

Introduction

The Ethernet Lite MAC (Media Access Controller) is designed to incorporate the applicable features described in the IEEE Std. 802.3 Media Independent Interface (MII) specification, which should be used as the definitive specification.

The Ethernet Lite MAC supports the IEEE Std. 802.3 Media Independent Interface (MII) to industry standard Physical Layer (PHY) devices and communicates to a processor via a Processor Local Bus (PLB) interface. The design provides a 10 megabits per second (Mbps) and 100 Mbps (also known as Fast Ethernet) Interface. The goal is to provide the minimal functions necessary to provide an Ethernet interface with the least resources used.

Features

- Connects as 32-bit slave on PLB V4.6 buses of 32, 64 or 128 bits
- Supports single beat and burst transactions
- Memory mapped direct I/O interface to the transmit and receive data dual port memory
- Media Independent Interface (MII) for connection to external 10/100 Mbps PHY transceivers
- Independent internal 2K byte Tx and Rx dual port memory for holding data for one packet
- Optional dual buffer memories, 4K byte ping-pong, for Tx and Rx
- Receive and Transmit Interrupts
- Optional MDIO interface for PHY access
- Internal loop back support

LogiCORE™ Facts		
Core Specifics		
Supported Device Family	Spartan®-3, Spartan-3E, Spartan-3A, Spartan-6, Spartan-3A DSP, Automotive Spartan-3/3A/3A DSP/ 3E, Virtex®-4, Virtex-4Q, Virtex-4QV, Virtex-5/5FX, Virtex-6	
Version of Core	xps_ethernetlite	v3.01a
Resources Used		
	Min	Max
Slices	Refer to Table 16 , Table 17 , Table 18 , Table 19 and Table 20	
LUTs		
FFs		
Block RAMs		
Special Features	N/A	
Provided with Core		
Documentation	Product Specification	
Design File Formats	VHDL	
Constraints File	N/A	
Verification	N/A	
Instantiation Template	N/A	
Reference Designs & Application Notes	N/A	
Design Tool Requirements		
Xilinx Implementation Tools	ISE® 11.2 or later	
Verification	N/A	
Simulation	QuestaSim PE/SE 6.4b or later	
Synthesis	XST	
Support		
Provided by Xilinx, Inc.		

Functional Description

The top level block diagram of the XPS Ethernet Lite MAC is shown in **Figure 1**.

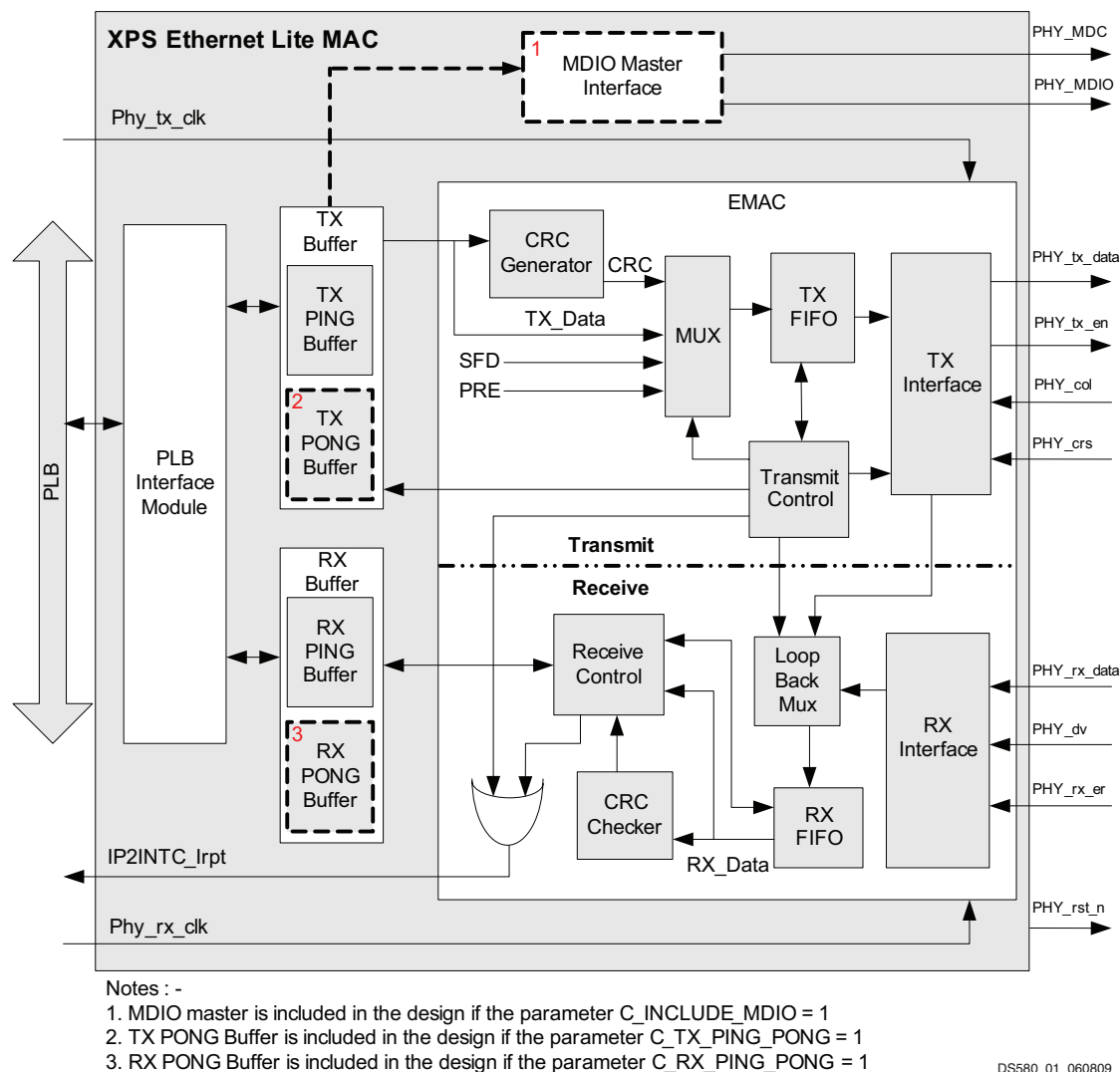


Figure 1: XPS Ethernet Lite Block Diagram

The XPS Ethernet Lite Mac core consists of following modules.

PLB Interface Module

The PLB Interface Module provides the interface between Ethernet Lite MAC and the PLB. Read and write transactions at the PLB are translated into equivalent IP Interconnect (IPIC) transactions. This module does the necessary protocol and timing translation between PLB and Ethernet Lite MAC. This module supports single as well as burst transactions to the Ethernet Lite MAC core.

TX Buffer

The TX Buffer module consists of 2K byte dual port memory to hold transmit data for one complete frame and the transmit interface control registers. It also includes optional 2K byte dual port memory for pong buffer based on the parameter C_TX_PING_PONG.

RX Buffer

The RX Buffer module consists of 2K byte dual port memory to hold receive data for one complete frame and the receive interface control register. It also includes optional 2K byte dual port memory for pong buffer based on the parameter C_RX_PING_PONG.

Transmit

This module consists transmit logic, CRC generator module, transmit data mux, TX FIFO and transmit interface module. CRC generator module calculates the CRC for the frame need to be transmitted. The transmit control mux arrange this frame and sends preamble, SFD, frame data, padding and CRC to the transmit FIFO in the required order. Once the frame is transmitted to PHY, this module generates transmit interrupt and updates the transmit control register.

Receive

This module consists of RX interface, loop back control mux, RX FIFO, CRC checker and receive control module. Receive data signals from the PHY are passed through loop back control mux and stored in RX FIFO. If loop back is enabled, data on TX lines is passed to RX FIFO. The CRC checker module calculates the CRC of the received frame and if the correct CRC is found, Receive control logic generates the frame receive interrupt.

MDIO Master Interface

MDIO Master Interface module is included in the design if the parameter C_INCLUDE_MDIO is set to '1'. This module provide access to PHY register for PHY management. The MDIO interface is described in [Management Data Input/Output \(MDIO\) Master Interface Module](#).

Ethernet Protocol

Ethernet data is encapsulated in frames as shown in [Figure 2](#). The fields in the frame are transmitted from left to right. The bits within the frame are transmitted from left to right (from least significant bit to most significant bit unless specified otherwise).

Preamble

The preamble field is used for synchronization and must contain seven bytes with the pattern "10101010". The pattern is transmitted from left to right. If a collision is detected during the transmission of the preamble or start of frame delimiter fields, the transmission of both fields will be completed.

For transmission, this field is always automatically inserted by the Ethernet Lite MAC and should never appear in the packet data provided to the Ethernet Lite MAC. For reception, this field is always stripped from the packet data. The Ethernet Lite MAC design does not support the ethernet 8-byte preamble frame type.

Start Frame Delimiter

The start frame delimiter field marks the start of the frame and must contain the pattern 10101011. The pattern is transmitted from left to right. If a collision is detected during the transmission of the preamble or start of frame delimiter fields, the transmission of both fields will be completed.

The receive data valid signal from the PHY (PHY_dv) may go active during the preamble but will be active prior to the start frame delimiter field. For transmission, this field is always automatically inserted by the Ethernet Lite MAC and should never appear in the packet data provided to the Ethernet Lite MAC. For reception, this field is always stripped from the packet data.

Destination Address

The destination address field is 6 bytes in length¹. The least significant bit of the destination address is used to determine if the address is an individual/unicast (0) or group/multicast (1) address. Multicast addresses are used to group logically related stations.

The broadcast address (destination address field is all 1's) is a multicast address that addresses all stations on the LAN. The Ethernet Lite MAC supports transmission and reception of unicast and broadcast packets.

This field is transmitted with the least significant bit first. This field is always provided in the packet data for transmissions and is always retained in the receive packet data.

Source Address

The source address field is 6 bytes in length². This field is transmitted with the least significant bit first. This field is always provided in the packet data for transmissions and is always retained in the receive packet data.

Type/Length

The type/length field is 2 bytes in length. When used as a length field, the value in this field represents the number of bytes in the following data field. This value does not include any bytes that may have been inserted in the padding field following the data field.

The value of this field determines if it should be interpreted as a length as defined by the IEEE 802.3 standard or a type field as defined by the ethernet protocol.

The maximum length of a data field is 1,500 bytes. Therefore, a value in this field that exceeds 1,500 (0x05DC) would indicate that a frame type rather than a length value is provided in this field. The IEEE 802.3 standard uses the value 1536 (0x0600) or greater to signal a type field.

The Ethernet Lite MAC does not perform any processing of the type/length field.

This field is transmitted with the least significant bit first but with the high order byte first. This field is always provided in the packet data for transmissions and is always retained in the receive packet data.

Data

The data field may vary from 0 to 1500 bytes in length. This field is transmitted with the least significant bit first. This field is always provided in the packet data for transmissions and is always retained in the receive packet data.

Pad

The pad field may vary from 0 to 46 bytes in length. This field is used to insure that the frame length is at least 64 bytes in length (the preamble and SFD fields are not considered part of the frame for this calculation) which is required for successful CSMA/CD operation.

1. The Ethernet Lite MAC design does not support 16-bit destination addresses as defined in the IEEE 802 standard
2. The Ethernet Lite MAC design does not support 16-bit source addresses as defined in the IEEE 802 standard

The values in this field are used in the frame check sequence calculation but are not included in the length field value if it is used. The length of this field and the data field combined must be at least 46 bytes. If the data field contains 0 bytes, the pad field will be 46 bytes. If the data field is 46 bytes or more, the pad field will have 0 bytes.

For transmission, this field will be inserted automatically by the Ethernet Lite MAC if needed to meet the minimum length requirement. If present during receive packet, this field is always retained in the receive packet data.

FCS

The FCS field is 4 bytes in length. The value of the FCS field is calculated over the source address, destination address, length/type, data, and pad fields using a 32-bit Cyclic Redundancy Check (CRC) defined as¹:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x^1 + x^0$$

The CRC bits are placed in the FCS field with the x^{31} term in the left most bit of the first byte and the x^0 term is the right most bit of the last byte (i.e., the bits of the CRC are transmitted in the order $x^{31}, x^{30}, \dots, x^1, x^0$).

