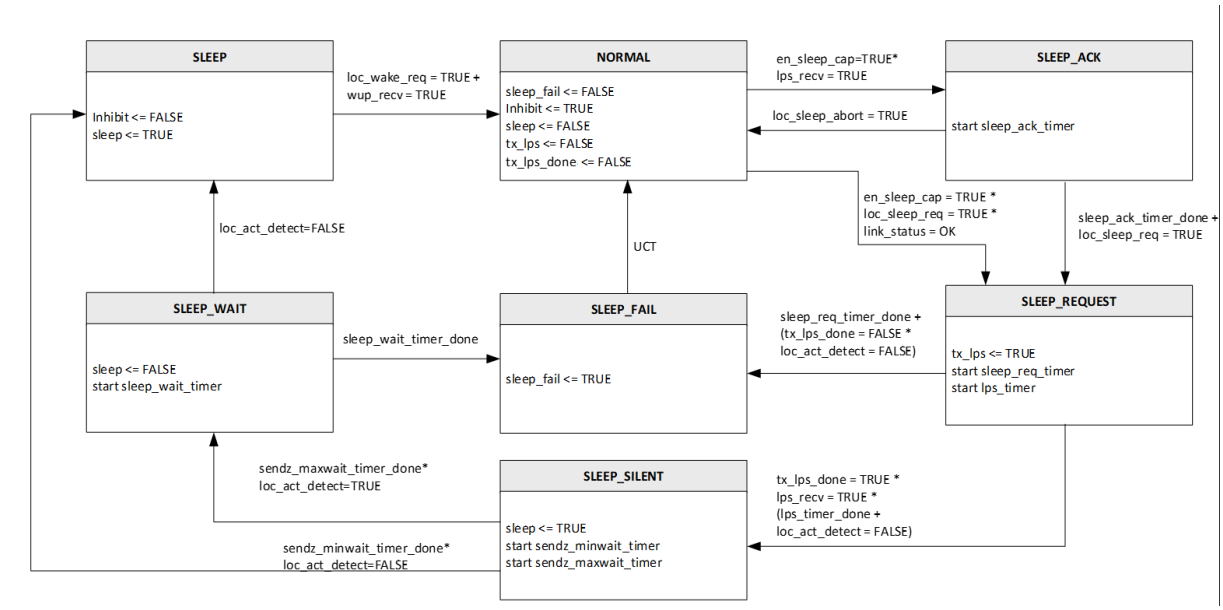


Figure 2 PHY power mode state diagram

A TC10-capable device shall always be in a well-defined state after power supplies have started up. This includes the case when the device is in SLEEP state and power supplies start up without any prior wakeup such as WUP over MDI or a wake over a dedicated WAKE pin with VDD_AO supplied at all time. The well-defined state refers to a state where behavior is clearly defined in the device datasheet

9.1.1 PHY reset and initialization

After a device reset the PHY may automatically assert loc_wake_req. This triggers a WUP transmission before normal training is performed.

9.1.2 Sleep

In case the link is up and *Sleep.request* is asserted the PHY will enter the Sleep Request state and will send LPS commands. The link partner receiving those LPS commands enters SLEEP_ACK state and starts sleep_ack_timer. If loc_sleep_abort is asserted, the sleep is aborted because of incoming data message. If sleep reject is not done, the link partner will enter SLEEP_REQUEST state and send LPS commands. If the PHY detects that it has sent and received LPS commands it transits to SLEEP_SILENT state and eventually to SLEEP. On the other hand, if the handshaking is not done before sleep_req_timer timeout, the PHY enters SLEEP_FAIL and back to SEND_DATA state.

9.1.3 Wakeup

The signalling of a *Wakeup.request* depends on the state of the link. If the link is up (tx_mode = SEND_N) the PHY will transmit a WUR command over the active link. If the link is down (link_control = DISABLE and sync_link_control = DISABLE) the PHY may transmit a WUP pulse. If the link is not yet established (!loc_rcvr_status) for instance because the link is still in training (tx_mode = SEND_T) then a WUR command is sent once the link is established.

The *Wakeup.indicate* shall be generated upon wakeup events. This service primitive is generated in any of the following cases:

- The device is in sleep state and a WUP pulse (wup_recv) is received over MDI
- The link is up and that a WUR has been received (wur_recv) is signalled
- A local wakeup (loc_wake_req) is asserted

The implementation of the energy detection process that asserts wup_recv is left to the PHY vendor. The energy detection process must not take longer than TWU_Link_passive as defined in Section 6. It must be ensured that a transmitted WUP pattern on the link reliably triggers the energy detection (wup_recv=TRUE).

