28.2.3.4.11 Use of Next Pages

a) Both devices must indicate Next Page ability for either to commence exchange of Next Pages.
b) If both devices are Next Page able, then both devices shall send at least one Next Page.
c) Next Page exchange shall continue until neither device on a link has more pages to transmit as indicated by the NP bit. A Message Page with a Null Message Code Field value shall be sent if the device has no other information to transmit.
d) A Message Code can carry either a specific message or information that defines how following Unformatted Page(s) should be interpreted.
e) If a Message Code references Unformatted Pages, the Unformatted Pages shall immediately follow the referencing Message Code in the order specified by the Message Code.
f) Unformatted Page users are responsible for controlling the format and sequencing for their Unformatted Pages.

28.2.3.4.12 MII register requirements

The Next Page Transmit register defined in 28.2.4.1.6 shall hold the Next Page to be sent by Auto-Negotiation. Received Next Pages may be stored in the Auto-Negotiation link partner ability register.

28.2.3.5 Remote fault sensing function

The Remote Fault function may indicate to the Link Partner that a fault condition has occurred using the Remote Fault bit and, optionally, the Next Page function.

Sensing of faults in a device as well as subsequent association of faults with the Remote Fault bit shall be optional. If the Local Device has no mechanism to detect a fault or associate a fault condition with the received Remote Fault bit indication, then it shall transmit the Remote Fault bit with the value contained in the Auto-Negotiation advertisement register bit (4.13).

A Local Device may indicate it has sensed a fault to its Link Partner by setting the Remote Fault bit in the Auto-Negotiation advertisement register and renegotiating.

If the Local Device sets the Remote Fault bit to logic one, it may also use the Next Page function to specify information about the fault that has occurred. Remote Fault Message Page Codes have been specified for this purpose.

The Remote Fault bit shall remain set until after successful negotiation with the base Link Code Word, at which time the Remote Fault bit shall be reset to a logic zero. On receipt of a base Link Code Word with the Remote Fault bit set to logic one, the device shall set the Remote Fault bit in the MII status register (1.4) to logic one if the MII management function is present.

28.2.4 Management function requirements

The management interface is used to communicate Auto-Negotiation information to the management entity. If an MII is physically implemented, then management access is via the MII Management interface. Where no physical embodiment of the MII exists, an equivalent to MII registers 0, 1, 4, 5, 6, and 7 (clause 22) are recommended to be provided.

28.2.4.1 Media Independent Interface

The Auto-Negotiation function shall have five dedicated registers:

a) MII control register (register 0).
b) MII status register (register 1).

c) Auto-Negotiation advertisement register (register 4).
d) Auto-Negotiation link partner ability register (register 5).
e) Auto-Negotiation expansion register (register 6).

If the Next Page function is implemented, the Auto-Negotiation Next Page Transmit Register (register 7) shall be implemented.

28.2.4.1.1 MII control register

MII control register (register 0) provides the mechanism to disable/enable and/or restart Auto-Negotiation. The definition for this register is provided in 22.2.4.1.

The Auto-Negotiation function shall be enabled by setting bit 0.12 to a logic one. If bit 0.12 is set to a logic one, then bits 0.13 and 0.8 shall have no effect on the link configuration, and the Auto-Negotiation process will determine the link configuration. If bit 0.12 is cleared to logic zero, then bits 0.13 and 0.8 will determine the link configuration regardless of the prior state of the link configuration and the Auto-Negotiation process.

A PHY shall return a value of one in bit 0.9 until the Auto-Negotiation process has been initiated. The Auto-Negotiation process shall be initiated by setting bit 0.9 to a logic one. If Auto-Negotiation was completed prior to this bit being set, the process shall be reinitiated. If a PHY reports via bit 1.3 that it lacks the ability to perform Auto-Negotiation, then this bit will have no meaning, and should be written as zero. This bit is self-clearing. The Auto-Negotiation process shall not be affected by clearing this bit to logic zero.

28.2.4.1.2 MII status register

The MII status register (register 1) includes information about all modes of operations supported by the Local Device's PHY, the status of Auto-Negotiation, and whether the Auto-Negotiation function is supported by the PHY or not. The definition for this register is provided in 22.2.4.2.

When read as a logic one, bit 1.5 indicates that the Auto-Negotiation process has been completed, and that the contents of registers 4, 5, and 6 are valid. When read as a logic zero, bit 1.5 indicates that the Auto-Negotiation process has not been completed, and that the contents of registers 4, 5, and 6 are meaningless. A PHY shall return a value of zero in bit 1.5 if Auto-Negotiation is disabled by clearing bit 0.12. A PHY shall also return a value of zero in bit 1.5 if it lacks the ability to perform Auto-Negotiation.

When read as logic one, bit 1.4 indicates that a remote fault condition has been detected. The type of fault as well as the criteria and method of fault detection is PHY specific. The Remote Fault bit shall be implemented with a latching function, such that the occurrence of a remote fault will cause the Remote Fault bit to become set and remain set until it is cleared. The Remote Fault bit shall be cleared each time register 1 is read via the management interface, and shall also be cleared by a PHY reset.

When read as a one, bit 1.3 indicates that the PHY has the ability to perform Auto-Negotiation. When read as a logic zero, bit 1.3 indicates that the PHY lacks the ability to perform Auto-Negotiation.

28.2.4.1.3 Auto-Negotiation advertisement register (register 4) (R/W)

This register contains the Advertised Ability of the PHY. (See table 28-2). The bit definition for the base page is defined in 28.2.1.2. On power-up, before Auto-Negotiation starts, this register shall have the following configuration: The Selector Field (4.4:0) is set to an appropriate code as specified in annex 28A. The Acknowledge bit (4.14) is set to logic zero. The Technology Ability Field (4.12:5) is set based on the values set in the MII status register (register 1) (1.15:11) or equivalent.

Only the bits in the Technology Ability Field that represent the technologies supported by the Local Device may be set. Any of the Technology Ability Field bits that may be set can also be cleared by management

Table 28-2—Advertisement register bit definitions

Bit(s)	Name	Description	R/W
4.15	Next Page	See 28.2.1.2	R/W
4.14	Reserved	Write as zero, ignore on read	RO
4.13	Remote Fault	See 28.2.1.2	R/W
4.12:5	Technology Ability Field	See 28.2.1.2	R/W
4.4:0	Selector Field	See 28.2.1.2	R/W

before a renegotiation. This can be used to enable management to Auto-Negotiate to an alternate common mode.

The management entity may initiate renegotiation with the Link Partner using alternate abilities by setting the Selector Field (4.4:0) and Technology Ability Field (4.12:5) to indicate the preferred mode of operation and setting the Restart Auto-Negotiation bit (0.9) in the control register (register 0) to logic one.

Any writes to this register prior to completion of Auto-Negotiation as indicated by bit 1.5 should be followed by a renegotiation for the new values to be properly used for Auto-Negotiation. Once Auto-Negotiation has completed, this register value may be examined by software to determine the highest common denominator technology.

28.2.4.1.4 Auto-Negotiation link partner ability register (register 5) (RO)

All of the bits in the Auto-Negotiation link partner ability register are read only. A write to the Auto-Negotiation link partner ability register shall have no effect.

This register contains the Advertised Ability of the Link Partner's PHY. (See tables 28-3 and 28-4.) The bit definitions shall be a direct representation of the received Link Code Word (figure 28-7). Upon successful completion of Auto-Negotiation, status register (register 1) Auto-Negotiation Complete bit (1.5) shall be set to logic one. If the Next Page function is supported, the Auto-Negotiation link partner ability register may be used to store Link Partner Next Pages.

Table 28-3—Link partner ability register bit definitions (Base Page)

Bit(s)	Name	Description	R/W
5.15	Next Page	See 28.2.1.2	RO
5.14	Acknowledge	See 28.2.1.2	RO
5.13	Remote Fault	See 28.2.1.2	RO
5.12:5	Technology Ability Field	See 28.2.1.2	RO
5.4:0	Selector Field	See 28.2.1.2	RO

The values contained in this register are only guaranteed to be valid once Auto-Negotiation has successfully completed, as indicated by bit 1.5 or, if used with Next Page exchange, after the Page Received bit (6.1) has been set to logic one.

