Data Sheet

FEBRUARY 2000
Revision 1.1

LXT972

3.3V Dual-Speed Fast Ethernet Transceiver

General Description

The LXT972 is an IEEE compliant Fast Ethernet PHY Transceiver that directly supports both 100BASE-TX and 10BASE-T applications. It provides a Media Independent Interface (MII) for easy attachment to 10/100 Media Access Controllers (MACs).

The LXT972 supports full-duplex operation at 10 Mbps and 100 Mbps. Its operating condition can be set using auto-negotiation, parallel detection, or manual control.

The LXT972 is fabricated with an advanced CMOS process and requires only a single 3.3V power supply.

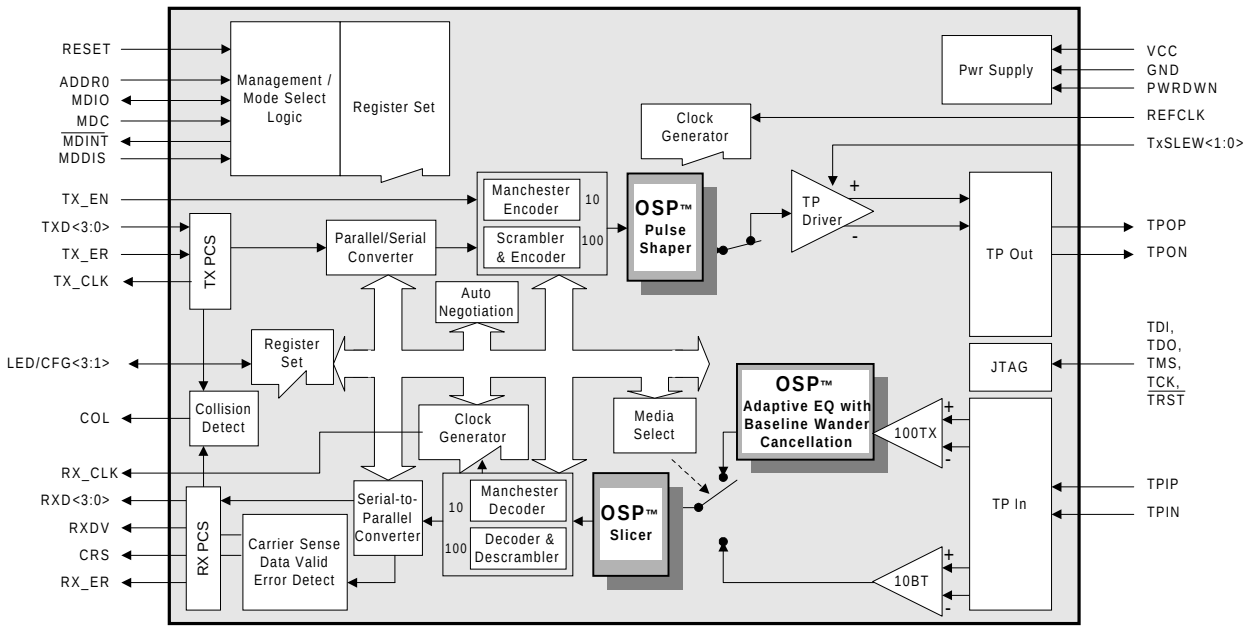
Applications

- Combination 10BASE-T/100BASE-TX Network Interface Cards (NICs)
- 10/100 PCMCIA Cards
- Cable Modems and Set-Top Boxes

Features

- 3.3V Operation.
- Low power consumption (300 mW typical).
- 10BASE-T and 100BASE-TX using a single RJ-45 connection.
- Supports auto-negotiation and parallel detection.
- MII interface with extended register capability.
- Robust baseline wander correction performance.
- Standard CSMA/CD or full-duplex operation.
- Configurable via MDIO serial port or hardware control pins.
- Integrated, programmable LED drivers.
- 64-pin Low-profile Quad Flat Package (LQFP).
  - LXT972LC - Commercial (0° to 70°C ambient).

LXT972 Block Diagram



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PIN ASSIGNMENTS

Figure 1: 64-Pin LQFP Pin Assignments

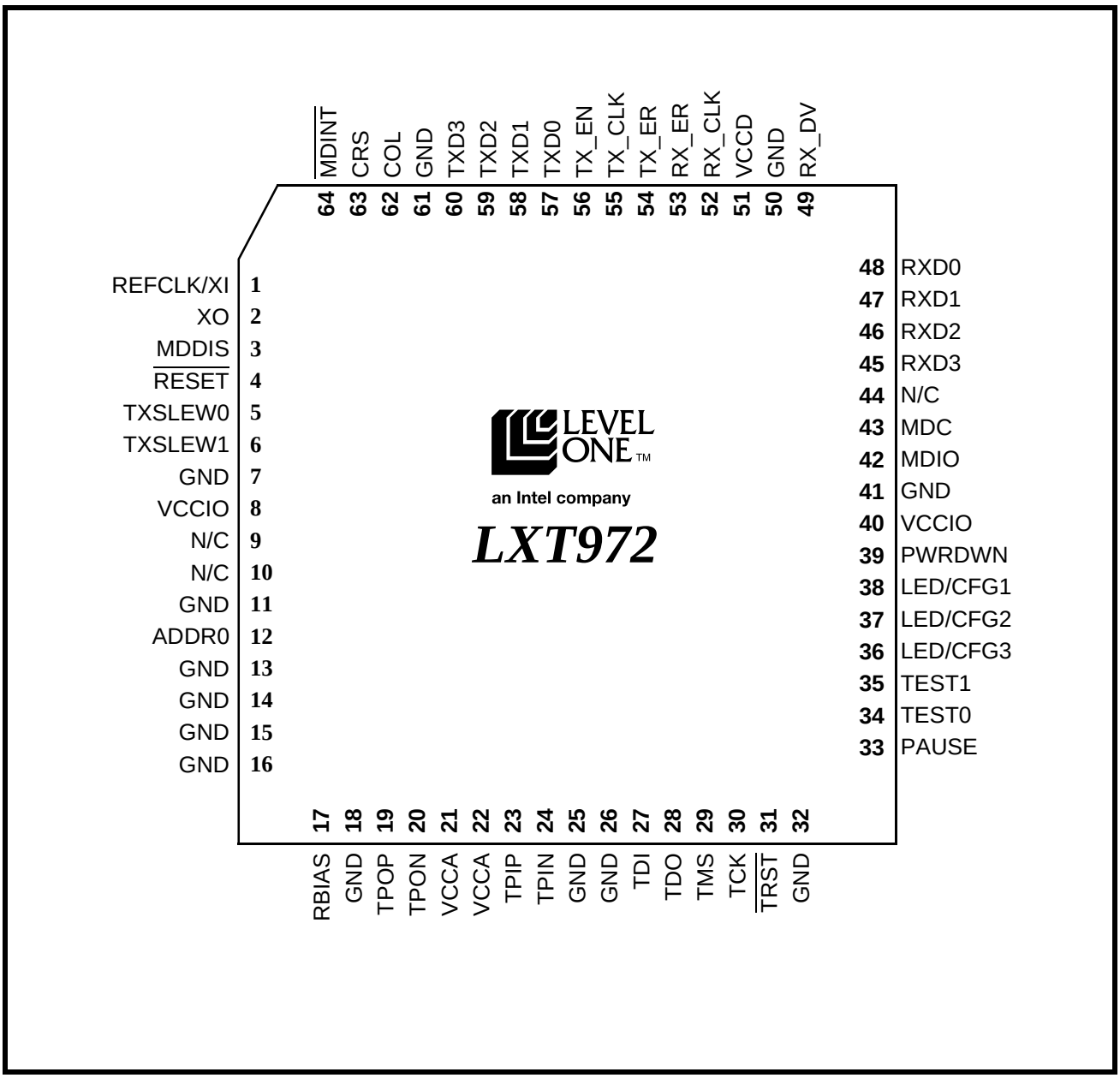


Table 1: LQFP Numeric Pin List

Pin	Symbol	Type	Reference for Full Description
1.	REFCLK/XI	Input	Table 4 on page 8
2.	XO	Output	Table 4 on page 8
3.	MDDIS	Input	Table 2 on page 6
4.	$\overline{\text{RESET}}$	Input	Table 4 on page 8
5.	TxSLEW0	Input	Table 4 on page 8
6.	TxSLEW1	Input	Table 4 on page 8
7.	GND	–	Table 5 on page 9
8.	VCCIO	–	Table 5 on page 9
9.	N/C	–	Table 4 on page 8
10.	N/C	–	Table 4 on page 8
11.	GND	–	Table 5 on page 9
12.	ADDR0	Input	Table 4 on page 8
13.	GND	–	Table 5 on page 9
14.	GND	–	Table 5 on page 9
15.	GND	–	Table 5 on page 9
16.	GND	–	Table 5 on page 9
17.	RBIAS	Analog Input	Table 4 on page 8
18.	GND	–	Table 5 on page 9
19.	TPOP	Output	Table 3 on page 7
20.	TPON	Output	Table 3 on page 7
21.	VCCA	–	Table 5 on page 9
22.	VCCA	–	Table 5 on page 9
23.	TPIP	Input	Table 3 on page 7
24.	TPIN	Input	Table 3 on page 7
25.	GND	–	Table 5 on page 9
26.	GND	–	Table 5 on page 9
27.	TDI	Input	Table 6 on page 9
28.	TDO	Output	Table 6 on page 9
29.	TMS	Input	Table 6 on page 9
30.	TCK	Input	Table 6 on page 9
31.	$\overline{\text{TRST}}$	Input	Table 6 on page 9
32.	GND	–	Table 5 on page 9
33.	PAUSE	Input	Table 4 on page 8