9.1.4 Wakeup-forwarding

Multi-PHY devices (e.g. switches) or PHYs that implement WAKE_FWRD or WAKE_IN_OUT pins shall have a selective wakeup forwarding mechanism. If a multi-PHY device detects a *Wakeup.Request in the form of WUP/WUR*, it shall be possible to forward the *indication* to one or multiple other PHYs of the device.

It shall be possible to forward a wakeup from the originating PHY to selectable target PHYs. On these target PHYs the wakeup is sent over MDI (as WUP or WUR, depending on the link status)[4].

In case the device implements a WAKE_FWRD or WAKE_IN_OUT pin, a wakeup forwarding shall be indicated by asserting the pin.

9.1.5 Variables

loc_act_detect : Local activity detection signal. The variable is set to FALSE if consecutive symbols of zeros have been received; otherwise set to TRUE. The value of loc_act_detect shall be set to TRUE (FALSE) within 1 us.

lps_recv : Set if a LPS command has been entirely received.

wur_recv : Set if a WUR command has been entirely received.

wup_recv : Set if WUP pulses have been sensed.

tx_lps : If set, LPS bits are transmitted.

tx_lps_done : Set after entire OAM frame (16 OAM symbol) containing the LPS command has been transmitted

lps_timer_done: Set after lps_timer has expired

loc_sleep_req : Set if a sleep is requested by the local PHY.

loc_wake_req : Set if a wakeup is requested by the local PHY.

[4] In case wakeup events arrive on multiple sources (e.g. pin and MDI) in a short interval, the wakeup event may be joint into a single event.

sleep_req_timer_done: Set when the sleep_req_timer has expired.

sleep_ack_timer_done: Set when the sleep_ack_timer has expired.

loc_sleep_abort: Set if a remote sleep request is to be rejected while still in SLEEP_ACK phase

sleep_fail : Set if a sleep handshake has been aborted by the link partner.

inhibit : Set if the (external) power supply shutdown is inhibited.

sleep : Set by the power state machine to notify PHY CTRL to disable transmission.

en_sleep_cap : Indicates whether sleep capability is enabled.

sleep_wait_timer_done: Set when sleep_wait_timer has expired.

9.1.6 Timers

wup_timer : A timer used to wait for reliable detection of WUP pulse. The timer shall expire 1ms +/- 0.3ms after being started.

lps_timer: Timer used to ensure reliable transmission and decoding of LPS command. The timer shall expire 94.504us +/- 2us

sleep_ack_timer : A timer used in SLEEP_ACK state to check whether NM decides to reject sleep flow on an incoming data message or not. The timer shall expire 8ms after being started.

sleep_req_timer : A timer set up in SLEEP_REQ to check if the handshaking is properly done by both PHYs. If the PHY does not enter SLEEP state before timeout, it enters SLEEP_FAIL state and back to NORMAL. The timer shall expire 16ms after being started.

sendz_minwait_timer: A timer to guarantee a minimum time SEND_Z is transmitted. The timer shall expire after 1.28us +/- 0.256us.

sendz_maxwait_timer: A timer to limit the maximum number of SEND_Z transmission. This timer shall expire after 2us +/- 0.2us.

sleep_wait_timer: A timer to limit the time to stay in SLEEP_WAIT state before going to SLEEP_FAIL state, if local_act_detect is always true during SLEEP_WAIT state. The timer shall expire after 4us +/- 0.4us

9.2 PMA PHY Link Synchronization

The diagram below shows the modified link sync state machine.