The Ethernet Lite MAC implementation of the CRC algorithm calculates the CRC value a nibble at a time to coincide with the data size exchanged with the external PHY interface for each transmit and receive clock period.

For transmission, this field is always inserted automatically by the Ethernet Lite MAC and is always retained in the receive packet data.

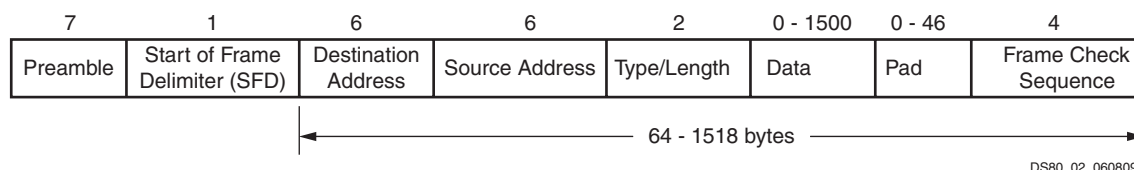


Figure 2: Ethernet Data Frame

Interframe Gap² and Deferring

Frames are transmitted over the serial interface with an interframe gap which is specified by the IEEE Std. 802.3 to be 96 bit times (9.6 uS for 10 MHz and 0.96 uS for 100 MHz). The process for deferring is different for half-duplex and full-duplex systems and is as follows:

Half-Duplex

1. Even when it has nothing to transmit, the Ethernet Lite MAC monitors the bus for traffic by watching the carrier sense signal (PHY_crs) from the external PHY. Whenever the bus is busy (PHY_crs = '1'), the Ethernet Lite MAC defers to the passing frame by delaying any pending transmission of its own.
2. After the last bit of the passing frame (when carrier sense signal changes from true to false), the Ethernet Lite MAC starts the timing of the interframe gap.
3. The Ethernet Lite MAC will reset the interframe gap timer if carrier sense becomes true.

1. Reference IEEE Std. 802.3 para. 3.2.8
2. Interframe Gap and interframe spacing are used interchangeably and are equivalent.

Full-Duplex

1. The Ethernet Lite MAC does not use the carrier sense signal from the external PHY when in full duplex mode because the bus is not shared and only needs to monitor its own transmissions. After the last bit of an Ethernet Lite MAC transmission, the Ethernet Lite MAC starts the timing of the interframe gap.

Carrier sense multiple access with collision detection (CSMA/CD) access method

A full duplex ethernet bus is by definition, a point to point dedicated connection between two ethernet devices capable of simultaneous transmit and receive with no possibility of collisions.

For a half duplex ethernet bus, the CSMA/CD media access method defines how two or more stations share a common bus.

To transmit, a station waits (defers) for a quiet period on the bus (no other station is transmitting (PHY_crs = '0')) and then starts transmission of its message after the interframe gap period.

If, after initiating a transmission, the message collides with the message of another station (PHY_col = '1'), then each transmitting station intentionally continues to transmit (jam) for an additional predefined period (32 bits for 10/100 Mbps) to ensure propagation of the collision throughout the system.

The station remains silent for a random amount of time (backoff) before attempting to transmit again.

A station can experience a collision during the beginning of its transmission (the collision window) before its transmission has had time to propagate to all stations on the bus. Once the collision window has passed, a transmitting station has acquired the bus.

Subsequent collisions (late collisions) are avoided because all other (properly functioning) stations are assumed to have detected the transmission and are deferring to it.

The time to acquire the bus is based on the round-trip propagation time of the bus (64 byte times for 10/100 Mbps).

Transmit Flow

The flow chart in **Figure 3** shows the high level flow followed for packet transmission.

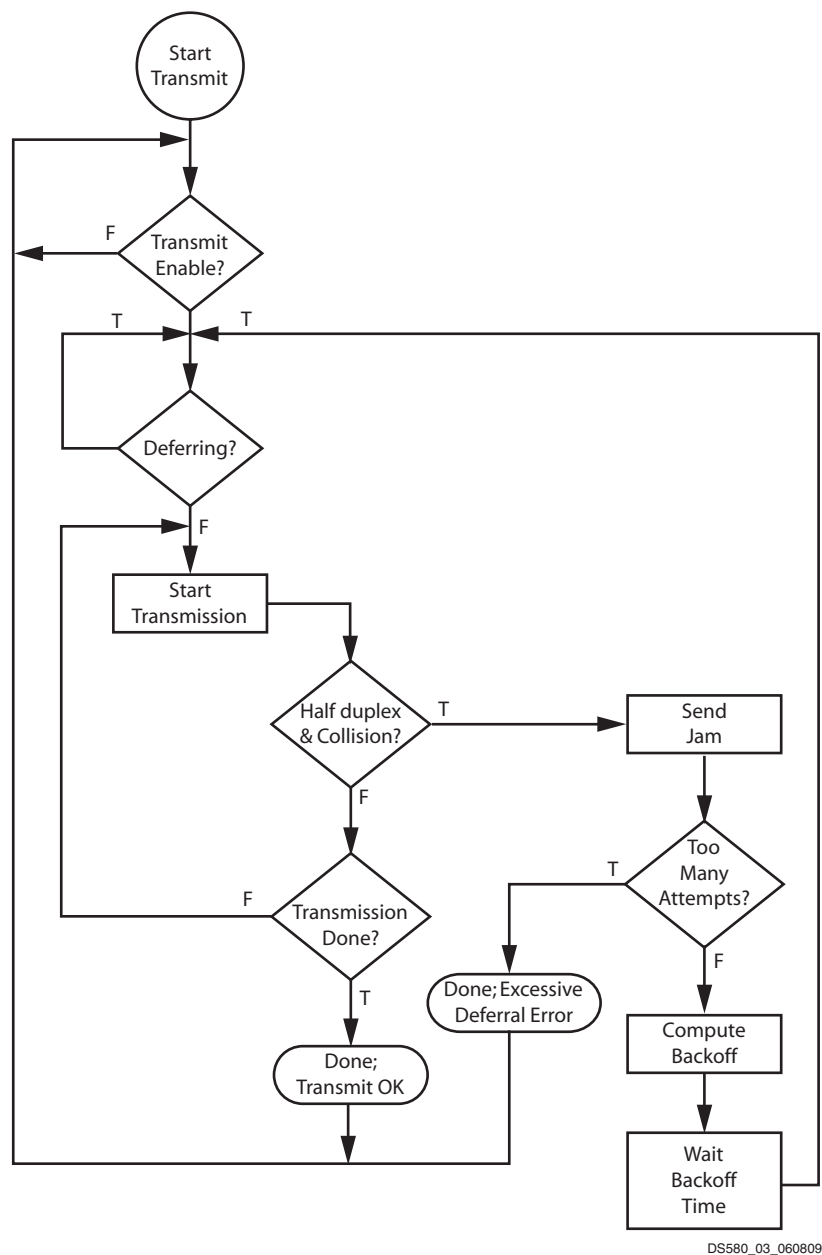


Figure 3: Transmit Flow

Receive Flow

The flow chart in **Figure 4** shows the high level flow followed for packet reception.

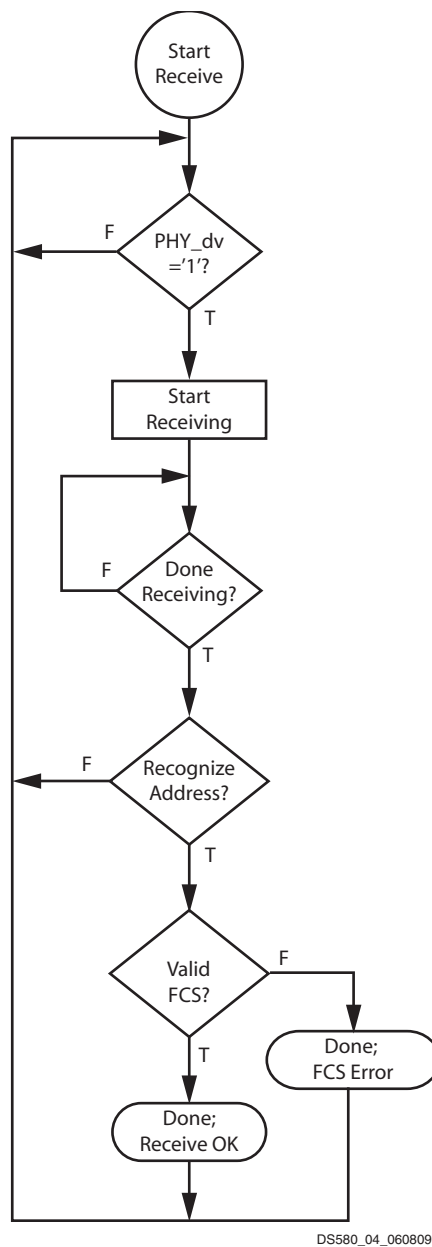


Figure 4: **Receive Flow**

Processor Interface

Single memory buffer Interface, C_TX_PING_PONG = C_RX_PING_PONG = 0

The Ethernet Lite MAC has a very simple interface to the processor. The interface is implemented with a 32-bit wide data interface to a 4K byte block of dual port memory. The registers are implemented in the dual port memory.

The dual port memory is allocated so that 2K bytes are dedicated to the transmit function and 2K bytes are dedicated to the receive function. This memory is capable of holding one maximum length ethernet packet in the receive and transmit memory areas simultaneously.

Transmit Interface

The transmit data should be stored in the dual port memory starting at address C_BASEADDR + 0x0. Due to the word aligned addressing, the second 4 bytes are located at C_BASEADDR + 0x4. The 32-bit interface requires that all 4 bytes be written at once, there is not individual byte enables within one 32-bit word.

The transmit data must include the destination address (6 bytes), the source address (6 bytes), the type/length field (2 bytes), and the data field (0 - 1500 bytes). The preamble, start of frame, and CRC should not be included in the dual port memory. The destination, source, type/length, and data must be packed together in contiguous memory.

Dual port memory address BASEADDR + 0x07F8 is used to set the global interrupt enable (GIE) bit. Setting the GIE = '0' prevents the IP2INTC_Irpt from going active during an interrupt event. Setting GIE = '1' allows the IP2INTC_Irpt to go active when an interrupt event has occurred.

Dual port memory addresses BASEADDR + 0x07F4 is used to store the length (in bytes) of the transmit data stored in dual port memory. The higher 8-bits of the length value should be stored in data bits (16 - 23), while the lower 8-bits should be stored data bits (24 - 31).

The least two significant bits of dual port memory address BASEADDR + 0x07FC are control bits (Program or "P" and Status or "S") that will be described below. The fourth bit (bit 28 on the data bus) (Transmit Interrupt Enable or "I") is used to enable transmit complete interrupt events. This event is a pulse and will occur anytime the memory is ready to accept new data. This includes the completion of programing the MAC address. The transmit complete interrupt will occur only if GIE and this bit are both set to '1'.

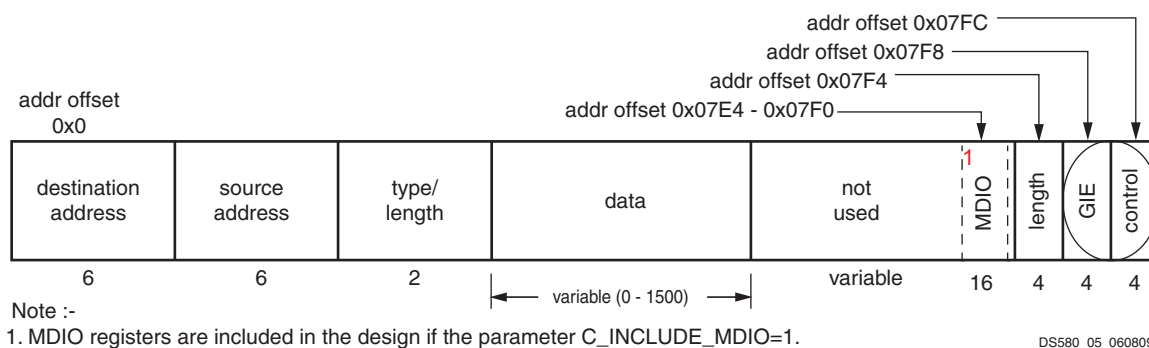


Figure 5: Transmit Dual Port Memory

Transmit Dual Port Memory Register Description

This section tabulates the transmit dual port memory registers and their reset values. All these register can be access by single word transaction only. Burst write to these registers will not have any effect on the registers and burst read from these register will return '0'.