Table 1: LQFP Numeric Pin List – continued

Pin	Symbol	Type	Reference for Full Description
34.	TEST0	Input	Table 4 on page 8
35.	TEST1	Input	Table 4 on page 8
36.	LED/CFG3	I/O	Table 7 on page 9
37.	LED/CFG2	I/O	Table 7 on page 9
38.	LED/CFG1	I/O	Table 7 on page 9
39.	PWRDWN	Input	Table 4 on page 8
40.	VCCIO	–	Table 5 on page 9
41.	GND	–	Table 5 on page 9
42.	MDIO	I/O	Table 2 on page 6
43.	MDC	Input	Table 2 on page 6
44.	N/C	–	Table 4 on page 8
45.	RXD3	Output	Table 2 on page 6
46.	RXD2	Output	Table 2 on page 6
47.	RXD1	Output	Table 2 on page 6
48.	RXD0	Output	Table 2 on page 6
49.	RX_DV	Output	Table 2 on page 6
50.	GND	–	Table 5 on page 9
51.	VCCD	–	Table 5 on page 9
52.	RX_CLK	Output	Table 2 on page 6
53.	RX_ER	Output	Table 2 on page 6
54.	TX_ER	Input	Table 2 on page 6
55.	TX_CLK	Output	Table 2 on page 6
56.	TX_EN	Input	Table 2 on page 6
57.	TXD0	Input	Table 2 on page 6
58.	TXD1	Input	Table 2 on page 6
59.	TXD2	Input	Table 2 on page 6
60.	TXD3	Input	Table 2 on page 6
61.	GND	–	Table 5 on page 9
62.	COL	Output	Table 2 on page 6
63.	CRS	Output	Table 2 on page 6
64.	$\overline{\text{MDINT}}$	Open Drain	Table 2 on page 6

SIGNAL DESCRIPTIONS

Table 2: LXT972 MII Signal Descriptions

LQFP Pin#	Symbol	Type[1]	Signal Description
Data Interface Pins			
60 59 58 57	TXD3 TXD2 TXD1 TXD0	I	**Transmit Data**. TXD is a bundle of parallel data signals that are driven by the MAC. TXD<3:0> shall transition synchronously with respect to the TX_CLK. TXD<0> is the least significant bit.
56	TX_EN	I	**Transmit Enable**. The MAC asserts this signal when it drives valid data on TXD. This signal must be synchronized to TX_CLK.
55	TX_CLK	O	**Transmit Clock**. TX_CLK is sourced by the PHY in both 10 and 100 Mbps operations. 2.5 MHz for 10 Mbps operation, 25 MHz for 100 Mbps operation.
45 46 47 48	RXD3 RXD2 RXD1 RXD0	O	**Receive Data**. RXD is a bundle of parallel signals that transition synchronously with respect to the RX_CLK. RXD<0> is the least significant bit.
49	RX_DV	O	**Receive Data Valid**. The LXT972 asserts this signal when it drives valid data on RXD. This output is synchronous to RX_CLK.
53	RX_ER	O	**Receive Error**. Signals a receive error condition has occurred. This output is synchronous to RX_CLK.
54	TX_ER	I	**Transmit Error**. Signals a transmit error condition. This signal must be synchronized to TX_CLK.
52	RX_CLK	O	**Receive Clock**. 25 MHz for 100 Mbps operation, 2.5 MHz for 10 Mbps operation. Refer to "Clock Requirements" on page 14 in the Functional Description section.
62	COL	O	**Collision Detected**. The LXT972 asserts this output when a collision is detected. This output remains High for the duration of the collision. This signal is asynchronous and is inactive during full-duplex operation.
63	CRS	O	**Carrier Sense**. During half-duplex operation (bit 0.8 = 0), the LXT972 asserts this output when either transmitting or receiving data packets. During full-duplex operation (bit 0.8 = 1), CRS is asserted during receive. CRS assertion is asynchronous with respect to RX_CLK. CRS is de-asserted on loss of carrier, synchronous to RX_CLK.
MII Control Interface Pins			
3	MDDIS	I	**Management Disable**. When MDDIS is High, the MDIO is disabled from read and write operations. When MDDIS is Low at power up or reset, the Hardware Control Interface pins control only the initial or "default" values of their respective register bits. After the power-up/reset cycle is complete, bit control reverts to the MDIO serial channel.

1. Type Column Coding: I = Input, O = Output, A = Analog, OD = Open Drain.

Table 2: LXT972 MII Signal Descriptions – continued

LQFP Pin#	Symbol	Type[1]	Signal Description
43	MDC	I	**Management Data Clock**. Clock for the MDIO serial data channel. Maximum frequency is 8 MHz.
42	MDIO	I/O	**Management Data Input/Output**. Bidirectional serial data channel for PHY/STA communication.
64	$\overline{\text{MDINT}}$	OD	**Management Data Interrupt**. When bit 18.1 = 1, an active Low output on this pin indicates status change. Interrupt is cleared by reading Register 19.

1. Type Column Coding: I = Input, O = Output, A = Analog, OD = Open Drain.

Table 3: LXT972 Network Interface Signal Descriptions

LQFP Pin#	Symbol	Type[1]	Signal Description
19 20	TPOP TPON	O	**Twisted-Pair Outputs, Positive & Negative.** During 100BASE-TX or 10BASE-T operation, TPOP/N pins drive 802.3 compliant pulses onto the line.
23 24	TPIP TPIN	I	**Twisted-Pair Inputs, Positive & Negative.** During 100BASE-TX or 10BASE-T operation, TPIP/N pins receive differential 100BASE-TX or 10BASE-T signals from the line.

1. Type Column Coding: I = Input, O = Output, A = Analog, OD = Open Drain

Table 4: LXT972 Miscellaneous Signal Descriptions

LQFP Pin#	Symbol	Type[1]	Signal Description
5 6	TxSLEW0 TxSLEW1	I	**Tx Output Slew Controls 0 and 1**. These pins select the TX output slew rate (rise and fall time) as follows:
			TxSLEW1 / **TxSLEW0** / **Slew Rate (Rise and Fall Time)**
			0 / 0 / 2.5 ns
			0 / 1 / 3.1 ns
			1 / 0 / 3.7 ns
			1 / 1 / 4.3 ns
4	$\overline{\text{RESET}}$	I	**Reset**. This active Low input is OR'ed with the control register Reset bit (0.15). The LXT972 reset cycle is extended to 258 µs (nominal) after reset is deasserted.
12	ADDR0	I	Address0. Sets device address.
17	RBIAS	AI	**Bias**. This pin provides bias current for the internal circuitry. Must be tied to ground through a 22.1 kΩ, 1% resistor.
33	PAUSE	I	**Pause**. When set High, the LXT972 advertises Pause capabilities during auto negotiation.
34	TEST0	I	**Test**. Tie Low.
35	TEST1	I	**Test**. Tie Low.
39	PWRDWN	I	**Power Down**. When set High, this pin puts the LXT972 in a power-down mode.
1 2	REFCLK/XI XO	I O	**Crystal Input and Output**. A 25 MHz crystal oscillator circuit can be connected across XI and XO. A clock can also be used at XI. Refer to Functional Description for detailed clock requirements.
9, 10, 44	N/C	-	**No Connection**. These pins are not used and should not be terminated.

1. Type Column Coding: I = Input, O = Output, A = Analog, OD = Open Drain

Table 5: LXT972 Power Supply Signal Descriptions

LQFP Pin#	Symbol	Type	Signal Description
51	VCCD	-	**Digital Power.** Requires a 3.3V power supply.
7, 11, 13, 14, 15, 16, 18, 25, 26, 32, 41, 50, 61	GND	-	**Ground.**
8, 40	VCCIO	-	**MII Power.** Requires either a 3.3V or a 2.5V supply. Must be supplied from the same source used to power the MAC on the other side of the MII.
21, 22	VCCA	-	**Analog Power.** Requires a 3.3V power supply.

Table 6: LXT972 JTAG Test Signal Descriptions

LQFP Pin#	Symbol	Type[1]	Signal Description
27	TDI[2]	I	**Test Data Input**. Test data sampled with respect to the rising edge of TCK.
28	TDO[2]	O	**Test Data Output**. Test data driven with respect to the falling edge of TCK.
29	TMS[2]	I	**Test Mode Select**.
30	TCK[2]	I	**Test Clock**. Test clock input sourced by ATE.
31	$\overline{\text{TRST}}$[2]	I	**Test Reset**. Test reset input sourced by ATE.

1. Type Column Coding: I = Input, O = Output, A = Analog, OD = Open Drain.
2. If JTAG port is not used, these pins do not need to be terminated.

Table 7: LXT972 LED Signal Descriptions

LQFP Pin#	Symbol	Type[1]	Signal Description
38 37 36	LED/CFG1 LED/CFG2 LED/CFG3	I/O	**LED Drivers 1 -3.** These pins drive LED indicators. Each LED can display one of several available status conditions as selected by the LED Configuration Register (refer to Table 50 on page 62 for details). **Configuration Inputs 1-3.** These pins also provide initial configuration settings (refer to Table 8 on page 16 for details).

1. Type Column Coding: I = Input, O = Output, A = Analog, OD = Open Drain

FUNCTIONAL DESCRIPTION

Introduction

The LXT972 is a single-port Fast Ethernet 10/100 Transceiver that supports 10 Mbps and 100 Mbps networks. It complies with all applicable requirements of IEEE 802.3. The LXT972 can directly drive either a 100BASE-TX line (up to 140 meters) or a 10BASE-T line (up to 185 meters).

Comprehensive Functionality

The LXT972 provides a standard Media Independent Interface (MII) for 10/100 MACs. The LXT972 performs all functions of the Physical Coding Sublayer (PCS) and Physical Media Attachment (PMA) sublayer as defined in the IEEE 802.3 100BASE-X standard. This device also performs all functions of the Physical Media Dependent (PMD) sublayer for 100BASE-TX connections.

On power-up, the LXT972 reads its configuration pins to check for forced operation settings. If not configured for forced operation, it uses auto-negotiation/parallel detection to automatically determine line operating conditions. If the PHY device on the other side of the link supports auto-negotiation, the LXT972 will auto-negotiate with it using Fast Link Pulse (FLP) Bursts. If the PHY partner does not support auto-negotiation, the LXT972 will automatically detect the presence of either link pulses (10 Mbps PHY) or Idle symbols (100 Mbps PHY) and set its operating conditions accordingly.