Table 28-4—Link partner ability register bit definitions (Next Page)

Bit(s)	Name	Description	R/W
5.15	Next Page	See 28.2.3.4	RO
5.14	Acknowledge	See 28.2.3.4	RO
5.13	Message Page	See 28.2.3.4	RO
5.12	Acknowledge 2	See 28.2.3.4	RO
5.11	Toggle	See 28.2.3.4	RO
5.10:0	Message/Unformatted Code Field	See 28.2.3.4	RO

NOTE—If this register is used to store Link Partner Next Pages, the previous value of this register is assumed to be stored by a management entity that needs the information overwritten by subsequent Link Partner Next Pages.

28.2.4.1.5 Auto-Negotiation expansion register (register 6) (RO)

All of the bits in the Auto-Negotiation expansion register are read only; a write to the Auto-Negotiation expansion register shall have no effect. (See table 28-5.)

Table 28-5—Expansion register bit definitions

Bit(s)	Name	Description	R/W	Default
6.15:5	Reserved	Write as zero, ignore on read	RO	0
6.4	Parallel Detection Fault	1 = A fault has been detected via the Parallel Detection function. 0 = A fault has not been detected via the Parallel Detection function.	RO/ LH	0
6.3	Link Partner Next Page Able	1 = Link Partner is Next Page able 0 = Link Partner is not Next Page able	RO	0
6.2	Next Page Able	1 = Local Device is Next Page able 0 = Local Device is not Next Page able	RO	0
6.1	Page Received	1 = A New Page has been received 0 = A New Page has not been received	RO/ LH	0
6.0	Link Partner Auto-Negotiation Able	1 = Link Partner is Auto-Negotiation able 0 = Link Partner is not Auto-Negotiation able	RO	0

Bits 6.15:5 are reserved for future Auto-Negotiation expansion.

The Parallel Detection Fault bit (6.4) shall be set to logic one to indicate that zero or more than one of the NLP Receive Link Integrity Test function, 100BASE-TX, or 100BASE-T4 PMAs have indicated link_status=READY when the autoneg_wait_timer expires. The Parallel Detection Fault bit shall be reset to logic zero on a read of the Auto-Negotiation expansion register (register 6).

The Link Partner Next Page Able bit (6.3) shall be set to logic one to indicate that the Link Partner supports the Next Page function. This bit shall be reset to logic zero to indicate that the Link Partner does not support the Next Page function.

The Next Page Able bit (6.2) shall be set to logic one to indicate that the Local Device supports the Next Page function. The Next Page Able bit (6.2) shall be set to logic zero if the Next Page function is not supported.

The Page Received bit (6.1) shall be set to logic one to indicate that a new Link Code Word has been received and stored in the Auto-Negotiation link partner ability register. The Page Received bit shall be reset to logic zero on a read of the Auto-Negotiation expansion register (register 6).

The Link Partner Auto-Negotiation Able bit (6.0) shall be set to logic one to indicate that the Link Partner is able to participate in the Auto-Negotiation function. This bit shall be reset to logic zero if the Link Partner is not Auto-Negotiation able.

28.2.4.1.6 Auto-Negotiation Next Page transmit register (register 7) (R/W)

The Auto-Negotiation Next Page Transmit register contains the Next Page Link Code Word to be transmitted when Next Page ability is supported. (See table 28-6.) The contents are defined in 28.2.3.4. On power-up, this register shall contain the default value of 2001H, which represents a Message Page with the Message Code set to Null Message. This value may be replaced by any valid Next Page Message Code that the device wishes to transmit. Writing to this register shall set mr_next_page_loaded to true.

Table 28-6—Next Page transmit register bit definitions

Bit(s)	Name	Description	R/W
7.15	Next Page	See 28.2.3.4	R/W
7.14	Reserved	Write as 0, ignore on read	RO
7.13	Message Page	See 28.2.3.4	R/W
7.12	Acknowledge 2	See 28.2.3.4	R/W
7.11	Toggle	See 28.2.3.4	RO
7.10:0	Message/Unformatted Code Field	See 28.2.3.4	R/W

28.2.4.1.7 State diagram variable to MII register mapping

The state diagrams of figures 28-14 to 28-17 generate and accept variables of the form “mr_x”, where x is an individual signal name. These variables comprise a management interface that may be connected to the MII management function or other equivalent function. Table 28-7 describes how the MII registers map to the management function interface signals.

28.2.4.2 Auto-Negotiation managed object class

The Auto-Negotiation Managed Object Class is defined in clause 30.

Table 28-7—State diagram variable to MII register mapping

State diagram variable	MII register
mr_adv_ability[16:1]	4.15:0 Auto-Negotiation advertisement register
mr_autoneg_complete	1.5 Auto-Negotiation Complete
mr_autoneg_enable	0.12 Auto-Negotiation Enable
mr_lp_adv_ability[16:1]	5.15:0 Auto-Negotiation link partner ability register
mr_lp_autoneg_able	6.0 Link Partner Auto-Negotiation Able
mr_lp_np_able	6.3 Link Partner Next Page Able
mr_main_reset	0.15 Reset
mr_next_page_loaded	Set on write to Auto-Negotiation Next Page Transmit register; cleared by Arbitration state diagram
mr_np_able	6.2 Next Page Able
mr_np_tx[16:1]	7.15:0 Auto-Negotiation Next Page Transmit Register
mr_page_rx	6.1 Page Received
mr_parallel_detection_fault	6.4 Parallel Detection Fault
mr_restart_negotiation	0.9 Auto-Negotiation Restart
set if Auto-Negotiation is available	1.3 Auto-Negotiation Ability

28.2.5 Absence of management function

In the absence of any management function, the advertised abilities shall be provided through a logical equivalent of mr_adv_ability[16:1]. A device shall comply with all Next Page function requirements, including the provision of the mr_np_able, mr_lp_np_able, and mr_next_page_loaded variables (or their logical equivalents), in order to permit the NP bit to be set to logic one in the transmitted Link Code Word.

NOTE—Storage of a valid base Link Code Word is required to prevent a deadlock situation where negotiation must start again while Next Pages are being transmitted. If a shared transmit register were used, then renegotiation could not occur when Next Pages were being transmitted because the base Link Code Word would not be available. This requirement can be met using a number of different implementations, including use of temporary registers or register stacks.

28.2.6 Technology-Dependent Interface

The Technology-Dependent Interface is the communication mechanism between each technology's PMA and the Auto-Negotiation function. Auto-Negotiation can support multiple technologies, all of which need not be implemented in a given device. Each of these technologies may utilize its own technology-dependent link integrity test function.

28.2.6.1 PMA_LINK.indicate

This primitive is generated by the PMA to indicate the status of the underlying medium. The purpose of this primitive is to give the PCS, repeater client, or Auto-Negotiation function a means of determining the validity of received code elements.

28.2.6.1.1 Semantics of the service primitive

PMA_LINK.indicate(link_status)

The link_status parameter shall assume one of three values: READY, OK, or FAIL, indicating whether the underlying receive channel is intact and ready to be enabled (READY), intact and enabled (OK), or not intact (FAIL). When link_status=FAIL or link_status=READY, the PMA_CARRIER.indicate and PMA_UNITDATA.indicate primitives are undefined.

28.2.6.1.2 When generated

A technology-dependent PMA and the NLP Receive Link Integrity Test state diagram (figure 28-17) shall generate this primitive to indicate the value of link_status.

28.2.6.1.3 Effect of receipt

The effect of receipt of this primitive shall be governed by the state diagrams of figure 28-16.

28.2.6.2 PMA_LINK.request

This primitive is generated by Auto-Negotiation to allow it to enable and disable operation of the PMA.

28.2.6.2.1 Semantics of the service primitive

PMA_LINK request(link_control)

The link_control parameter shall assume one of three values: SCAN_FOR_CARRIER, DISABLE, or ENABLE.

The link_control=SCAN_FOR_CARRIER mode is used by the Auto-Negotiation function prior to receiving any FLP Bursts or link_status=READY indications. During this mode, the PMA shall search for carrier and report link_status=READY when carrier is received, but no other actions shall be enabled.

The link_control=DISABLE mode shall be used by the Auto-Negotiation function to disable PMA processing.