Transmit Length Register

The Transmit Length Register is an 32-bit read/write register as shown in **Figure 6**. This register is used to store the length (in bytes) of the transmit data stored in dual port memory. The higher 8-bits of the length value should be stored in data bits (16 - 23), while the lower 8-bits should be stored data bits (24 - 31). The bit definition and accessibility of this register for Ping and Pong buffer interface is shown in **Table 1**.



Figure 6: Transmit Length Register

Table 1: Transmit Length Register Bit Definitions (C_BASEADDR + 0x07F4),(C_BASEADDR + 0x0FF4)

Bit	Name	Access	Reset value	Description
0-15	Reserved	N/A	N/A	Reserved
16-23	MSB	Read/Write	"0x00"	The higher 8-bits of the frame length
24-31	LSB	Read/Write	"0x00"	The lower 8-bits of the frame length

Global Interrupt Enable Register (GIE)

The Global Interrupt Enable Register is an 32-bit read/write register as shown in **Figure 7**. The GIE register is used to enable transmit complete interrupt events. This event is a pulse and will occur anytime the memory is ready to accept new data. This includes the completion of programing the MAC address. The transmit complete interrupt will occur only if GIE and transmit/receive interrupt enable bit are both set to '1'. The bit definition and accessibility of this register is shown in **Table 2**.

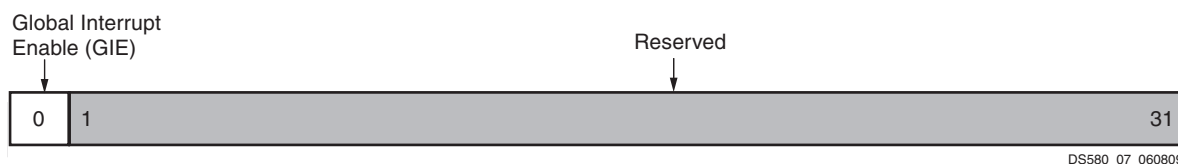


Figure 7: Global Interrupt Enable

Table 2: Global Interrupt Enable Register Bit Definitions (C_BASEADDR + 0x07F8)

Bit	Name	Access	Reset value	Description
0	GIE	Read/Write	'0'	Global Interrupt Enable bit
1-31	Reserved	N/A	N/A	Reserved

Transmit Control Register (Ping)

The Transmit Control Register for ping buffer is an 32-bit read/write register as shown in **Figure 8**. This register is used to enable the global interrupt, internal loop back and to initiate transmit transaction. The bit definition and accessibility of this register is shown in **Table 3**.

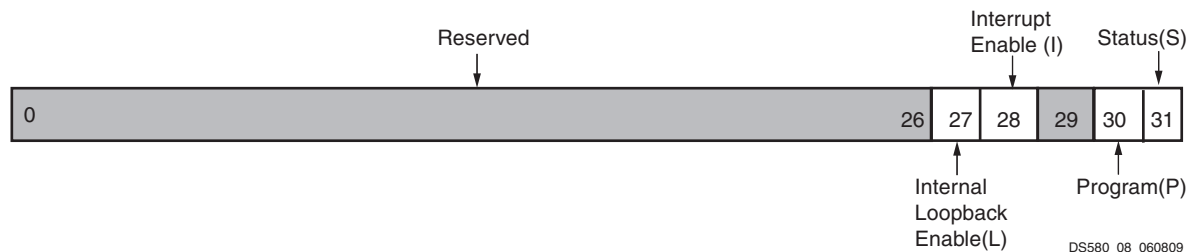


Figure 8: Transmit Control Register

Table 3: Transmit Control Register Bit Definitions (C_BASEADDR + 0x07FC)

Bit	Name	Access	Reset value	Description
0-26	Reserved	N/A	N/A	Reserved
27	Loop back	Read/Write	'0'	Internal Loop back enable bit 0 - No internal loop back 1 - Internal loop back enable
28	Interrupt Enable ^[1]	Read/Write	'0'	Transmit Interrupt Enable bit 0 - Disable transmit interrupt 1 - Enable transmit interrupt
29	Reserved	N/A	N/A	Reserved
30	Program	Read/Write	'0'	Ethernet Lite MAC address program bit. Setting this bit and Status bit will configure the new MAC address for the core as described in MAC Address .
31	Status	Read/Write	'0'	Transmit ping buffer status indicator 0 - Transmit ping buffer is ready to accept new frame 1 - Frame transfer is in progress. Setting this bit will initiate transmit transaction. Once transmit is complete, Ethernet Lite MAC core clears this bit.
Note:- 1. Internal Loop back is supported only in full duplex operation mode.				

Transmit Control Register (Pong)

The Transmit Control Register for pong buffer is an 32-bit read/write register as shown in [Figure 9](#). This register is used for MAC address programming and to initiate transmit transaction from pong buffer. The bit definition and accessibility of this register is shown in [Table 4](#).

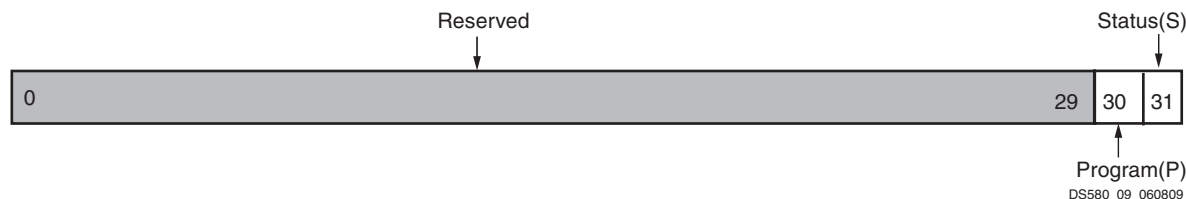


Figure 9: Transmit Control Register (Pong)

Table 4: Transmit Control Register Bit Definitions (C_BASEADDR + 0x0FFC)

Bit	Name	Access	Reset value	Description
0-29	Reserved	N/A	N/A	Reserved
30	Program	Read/Write	'0'	Ethernet Lite MAC address program bit. Setting this bit and Status bit will configure the new MAC address for the core as described in MAC Address .
31	Status	Read/Write	'0'	Transmit pong buffer status indicator 0 - Transmit pong buffer is ready to accept new frame 1 - Frame transfer is in progress. Setting this bit will initiate transmit transaction. Once transmit is complete, Ethernet Lite MAC core clears this bit.

Software Sequence for Transmit with Ping Buffer

The Ethernet Lite MAC requires that the length of the transmit data be stored in address offset 0x07F4 before the software sets the status bit at offset 0x07FC.

The proper software sequence for initiating a transmit is as follows:

- The software stores the transmit data in the dual port memory starting at address offset 0x0
- The software writes the length data in the dual port memory at address offset 0x07F4
- The software writes a '1' to the Status bit at address offset 0x07FC (bit 31 on the data bus)
- The software monitors the Status bit and waits until it is set to '0' by the Ethernet Lite MAC before initiating another transmit
- If the transmit interrupt and the global interrupt are both enabled, an interrupt will occur when the Ethernet Lite MAC clears the Status bit
- The transmit interrupt if enabled will also occur with the completion on writing the MAC address

Setting the Status bit to a '1' initiates the Ethernet Lite MAC transmit which will perform the following functions:

- Generate the preamble and start of frame fields

- Read the length and the specified amount of data out of the dual port memory according to the length value adding padding if required
- Detect any collision and performing any jamming, backoff, and retry if necessary
- Calculates the CRC and appends it to the end of the data
- Clears the status bit at the completion of the transmission
- Clearing the status bit will cause a transmit complete interrupt if enabled

Transmit Ping-Pong

If C_TX_PING_PONG is set to 1 then two memory buffers exist for the transmit data. The original (ping transmit buffer) remains at the same memory address and controls the global interrupt enable. The second (pong buffer) is mapped at BASEADDR + 0x0800 through 0x0FFC. The length and status must be used in the pong buffer the same as in the ping buffer. The I bit and GIE bit are not used from the pong buffer (i.e., the I bit and GIE bit of the ping buffer alone control the I bit and GIE bit settings for both buffers). The MAC address may be set from the pong buffer. The transmitter will always empty the ping buffer first after a reset. Then if data is ready to be transmitted from the pong buffer that will occur. However, if the pong buffer is not ready to transmit data the Ethernet Lite MAC will begin to monitor both the ping and pong buffer and transmit which ever buffer is ready first.

The proper software sequence for initiating a transmit with both a ping and pong buffer is as follows:

- The software stores the transmit data in the dual port memory starting at address offset 0x0
- The software writes the length data in the dual port memory at address offset 0x07F4
- The software writes a '1' to the Status bit at address offset 0x07FC (bit 31 on the data bus)
- The software may write to the pong buffer (0x0800 - 0x0FFC) at any time
- The software monitors the Status bit in the ping buffer and waits until it is set to '0', or waits for a transmit complete interrupt, before filling the ping buffer again
- If the transmit interrupt and the global interrupt are both enabled, an interrupt will occur when the Ethernet Lite MAC clears the Status bit
- The transmit interrupt if enabled will also occur with the completion of writing the MAC address

Setting the Status bit to a '1' initiates the Ethernet Lite MAC transmit which will perform the following functions:

- Generate the preamble and start of frame fields
- Read the length and the specified amount of data out of the dual port memory according to the length value adding padding if required
- Detect any collision and performing any jamming, backoff, and retry if necessary
- Calculates the CRC and appends it to the end of the data
- Clears the status bit at the completion of the transmission
- Clearing the status bit will cause a transmit complete interrupt if enabled
- The hardware will then transmit the pong buffer if it is available, or begin monitoring both ping and pong buffers until data is available

MAC Address

The 48-bit MAC address defaults at reset to 00-00-5E-00-FA-CE. This value can be changed by performing an address program operation via the transmit dual port memory.

The proper software sequence for programming a new MAC address is as follows:

- The software loads the new MAC address, in the transmit dual port memory starting at address offset 0x0. The most significant four bytes are stored at address offset 0x0 and the least significant two bytes are stored at address offset 0x4. The MAC address may also be programmed from the pong buffer starting at 0x0800
- The software writes a '1' to both the Program bit (bit 30 on the data bus) and the Status bit (bit 31 on the data bus) at address offset 0x07FC. The pong buffer address is 0x0FFC
- The software monitors the Status and Program bits and waits until they are set to '0's before performing any additional ethernet operations
- A transmit complete interrupt, if enabled, will occur when the Status and Program bits are cleared

Receive Interface

The entire received frame data from destination address to the end of the CRC is stored in the receive dual port memory area which starts at address BASEADDR + 0x1000. The preamble and start of frame fields are not stored in dual port memory.

Dual port memory address offset 0x17FC (bit 31 on the data bus) is used as a status to indicated the presence of a receive packet that is ready for processing by the software.

Dual port memory address offset 0x17FC (bit 28 on the data bus) is the Receive Interrupt enable. This event is a pulse and will occur anytime the memory has data available. The receive complete interrupt will occur only if GIE and this bit are both set to '1'.

When the Status bit is '0', the Ethernet Lite MAC will monitor the ethernet for packets with a destination address that matches its MAC address or the broadcast address. If a packet satisfies either of these conditions, the packet is received and stored in dual port memory starting at address offset 0x1000.

Once the packet has been received, the Ethernet Lite MAC verifies the CRC. If the CRC value is correct, the status bit is set. If the CRC bit is incorrect, the status bit is not set and the Ethernet Lite MAC resumes monitoring the ethernet bus. Also, if the Ethernet Lite MAC core receive Runt Frame (frame length less than the 60 Bytes) with valid CRC, the core will not set the status bit and interrupt will not be generated.

Once the Status bit is set, the Ethernet Lite MAC will not perform any receive operations until the bit has been cleared to '0' by software indicating that all of the receive data has been retrieved from the dual port memory.