The LXT972 provides half-duplex and full-duplex operation at 100 Mbps and 10 Mbps.

OSP™ Architecture

Level One's LXT972 incorporates high-efficiency Optimal Signal Processing™ design techniques, combining the best properties of digital and analog signal processing to produce a truly optimal device.

The receiver utilizes decision feedback equalization to increase noise and cross-talk immunity by as much as 3 dB over an ideal all-analog equalizer. Using OSP mixed-signal processing techniques in the receive equalizer avoids the quantization noise and calculation truncation errors found in traditional DSP-based receivers (typically complex DSP engines with A/D converters). This results in improved receiver noise and cross-talk performance.

The OSP signal processing scheme also requires substantially less computational logic than traditional DSP-based designs. This lowers power consumption and also reduces the logic switching noise generated by DSP engines. This logic switching noise can be a considerable source of EMI generated on the device’s power supplies.

The OSP-based LXT972 provides improved data recovery, EMI performance and low power consumption.

Network Media / Protocol Support

The LXT972 supports both 10BASE-T and 100BASE-TX Ethernet over twisted-pair.

10/100 Network Interface

The network interface port consists of two differential signal pairs. Refer to Table 3 for specific pin assignments.

The LXT972 output drivers generate either 100BASE-TX or 10BASE-T. When not transmitting data, the LXT972 generates 802.3-compliant link pulses or idle code. Input signals are decoded either as a 100BASE-TX or 10BASE-T input, depending on the mode selected. Auto-negotiation/parallel detection or manual control is used to determine the speed of this interface.

Twisted-Pair Interface

The LXT972 supports either 100BASE-TX or 10BASE-T connections over 100Ω, Category 5, Unshielded Twisted Pair (UTP) cable. When operating at 100 Mbps, the LXT971 continuously transmits and receives MLT3 symbols. When not transmitting data, the LXT971 generates “IDLE” symbols.

During 10 Mbps operation, Manchester-encoded data is exchanged. When no data is being exchanged, the line is left in an idle state. Link pulses are transmitted periodically to keep the link up.

Only a transformer, RJ-45 connector, load resistor, and bypass capacitors are required to complete this interface. On the transmit side, the LXT972 has an active internal termination and does not require external termination resistors. Level One's patented wave-shaping technology shapes the outgoing signal to help reduce the need for external EMI filters. Four slew rate settings (refer to Table 4 on page 8) allow the designer to match the output waveform to the magnetic characteristics. On the receive side, the internal impedance is high enough that it has no practical effect on the external termination circuit.

Fault Detection and Reporting

The LXT972 supports one fault detection and reporting mechanism. “Remote Fault” refers to a MAC-to-MAC communication function that is essentially transparent to PHY layer devices. It is used only during Auto-Negotiation, and therefore is applicable only to twisted-pair links. “Far-End Fault”, on the other hand, is an optional PMA-layer function that may be embedded within PHY devices. The LXT972 supports only the Remote Fault Function, explained in the paragraph that follows.

Remote Fault

Bit 4.13 in the Auto-Negotiation Advertisement Register is reserved for Remote Fault indications. It is typically used when re-starting the auto-negotiation sequence to indicate to the link partner that the link is down because the advertising device detected a fault.

When the LXT972 receives a Remote Fault indication from its partner during auto-negotiation it:

- sets bit 5.13 in the Link Partner Base Page Ability Register, and
- sets the Remote Fault bit 1.4 in the MII Status Register to pass this information to the local controller.

MII Data Interface

The LXT972 supports a standard Media Independent Interface (MII). The MII consists of a data interface and a management interface. The MII Data Interface passes data between the LXT972 and a Media Access Controller (MAC). Separate parallel buses are provided for transmit and receive. This interface operates at either 10 Mbps or 100 Mbps. The speed is set automatically, once the operating conditions of the network link have been determined. Refer to "MII Operation" on page 18 for additional details.

Configuration Management Interface

The LXT972 provides both an MDIO interface and a Hardware Control Interface for device configuration and management.

MDIO Management Interface

The LXT972 supports the IEEE 802.3 MII Management Interface also known as the Management Data Input/Output (MDIO) Interface. This interface allows upper-layer devices to monitor and control the state of the LXT972. The MDIO interface consists of a physical connection, a specific protocol that runs across the connection, and an internal set of addressable registers.

Some registers are required and their functions are defined by the IEEE 802.3 standard. The LXT972 also supports additional registers for expanded functionality. The LXT972 supports multiple internal registers, each of which is 16 bits wide. Specific register bits are referenced using an "X.Y" notation, where X is the register number (0-31) and Y is the bit number (0-15).

The physical interface consists of a data line (MDIO) and clock line (MDC). Operation of this interface is controlled by the MDDIS input pin. When MDDIS is High, the MDIO read and write operations are disabled and the Hardware Control Interface provides primary configuration control. When MDDIS is Low, the MDIO port is enabled for both read and write operations and the Hardware Control Interface is not used.

MDIO Addressing

The protocol allows one controller to communicate between two LXT972 chips. Pin ADDR0 is set high or low to determine the chip address.

MDIO Frame Structure

The physical interface consists of a data line (MDIO) and clock line (MDC). The frame structure is shown in Figures 2 and 3 (read and write). MDIO Interface timing is shown in Table 32 on page 46.

Figure 2: Management Interface Read Frame Structure

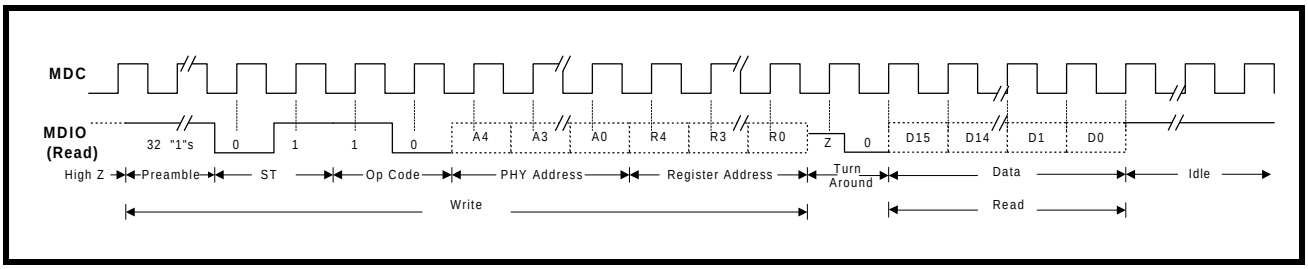
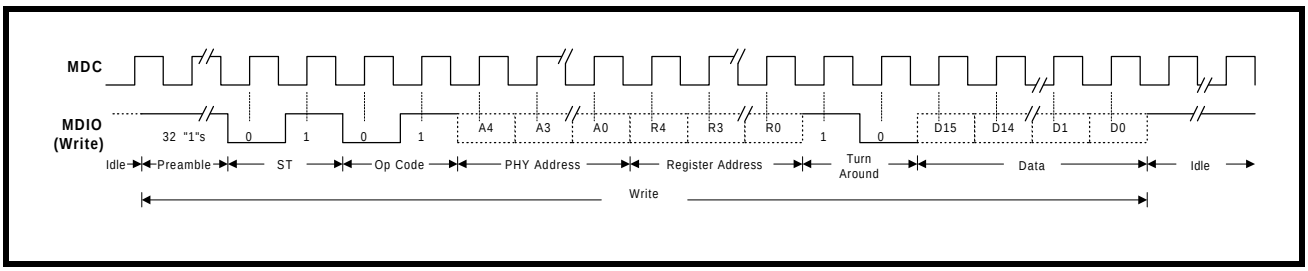


Figure 3: Management Interface Write Frame Structure



MII Interrupts

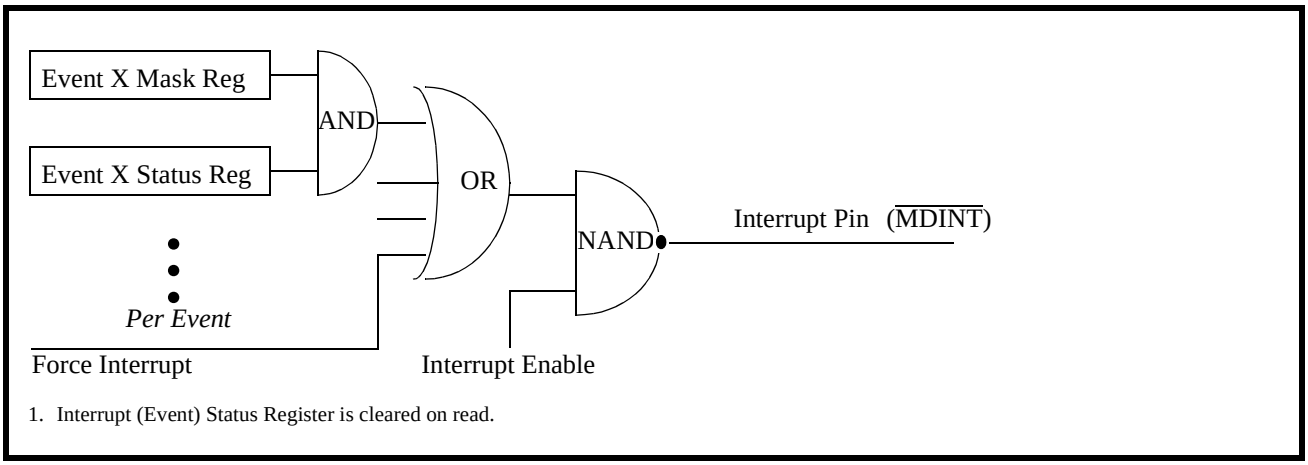
The LXT972 provides a single interrupt pin ($\overline{\text{MDINT}}$). Interrupt logic is shown in Figure 4. The LXT972 also provides two dedicated interrupt registers. Register 18 provides interrupt enable and mask functions and Register 19 provides interrupt status. Setting bit 18.1 = 1, enables the device to request interrupt via the $\overline{\text{MDINT}}$ pin. An active Low on this pin indicates a status change on the LXT972. Interrupts may be caused by four conditions:

- Auto-negotiation complete
- Speed status change
- Duplex status change
- Link status change

Hardware Control Interface

The LXT972 provides a Hardware Control Interface for applications where the MDIO is not desired. The Hardware Control Interface uses the three LED driver pins to set device configuration. Refer to the Hardware Configuration Settings section on page 16 for additional details.