The link_control=ENABLE mode shall be used by Auto-Negotiation to turn control over to a single PMA for all normal processing functions.

28.2.6.2.2 When generated

The Auto-Negotiation function shall generate this primitive to indicate to the PHY how to respond, in accordance with the state diagrams of figures 28-15 and 28-16.

Upon power-on or reset, if the Auto-Negotiation function is enabled (mr_autoneg_enable=true) the PMA_LINK request(DISABLE) message shall be issued to all technology-dependent PMAs. If Auto-Negotiation is disabled at any time including at power-on or reset, the state of PMA_LINK.request(link_control) is implementation dependent.

28.2.6.2.3 Effect of receipt

The effect of receipt of this primitive shall be governed by the NLP Receive Link Integrity Test state diagram (figure 28-17) and the receiving technology-dependent link integrity test function, based on the intent specified in the primitive semantics.

28.3 State diagrams and variable definitions

The notation used in the state diagrams (figures 28-14 to 28-17) follows the conventions in 21.5. State diagram variables follow the conventions of 21.5.2 except when the variable has a default value. Variables in a state diagram with default values evaluate to the variable default in each state where the variable value is not explicitly set. Variables using the "mr_x" notation do not have state diagram defaults; however, their appropriate initialization conditions when mapped to the MII interface are covered in 28.2.4 and 22.2.4. The variables, timers, and counters used in the state diagrams are defined in 28.3, 14.2.3, and 28.2.6.

Auto-Negotiation shall implement the Transmit state diagram, Receive state diagram, Arbitration state diagram, and NLP Receive Link Integrity Test state diagram as depicted in 28.3. Additional requirements to these state diagrams are made in the respective functional requirements sections. Options to these state diagrams clearly stated as such in the functional requirements sections or state diagrams shall be allowed. In the case of any ambiguity between stated requirements and the state diagrams, the state diagrams shall take precedence.

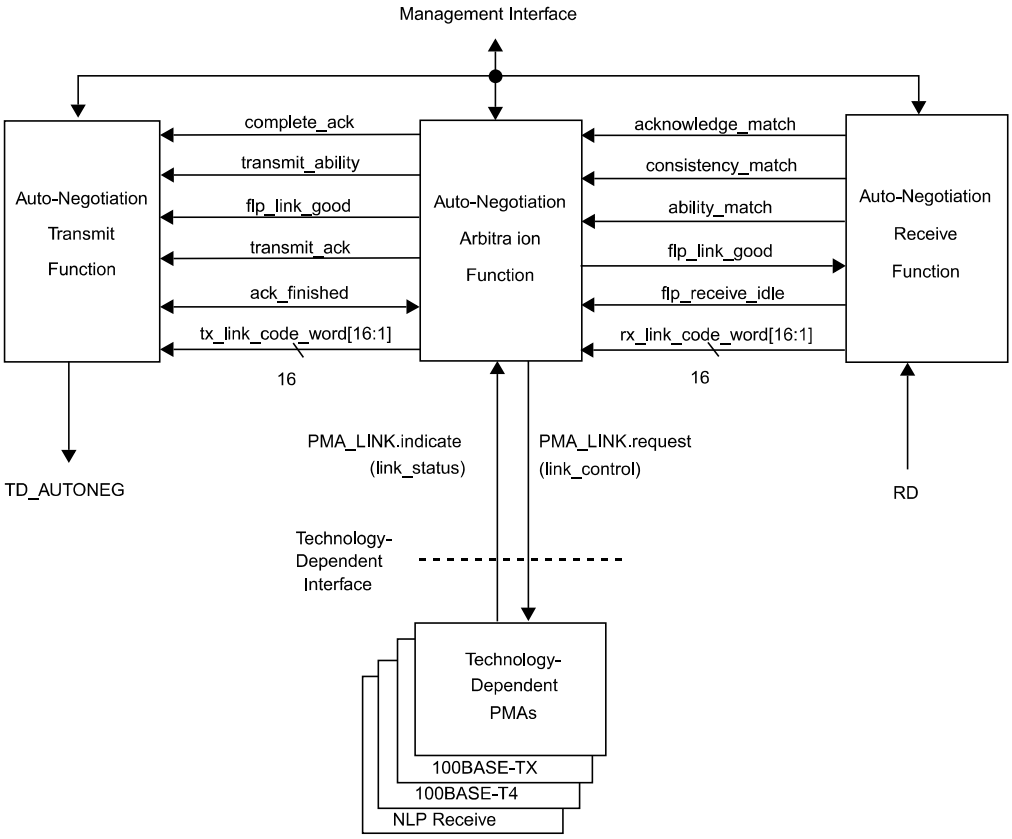


Figure 28-13—Functional reference diagram

28.3.1 State diagram variables

A variable with "_[x]" appended to the end of the variable name indicates a variable or set of variables as defined by "x". "x" may be as follows:

all; represents all specific technology-dependent PMAs supported in the Local Device and the NLP

Receive Link Integrity Test state diagram.

HCD; represents the single technology-dependent PMA chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or Parallel Detection function. To select 10BASE-T, LIT is used instead of NLP to enable the full 10BASE-T Link Integrity Test function state diagram.

notHCD; represents all technology-dependent PMAs not chosen by Auto-Negotiation as the highest common denominator technology through the Priority Resolution or Parallel Detection function.

TX; represents that the 100BASE-TX PMA is the signal source.

T4; represents that the 100BASE-T4 PMA is the signal source.

NLP; represents that the NLP Receive Link Integrity Test function is the signal source.

PD; represents all of the following that are present: 100BASE-TX PMA, 100BASE-T4 PMA, and the NLP Receive Link Integrity Test state diagram.

LIT; represents the 10BASE-T Link Integrity Test function state diagram is the signal source or destination.

Variables with [16:1] appended to the end of the variable name indicate arrays that can be directly mapped to 16-bit registers. For these variables, "[x]" indexes an element or set of elements in the array, where "[x]" may be as follows:

— Any integer.
— Any variable that takes on integer values.
— NP; represents the index of the Next Page bit.
— ACK; represents the index of the Acknowledge bit.
— RF; represents the index of the Remote Fault bit.

Variables of the form "mr_x", where x is a label, comprise a management interface that is intended to be connected to the MII Management function. However, an implementation-specific management interface may provide the control and status function of these bits.

ability_match
Indicates that three consecutive Link Code Words match, ignoring the Acknowledge bit. Three consecutive words are any three words received one after the other, regardless of whether the word has already been used in a word-match comparison or not.

Values: false; three matching consecutive Link Code Words have not been received, ignoring the Acknowledge bit (default).
true; three matching consecutive Link Code Words have been received, ignoring the Acknowledge bit.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

ack_finished
Status indicating that the final remaining_ack_cnt Link Code Words with the Ack bit set have been transmitted.

Values: false; more Link Code Words with the Ack bit set to logic one must be transmitted.
true; all remaining Link Code Words with the Ack bit set to logic one have been transmitted.

acknowledge_match
Indicates that three consecutive Link Code Words match and have the Acknowledge bit set. Three consecutive words are any three words received one after the other, regardless of whether the word has already been used in a word match comparison or not.

Values: false; three matching and consecutive Link Code Words have not been received with the

Acknowledge bit set (default).
true; three matching and consecutive Link Code Words have been received with the Acknowledge bit set.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

base_page
Status indicating that the page currently being transmitted by Auto-Negotiation is the initial Link Code Word encoding used to communicate the device's abilities.

Values: false; a page other than base Link Code Word is being transmitted.
true; the base Link Code Word is being transmitted.

complete_ack
Controls the counting of transmitted Link Code Words that have their Acknowledge bit set.

Values: false; transmitted Link Code Words with the Acknowledge bit set are not counted (default).
true; transmitted Link Code Words with the Acknowledge bit set are counted.

consistency_match
Indicates that the Link Code Word that caused ability_match to be set is the same as the Link Code Word that caused acknowledge_match to be set.