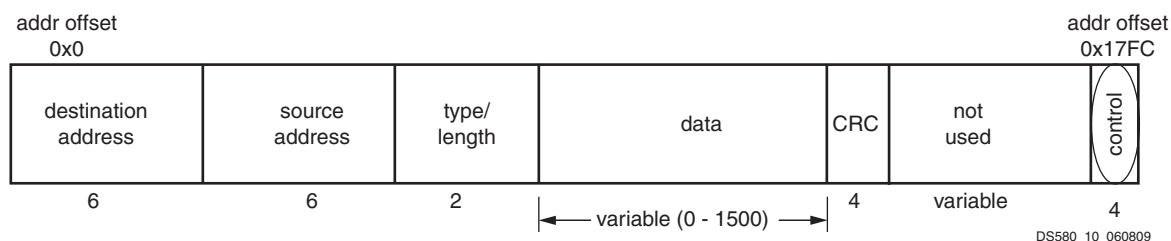


Figure 10: Receive Dual Port Memory

Receive Dual Port Memory Register Description

This section tabulates the receive dual port memory registers and their reset values. All these register can be access by single word transaction only. Burst write to these registers will not have any effect on the registers and burst read from these register will return '0'.

Receive Control Register (Ping)

The Receive Control Register for ping buffer is an 32-bit read/write register as shown in **Figure 11**. This register is used to inform about the availability of new packet in the ping buffer. The bit definition and accessibility of this register is shown in **Table 5**.

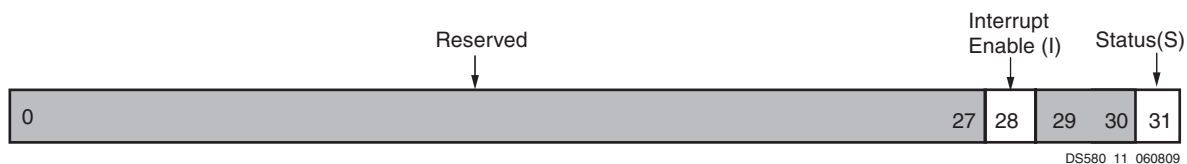


Figure 11: Receive Control Register

Table 5: Receive Control Register Bit Definitions (C_BASEADDR + 0x17FC)

Bit	Name	Access	Reset value	Description
0-27	Reserved	N/A	N/A	Reserved
28	Interrupt Enable	Read/Write	'0'	Receive Interrupt Enable bit 0 - Disable receive interrupt 1 - Enable receive interrupt
29-30	Reserved	N/A	N/A	Reserved
31	Status	Read/Write	'0'	Receive status indicator 0 - Receive ping buffer is empty. Ethernet Lite MAC can accept new available valid packet. 1 - Indicates presence of receive packet ready for software processing. Once software reads the packet from the receive ping buffer, software must clears this bit.

Receive Control Register (Pong)

The Receive Control Register for pong buffer is an 32-bit read/write register as shown in **Figure 12**. This register is used to inform about the availability of new packet in the pong buffer. The bit definition and accessibility of this register is shown in **Table 6**.



Figure 12: Receive Control Register

Table 6: Receive Control Register Bit Definitions (C_BASEADDR + 0x1FFC)

Bit	Name	Access	Reset value	Description
0-30	Reserved	N/A	N/A	Reserved
31	Status	Read/Write	'0'	Receive status indicator 0 - Receive pong buffer is empty. Ethernet Lite MAC can accept new available valid packet. 1 - Indicates presence of receive packet ready for software processing. Once software reads the packet from the receive pong buffer, software must clear this bit.

Software Sequence for Receive with Ping Buffer

The proper software sequence for processing a receive is as follows:

- The software monitors the receive Status bit until it is set to '1' by the Ethernet Lite MAC, waits for a receive complete interrupt if enabled
- Once the Status is set to '1', or a receive complete interrupt has occurred, the software reads the entire receive data out of the dual port memory
- The software writes a '0' to the receive Status bit enabling the Ethernet Lite MAC to resume receive processing

Receive Ping-Pong

If C_RX_PING_PONG is set to '1' then two memory buffers exist for the receive data. The original (ping receive buffer) remains at the same memory location. The second (pong receiver buffer) is mapped at BASEADDR + 0x1800 through 0x1FFC. Data is stored the same in the pong buffer as it is in the ping buffer.

The proper software sequence for processing a receive packet(s) with C_RX_PING_PONG = 1 is as follows:

- The software monitors the ping receive Status bit until it is set to '1' by the Ethernet Lite MAC, or waits for a receive complete interrupt if enabled
- Once the ping Status is set to '1', or a receive complete interrupt has occurred, the software reads the entire receive data out of the ping dual port memory
- The Ethernet Lite MAC will receive the next packet and store it in the pong receive buffer
- The software writes a '0' to the ping receive Status bit enabling the Ethernet Lite MAC to receive another packet in the ping receive buffer
- The software monitors the pong receive Status bit until it is set to '1' by the Ethernet Lite MAC, or waits for a receive complete interrupt if enabled
- Once the pong Status is set to '1', or a receive complete interrupt has occurred, the software reads the entire receive data out of the ping dual port memory
- The hardware will always write the first received packet after a reset to the ping buffer, the second received packet will be written to the pong buffer and the third received packet will be written to the ping buffer

Management Data Input/Output (MDIO) Master Interface Module

The Management Data Input/Output Master Interface module is included in the design if the parameter C_INCLUDE_MDIO = 1. Including this logic allows Ethernet Lite MAC core to access PHY configuration registers. The MDIO Master Interface module is designed to incorporate the features described in IEEE 802.3 Media Independent Interface (MII) specification.

The MDIO module generates management data clock to the PHY(PHY_MDC) with minimum period of 400 ns. PHY_MDC is sourced to PHY as timing reference for transfer of information on the PHY_MDIO (Management Data Input/Output) data signal.

PHY_MDIO is a bi-directional signal between the PHY and MDIO module. It is used to transfer control and status information between the PHY and the MDIO module. The control information is driven by the MDIO module synchronously with respect to PHY_MDC and is sampled synchronously by the PHY. The status information is driven by the PHY synchronously with respect to PHY_MDC and is sampled synchronously by the MDIO module. PHY_MDIO is driven through three-state circuit that enable either the MDIO module or the PHY to drive the circuit.

The MDIO interface uses standard method to access PHY management registers. The MDIO module supports up to 32 PHY devices. To access each PHY devices, the PHY device address must be written into the MIDO Address (MDIOADDR) register followed by PHY register address as shown in Figure 13. This module supports up to 32 PHY management registers access. The write transaction data for the PHY must be written into MDIO Write Data (MDIOWR) register and the status data from the PHY register can be read from MDIO Read Data (MDIORD) register. The MDIO Control (MDIOCTRL) register is used to initiate to management transaction on the MDIO lines.

MDIO Register Descriptions

This section tabulates the MDIO registers and their reset values. All these register can be access by single word transaction only. Burst write to these registers will not have any effect on the registers and burst read from these register will return '0'.

MDIO Address Register (MDIOADDR)

The MDIOADDR is an 32-bit read/write register as shown in Figure 13. This register is used to configure the PHY device address, PHY register address and type of MDIO transaction. The bit definition and accessibility of this register is shown in Table 7.



Figure 13: MDIO Address Register

Table 7: MDIO Address Register Bit Definition (C_BASEADDR + 0x07E4)

Bit	Name	Access	Reset Value	Description
0-20	Reserved	N/A	N/A	Reserved
21	OP	Read/Write	'0'	Operation Access Type 0 - Write Access 1 - Read Access
22-26	PHYADDR	Read/Write	"00000"	PHY device address
27-31	REGADDR	Read/Write	"00000"	PHY register address

MDIO Write Data Register (MDIOWR)

The MDIOWR is an 32-bit read/write register as shown in Figure 14. This register contains 16-bit data to be written in to the PHY register. The bit definition and accessibility of this register is shown in Table 8.

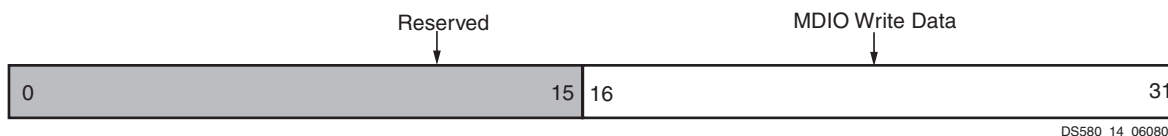


Figure 14: MDIO Write Data Register

Table 8: MDIO Write Data Register Bit Definition (C_BASEADDR + 0x07E8)

Bit	Name	Access	Reset Value	Description
0-15	Reserved	N/A	N/A	Reserved
16-31	Write Data	Read/Write	0x0000	MDIO write data to be written to PHY register

MDIO Read Data Register (MDIORD)

The MDIORD is an 32-bit read/write register as shown in Figure 15. This register contains 16-bit read data from the PHY register. The bit definition and accessibility of this register is shown in Table 9.

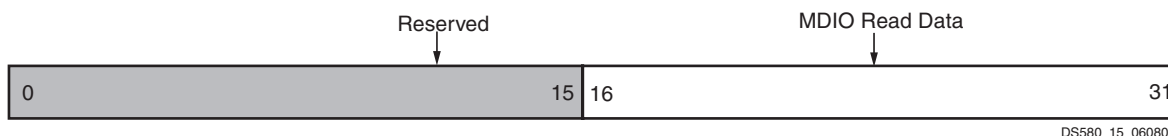


Figure 15: MDIO Read Data Register

Table 9: MDIO Read Data Register Bit Definition (C_BASEADDR + 0x07EC)

Bit	Name	Access	Reset Value	Description
0-15	Reserved	N/A	N/A	Reserved
16-31	Read Data	Read	0x0000	MDIO read data from the PHY register

MDIO Control Register (MDIOCTRL)

The MDIOCTRL is an 32-bit read/write register as shown in [Figure 16](#). This register contains status and control information of the MDIO interface. The MDIO Enable (bit-28) of this register is used to enable the MDIO interface. The bit definition and accessibility of this register is shown in [Table 10](#).

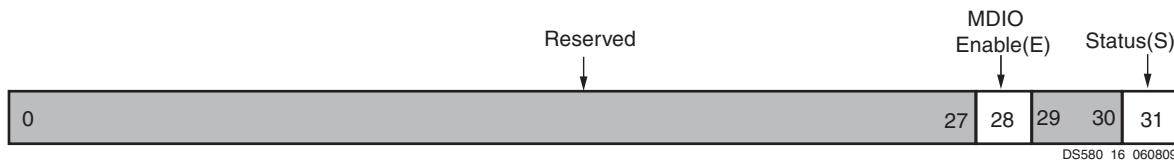


Figure 16: MDIO Control Register

Table 10: MDIO Control Register Bit Definition (C_BASEADDR + 0x07F0)

Bit	Name	Access	Reset Value	Description
0-27	Reserved	N/A	N/A	Reserved
28	MDIO Enable	Read/Write	'0'	MDIO enable bit 0 - Disable MDIO interface 1 - Enable MDIO interface
29-30	Reserved	N/A	N/A	Reserved
31	Status	Read/Write	'0'	MDIO status bit 0 - MDIO transfer is complete and core is ready to accept new MDIO request 1 - MDIO transfer is in progress. Setting this bit will initiate MDIO transaction. Once MDIO transaction is complete, Ethernet Lite MAC core clears this bit

MDIO Transactions

The Ethernet Lite MAC requires that the PHY device address and PHY register address to be stored in MDIO Address Register at address offset 0x07E4 before the software sets the status bit in MDIO Control Register at offset 0x07F0.

The proper software sequence for initiating a PHY register write transaction is as follows:

- The software reads MDIOCTRL register to verify if MDIO master is busy in executing previous request. If the Status bit is '0', MDIO master can accept new request.
- The software stores the PHY device address and PHY register address and writes '0' in bit 21 in MDIOADDR register at address offset 0x07E4.
- The software stores the PHY register write data in the MDIOWR register at address offset 0x07E8.
- The software writes '1' in MDIO enable bit in MDIOCTRL register at address offset 0x07F0.
- The software writes a '1' to the Status bit at address offset 0x07F0 (bit 31 on the data bus) to start the MDIO transaction.
- After completing MDIO write transaction, Ethernet Lite MAC will clear the status bit.
- The software monitors the Status bit and waits until it is set to '0' by the Ethernet Lite MAC before initiating new transaction on MDIO lines.