Figure 4: Interrupt Logic



1. Interrupt (Event) Status Register is cleared on read.

Operating Requirements

Power Requirements

The LXT972 requires three power supply inputs (VCCD, VCCA, and VCCIO). The digital and analog circuits require 3.3V supplies (VCCD and VCCA). These inputs may be supplied from a single source. Each supply input must be decoupled to ground.

An additional supply may be used for the MII (VCCIO). The supply may be either +2.5V or +3.3V. Also, the inputs on the MII interface are tolerant to 5V signals from the controller on the other side of the MII interface. Refer to Table 19 on page 37 for MII I/O characteristics.

As a matter of good practice, these supplies should be as clean as possible.

Clock Requirements

External Crystal/Oscillator

The LXT972 requires a reference clock input. It may be provided by either of two methods: by connecting a crystal across the oscillator pins (XI and XO), or by connecting an external clock source to pin XI. When a clock is supplied to XI, XO is left open.

A crystal is typically used in NIC applications. An external 25 MHz clock source, rather than a crystal, is frequently used in switch applications. Refer to Preliminary Test Specifications, Table 20 on page 37, for clock timing requirements.

MDIO Clock

The MII management channel (MDIO) also requires an external clock. The managed data clock (MDC) speed is a maximum of 8 MHz. Refer to Table 32 on page 46 for details.

Initialization

When the LXT972 is first powered on, reset, or encounters a link failure state, it checks the MDIO register configuration bits to determine the line speed and operating conditions to use for the network link. The configuration bits may be set by the Hardware Control or MDIO interface as shown in Figure 5.

MDIO Control Mode

In the MDIO Control mode, the LXT972 reads the Hardware Control Interface pins to set the initial (default) values of the MDIO registers. Once the initial values are set, bit control reverts to the MDIO interface.

Hardware Control Mode

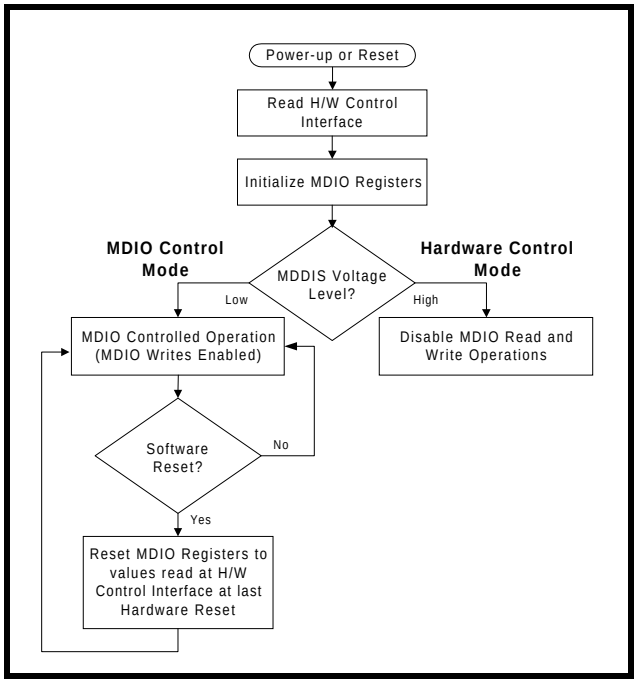
In the Hardware Control Mode, LXT972 disables direct write operations to the MDIO registers via the MDIO Interface. On power-up or hardware reset the LXT972 reads the Hardware Control Interface pins and sets the MDIO registers accordingly.

The following modes are available using either Hardware Control or MDIO Control:

- Force network link operation to:
  - 100TX, Full-Duplex.
  - 100TX, Half-Duplex.
  - 10BASE-T, Full-Duplex.
  - 10BASE-T, Half-Duplex.
- Allow auto-negotiation / parallel-detection.

When the network link is forced to a specific configuration, the LXT972 immediately begins operating the network interface as commanded. When auto-negotiation is enabled, the LXT972 begins the auto-negotiation / parallel-detection operation.

Figure 5: Initialization Sequence



Reduced Power Modes

The LXT972 offers two power-down modes.

Hardware Power Down

The hardware power-down mode is controlled by the PWRDWN pin. When PWRDWN is High, the following conditions are true:

- The LXT972 network port and clock are shut down.
- All outputs are tri-stated.
- All weak pad pull-up and pull-down resistors are disabled.
- The MDIO registers are not accessible.

Software Power Down

Software power-down control is provided by bit 0.11 in the Control Register (refer to Table 37 on page 51). During soft power-down, the following conditions are true:

- The network port is shut down.
- The MDIO registers remain accessible.

Reset

The LXT972 provides both hardware and software resets. Configuration control of Auto-Negotiation, speed and duplex mode selection is handled differently for each. During a hardware reset, Auto-Negotiation and Speed are read in from pins (refer to Table 8 on page 16 for pin settings and to Table 37 on page 51 for register bit definitions).

During a software reset (0.15 = 1), these bit settings are not re-read from the pins. They revert back to the values that were read in during the last hardware reset. Therefore, any changes to pin values made since the last hardware reset will not be detected during a software reset.

During a hardware reset, register information is unavailable for 1 ms after de-assertion of the reset. During a software reset (0.15 = 1) the registers are available for reading. The reset bit should be polled to see when the part has completed reset (0.15 = 0).

Hardware Configuration Settings

The LXT972 provides a hardware option to set the initial device configuration. The hardware option uses the three LED driver pins. This provides three control bits, as listed in Table 8. The LED drivers can operate as either open-drain or open-source circuits as shown in Figure 6.

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Figure 6: Hardware Configuration Settings

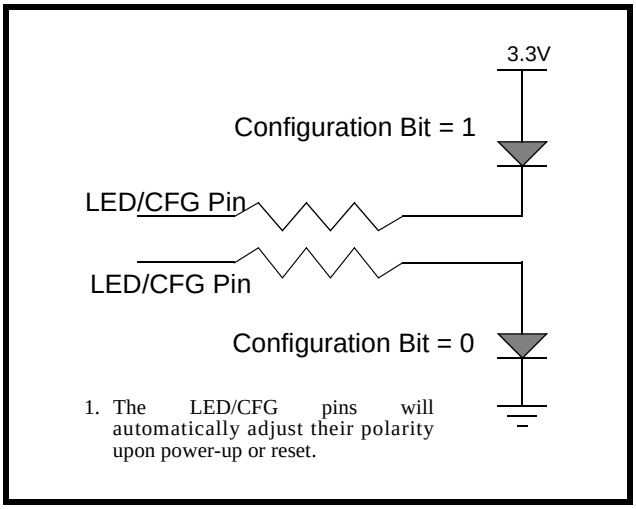


Table 8: Hardware Configuration Settings

Desired Mode			LED/CFG*n* Pin Settings[1]			Resulting Register Bit Values						
						Control Register			Auto-Neg Advertisement			
Auto-Neg	Speed (Mbps)	Duplex	1	2	3	AutoNeg 0.12	Speed 0.13	FD 0.8	100FD 4.8	100TX 4.7	10FD 4.6	10T 4.5
Disabled	10	Half	Low	Low	Low	0	0	0	N/A Auto-Negotiation Advertisement			
		Full	Low	Low	High			1				
	100	Half	Low	High	Low		1	0				
		Full	Low	High	High			1				
Enabled	100 Only	Half	High	Low	Low	1	1	0	0	1	0	0
		Full	High	Low	High			1	1	1	0	0
	10/100	Half Only	High	High	Low			0	0	1	0	1
		Full or Half	High	High	High			1	1	1	1	1

1. Refer to Table 7 on page 9 for LED/CFG pin assignments.

Establishing Link

See Figure 7 for an overview of link establishment.

Auto-Negotiation

If not configured for forced operation, the LXT972 attempts to auto-negotiate with its link partner by sending Fast Link Pulse (FLP) bursts. Each burst consists of up to 33 link pulses spaced 62.5 µs apart. Odd link pulses (clock pulses) are always present. Even link pulses (data pulses) may be present or absent to indicate a "1" or a "0". Each FLP burst exchanges 16 bits of data, which are referred to as a "link code word". All devices that support auto-negotiation must implement the "Base Page" defined by IEEE 802.3 (registers 4 and 5). LXT972 also supports the optional "Next Page" function as described in Tables 44 and 45 (registers 7 and 8).

Base Page Exchange

By exchanging Base Pages, the LXT972 and its link partner communicate their capabilities to each other. Both sides must receive at least three identical base pages for negotiation to continue. Each side identifies the highest common capabilities that both sides support and configures itself accordingly.

Next Page Exchange

Additional information, above that required by base page exchange, is also sent via "Next Pages'. The LXT972 fully supports the IEEE 802.3ab method of negotiation via Next Page exchange.