Values: false; the Link Code Word that caused ability_match to be set is not the same as the Link Code Word that caused acknowledge_match to be set, ignoring the Acknowledge bit value.
true; the Link Code Word that caused ability_match to be set is the same as the Link Code Word that caused acknowledge_match to be set, independent of the Acknowledge bit value.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

desire_np
Status indicating that the Local Device desires to engage in Next Page exchange. This information comes from the setting of the NP bit in the base Link Code Word stored in the Auto-Negotiation advertisement register (register 4).

Values: false; Next Page exchange is not desired.
true; Next Page exchange is desired.

flp_link_good
Indicates that Auto-Negotiation has completed.

Values: false; negotiation is in progress (default).
true; negotiation is complete, forcing the Transmit and Receive functions to IDLE.

flp_receive_idle
Indicates that the Receive state diagram is in the IDLE, LINK PULSE DETECT, or LINK PULSE COUNT state.

Values: false; the Receive state diagram is not in the IDLE, LINK PULSE DETECT, or LINK PULSE COUNT state (default).
true; the Receive state diagram is in the IDLE, LINK PULSE DETECT, or LINK PULSE COUNT state.

link_control
This variable is defined in 28.2.6.2.1.

link_status
This variable is defined in 28.2.6.1.1.

linkpulse
Indicates that a valid Link Pulse as transmitted in compliance with figure 14-12 has been received.

Values: false; linkpulse is set to false after any Receive State Diagram state transition (default).

true; linkpulse is set to true when a valid Link Pulse is received.

mr_autoneg_complete
Status indicating whether Auto-Negotiation has completed or not.

Values: false; Auto-Negotiation has not completed.
true; Auto-Negotiation has completed.

mr_autoneg_enable
Controls the enabling and disabling of the Auto-Negotiation function.

Values: false; Auto-Negotiation is disabled.
true; Auto-Negotiation is enabled.

mr_adv_ability[16:1]
A 16-bit array that contains the Advertised Abilities Link Code Word.
For each element within the array:

Values: Zero; data bit is logical zero.
One; data bit is logical one.

mr_lp_adv_ability[16:1]
A 16-bit array that contains the Link Partner's Advertised Abilities Link Code Word.
For each element within the array:

Values: Zero; data bit is logical zero.
One; data bit is logical one.

mr_lp_np_able
Status indicating whether the Link Partner supports Next Page exchange.

Values: false; the Link Partner does not support Next Page exchange.
true; the Link Partner supports Next Page exchange.

mr_np_able
Status indicating whether the Local Device supports Next Page exchange.

Values: false; the Local Device does not support Next Page exchange.
true; the Local Device supports Next Page exchange.

mr_lp_autoneg_able
Status indicating whether the Link Partner supports Auto-Negotiation.

Values: false; the Link Partner does not support Auto-Negotiation.
true; the Link Partner supports Auto-Negotiation.

mr_main_reset
Controls the resetting of the Auto-Negotiation state diagrams.

Values: false; do not reset the Auto-Negotiation state diagrams.
true; reset the Auto-Negotiation state diagrams.

mr_next_page_loaded
Status indicating whether a new page has been loaded into the Auto-Negotiation Next Page Transmit register (register 7).

Values: false; a New Page has not been loaded.
true; a New Page has been loaded.

mr_np_tx[16:1]
A 16-bit array that contains the new Next Page to transmit.
For each element within the array:

Values: Zero; data bit is logical zero.
One; data bit is logical one.

mr_page_rx

Status indicating whether a New Page has been received. A New Page has been successfully received when acknowledge_match=true and consistency_match=true and the Link Code Word has been written to mr_lp_adv_ability[16:1].

Values: false; a New Page has not been received.
true; a New Page has been received.

mr_parallel_detection_fault

Error condition indicating that while performing Parallel Detection, either flp_receive_idle = false, or zero or more than one of the following indications were present when the autoneg_wait_timer expired. This signal is cleared on read of the Auto-Negotiaion expansion register.

1) link_status_ [NLP] = READY
2) link_status_[TX] = READY
3) link_status_[T4] = READY

Values: false; Exactly one of the above three indications was true when the autoneg_wait_timer expired, and flp_receive_idle = true.
true; either zero or more than one of the above three indications was true when the autoneg_wait_timer expired, or flp_receive_idle = false.

mr_restart_negotiation

Controls the entrance to the TRANSMIT DISABLE state to break the link before Auto-Negotiation is allowed to renegotiate via management control.

Values: false; renegotiation is not taking place.
true; renegotiation is started.

power_on

Condition that is true until such time as the power supply for the device that contains the Auto-Negotiation state diagrams has reached the operating region or the device has low power mode set via MII control register bit 0.11.

Values: false; the device is completely powered (default).
true; the device has not been completely powered.

rx_link_code_word[16:1]

A 16-bit array that contains the data bits to be received from an FLP Burst.
For each element within the array:

Values: zero; data bit is a logical zero.
one; data bit is a logical one.

single_link_ready

Status indicating that flp_receive_idle = true and only one the of the following indications is being received:

1) link_status_[NLP] = READY
2) link_status_[TX] = READY
3) link_status_[T4] = READY

Values: false; either zero or more than one of the above three indications are true or flp_receive_idle = false.
true; Exactly one of the above three indications is true and flp_receive_idle = true.

NOTE—This variable is set by this variable definition; it is not set explicitly in the state diagrams.

TD_AUTONEG

Controls the signal sent by Auto-Negotiation on the TD_AUTONEG circuit.

Values: idle; Auto-Negotiation prevents transmission of all link pulses on the MDI.
link_test_pulse; Auto-Negotiation causes a single link pulse as defined by figure 14-12 to be transmitted on the MDI.

toggle_rx

Flag to keep track of the state of the Link Partner's Toggle bit.

Values: 0; Link Partner's Toggle bit equals logic zero.
1; Link Partner's Toggle bit equals logic one.

toggle_tx

Flag to keep track of the state of the Local Device's Toggle bit.

Values: 0; Local Device's Toggle bit equals logic zero.
1; Local Device's Toggle bit equals logic one.

transmit_ability

Controls the transmission of the Link Code Word containing tx_link_code_word[16:1].

Values: false; any transmission of tx_link_code_word[16:1] is halted (default).
true; the transmit state diagram begins sending tx_link_code_word[16:1].

transmit_ack

Controls the setting of the Acknowledge bit in the tx_link_code_word[16:1] to be transmitted.

Values: false; sets the Acknowledge bit in the transmitted tx_link_code_word[16:1] to a logic zero (default).
true; sets the Acknowledge bit in the transmitted tx_link_code_word[16:1] to a logic one.

transmit_disable

Controls the transmission of tx_link_code_word[16:1].

Values: false; tx_link_code_word[16:1] transmission is allowed (default).
true; tx_link_code_word[16:1] transmission is halted.

tx_link_code_word[16:1]

A 16-bit array that contains the data bits to be transmitted in an FLP Burst. This array may be loaded from mr_adv_ability or mr_np_tx.
For each element within the array:

Values: Zero; data bit is logical zero.
One; data bit is logical one.

28.3.2 State diagram timers

All timers operate in the manner described in 14.2.3.2.

autoneg_wait_timer

Timer for the amount of time to wait before evaluating the number of link integrity test functions with link_status=READY asserted. The autoneg_wait_timer shall expire 500–1000 ms from the assertion of link_status=READY from the 100BASE-TX PMA, 100BASE-T4 PMA, or the NLP Receive State diagram.

break_link_timer

Timer for the amount of time to wait in order to assure that the Link Partner enters a Link Fail state. The timer shall expire 1200–1500 ms after being started.

data_detect_max_timer

Timer for the maximum time between a clock pulse and the next link pulse. This timer is used in conjunction with the data_detect_min_timer to detect whether the data bit between two clock pulses is a logic zero or a logic one. The data_detect_max_timer shall expire 78–100 µs from the last clock pulse.

data_detect_min_timer

Timer for the minimum time between a clock pulse and the next link pulse. This timer is used in conjunction with the data_detect_max_timer to detect whether the data bit between two clock pulses is a logic zero or a logic one. The data_detect_min_timer shall expire 15–47 µs from the last clock pulse.

flp_test_max_timer
: Timer for the maximum time between two link pulses within an FLP Burst. This timer is used in conjunction with the flp_test_min_timer to detect whether the Link Partner is transmitting FLP Bursts. The flp_test_max_timer shall expire 165–185 µs from the last link pulse.

flp_test_min_timer
: Timer for the minimum time between two link pulses within an FLP Burst. This timer is used in conjunction with the flp_test_max_timer to detect whether the Link Partner is transmitting FLP Bursts. The flp_test_min_timer shall expire 5–25 µs from the last link pulse.

interval_timer
: Timer for the separation of a transmitted clock pulse from a data bit. The interval_timer shall expire 55.5–-69.5 µs from each clock pulse and data bit.

link_fail_inhibit_timer
: Timer for qualifying a link_status=FAIL indication or a link_status=READY indication when a specific technology link is first being established. A link will only be considered "failed" if the link_fail_inhibit_timer has expired and the link has still not gone into the link_status=OK state. The link_fail_inhibit_timer shall expire 750–1000 ms after entering the FLP LINK GOOD CHECK state.