The proper software sequence for initiating a PHY register Read transaction is as follows:

- The software reads MDIOCTRL register to verify if MDIO master is busy in executing previous request. If the Status bit is '0', MDIO master can accept new request.
- The software stores the PHY device address and PHY register address and writes '1' in bit 21 in MDIOADDR register at address offset 0x07E4.
- The software writes '1' in MDIO enable bit in MDIOCTRL register at address offset 0x07F0.
- The software writes a '1' to the Status bit at address offset 0x07F0 (bit 31 on the data bus) to start the MDIO transaction.
- After completing MDIO Read transaction, Ethernet Lite MAC will clear the status bit.
- The software monitors the Status bit and waits until it is set to '0' by the Ethernet Lite MAC before initiating new transaction on MDIO lines.

Internal Loop back Mode

The XPS Ethernet Lite MAC core can be configured in internal loop back mode when the parameter C_INCLUDE_INTERNAL_LOOPBACK is set to '1' and by setting bit 27 of Transmit Control Register (Ping). Including the loop back logic uses BUFG for PHY clock switching. In this mode, the Ethernet Lite MAC core route back data on TX lines on RX line. Loop back mode can be tested only in full duplex mode. In this mode, core does not accept any data from PHY and PHY_tx_clk and PHY_tx_en are used as PHY_rx_clk and PHY_dv internally as shown in [Figure 17](#).

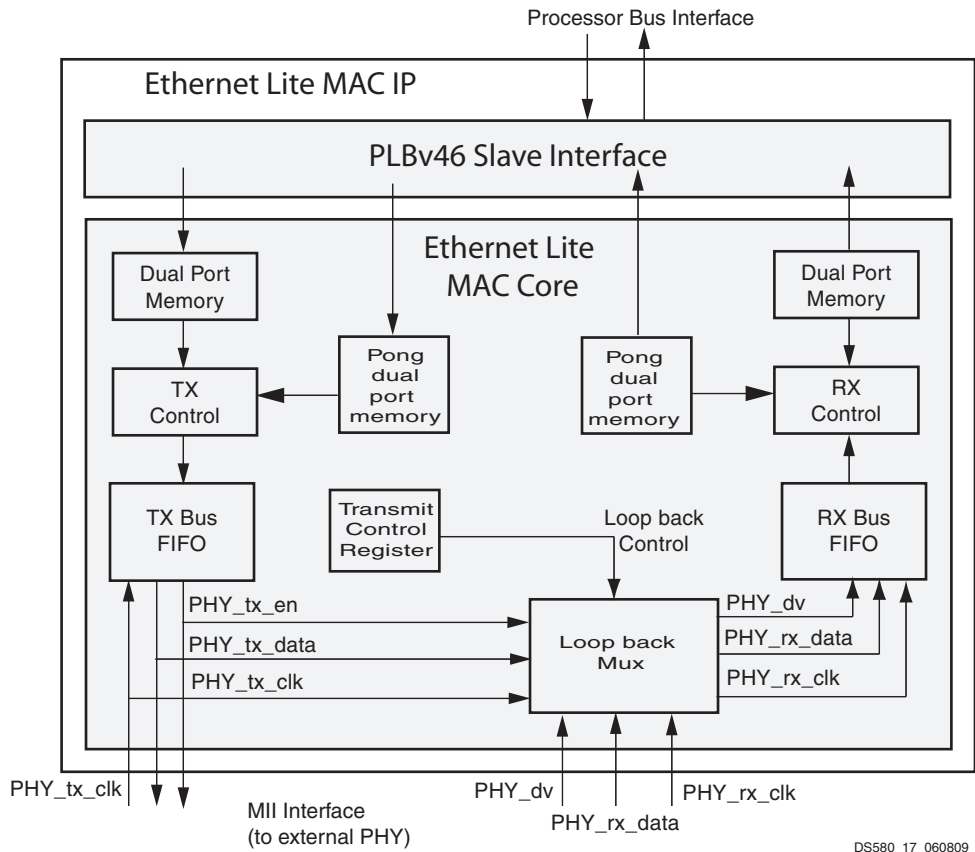


Figure 17: Internal Loop back Mode

XPS Ethernet Lite Mac Memory Map

The XPS Ethernet Lite MAC memory map is shown in Table 11.

Table 11: XPS Ethernet Lite MAC Memory Map

Address Offset	Parameter Dependency	Memory Location Function
0x0000	Tx PING Buffer C_TX_PING_PONG = '0' or '1'	Destination Address Bytes 0 - 3 or MAC Address Bytes 0 - 3
0x0004		Destination Address Bytes 4 - 5 Source Address Bytes 0 - 1 or MAC Address Bytes 4 - 5
0x0008		Source Address Bytes 2 - 5
0x000C		Type/Length Field Data Field Bytes 0 - 1
0x0010 - 0x07E0		Remaining Data Field Bytes

Table 11: XPS Ethernet Lite MAC Memory Map (Contd)

Address Offset	Parameter Dependency	Memory Location Function
0x7E4	MDIO Registers ^[1]	MDIO Address
0x7E8		MDIO Write Data
0x7EC		MDIO Read Data
0x07F0		MDIO Control
0x07F4	Transmit Register	Packet Length
0x07F8		Global Interrupt Enable
0x07FC		Control
0x0800	Tx PONG Buffer C_TX_PING_PONG = '1' else unused	Destination Address Bytes 0 - 3 or MAC Address Bytes 0 - 3
0x0804		Destination Address Bytes 4 - 5 Source Address Bytes 0 - 1 or MAC Address Bytes 4 - 5
0x0808		Source Address Bytes 2 - 5
0x080C		Type/Length Field Data Field Bytes 0 - 1
0x0810 - 0x0FE0		Remaining Data Field Bytes
0x0FE4 - 0x0FF0		Reserved
0x0FF4		Packet Length
0x0FF8		Reserved
0x0FFC		Control
0x1000	Rx PING Buffer C_RX_PING_PONG = '0' or '1'	Destination Address Bytes 0 - 3
0x1004		Destination Address Bytes 0 - 3 Source Address Bytes 4 - 5
0x1008		Source Address Bytes 2 - 5
0x100C		Type/Length Field Data Field Bytes 0 - 1
0x1010 - 0x17E0		Remaining Data and CRC Field Bytes
0x17E4 - 0x17F8		Reserved
0x17FC		Control

Table 11: XPS Ethernet Lite MAC Memory Map (Contd)

Address Offset	Parameter Dependency	Memory Location Function
0x1800	Rx PONG Buffer C_RX_PING_PONG = '1' else unused	Destination Address Bytes 0 - 3
0x1804		Destination Address Bytes 4 - 5 Source Address Bytes 0 - 1
0x1808		Source Address Bytes 2 - 5
0x180C		Type/Length Field Data Field Bytes 0 - 1
0x1810 - 0x1FE0		Remaining Data and CRC Field Bytes
0x1FE4 - 0x1FF8		Reserved
0x1FFC		Control
Notes:- 1. MDIO registers are included in the memory map only if C_INCLUDE_MDIO = 1. If MDIO interface is not enabled, this register space will be treated as reserved.		

XPS Ethernet Lite MAC I/O Signals

The XPS Ethernet Lite MAC I/O signals are listed and described in Table 12.

Table 12: XPS Ethernet Lite MAC I/O Signal Description

Port	Signal Name	Interface	I/O	Initial State	Description
System Signals					
P1	SPLB_Clk	System	I	-	PLB clock
P2	SPLB_Rst	System	I	-	PLB reset, active high
P3	IP2INTC_Irpt	System	O	0	System Interrupt
PLB Interface Signals					
P4	PLB_ABus[0:C_SPLB_AWIDTH - 1]	PLB	I	-	PLB address bus
P5	PLB_PValid	PLB	I	-	PLB primary address valid
P6	PLB_masterID[0:C_SPLB_MID_WIDTH - 1]	PLB	I	-	PLB current master identifier
P7	PLB_RNW	PLB	I	-	PLB read not write
P8	PLB_BE[0:(C_SPLB_DWIDTH / 8) - 1]	PLB	I	-	PLB byte enables
P9	PLB_size[0:3]	PLB	I	-	PLB size of requested transfer
P10	PLB_type[0:2]	PLB	I	-	PLB transfer type
P11	PLB_wrDBus[0:C_SPLB_DWIDTH - 1]	PLB	I	-	PLB write data bus
Unused PLB Interface Signals					

Table 12: XPS Ethernet Lite MAC I/O Signal Description (Contd)

Port	Signal Name	Interface	I/O	Initial State	Description
P12	PLB_UABus[0:C_SPLB_AWIDTH - 1]	PLB	I	-	PLB upper Address bits
P13	PLB_SAVValid	PLB	I	-	PLB secondary address valid
P14	PLB_rdPrim	PLB	I	-	PLB secondary to primary read request indicator
P15	PLB_wrPrim	PLB	I	-	PLB secondary to primary write request indicator
P16	PLB_abort	PLB	I	-	PLB abort bus request
P17	PLB_busLock	PLB	I	-	PLB bus lock
P18	PLB_MSize	PLB	I	-	PLB data bus width indicator
P19	PLB_lockErr	PLB	I	-	PLB lock error
P20	PLB_wrBurst	PLB	I	-	PLB burst write transfer
P21	PLB_rdBurst	PLB	I	-	PLB burst read transfer
P22	PLB_wrPendReq	PLB	I	-	PLB pending bus write request
P23	PLB_rdPendReq	PLB	I	-	PLB pending bus read request
P24	PLB_wrPendPri[0:1]	PLB	I	-	PLB pending write request priority
P25	PLB_rdPendPri[0:1]	PLB	I	-	PLB pending read request priority
P26	PLB_reqPri[0:1]	PLB	I	-	PLB current request priority
P27	PLB_TAtribute	PLB	I	-	PLB transfer attribute
PLB Slave Interface Signals					
P28	SI_addrAck	PLB	O	0	Slave address acknowledge
P29	SI_SSize[0:1]	PLB	O	0	Slave data bus size
P30	SI_wait	PLB	O	0	Slave wait
P31	SI_rearbitrate	PLB	O	0	Slave bus rearbitrate
P32	SI_wrDAck	PLB	O	0	Slave write data acknowledge
P33	SI_wrComp	PLB	O	0	Slave write transfer complete
P34	SI_rDBus[0:C_SPLB_DWIDTH - 1]	PLB	O	0	Slave read data bus
P35	SI_rDAck	PLB	O	0	Slave read data acknowledge
P36	SI_rDComp	PLB	O	0	Slave read transfer complete
P37	SI_MBusy[0:C_SPLB_NUM_MASTERS - 1]	PLB	O	0	Slave busy
P38	SI_MWrErr[0:C_SPLB_NUM_MASTERS - 1]	PLB	O	0	Slave write error
P39	SI_MRdErr[0:C_SPLB_NUM_MASTERS - 1]	PLB	O	0	Slave read error

Table 12: XPS Ethernet Lite MAC I/O Signal Description (Contd)

Port	Signal Name	Interface	I/O	Initial State	Description
Unused PLB Slave Interface Signals					
P40	SI_wrBTerm	PLB	O	0	Slave terminate write burst transfer
P41	SI_rdWdAddr[0:3]	PLB	O	0	Slave read word address
P42	SI_rdBTerm	PLB	O	0	Slave terminate read burst transfer
P43	SI_MIRQ[0:C_SPLB_NUM_MASTERS - 1]	PLB	O	0	Master interrupt request
Ethernet Lite MAC Signals					
P44	PHY_rx_data[3:0]	PHY	I	-	Ethernet receive data. Input from Ethernet PHY.
P45	PHY_tx_data[3:0]	PHY	O	0	Ethernet transmit data. Output to Ethernet PHY.
P46	PHY_dv	PHY	I	-	Ethernet receive data valid. Input from Ethernet PHY.
P47	PHY_rx_er	PHY	I	-	Ethernet receive error. Input from Ethernet PHY.
P48	PHY_tx_en	PHY	O	0	Ethernet transmit enable. Output to Ethernet PHY.
P49	PHY_tx_clk	PHY	I	-	Ethernet transmit clock
P50	PHY_rx_clk	PHY	I	-	Ethernet receive clock
P51	PHY_crs	PHY	I	-	Ethernet carrier sense input from Ethernet PHY
P52	PHY_col	PHY	I	-	Ethernet collision input from Ethernet PHY
P53	PHY_rst_n	PHY	O	1	Ethernet PHY reset output to Ethernet PHY
P54	PHY_MDC	PHY	O	0	Ethernet to PHY MII Management clock
P55	PHY_MDIO_I	PHY	I	-	PHY MDIO data input from 3-state buffer
P56	PHY_MDIO_O	PHY	O	0	PHY MDIO data output to 3-state buffer
P57	PHY_MDIO_T	PHY	O	0	PHY MDIO data output enable to 3-state buffer

XPS Ethernet Lite MAC Design Parameters

To obtain an XPS Ethernet Lite MAC that is uniquely tailored to the user system requirements, certain features can be parameterized in the XPS Ethernet Lite MAC design. This allows a design that utilizes

only the resources required by the system and runs at the best possible performance. The features that can be parameterized in the Xilinx XPS Ethernet Lite MAC design are shown in [Table 13](#).