Controlling Auto-Negotiation

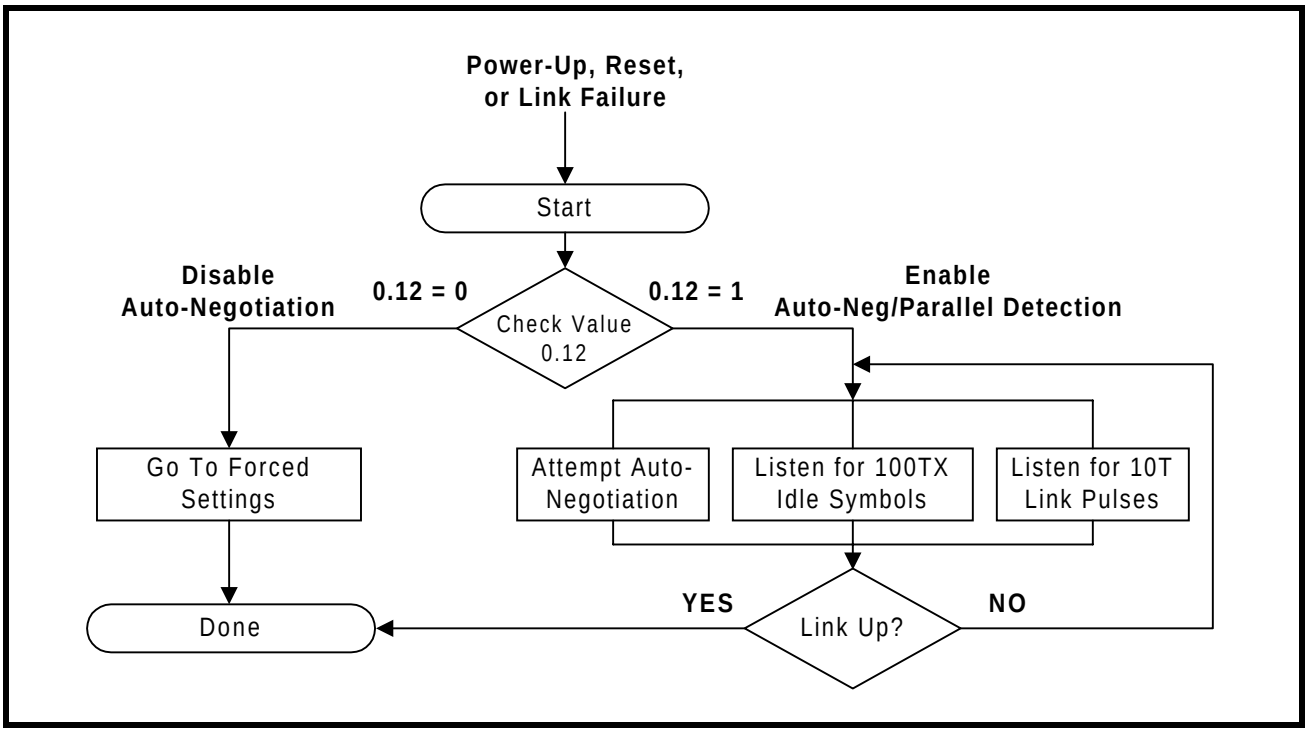
When auto-negotiation is controlled by software, the following steps are recommended:

- After power-up, power-down, or reset, the power-down recovery time, as specified in Table 34 on page 47, must be exhausted before proceeding.
- Set the auto-negotiation advertisement register bits.
- Enable auto-negotiation (set MDIO bit 0.12 = 1).

Parallel Detection

For the parallel detection feature of auto-negotiation, the LXT972 also monitors for 10BASE-T Normal Link Pulses (NLP) and 100BASE-TX Idle symbols. If either is detected, the device automatically reverts to the corresponding operating mode. Parallel detection allows the LXT972 to communicate with devices that do not support auto-negotiation.

Figure 7: Link Establishment Overview



MII Operation

The LXT972 device implements the Media Independent Interface (MII) as defined in the IEEE 802.3 standard. Separate channels are provided for transmitting data from the MAC to the LXT972 (TXD), and for passing data received from the line (RXD) to the MAC. Each channel has its own clock, data bus, and control signals. Nine signals are used to pass received data to the MAC: RXD<3:0>, RX_CLK, RX_DV, RX_ER, COL, and CRS. Seven signals are used to transmit data from the MAC: TXD<3:0>, TX_CLK, TX_EN, and TX_ER.

The LXT972 supplies both clock signals as well as separate outputs for carrier sense and collision. Data transmission across the MII is normally implemented in 4-bit-wide nibbles.

MII Clocks

The LXT972 is the master clock source for data transmission and supplies both MII clocks (RX_CLK and TX_CLK). It automatically sets the clock speeds to match link conditions. When the link is operating at 100 Mbps, the clocks are set to 25 MHz. When the link is operating at 10 Mbps, the clocks are set to 2.5 MHz. Figures 8 through 10 show the clock cycles for each mode. The transmit data and control signals must always be synchronized to TX_CLK by the MAC. The LXT972 samples these signals on the rising edge of TX_CLK.

Transmit Enable

The MAC must assert TX_EN the same time as the first nibble of preamble, and de-assert TX_EN after the last bit of the packet.

Receive Data Valid

The LXT972 asserts RX_DV when it receives a valid packet. Timing changes depend on line operating speed:

- For 100TX links, RX_DV is asserted from the first nibble of preamble to the last nibble of the data packet.
- For 10BT links, the entire preamble is truncated. RX_DV is asserted with the first nibble of the Start of Frame Delimiter (SFD) “5D” and remains asserted until the end of the packet.

Carrier Sense

Carrier sense (CRS) is an asynchronous output. It is always generated when a packet is received from the line and in half-duplex when a packet is transmitted.

Carrier sense is not generated when a packet is transmitted and in full-duplex mode. Table 9 summarizes the conditions for assertion of carrier sense, collision, and data loopback signals.

Error Signals

When LXT972 is in 100 Mbps mode and receives an invalid symbol from the network, it asserts RX_ER and drives “1110” on the RXD pins.

When the MAC asserts TX_ER, the LXT972 will drive “H” symbols out on the TPOP/N pins.

Collision

The LXT972 asserts its collision signal, asynchronously to any clock, whenever the line state is half-duplex and the transmitter and receiver are active at the same time. Table 9 summarizes the conditions for assertion of carrier sense, collision, and data loopback signals.