  NOTE—The link_fail_inhibit_timer expiration value must be greater than the time required for the Link Partner to complete Auto-Negotiation after the Local Device has completed Auto-Negotiation plus the time required for the specific technology to enter the link_status=OK state. The maximum time difference between a Local Device and its Link Partner completing Auto-Negotiation is

  (Maximum FLP Burst to FLP Burst separation) × (Maximum number of FLP Bursts needed to complete acknowledgment) = (24 ms) × (8 bursts) = 192 ms.

  For example, 100BASE-T4 requires approximately 460 ms to enter link_status=OK for a total minimum link_fail_inhibit_timer time of 652 ms. The lower bound for the link_fail_inhibit_timer was chosen to provide adequate margin for the current technologies and any future PMAs.

nlp_test_max_timer
: Timer for the maximum time that no FLP Burst may be seen before forcing the receive state diagram to the IDLE state. The nlp_test_max_timer shall expire 50–150 ms after being started or restarted.

nlp_test_min_timer
: Timer for the minimum time between two consecutive FLP Bursts. The nlp_test_min_timer shall expire 5–7 ms after being started or restarted.

transmit_link_burst_timer
: Timer for the separation of a transmitted FLP Burst from the next FLP Burst. The transmit_link_burst_timer shall expire 5.7-22.3 ms after the last transmitted link pulse in an FLP Burst.

Table 28-8—Timer min./max. value summary

Parameter	Min.	Typ.	Max.	Units
autoneg_wait_timer	500		1000	ms
break_link_timer	1200		1500	ms
data_detect_min_timer	15		47	µs
data_detect_max_timer	78		100	µs

Table 28-8—Timer min./max. value summary *(Continued)*

Parameter	Min.	Typ.	Max.	Units
flp_test_min_timer	5		25	µs
flp_test_max_timer	165		185	µs
interval_timer	55.5	62.5	69.5	µs
link_fail_inhibit_timer	750		1000	ms
nlp_test_max_timer	50		150	ms
nlp_test_min_timer	5		7	ms
transmit_link_burst_timer	5.7	14	22.3	ms

28.3.3 State diagram counters

flp_cnt

A counter that may take on integer values from 0 to 17. This counter is used to keep a count of the number of FLPs detected to enable the determination of whether the Link Partner supports Auto-Negotiation.

Values: not_done; 0 to 5 inclusive.
done; 6 to 17 inclusive.
init; counter is reset to zero.

remaining_ack_cnt

A counter that may take on integer values from 0 to 8. The number of additional Link Code Words with the Acknowledge Bit set to logic one to be sent to ensure that the Link Partner receives the acknowledgment.

Values: not_done; positive integers between 0 and 5 inclusive.
done; positive integers 6 to 8 inclusive (default).
init; counter is reset to zero.

rx_bit_cnt

A counter that may take on integer values from 0 to 17. This counter is used to keep a count of data bits received from an FLP Burst and to ensure that when erroneous extra pulses are received, the first 16 bits are kept while the rest are ignored. When this variable reaches 16 or 17, enough data bits have been received. This counter does not increment beyond 17 and does not return to 0 until it is reinitialized.

Values: not_done; 1 to 15 inclusive.
done; 16 or 17
init; counter is reset to zero.
rx_bit_cnt_check; 10 to 17 inclusive.

tx_bit_cnt

A counter that may take on integer values from 1 to 17. This counter is used to keep a count of data bits sent within an FLP Burst. When this variable reaches 17, all data bits have been sent.

Values: not_done; 1 to 16 inclusive.
done; 17.
init; counter is initialized to 1.