Table 13: XPS Ethernet Lite MAC Design Parameters

Generic	Feature / Description	Parameter Name	Allowable Values	Default Value	VHDL Type
System parameters					
G1	Device family	C_FAMILY	aspartan3, spartan3, spartan3a, spartan3e, aspartan3e, aspartan3a, aspartan3adsp, spartan6, virtex4, qvirtex4, qvirtex4, virtex5, virtex6	virtex5	string
PLB parameters					
G2	Device base address	C_BASEADDR	Valid word aligned address range ^[1]	None ^[2, 3]	std_logic_vector
G3	Device maximum address	C_HIGHADDR	Refer to “Allowable Parameter Combinations” section	None ^[2, 3]	std_logic_vector
G4	BUS clock period in ps	C_SPLB_CLK_PERIOD_PS	Requirements as stated in note ^[4]	10000	integer
G5	PLB address bus width (in bits)	C_SPLB_AWIDTH	32	32	integer
G6	PLB data bus width (in bits)	C_SPLB_DWIDTH	32, 64, 128	32	integer
G7	Selects point-to-point or shared PLB topology	C_SPLB_P2P	0 = Shared bus topology	0	integer
G8	PLB Master ID width	C_SPLB_MID_WIDTH	\log_2 (C_SPLB_NUM_MASTERS), with minimum value of 1	1	integer
G9	Number of PLB Masters	C_SPLB_NUM_MASTERS	1 - 16	1	integer
G10	Width of IPIF Data Bus	C_SPLB_NATIVE_DWIDTH	32	32	integer
G11	Width of smallest PLB Master	C_SPLB_SMALLEST_MASTER	32, 64, 128	32	integer
G12	Burst Support	C_SPLB_SUPPORT_BURSTS	0 - 1	0	integer
Ethernet Lite MAC parameters					
G13	Half duplex transmit	C_DUPLEX	1 = Only full duplex operation available 0 = Only half duplex operation available	1	integer

Table 13: XPS Ethernet Lite MAC Design Parameters (Contd)

Generic	Feature / Description	Parameter Name	Allowable Values	Default Value	VHDL Type
G14	Include second transmit buffer	C_TX_PING_PONG	1 = Two transmit buffers 0 = Single memory transmit buffer	0	integer
G15	Include second receive buffer	C_RX_PING_PONG	1 = Two receive buffers 0 = Single memory receive buffer	0	integer
G16	Include MII Management module	C_INCLUDE_MDIO ^[5]	1 = Include MDIO module 0 = No MDIO module	1	integer
G17	Include Internal Loop back	C_INCLUDE_INTERNAL_LOOPBACK ^[6]	1 = Include internal loop back support 0 = No internal loop back support	0	integer

Notes:

1. Address range specified by C_BASEADDR and C_HIGHADDR must be at least 0X2000 and must be a power of 2. C_BASEADDR must be a multiple of the range, where the range is C_HIGHADDR - C_BASEADDR + 1
2. No default value will be specified for values to insure that the actual value is set, i.e if the value is not set, a compiler error will be generated. The address range must be at least 1FFF
3. For example, C_BASEADDR = 0xE0000000, C_HIGHADDR = 0xE0001FFF
4. The PLB clock frequency must be ≥ 50 MHz for 100 Mbps ethernet operation and greater than or equal to 5 MHz for 10 Mbps ethernet operation
5. Including MDIO interface allows PHY register access from XPS Ethernet Lite MAC core.
6. Enabling this parameter includes BUFG for PHY clock switching when loop back is enabled.

Allowable Parameter Combinations

The XPS Ethernet Lite MAC is a synchronous design. Due to the state machine control architecture of receive and transmit operations, the PLB Clock must be greater than or equal to 50 MHz to allow ethernet operation at 100 Mbps and greater than or equal to 5 MHz for ethernet operation at 10 Mbps.

The address range specified by C_BASEADDR and C_HIGHADDR must be a power of 2, and C_HIGHADDR range must be at least 0x2000. For example, if C_BASEADDR = 0xE0000000, C_HIGHADDR must be at least = 0xE0001FFF.

XPS Ethernet Lite MAC Port Dependencies

The dependencies between the XPS Ethernet Lite MAC design parameters and I/O signals are described in Table 14. In addition, when certain features are parameterized out of the design, the

related logic will no longer be apart of the design. The unused input signals and related output signals are set to a specified value.

Table 14: XPS Ethernet Lite MAC Parameter - Port Dependencies

Generic or Port	Name	Affects	Depends	Relationship Description
Design Parameters				
G5	C_SPLB_AWIDTH	P4	-	Width of the PLB Address Bus
G6	C_SPLB_DWIDTH	P8, P11, P34	-	Width of the PLB Data Bus and PLB Slave Data Bus
G8	C_SPLB_MID_WIDTH	P6	-	Width of the PLB Address Bus
G9	C_SPLB_NUM_MASTERS	P37, P38, P39, P43	-	Width of number of masters
G16	C_INCLUDE_MDIO	P54, P55		PHY_MDC and PHY_MDIO are included in the core only if C_INCLUDE_MDIO = 1
I/O Signals				
P4	PLB_ABus[0:C_SPLB_AWIDTH - 1]	-	G5	Width of the PLB Address Bus varies according to C_SPLB_AWIDTH
P6	PLB_masterID[0:C_SPLB_MID_WIDTH - 1]	-	G8	Width of the PLB_masterID varies according to C_SPLB_MID_WIDTH
P8	PLB_BE[0:(C_SPLB_DWIDTH/8) - 1]	-	G6	Width of the PLB Byte Enable varies according to C_SPLB_DWIDTH
P11	PLB_wrDBus[0:C_SPLB_DWIDTH - 1]	-	G6	Width of the PLB WriteData Bus varies according to C_SPLB_DWIDTH
P34	SI_rdBus[0:C_SPLB_DWIDTH - 1]	-	G6	Width of the Slave Read Data Bus varies according to C_SPLB_DWIDTH
P37	SI_MBusy[0:C_SPLB_NUM_MASTERS - 1]	-	G9	Width of the SI_MBusy varies according to C_SPLB_NUM_MASTERS
P38	SI_MWrErr[0:C_SPLB_NUM_MASTERS - 1]	-	G9	Width of the SI_MWrErr varies according to C_SPLB_NUM_MASTERS
P39	SI_MRdErr[0:C_SPLB_NUM_MASTERS - 1]	-	G9	Width of the SI_MRdErr varies according to C_SPLB_NUM_MASTERS
P43	SI_MIRQ[0:C_SPLB_NUM_MASTERS - 1]	-	G9	Width of the SI_MIRQ varies according to C_SPLB_NUM_MASTERS
P54	PHY_MDC	-	G16	This port is included in the core only if C_INCLUDE_MDIO = 1

Table 14: XPS Ethernet Lite MAC Parameter - Port Dependencies

Generic or Port	Name	Affects	Depends	Relationship Description
P55	PHY_MDIO_I	-	G16	This port is included in the core only if C_INCLUDE_MDIO = 1
P56	PHY_MDIO_O	-	G16	This port is included in the core only if C_INCLUDE_MDIO = 1
P57	PHY_MDIO_T	-	G16	This port is included in the core only if C_INCLUDE_MDIO = 1

Clocks

The Ethernet Lite MAC design has three clock domains that are all asynchronous to each other. The clock domain diagram for the Ethernet Lite MAC is shown in Figure 18. These clock domains and any special requirements regarding them are discussed below.

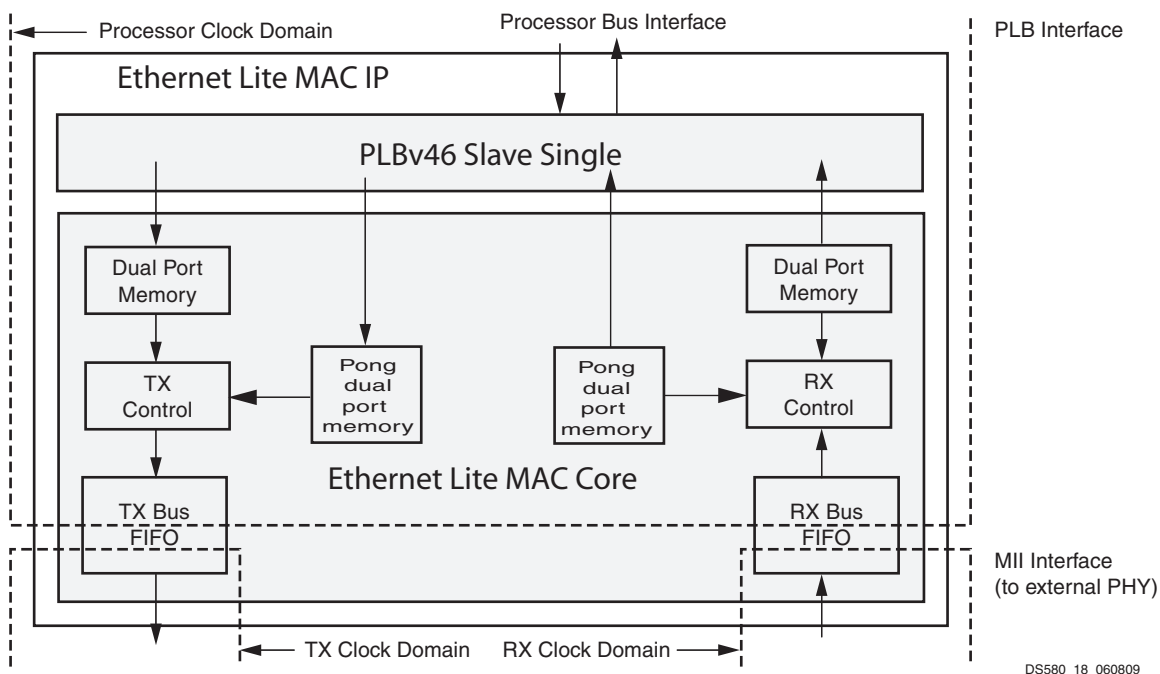


Figure 18: Ethernet Lite MAC Clock Domain Diagram

Transmit Clock

The transmit clock [PHY_tx_clk] is generated by the external PHY and must be used by the Ethernet Lite MAC to provide transmit data [PHY_tx_data (3:0)] and control signals [PHY_tx_en and PHY_tx_er] to the PHY.

The PHY provides one clock cycle for each nibble of data transferred resulting in a 2.5 MHz clock for 10BASE-T operation and 25 MHz for 100BASE-T operation at +/- 100 ppm with a duty cycle of between 35% and 65% inclusive. The PHY derives this clock from an external oscillator or crystal.

Receive Clock

The receive clock [PHY_rx_clk] is also generated by the external PHY but is derived from the incoming ethernet traffic. Like the transmit clock, the PHY provides one clock cycle for each nibble of data transferred resulting in a 2.5 MHz clock for 10BASE-T operation and 25 MHz for 100BASE-T operation with a duty cycle of between 35% and 65% inclusive while incoming data is valid [PHY_dv is '1'].