Figure 8: 10BASE-T Clocking

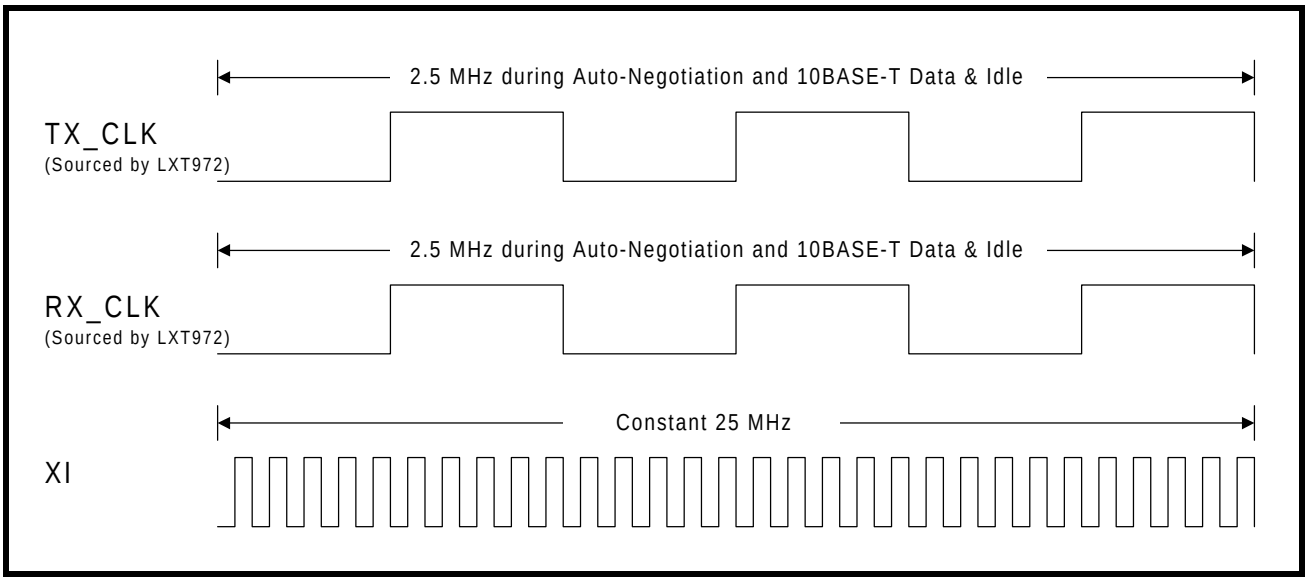


Figure 9: 100BASE-X Clocking

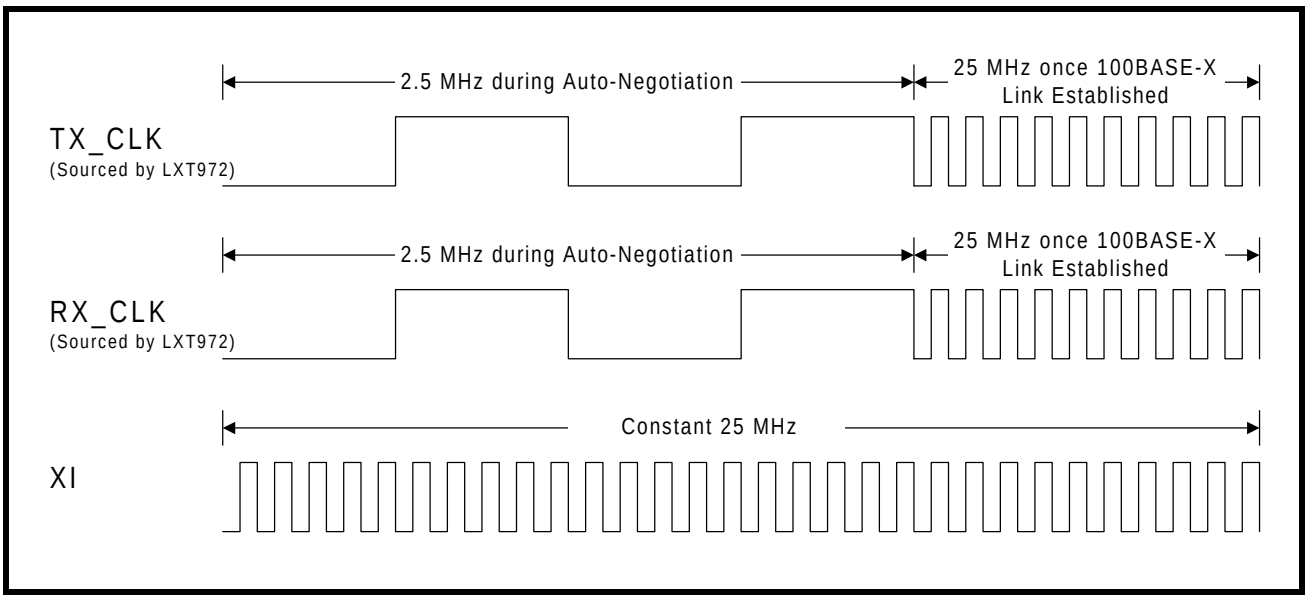
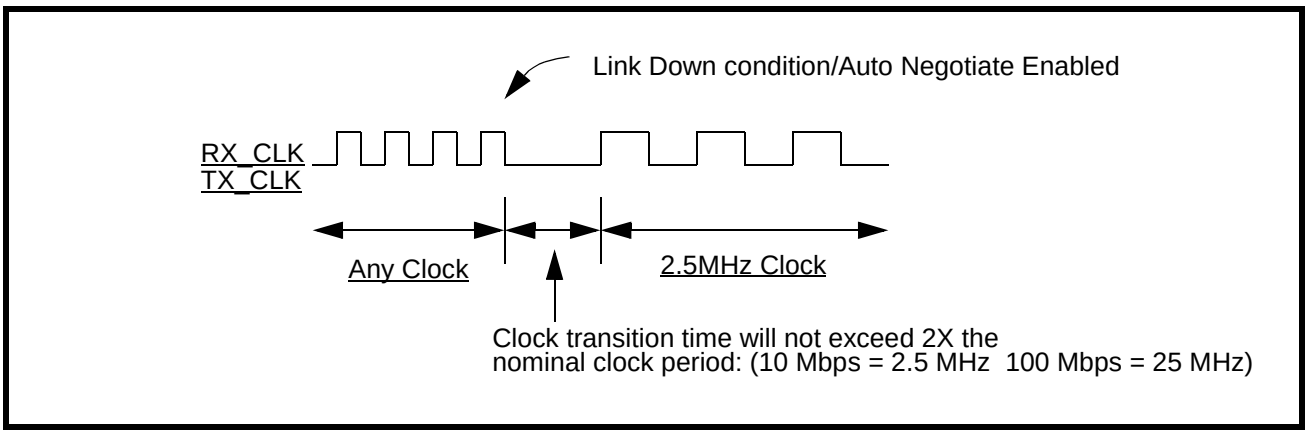


Figure 10: Link Down Clock Transition



Loopback

The LXT972 provides two loopback functions, operational and test (see Table 9). Loopback paths are shown in Figure 11.

Operational Loopback

Operational loopback is provided for 10 Mbps half-duplex links when bit 16.8 = 0. Data transmitted by the MAC (TXData) will be looped back on the receive side of the MII (RXData). Operational loopback is not provided for 100 Mbps links, full-duplex links, or when 16.8 = 1.

Test Loopback

A test loopback function is provided for diagnostic testing of the LXT972. During test loopback, the twisted-pair interface is disabled. Data transmitted by the MAC is internally looped back by the LXT972 and returned to the MAC.

Test loopback is available for both 100TX and 10T operation. Test loopback is enabled by setting bits as follows:

- 0.14 = 1
- 0.8 = 1 (full-duplex)
- 0.12 = 0 (disable auto-negotiation).

Figure 11: Loopback Paths

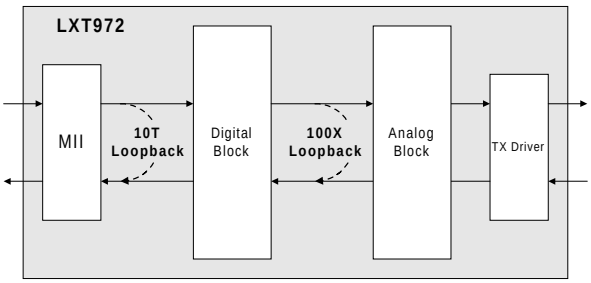


Table 9: Carrier Sense, Loopback, and Collision Conditions

Speed	Duplex Condition	Carrier Sense	Test[1] Loopback	Operational Loopback	Collision
100 Mbps	Full-Duplex	Receive Only	Yes	No	None
	Half-Duplex	Transmit or Receive	No	No	Transmit and Receive
10 Mbps	Full-Duplex	Receive Only	Yes	No	None
	Half-Duplex, 16.8 = 0	Transmit or Receive	Yes	Yes	Transmit and Receive
	Half-Duplex, 16.8 = 1	Transmit or Receive	No	No	Transmit and Receive

1. Test Loopback is enabled when 0.14 = 1

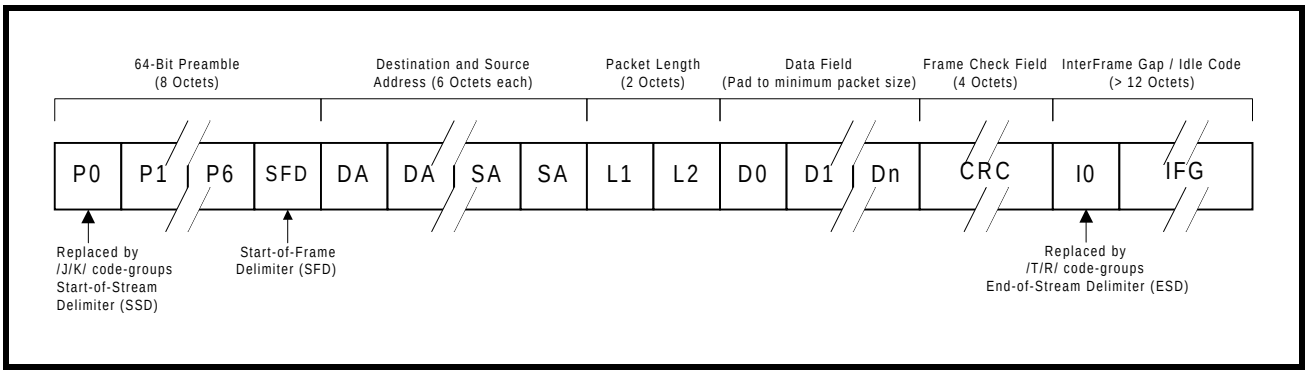
100 Mbps Operation

100BASE-X Network Operations

During 100BASE-X operation, the LXT972 transmits and receives 5-bit symbols across the network link. Figure 12 shows the structure of a standard frame packet. When the MAC is not actively transmitting data, the LXT972 sends out Idle symbols on the line.

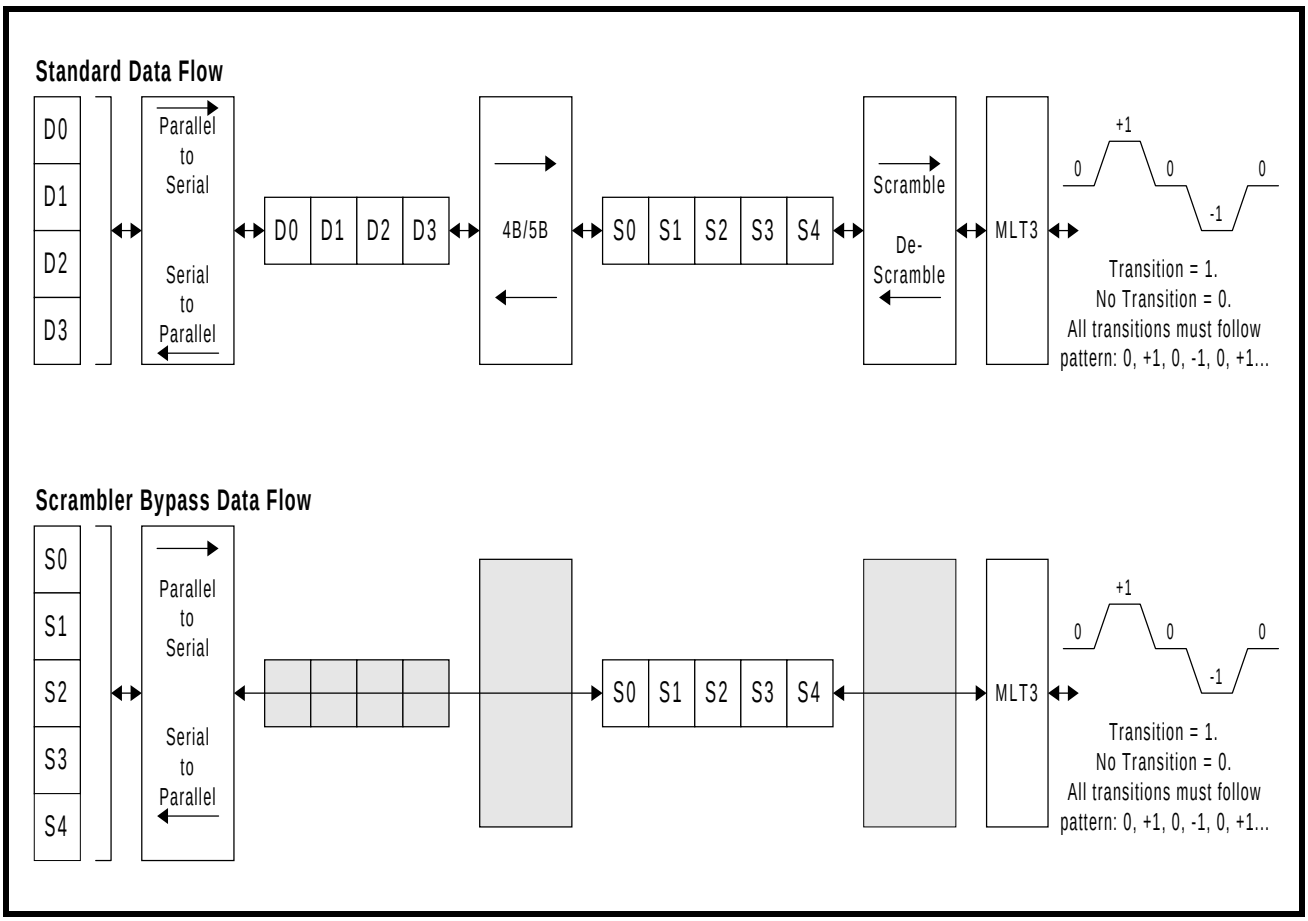
In 100TX mode, the LXT972 scrambles and transmits the data to the network using MLT-3 line code (Figure 13 on page 22). MLT-3 signals received from the network are descrambled, decoded, and sent across the MII to the MAC.