28.3.4 State diagrams

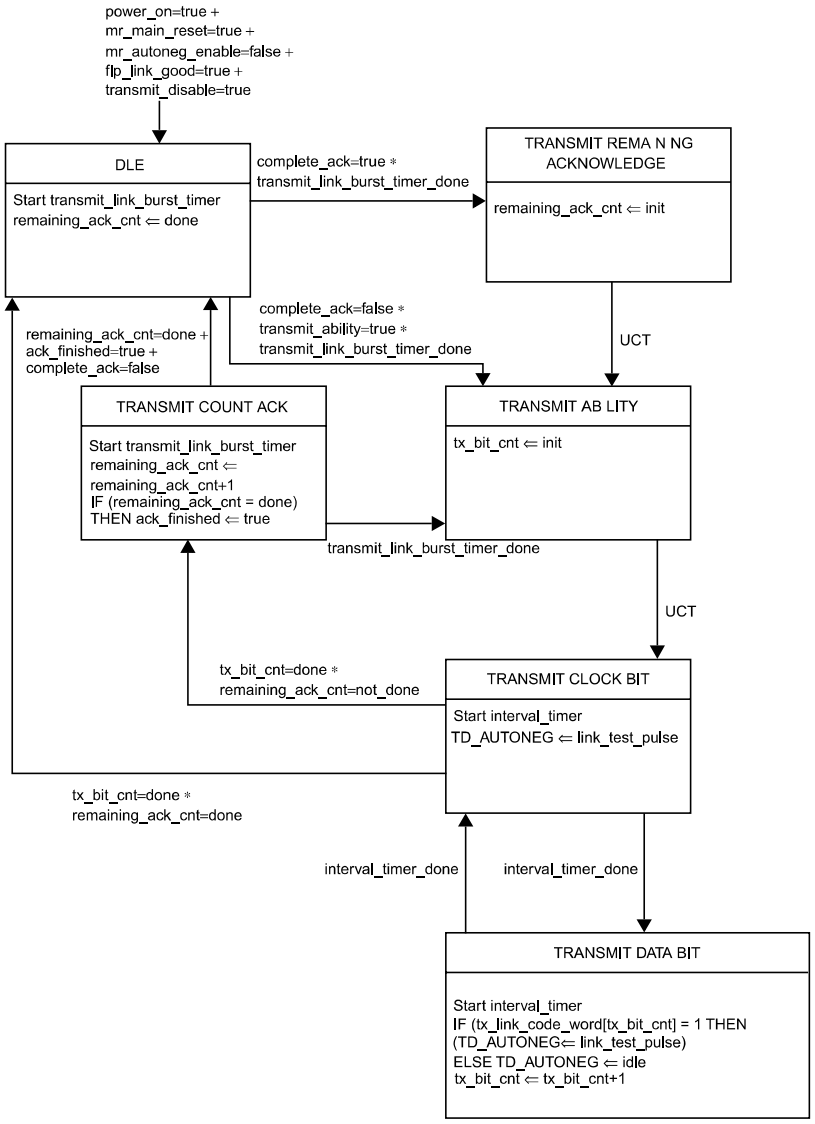


Figure 28-14—Transmit state diagram

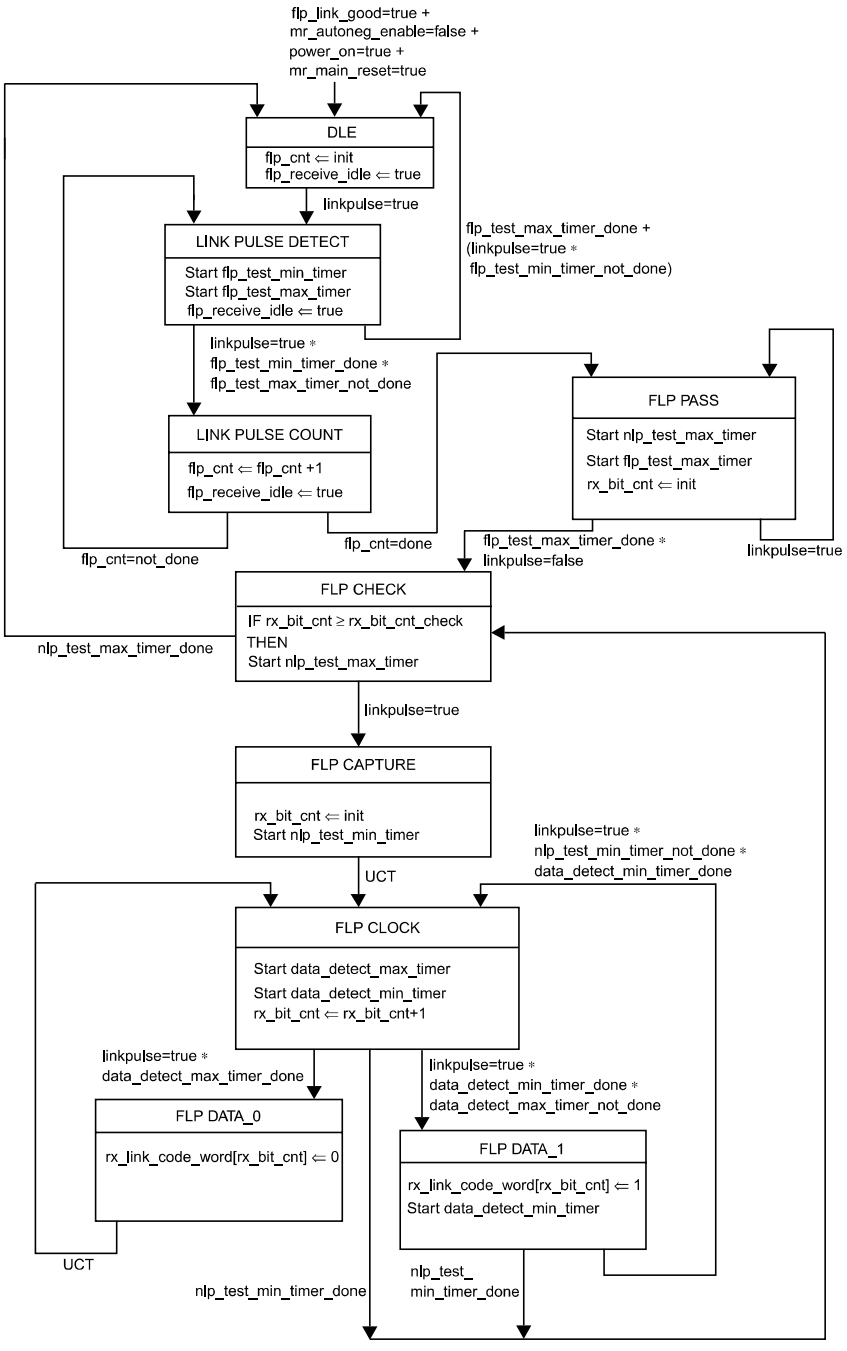


Figure 28-15—Receive state diagram

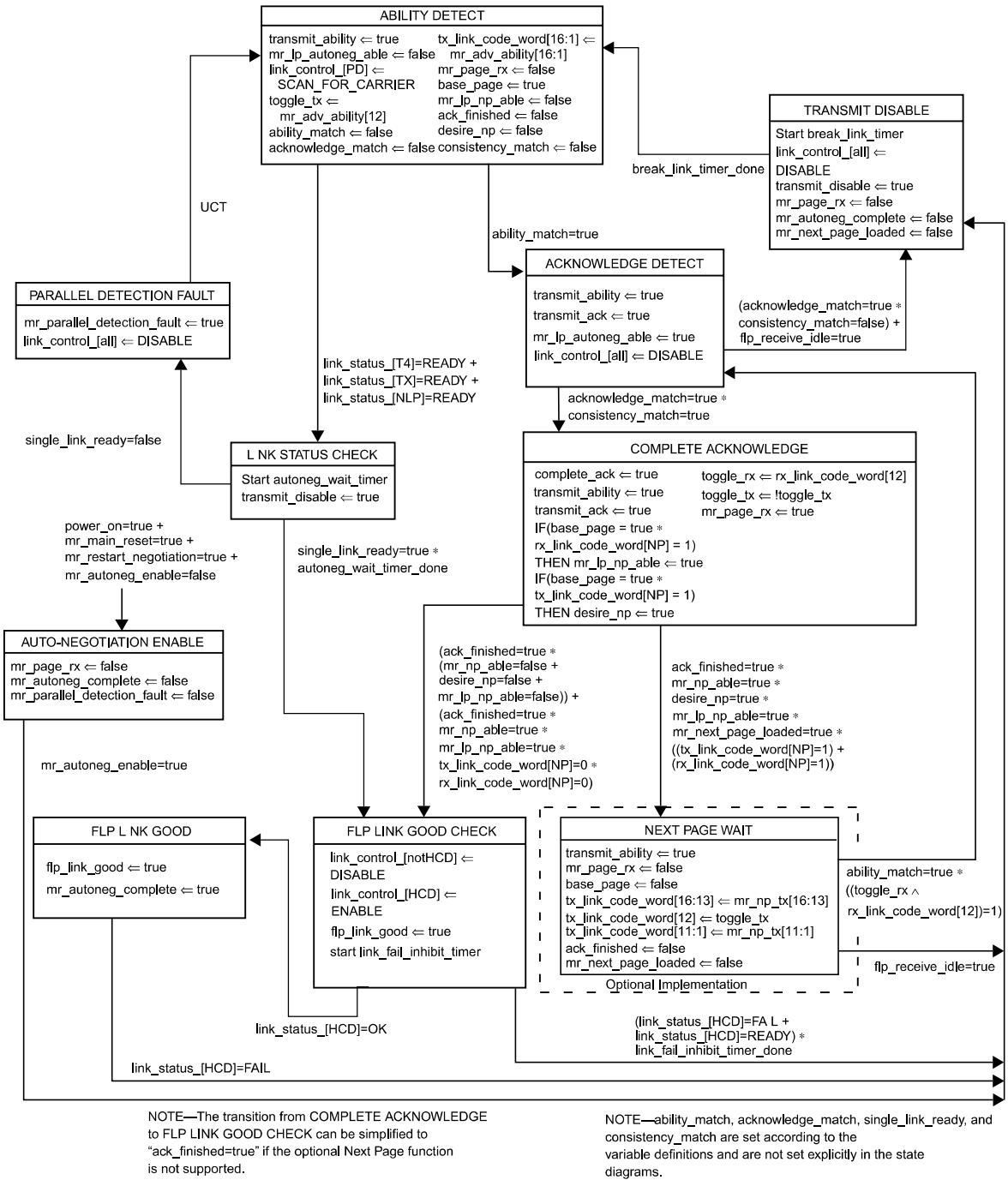
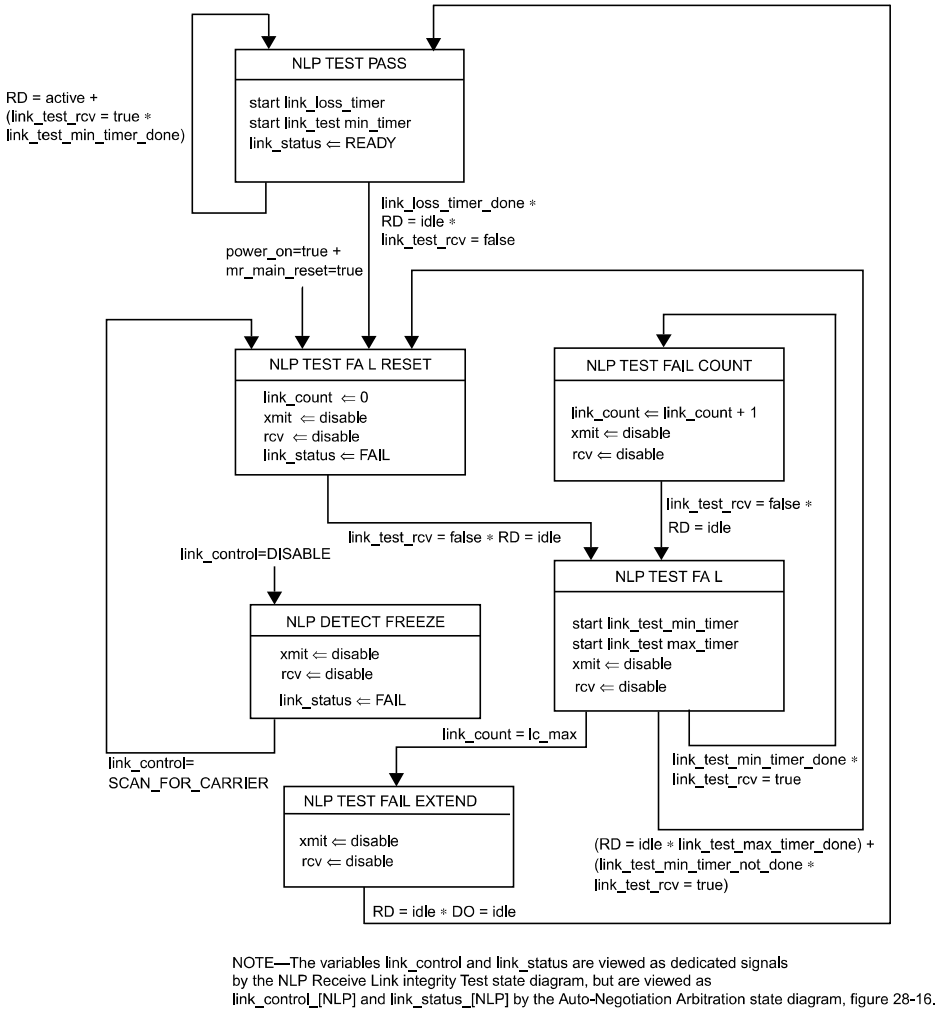