The minimum high and low times of the receive clock are at least 35% of the nominal period under all conditions. The receive clock is used by the Ethernet Lite MAC to sample the receive data [PHY_rx_data(3:0)] and control signals [PHY_dv and PHY_rx_er] from the PHY.

Processor Bus Clock

The majority of the Ethernet Lite MAC operation functions in the processor bus clock domain. This clock must be greater than or equal to 50 MHz in order to transmit and receive ethernet data at 100 Mbps and greater than or equal to 5 MHz in order to transmit and receive ethernet data at 10 Mbps.

PHY Interface Signals

PHY_rst_n

Many PHY devices require that they be held in reset for some period after power becomes valid in order for the PHY device to be operational following the power-up sequence. The PHY_rst_n signal is an active low reset which is tied directly to the PLB reset signal (SPLB_Rst). This output signal may be connected to the active low reset input of a PHY device.

PHY_tx_en

The Ethernet Lite MAC uses the Transmit Enable signal (PHY_tx_en) to indicate to the PHY that it is providing nibbles at the MII interface for transmission. It is asserted synchronously to PHY_tx_clk with the first nibble of the preamble and remains asserted while all nibbles have been transmitted. PHY_tx_en is negated prior to the first PHY_tx_clk following the final nibble of a frame.

This signal is transferred between the PHY_tx_clk and processor clock domains at the asynchronous TX bus FIFO interface. The clock to output delay of this signal must be 0 to 25 nS. **Figure 19** shows PHY_tx_en timing during a transmission with no collisions.

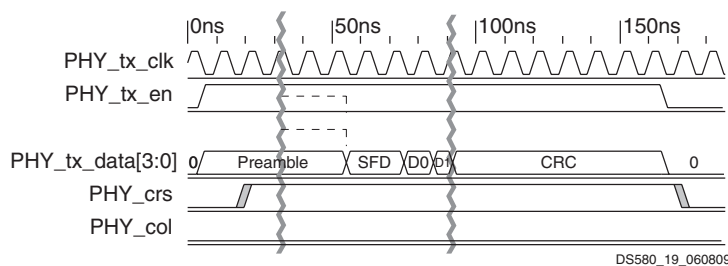


Figure 19: Transmission with no Collision

PHY_tx_data(3:0)

The Ethernet Lite MAC drives the Transmit Data bus PHY_tx_data(3:0) synchronously to PHY_tx_clk. PHY_tx_data(0) is the least significant bit. The PHY will transmit the value of PHY_tx_data on every clock cycle that PHY_tx_en is asserted.

This bus is transferred between the PHY_tx_clk and processor clock domains at the asynchronous TX bus FIFO interface. The clock to output delay of this signal must be 0 to 25 nS. The order of the bits, nibbles, and bytes for transmit and receive are shown in **Figure 20**.

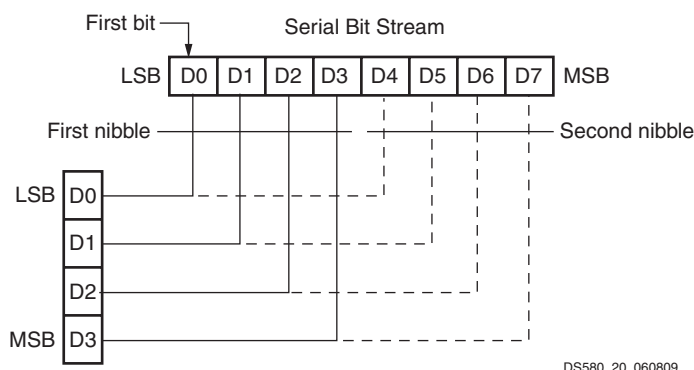


Figure 20: **Byte/Nibble Transmit and Receive Order**

PHY_dv

The PHY drives the Receive Data Valid (PHY_dv) signal to indicate that the PHY is driving recovered and decoded nibbles on the PHY_rx_data(3:0) bus and that the data on PHY_rx_data(3:0) is synchronous to PHY_rx_clk. PHY_dv is driven synchronously to PHY_rx_clk. PHY_dv remains asserted continuously from the first recovered nibble of the frame through the final recovered nibble and is negated prior to the first PHY_rx_clk that follows the final nibble.

In order for a received frame to be correctly received by the Ethernet Lite MAC, PHY_dv must encompass the frame, starting no later than the Start-of-Frame Delimiter (SFD) and excluding any End-of-Frame delimiter.

This signal is transferred between the PHY_rx_clk and processor clock domains at the asynchronous RX bus FIFO interface. The PHY will provide a minimum of 10 nS setup and hold time for this signal in reference to PHY_rx_clk. **Figure 21** shows the behavior of PHY_dv during frame reception.

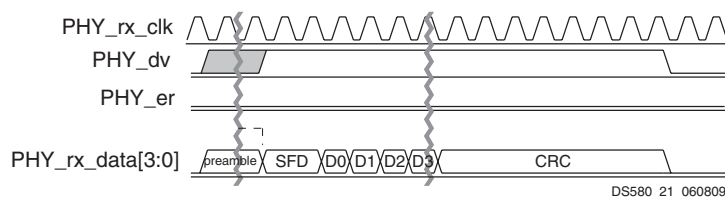


Figure 21: **Receive With No Errors**

PHY_rx_data(3:0)

The PHY drives the Receive Data bus PHY_rx_data(3:0) synchronously to PHY_rx_clk. PHY_rx_data(3:0) contains recovered data for each PHY_rx_clk period in which PHY_dv is asserted. PHY_rx_data(0) is the least significant bit. The Ethernet Lite MAC must not be affected by PHY_rx_data(3:0) while PHY_dv is de-asserted.

Also, the Ethernet Lite MAC should ignore a special condition that occurs while PHY_dv is de-asserted when the PHY may provide a False Carrier indication by asserting the PHY_rx_er signal while driving the value 1110 onto PHY_rx_data(3:0). This bus is transferred between the PHY_rx_clk and processor

clock domains at the asynchronous RX bus FIFO interface. The PHY will provide a minimum of 10 nS setup and hold time for this signal in reference to PHY_rx_clk.

PHY_rx_er

The PHY drives the Receive Error signal (PHY_rx_er) synchronously to PHY_rx_clk. The PHY drives PHY_rx_er for one or more PHY_rx_clk periods to indicate that an error (e.g., a coding error, or any error that the PHY is capable of detecting) was detected somewhere in the frame presently being transferred from the PHY to the Ethernet Lite MAC.

PHY_rx_er should have no effect on the Ethernet Lite MAC while PHY_dv is de-asserted. This signal is transferred between the PHY_rx_clk and processor clock domains at the asynchronous RX bus FIFO interface.

The PHY will provide a minimum of 10 nS setup and hold time for this signal in reference to PHY_rx_clk. **Figure 22** shows the behavior of PHY_rx_er during frame reception with errors.

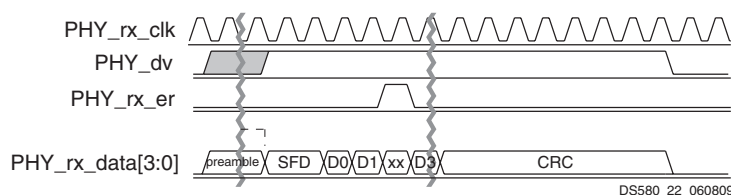


Figure 22: Receive With Errors

Table 15 shows the possible combinations for the receive signals.

Table 15: Possible Values for PHY_dv, PHY_rx_er, and PHY_rx_data[3:0]

PHY_dv	PHY_rx_er	PHY_rx_data[3:0]	Indication
0	0	0000 through 1111	Normal inter-frame
0	1	0000	Normal inter-frame
0	1	0001 through 1101	Reserved
0	1	1110	False carrier indication
0	1	1111	Reserved
1	0	0000 through 1111	Normal data reception
1	1	0000 through 1111	Data reception with errors

PHY_crs

The PHY drives the Carrier Sense signal (PHY_crs) active to indicate that either the transmit or receive is non-idle when operating in half duplex mode. PHY_crs is de-asserted when both the transmit and receive are idle.

The PHY drives PHY_crs asserted throughout the duration of a collision condition. PHY_crs is not synchronous to either the PHY_tx_clk or the PHY_rx_clk. The PHY_crs signal is not used in full duplex mode. The PHY_crs signal is used by both the Ethernet Lite MAC transmit and receive circuitry and is double synchronized to the processor clock as it enters the Ethernet Lite MAC.

PHY_col

The PHY drives the Collision detected signal (PHY_col) active to indicate the detection of a collision on the bus. The PHY drives PHY_crs asserted while the collision condition persists. The PHY also drives PHY_col asserted when operating at 10 Mbps for signal_quality_error (SQE) testing.

PHY_col is not synchronous to either the PHY_tx_clk or the PHY_rx_clk. The PHY_col signal is not used in full duplex mode. The PHY_col signal is used by both the Ethernet Lite MAC transmit and receive circuitry and is double synchronized to the processor clock as it enters the Ethernet Lite MAC. **Figure 23** shows the behavior of PHY_col during frame transmission with a collision.

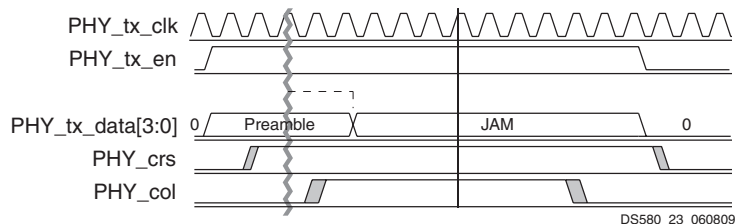


Figure 23: Transmission With Collision

Receive Address Validation

Destination addresses are classified as either unicast (a single station address indicated by the I/G bit = '0'), multicast (a group of stations indicated by the I/G bit = '1'), and the multicast subgroup broadcast (all stations on the network). The Ethernet Lite MAC accepts messages addressed to its unicast address and the broadcast address.

Design Constraints

The Ethernet Lite MAC core is designed to not use global buffers for the Tx and Rx clocks in default condition. Hence, Ethernet Lite MAC core requires design constraints as shown in [Figure 24](#) to guarantee performance. Please refer constraints guide for additional constraints, if required. If the global clock buffers are used for TX/RX clocks, then MAXSKEW constraints are not required. These constraints should be placed in a .UCF file for the top level of the design. The following example of the constraint is for 25 Mhz PHY clock and text is based on the port names of the Ethernet Lite MAC core. If these ports are mapped to FPGA pin names that are different, the FPGA pin names should be substituted for the port names.

Common Constraints for all FPGA devices

```
NET "phy_rx_clk" PERIOD = 40 ns HIGH 14 ns;
NET "phy_tx_clk" PERIOD = 40 ns HIGH 14 ns;
OFFSET = OUT 10 ns AFTER "phy_tx_clk" ;
OFFSET = IN 6 ns BEFORE "phy_rx_clk" ;
NET "SPLB_Rst" TIG;
NET "phy_rx_data<3>" IOBDELAY = NONE;
NET "phy_rx_data<2>" IOBDELAY = NONE;
NET "phy_rx_data<1>" IOBDELAY = NONE;
NET "phy_rx_data<0>" IOBDELAY = NONE;
NET "phy_dv" IOBDELAY = NONE;
NET "phy_rx_er" IOBDELAY = NONE;
NET "phy_crs" IOBDELAY = NONE;
NET "phy_col" IOBDELAY = NONE;
```

Constraints for Spartan-3 FPGA devices

```
NET "phy_tx_clk" USELOWSKEWLINES;
NET "phy_rx_clk" USELOWSKEWLINES;
NET "phy_tx_clk" MAXSKEW = 5.0 ns;
NET "phy_rx_clk" MAXSKEW = 5.0 ns;
```

Constraints for Virtex-4 and Virtex-5 FPGA devices

```
NET "phy_tx_clk" MAXSKEW = 5.0 ns;
NET "phy_rx_clk" MAXSKEW = 5.0 ns;
```

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Figure 24: Design constraints

Design Implementation

Target Technology

The intended target technology is an FPGA in one of the following families: Spartan-3, Spartan-3E, Spartan-3A, Spartan-3A DSP, Automotive Spartan-3/3A/3E/3A DSP, Spartan-6, Virtex-4, Virtex-4QV, Virtex-4Q, Virtex-5, Virtex-5 FX, Virtex-6.