Figure 12: 100BASE-X Frame Format



.

Figure 13: 100BASE-TX Data Path



As shown in Figure 12 on page 21, the MAC starts each transmission with a preamble pattern. As soon as the LXT972 detects the start of preamble, it transmits a Start-of-Stream Delimiter (SSD, symbols J and K) to the network. It then encodes and transmits the rest of the packet, including the balance of the preamble, the SFD, packet data, and CRC.

Once the packet ends, the LXT972 transmits the End-of Stream-Delimiter (ESD, symbols T and R) and then returns to transmitting Idle symbols. 4B/5B coding is shown in Table 10 on page 26.

Figure 14 shows normal reception with no errors. When the LXT972 receives invalid symbols from the line, it asserts RX_ER as shown in Figure 15.

Figure 14: 100BASE-TX Reception with no Errors

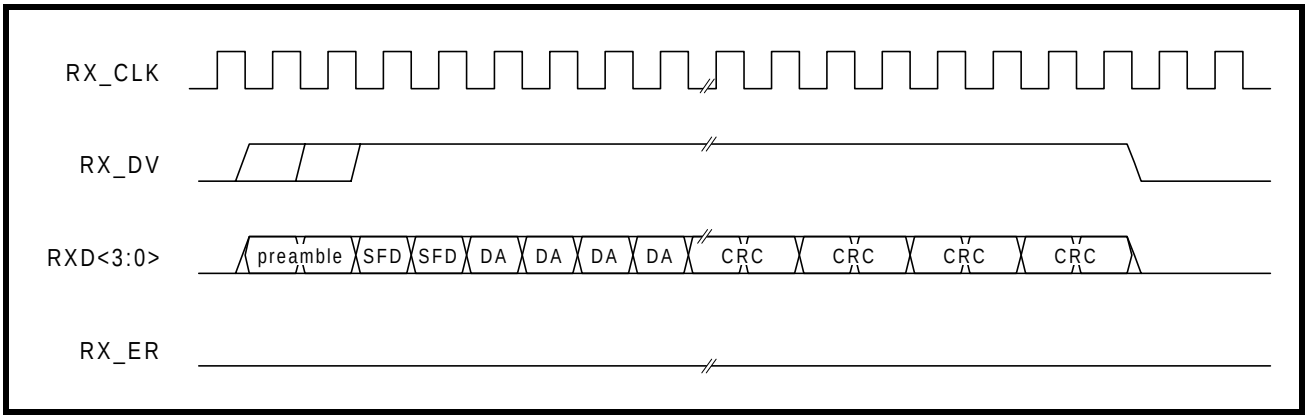
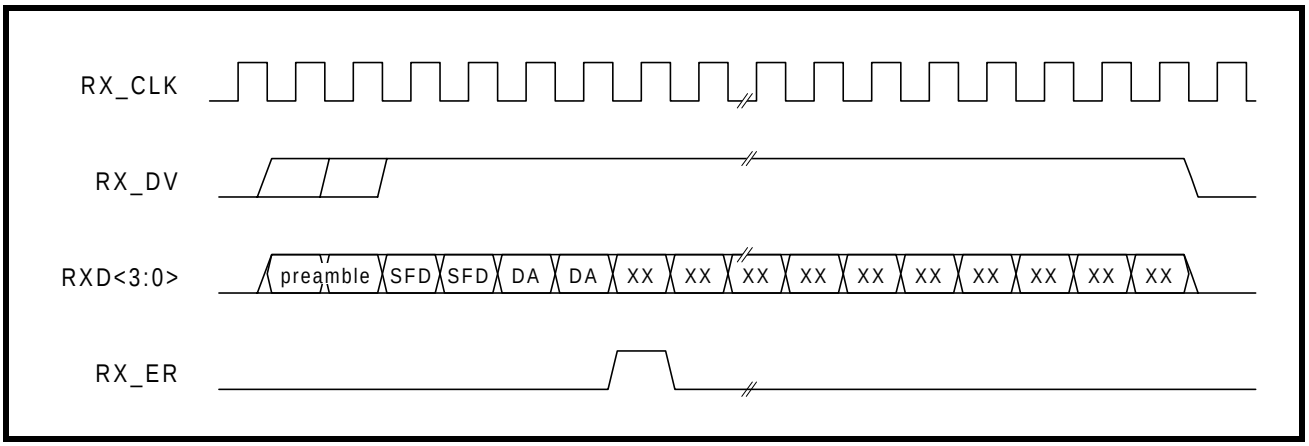


Figure 15: 100BASE-TX Reception with Invalid Symbol



Collision Indication

Figure 16 shows normal transmission. Upon detection of a collision, the COL output is asserted and remains asserted for the duration of the collision as shown in Figure 17.

Figure 16: 100BASE-TX Transmission with no Errors

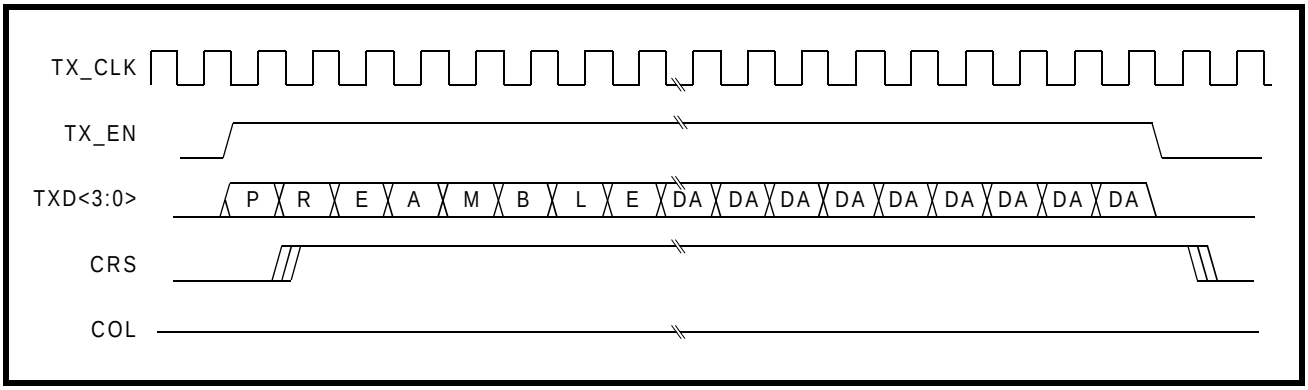
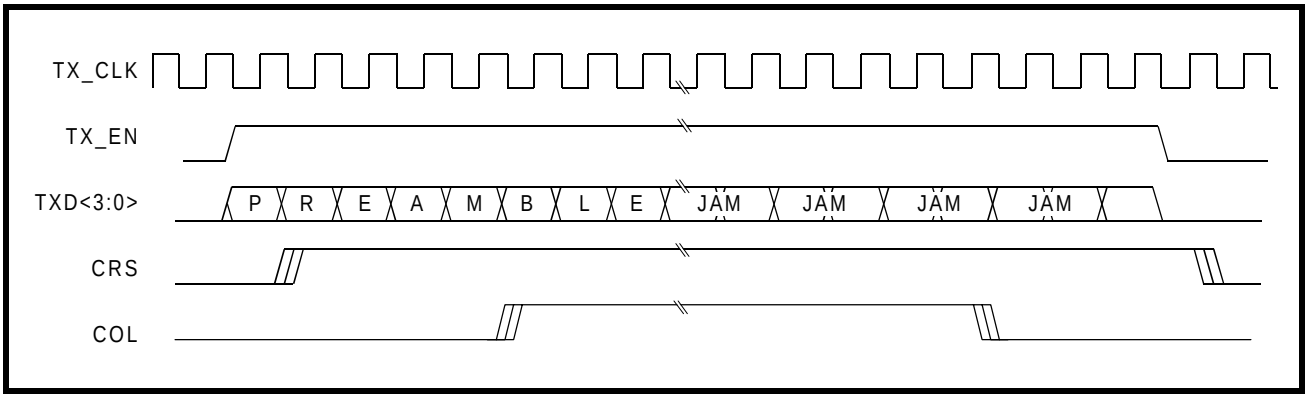


Figure 17: 100BASE-TX Transmission with Collision



100BASE-X Protocol Sublayer Operations

With respect to the 7-layer communications model, the LXT972 is a Physical Layer 1 (PHY) device. The LXT972 implements the Physical Coding Sublayer (PCS), Physical Medium Attachment (PMA), and Physical Medium Dependent (PMD) sublayers of the reference model defined by the IEEE 802.3u standard. The following paragraphs discuss LXT972 operation from the reference model point of view.

PCS Sublayer

The Physical Coding Sublayer (PCS) provides the MII interface, as well as the 4B/5B encoding/ decoding function.

For 100TX operation, the PCS layer provides IDLE symbols to the PMD-layer line driver as long as TX_EN is de-asserted.

Preamble Handling

When the MAC asserts TX_EN, the PCS substitutes a /J/K symbol pair, also known as the Start-of-Stream Delimiter (SSD), for the first two nibbles received across the MII. The PCS layer continues to encode the remaining MII data, following the coding in Table 10 on page 26, until TX_EN is de-asserted. It then returns to supplying IDLE symbols to the line driver.

In the receive direction, the PCS layer performs the opposite function, substituting two preamble nibbles for the SSD.

Dribble Bits

The LXT972 handles dribbles bits in all modes. If between 1-4 dribble bits are received, the nibble will be passed across the MII, padded with 1s if necessary. If between 5-7 dribble bits are received, the second nibble will not be sent onto the MII bus.