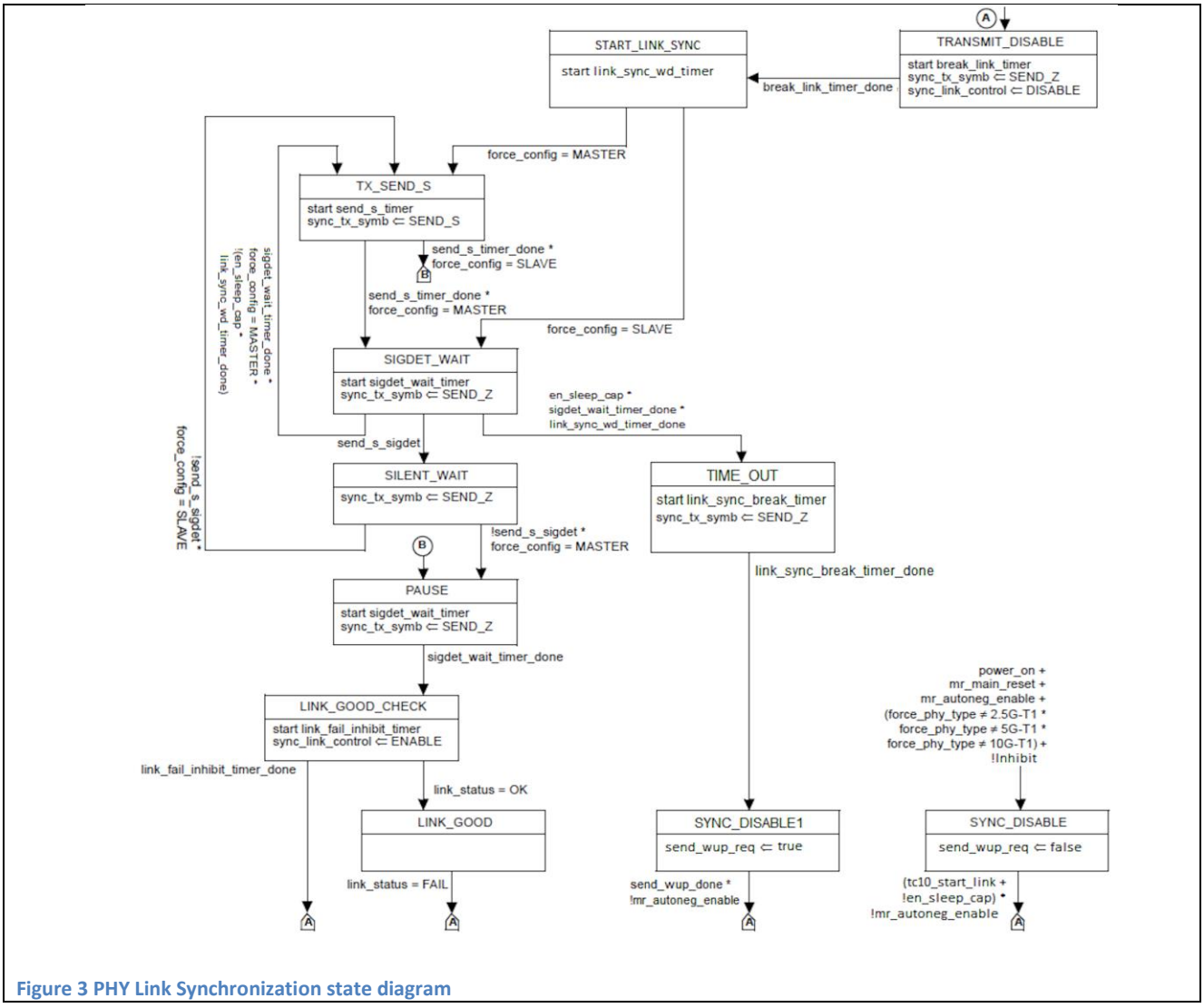


Figure 3 PHY Link Synchronization state diagram

9.2.1 Timers

link_sync_wd_timer: Link sync watchdog timer of 40ms (+/- 400us). When link_sync_wd_timer has expired, WUP pattern is transmitted in another attempt to wake up the link partner. Optionally, a 80ms (+/- 800us) watchdog timer can be implemented in addition to the mandatory 40ms (+/- 400us) if longer interval between retry attempt is desired in situation where link partner is known to not begin link training within 40ms.

link_sync_break_timer: Link sync break timer of 37.5us +/- 1.2us.

9.2.2 Variables

send_wup_req: The variable is set by Link synchronization state machine to request a retransmission of WUP pattern from the PHY control state machine.

tc10_start_link: Asserted by the PHY when it is ready to start link_sync or AutoNeg. The implementation is vendor specific.

9.3 PMA PHY Control State Diagram

The following Figure shows the Modified PMA PHY Control State machine which implements parts of the power sequencing state machine.