Figure 28-16—Arbitration state diagram



NOTE—The variables link_control and link_status are viewed as dedicated signals by the NLP Receive Link integrity Test state diagram, but are viewed as link_control_[NLP] and link_status_[NLP] by the Auto-Negotiation Arbitration state diagram, figure 28-16.

Figure 28-17—NLP Receive Link Integrity Test state diagram

28.4 Electrical specifications

The electrical characteristics of pulses within FLP Bursts shall be identical to the characteristics of NLPs and shall meet the requirements of figure 14-12.

It is the responsibility of the technology-specific Transmit and Receive functions to interface to the MDI correctly.

NOTE—The requirements relative to the interface to the MDI are specified via the Transmit Switch and Receive Switch functions.

28.5 Protocol Implementation Conformance Statement (PICS) proforma for clause 28, Physical Layer link signaling for 10 Mb/s and 100 Mb/s Auto-Negotiation on twisted pair[27]

28.5.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.3u-1995, Physical Layer link signaling for 10 Mb/s and 100 Mb/s Auto-Negotiation on twisted pair, shall complete the following Protocol Implementation Conformance Statement (PICS) proforma.

A detailed description of the symbols used in the PICS proforma, along with instructions for completing the PICS proforma, can be found in clause 21.

28.5.2 Identification

28.5.2.1 Implementation identification

Supplier	
Contact point for enquiries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification—e.g., name(s) and version(s) for machines and/or operating systems; System Names(s)	
NOTES 1—Only the first three items are required for all implementations; other information may be completed as appropriate in meeting the requirements for the identification. 2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).	

28.5.2.2 Protocol summary

Identification of protocol standard	IEEE Std 802.3u-1995, Physical Layer link signaling for 10 Mb/s and 100 Mb/s Auto-Negotiation on twisted pair
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	
Have any Exception items been required? No [ ] Yes [ ] (See clause 21; the answer Yes means that the implementation does not conform to IEEE Std 802.3u-1995.)	
Date of Statement	

[27] *Copyright release for PICS proformas* Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

28.5.3 Major capabilities/options

Item	Feature	Subclause	Status	Support	Value/comment
10BT	Implementation supports a 10BASE-T data service	28.1.2	O		N/A
*NP	Implementation supports Next Page function	28.1.2	O		N/A
*MII	Implementation supports the MII Management Interface	28.1.2	O/1		N/A
MGMT	Implementation supports a non-MII Management Interface	28.1.2	O/1		N/A
*NOM	Implementation does not support management	28.1.2	O/1		N/A
*RF	Implementation supports Remote Fault Sensing	28.2.3.5	O		N/A

28.5.4 PICS proforma tables for Physical Layer link signaling for 10 Mb/s and 100 Mb/s Auto-Negotiation on twisted pair

28.5.4.1 Scope

Item	Feature	Subclause	Status	Support	Value/comment
1	MII Management Interface control and status registers	28.1.3	MII:M		Implemented in accordance with the definitions in clause 22 and 28.2.4
2	CSMA/CD compatible devices using an eight-pin modular connector and using a signaling method to automatically configure the preferred mode of operation	28.1.4	M		Auto-Negotiation function implemented in compliance with clause 28
3	Device uses 10BASE-T compatible link signaling to advertise non-CSMA/CD abilities	28.1.4	M		Auto-Negotiation function implemented in compliance with clause 28
4	Future CSMA/CD implementations that use an eight-pin modular connector	28.1.4	M		Interoperable with devices compliant with clause 28

28.5.4.2 Auto-Negotiation functions

Item	Feature	Subclause	Status	Support	Value/comment
1	Transmit	28.2	M		Complies with figure 28-14
2	Receive	28.2	M		Complies with figure 28-15
3	Arbitration	28.2	M		Complies with figure 28-16
4	NLP Receive Link Integrity Test	28.2	M		Complies with figure 28-17
5	Technology-Dependent Interface	28.2	M		Complies with 28.2.6
6	Technology-dependent link integrity test	28.2	M		Implemented and interfaced to for those technologies supported by device
7	Management	28.2	O		MII based or alternate management

28.5.4.3 Transmit function requirements

Item	Feature	Subclause	Status	Support	Value/comment
1	FLP Burst transmission	28.2.1.1	M		Not transmitted once Auto-Negotiation is complete and highest common denominator PMA has been enabled. Prohibited other than for link start-up
2	FLP Burst composition	28.2.1.1.1	M		Pulses in FLP Bursts meet the requirements of figure 14-12
3	FLP Burst pulse definition	28.2.1.1.1	M		17 odd-numbered pulse positions represent clock information; 16 even-numbered pulse positions represent data information
4	The first pulse in an FLP Burst	28.2.1.1.2	M		Defined as a clock pulse for timing purposes
5	FLP Burst clock pulse spacing	28.2.1.1.2	M		Within an FLP Burst, spacing is 125 ± 14 µs
6	Logic one data bit representation	28.2.1.1.2	M		Pulse transmitted 62.5 ± 7 µs after the preceding clock pulse
7	Logic zero data bit representation	28.2.1.1.2	M		No link integrity test pulses within 111 µs of the preceding clock pulse
8	Consecutive FLP Bursts	28.2.1.1.2	M		The first link pulse in each FLP Burst is separated by 16 ± 8 ms
9	FLP Burst base page	28.2.1.2	M		Conforms to figure 28-7

Item	Feature	Subclause	Status	Support	Value/comment
10	FLP Burst bit transmission order	28.2.1.2	M		Transmission is D0 first to D15 last
11	Selector Field values	28.2.1.2.1	M		Only defined values transmitted
12	Technology Ability Field values	28.2.1.2.2	M		Implementation supports a data service for each ability set in the Technology Ability Field
13	Remote Fault bit	28.2.1.2.3	M		Used in accordance with the Remote Fault function specifications
14	Acknowledge bit set, no Next Page to be sent	28.2.1.2.4	M		Set to logic one in the Link Code Word after the reception of at least three consecutive and consistent FLP Bursts
15	Acknowledge bit set, Next Page to be sent	28.2.1.2.4	NP:M		Set to logic one in the transmitted Link Code Word after the reception of at least three consecutive and consistent FLP Bursts and the current receive Link Code Word is saved
16	Number of Link Code Words sent with Acknowledge bit set	28.2.1.2.4	M		6 to 8 inclusive after COMPLETE ACKNOWLEDGE state entered
17	Device does not implement optional Next Page ability	28.2.1.2.5	M		NP=0 in base Link Code Word
18	Device implements optional Next Page ability and wishes to engage in Next Page exchange	28.2.1.2.5	NP:M		NP=1 in base Link Code Word
19	Transmit Switch function on completion of Auto-Negotiation	28.2.1.3	M		Enables the transmit path from a single technology-dependent PMA to the MDI once the highest common denominator has been selected
20	Transmit Switch function during Auto-Negotiation	28.2.1.3	M		Connects FLP Burst generator governed by figure 28-14 to the MDI
21	Signals presented at MDI after connection through Transmit Switch from PMA	28.2.1.3	M		Conform to appropriate PHY specifications