Device Utilization and Performance Benchmarks

Core Performance

To analyze the XPS Ethernet Lite Controller timing within the FPGA, a design was generated that enclosed the Core in a wrapper. For sizing estimates, a simple wrapper that connected all I/O to the ports of the wrapper was utilized. For F_{MAX} , the wrapper was modified to incorporate input and output registers on all input and output ports respectively. The XPS Ethernet Lite MAC resource utilization for various parameter combinations measured with Virtex-4 as the target device are detailed in [Table 16](#).

Table 16: Ethernet Lite MAC Performance and Resource Utilization for Virtex-4 (Device: xc4vlx40-ff1148-10)

Parameter Values					Device Resources				Performance
C_DUPLEX	C_RX_PING_PONG	C_TX_PING_PONG	C_SPLB_SUPPORT_BURSTS	C_INCLUDE_MDIO	Slices	Slice Flip-Flops	LUTs	Block RAMS	F_{Max} (MHz)
0	0	0	0	0	634	501	860	2	125
1	0	0	0	0	578	443	754	2	125
1	1	1	0	0	663	467	908	4	125
1	1	1	1	0	662	525	968	4	125
1	0	0	1	0	603	501	851	2	125
1	1	1	0	1	758	562	1037	4	125
1	1	1	1	1	741	620	1097	4	125
1	0	0	0	1	691	537	917	2	125

The XPS Ethernet Lite MAC resource utilization for various parameter combinations measured with Virtex-5 as the target device are detailed in [Table 17](#).

Table 17: Ethernet Lite MAC Performance and Resource Utilization for Virtex-5 (Device: xc5vlx50-ff1153-1)

Parameter Values					Device Resources				Performance
C_DUPLEX	C_RX_PING_PONG	C_TX_PING_PONG	C_SPLB_SUPPORT_BURSTS	C_INCLUDE_MDIO	Slices	Slice Flip-Flops	LUTs	Block RAMS	F _{Max} (MHz)
0	0	0	0	0	371	502	709	2	150
1	0	0	0	0	323	443	610	2	150
1	1	1	0	0	358	467	696	4	150
1	1	1	1	0	374	525	754	4	150
1	0	0	1	0	329	501	665	2	150
1	1	1	0	1	395	561	790	4	150
1	1	1	1	1	451	619	871	4	150
1	0	0	0	1	391	537	733	2	150

The XPS Ethernet Lite MAC resource utilization for various parameter combinations measured with Spartan-3E as the target device are detailed in [Table 18](#).

Table 18: Ethernet Lite MAC Performance and Resource Utilization for Spartan-3E (Device: XC3S1600E-fg320-5)

Parameter Values					Device Resources				Performance
C_DUPLEX	C_RX_PING_PONG	C_TX_PING_PONG	C_SPLB_SUPPORT_BURSTS	C_INCLUDE_MDIO	Slices	Slice Flip-Flops	LUTs	Block RAMS	F _{Max} (MHz)
0	0	0	0	0	673	503	888	2	100
1	0	0	0	0	656	444	808	2	100
1	1	1	0	0	699	468	903	4	100
1	1	1	1	0	775	526	962	4	100
1	0	0	1	0	717	502	869	2	100

Table 18: Ethernet Lite MAC Performance and Resource Utilization for Spartan-3E
(Device: XC3S1600E-fg320-5)

1	1	1	0	1	834	563	1067	4	100
1	1	1	1	1	931	621	1126	4	100
1	0	0	0	1	752	538	932	2	100

The XPS Ethernet Lite MAC resource utilization for various parameter combinations measured with Virtex-6 as the target device are detailed in [Table 19](#).

Table 19: Ethernet Lite MAC Performance and Resource Utilization for Virtex-6
(Device: xc6vlx75t-ff784-1)

Parameter Values					Device Resources				Performance
C_DUPLEX	C_RX_PING_PONG	C_TX_PING_PONG	C_SPLB_SUPPORT_BURSTS	C_INCLUDE_MDIO	Slices	Slice Flip-Flops	LUTs	Block RAMS	F _{Max} (MHz)
0	0	0	0	0	307	506	816	2	160
1	0	0	0	0	263	448	716	2	160
1	1	1	0	0	290	472	784	4	160
1	1	1	1	0	324	531	833	4	160
1	0	0	1	0	292	507	761	2	160
1	1	1	0	1	349	558	939	4	160
1	1	1	1	1	360	617	983	4	160
1	0	0	0	1	319	534	830	2	160

The XPS Ethernet Lite MAC resource utilization for various parameter combinations measured with Spartan-6 as the target device are detailed in [Table 20](#).

Table 20: Ethernet Lite MAC Performance and Resource Utilization for Spartan-6
(Device: xc6slx45t-fgg484-2)

Parameter Values					Device Resources				Performance
C_DUPLEX	C_RX_PING_PONG	C_TX_PING_PONG	C_SPLB_SUPPORT_BURSTS	C_INCLUDE_MDIO	Slices	Slice Flip-Flops	LUTs	Block RAMs	F _{Max} (MHz)
0	0	0	0	0	360	505	778	2	105
1	0	0	0	0	319	447	693	2	105
1	1	1	0	0	352	471	745	4	105
1	1	1	1	0	336	530	779	4	105
1	0	0	1	0	312	506	731	2	105
1	1	1	0	1	371	557	875	4	105
1	1	1	1	1	315	616	900	4	105
1	0	0	0	1	341	532	786	2	105

System Performance

To measure the system performance (F_{MAX}) of this core, it was added to a Virtex-4 system, a Virtex-5 system, and a Spartan-3A system as the Device Under Test (DUT) as shown in [Figure 25](#), [Figure 26](#), and [Figure 27](#).

Because the XPS Ethernet Lite MAC core will be used with other design modules in the FPGA, the utilization and timing numbers reported in this section are estimates only. When this core is combined with other designs in the system, the utilization of FPGA resources and timing of the design will vary from the results reported here.

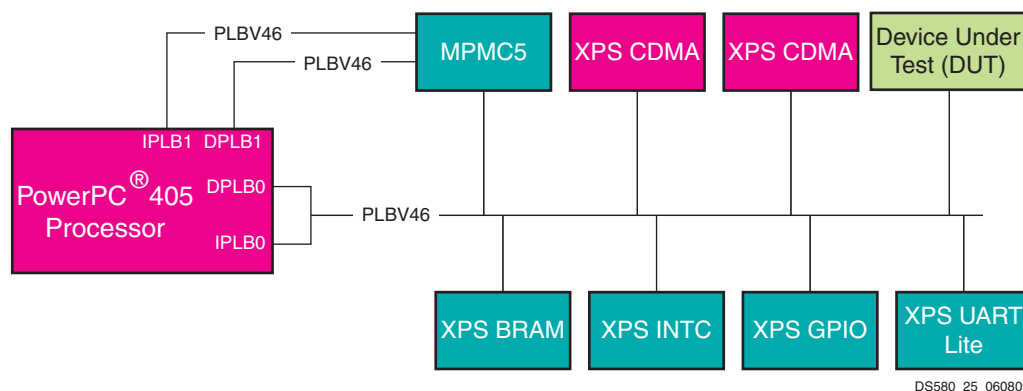
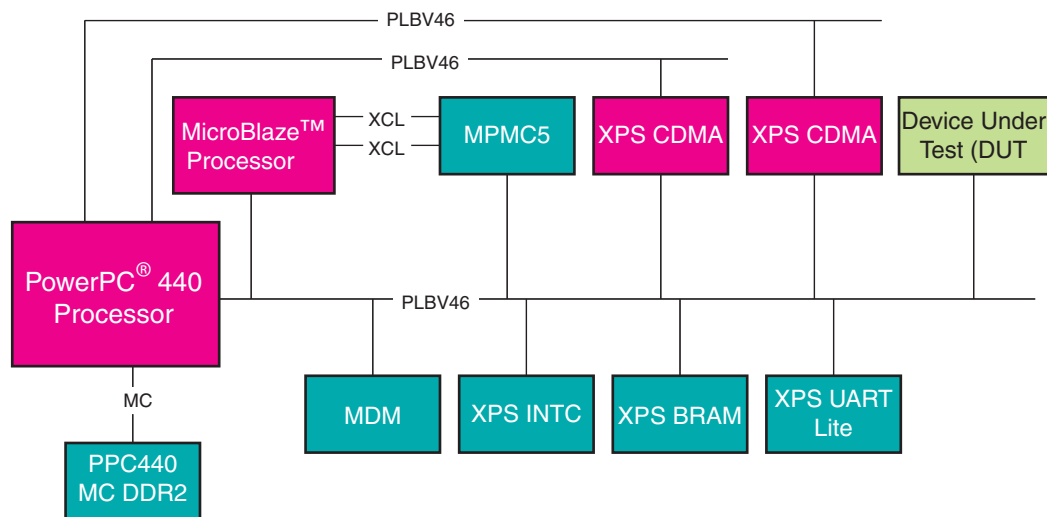
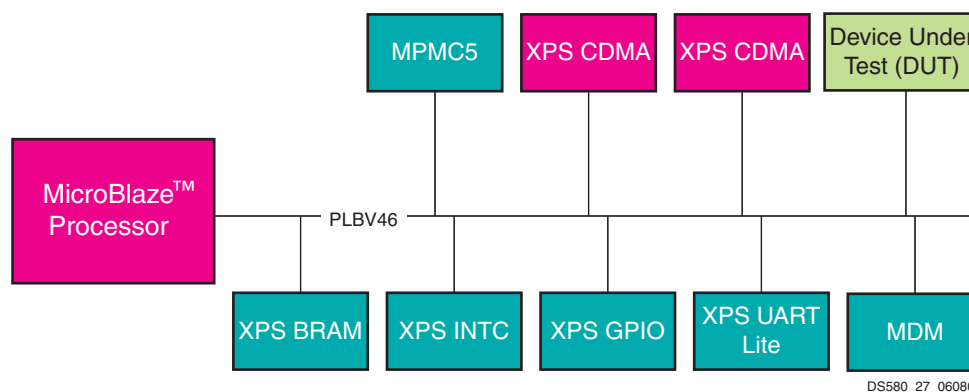


Figure 25: Virtex-4 FX System



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Figure 26: Virtex-5 FX System



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Figure 27: Spartan-3ADSP System

The target FPGA was then filled with logic to drive the LUT and BRAM utilization to approximately 70% and the I/O utilization to approximately 80%. Using the default tool options and the slowest speed grade for the target FPGA, the resulting target F_{MAX} numbers are shown in Table 21.

Table 21: XPS Ethernet Lite MAC System Performance

Target FPGA	Target F_{MAX} (MHz)
S3ADSP3400-4	90
V4FX60 -10	100
V5FXT70 -1	120

The target F_{MAX} is influenced by the exact system and is provided for guidance. It is not a guaranteed value across all systems.

Reference Documents

1. *IBM CoreConnect 128-Bit Processor Local Bus: Architecture Specifications version 4.6.*

Revision History

Date	Version	Revision
10/31/2006	1.0	Initial Xilinx release.
9/26/07	1.1	Added Fmax Margin System Performance section.
11/27/07	1.2	Added SP-3A DSP support.
07/12/07	1.3	New version of DS created to make the core license free.
4/22/08	1.4	Added Automotive Spartan-3E, Automotive Spartan-3A, Automotive Spartan-3, and Automotive Spartan-3A DSP support.
7/22/08	1.5	Updated timing constraints section.
7/29/08	1.6	Added QPro Virtex-4 Hi-Rel and QPro Virtex-4 Rad Tolerant support.
11/11/08	1.7	Removed Virtex2P support.
12/16/08	1.8	Updated design constraint section.
4/28/09	1.9	Replaced references to supported device families and tool name(s) with hyperlink to PDF file; creaed v3.00a; added MDIO interface description.
6/24/09	2.0	Updated for EDK_L 11.2; added supported device family and tools listing.

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