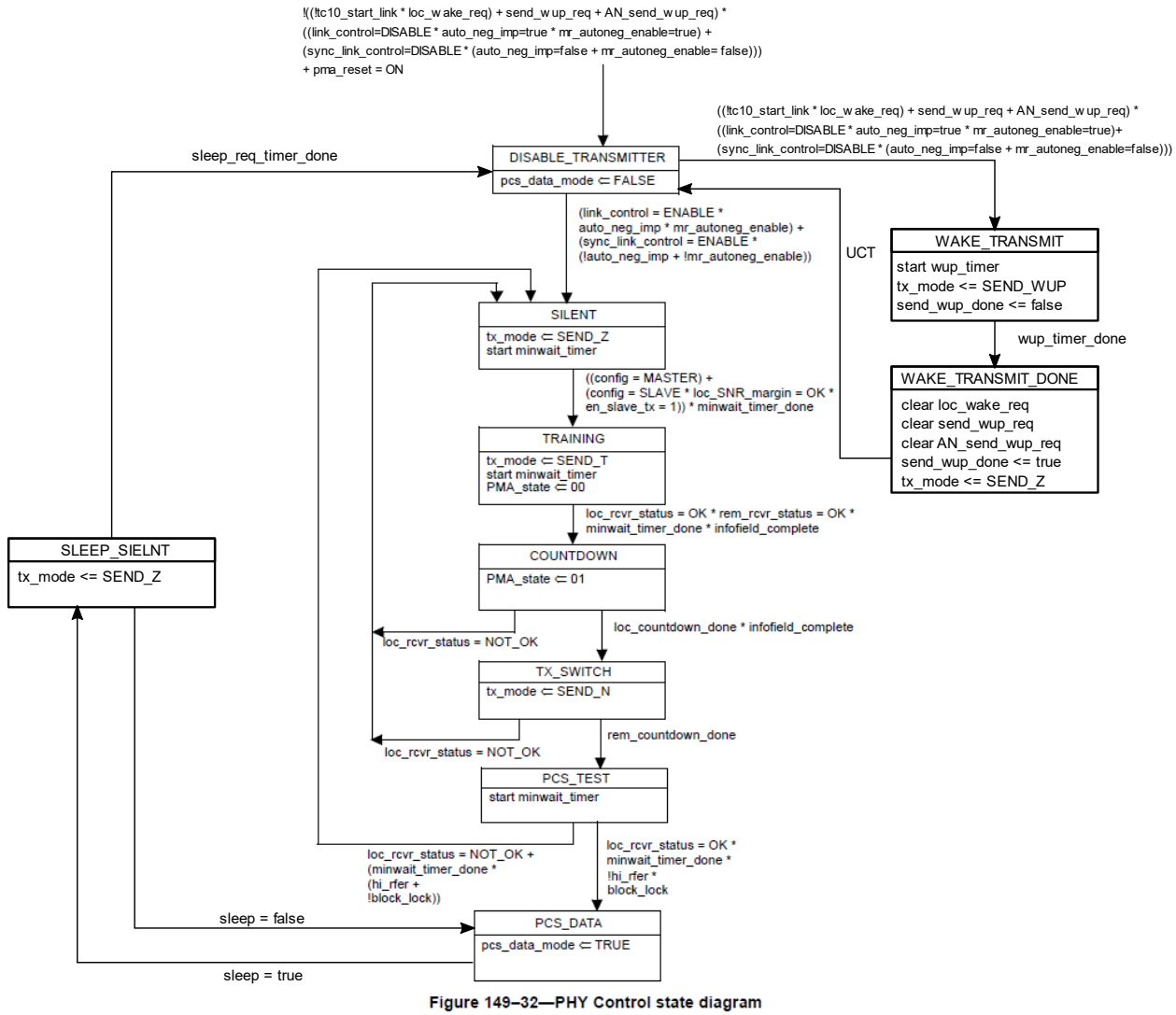


Figure 149–32—PHY Control state diagram

5

Figure 4 PHY Control state diagram

[5] UCT: Unconditional transition

9.3.1 Variables

sleep : Set by the power state machine to notify PHY CTRL to disable transmission.

AN_send_wup_req: Set by the Auto-Negotiation arbitration state machine to request a retransmission of a WUP command in [3].

send_wup_req: Set by the PHY Link Synchronization state machine to request a retransmission of a WUP command.

mr_autoneg_enable : controls the enabling and disabling of the Auto-Negotiation function in [3].

auto_neg_imp : This variable indicates if an optional Auto-Negotiation sublayer is associated with the PMA.

link_control : Used by Auto-Negotiation to disable or enable PMA processing [3].

sync_link_control : Used by Link Synchronization to indicates the data source for the PMA transmit function.

9.3.2 Timers

sleep_req_timer : see 9.1.6

wup_timer : See 9.1.6

10 Auto-Negotiation

Ethernet Transceiver that implement Auto-Negotiation capability shall additionally support Open Alliance TC10 Sleep/Wake-up Auto-negotiation Specification.