28.5.4.4 Receive function requirements

Item	Feature	Subclause	Status	Support	Value/comment
1	Timer expiration	28.2.2.1	M		Timer definition in 28.3.2, values shown in table 28-8
2	Identification of Link Partner as Auto-Negotiation able	28.2.2.1	M		Reception of 6 to 17 (inclusive) consecutive link pulses separated by at least flp_test_min_timer time but less than flp_test_max_timer time
3	First FLP Burst identifying Link Partner as Auto-Negotiation able	28.2.2.1	M		Data recovered is discarded if FLP Burst is incomplete
4	First link pulse in an FLP Burst	28.2.2.1	M		Interpreted as a clock link pulse
5	Restart of the data_detect_min_timer and data_detect_max_timer	28.2.2.1	M		Detection of a clock link pulse (figure 28-9)
6	Reception of logic one	28.2.2.1	M		Link pulse received between greater than data_detect_min_timer time and less than data_detect_max_timer time after a clock pulse (figure 28-9)
7	Reception of logic zero	28.2.2.1	M		Link pulse received after greater than data_detect_max_timer time after clock pulse, is treated as clock pulse (figure 28-9)
8	FLP Bursts separation	28.2.2.1	M		Conforms to the nlp_test_min_timer and nlp_test_max_timer timing (figure 28-10)
9	Receive Switch function on completion of Auto-Negotiation	28.2.2.3	M		Enables the receive path from the MDI to a single technology-dependent PMA once the highest common denominator has been selected
10	Receive Switch function during Auto-Negotiation	28.2.2.3	M		Connects the MDI to the FLP and NLP receivers governed by figures 28-15 and 28-17, and to the 100BASE-TX and 100BASE-T4 receivers if present
11	Signals presented to PMA after connection through Receive Switch from MDI	28.2.2.3	M		Conform to appropriate PHY specifications
12	Generation of ability_match, acknowledge_match, and consistency_match	28.2.2.4	M		Responsibility of Receive function in accordance with 28.3.1

28.5.4.5 Arbitration functions

Item	Feature	Subclause	Status	Support	Value/comment
1	MDI receive connection during Auto-Negotiation, prior to FLP detection	28.2.3.1	M		Connected to the NLP Receive Link Integrity Test state diagram, and the link integrity test functions of 100BASE-TX and/or 100BASE-T4. Not connected to the 10BASE-T or any other PMA
2	Parallel detection operational mode selection	28.2.3.1	M		Set link_control=ENABLE for the single PMA indicating link_status=READY when the autoneg_wait_timer expires
3	Parallel detection PMA control	28.2.3.1	M		Set link_control=DISABLE to all PMAs except the selected operational PMA and indicate Auto-Negotiation has completed
4	Parallel detection setting of link partner ability register	28.2.3.1	M		On transition to the FLP LINK GOOD CHECK state from the LINK STATUS CHECK state the Parallel Detection function shall set the bit in the link partner ability register (register 5) corresponding to the technology detected by the Parallel Detection function
5	Response to renegotiation request	28.2.3.2	M		Disable all technology-dependent link integrity test functions and halt transmit activity until break_link_timer expires
6	Auto-Negotiation resumption	28.2.3.2	M		Issue FLP Bursts with base page valid in tx_link_code_word[16:1] after break_link_timer expires
7	Priority resolution	28.2.3.3	M		Single PMA connected to MDI is enabled corresponding to Technology Ability Field bit common to both Local/Link Partner Device and that has highest priority as defined by annex 28B
8	Effect of receipt of reserved Technology Ability Field bit on priority resolution	28.2.3.3	M		Local Device ignores during priority resolution
9	Effect of parallel detection on priority resolution	28.2.3.3	M		Local Device considers technology identified by parallel detection as HCD
10	Values for HCD and link_status_[HCD] in the event there is no common technology	28.2.3.3	M		HCD=NULL link_status_[HCD]=FAIL

Item	Feature	Subclause	Status	Support	Value/comment
11	Message Page to Unformatted Page relationship for non-matching Selector Fields	28.2.3.4	NP:M		Each series of Unformatted Pages is preceded by an Message Page containing a message code that defines how the following Unformatted Page(s) will be interpreted
12	Message Page to Unformatted Page relationship for matching Selector Fields	28.2.3.4	NP:M		Use of Message Pages is specified by the Selector Field value
13	Transmission of Null message codes	28.2.3.4	NP:M		Sent with NP=0 on completion of all Next Pages while Link Partner continues to transmit valid Next Page information
14	Reception of Null message codes	28.2.3.4	NP:M		Recognized as indicating end of Link Partner's Next Page information
15	Next Page encoding	28.2.3.4.1	NP:M		Comply with figures 28-11 and 28-12 for the NP, Ack, MP, Ack2, and T bits
16	Message/Unformatted Code Field	28.2.3.4.1	NP:M		D10-D0 encoded as Message Code Field if MP=1 or Unformatted Code Field if MP=0
17	NP bit encoding	28.2.3.4.2	NP:M		Logic 0=last page, logic 1=additional Next Page(s) follow
18	Message Page bit encoding	28.2.3.4.4	NP:M		Logic 0=Unformatted Page, logic 1=Message Page
19	Ack2 bit encoding	28.2.3.4.5	NP:M		Logic 0=cannot comply with message; logic 1= will comply with message
20	Toggle	28.2.3.4.6	NP:M		Takes the opposite value of the Toggle bit in the previously exchanged Link Code Word
21	Toggle encoding	28.2.3.4.6	NP:M		Logic zero = previous value of the transmitted Link Code Word equalled logic one Logic one = previous value of the transmitted Link Code Word equalled logic zero
22	Message Page encoding	28.2.3.4.7	NP:M		If MP=1, Link Code Word interpreted as Message Page
23	Message Code Field	28.2.3.4.8	NP:M		Combinations not shown in annex 28B are reserved and may not be transmitted
24	Unformatted Page encoding	28.2.3.4.9	NP:M		If MP=0, Link Code Word interpreted as Unformatted Page

Item	Feature	Subclause	Status	Support	Value/comment
25	Minimum Next Page exchange	28.2.3.4.11	NP:M		If both devices indicate Next Page able, both send a minimum of one Next Page
26	Multiple Next Page exchange	28.2.3.4.11	NP:M		If both devices indicate Next Page able, exchange continues until neither Local/Remote Device has additional information; device sends Next Page with Null Message Code if it has no information to transmit
27	Unformatted Page ordering	28.2.3.4.11	NP:M		Unformatted Pages immediately follow the referencing Message Code in the order specified by the Message Code
28	Next Page Transmit register	28.2.3.4.12	NP:M		Defined in 28.2.4.1.6
29	Next Page receive data	28.2.3.4.12	NP:O		May be stored in Auto-Negotiation link partner ability register
30	Remote Fault sensing	28.2.3.5	RF:M		Optional
31	Transmission of RF bit by Local Device	28.2.3.5	M		If Local Device has no method to set RF bit, it must transmit RF bit with value of RF bit in Auto-Negotiation advertisement register (4.13)
32	RF bit reset	28.2.3.5	M		Once set, the RF bit remains set until successful renegotiation with the base Link Code Word
33	Receipt of Remote Fault indication in Base Link Code Word	28.2.3.5	MII:M		Device sets the Remote Fault bit in the MII status register (1.4) to logic one if MII is present