Figure 18: Protocol Sublayers

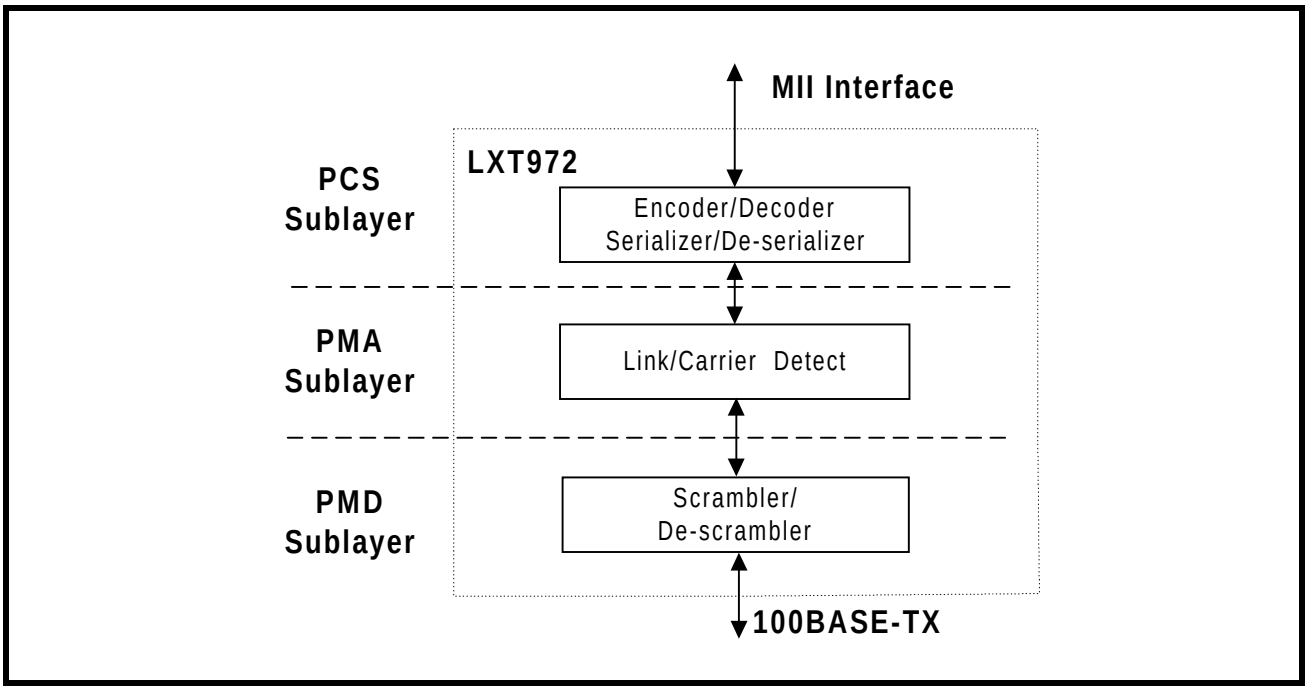


Table 10: 4B/5B Coding

Code Type	4B Code 3 2 1 0	Name	5B Code 4 3 2 1 0	Interpretation
DATA	0 0 0 0	0	1 1 1 1 0	Data 0
	0 0 0 1	1	0 1 0 0 1	Data 1
	0 0 1 0	2	1 0 1 0 0	Data 2
	0 0 1 1	3	1 0 1 0 1	Data 3
	0 1 0 0	4	0 1 0 1 0	Data 4
	0 1 0 1	5	0 1 0 1 1	Data 5
	0 1 1 0	6	0 1 1 1 0	Data 6
	0 1 1 1	7	0 1 1 1 1	Data 7
	1 0 0 0	8	1 0 0 1 0	Data 8
	1 0 0 1	9	1 0 0 1 1	Data 9
	1 0 1 0	A	1 0 1 1 0	Data A
	1 0 1 1	B	1 0 1 1 1	Data B
	1 1 0 0	C	1 1 0 1 0	Data C
	1 1 0 1	D	1 1 0 1 1	Data D
	1 1 1 0	E	1 1 1 0 0	Data E
	1 1 1 1	F	1 1 1 0 1	Data F
IDLE	undefined	I [1]	1 1 1 11	Idle. Used as inter-stream fill code
CONTROL	0 1 0 1	J [2]	1 1 0 0 0	Start-of-Stream Delimiter (SSD), part 1 of 2
	0 1 0 1	K [2]	1 0 0 0 1	Start-of-Stream Delimiter (SSD), part 2 of 2
	undefined	T [3]	0 1 1 0 1	End-of-Stream Delimiter (ESD), part 1 of 2
	undefined	R [3]	0 0 1 1 1	End-of-Stream Delimiter (ESD), part 2 of 2
INVALID	undefined	H [4]	0 0 1 0 0	Transmit Error. Used to force signaling errors
	undefined	Invalid	0 0 0 0 0	Invalid
	undefined	Invalid	0 0 0 0 1	Invalid
	undefined	Invalid	0 0 0 1 0	Invalid
	undefined	Invalid	0 0 0 1 1	Invalid
	undefined	Invalid	0 0 1 0 1	Invalid
	undefined	Invalid	0 0 1 1 0	Invalid
	undefined	Invalid	0 1 0 0 0	Invalid
	undefined	Invalid	0 1 1 0 0	Invalid
	undefined	Invalid	1 0 0 0 0	Invalid
	undefined	Invalid	1 1 0 0 1	Invalid

1. The /I/ (Idle) code group is sent continuously between frames.
2. The /J/ and /K/ (SSD) code groups are always sent in pairs; /K/ follows /J/.
3. The /T/ and /R/ (ESD) code groups are always sent in pairs; /R/ follows /T/.
4. An /H/ (Error) code group is used to signal an error condition.

PMA Sublayer

Link

In 100 Mbps mode, the LXT972 establishes a link whenever the scrambler becomes locked and remains locked for approximately 50 ms. Whenever the scrambler loses lock (receiving less than 12 consecutive idle symbols during a 2 ms window), the link will be taken down. This provides a very robust link, essentially filtering out any small noise hits that may otherwise disrupt the link. Furthermore 100M idle patterns will not bring up a 10M link.

The LXT972 reports link failure via the MII status bits (1.2 and 17.10) and interrupt functions. If auto-negotiation is enabled, link failure causes the LXT972 to re-negotiate.

Link Failure Override

The LXT972 will normally transmit data packets only if it detects the link is up. Setting bit 16.14 = 1 overrides this function, allowing the LXT972 to transmit data packets even when the link is down. This feature is provided as a diagnostic tool. Note that auto-negotiation must be disabled to transmit data packets in the absence of link. If auto-negotiation is enabled, the LXT972 will automatically transmit FLP bursts if the link is down.

Carrier Sense

For 100TX links, a start-of-stream delimiter (SSD) or /J/K symbol pair causes assertion of carrier sense (CRS). An end-of-stream delimiter (ESD) or /T/R symbol pair causes de-assertion of CRS. The PMA layer will also de-assert CRS if IDLE symbols are received without /T/R; however, in this case RX_ER will be asserted for one clock cycle when CRS is de-asserted.

Usage of CRS for Interframe Gap (IFG) timing is *not* recommended for the following reasons:

- De-assertion time for CRS is slightly longer than assertion time. This causes IFG intervals to appear somewhat shorter to the MAC than it actually is on the wire.
- CRS de-assertion is not aligned with TX_EN de-assertion on transmit loopbacks in half-duplex mode.

Receive Data Valid

The LXT972 asserts RX_DV to indicate that the received data maps to valid symbols. However, RXD outputs zeros until the received data is decoded and available for transfer to the controller.

Twisted-Pair PMD Sublayer

The twisted-pair Physical Medium Dependent (PMD) layer provides the signal scrambling and descrambling, line coding and decoding (MLT-3 for 100TX, Manchester for 10T), as well as receiving, polarity correction, and baseline wander correction functions.

Scrambler/Descrambler

The purpose of the scrambler is to spread the signal power spectrum and further reduce EMI using an 11-bit, data-independent polynomial. The receiver automatically decodes the polynomial whenever IDLE symbols are received.

Scrambler Seeding. Once the transmit data (or Idle symbols) are properly encoded, they are scrambled to further reduce EMI and to spread the power spectrum using an 11-bit scrambler seed. Five seed bits are determined by the PHY address, and the remaining bits are hard coded in the design.

Scrambler Bypass. The scrambler/descrambler can be bypassed by setting bit 16.12 = 1. Scrambler bypass is provided for diagnostic and test support.

Baseline Wander Correction

The LXT972 provides a baseline wander correction function which makes the device robust under all network operating conditions. The MLT3 coding scheme used in 100BASE-TX is by definition “unbalanced”. This means that the average value of the signal voltage can “wander” significantly over short time intervals (tenths of seconds). This wander can cause receiver errors at long-line lengths (100 meters) in less robust designs. Exact characteristics of the wander are completely data dependent.

The LXT972 baseline wander correction characteristics allow the device to recover error-free data while receiving worst-case “killer” packets over all cable lengths.

Polarity Correction

The 100BASE-TX descrambler automatically detects and corrects for the condition where the receive signal at TPIP and TPIN is inverted.

Programmable Slew Rate Control

The LXT972 device supports a slew rate mechanism whereby one of four pre-selected slew rates can be used. This allows the designer to optimize the output waveform to match the characteristics of the magnetics. The slew rate is determined by the TxSLEW pins as shown in Table 4 on page 8.

10 Mbps Operation

The LXT972 operates as a standard 10BASE-T transceiver. The LXT972 supports all the standard 10 Mbps functions. During 10BASE-T (10T) operation, the LXT972 transmits and receives Manchester-encoded data across the network link. When the MAC is not actively transmitting data, the LXT972 drives link pulses onto the line.

In 10T mode, the polynomial scrambler/descrambler is inactive. Manchester-encoded signals received from the network are decoded by the LXT972 and sent across the MII to the MAC.

10T Preamble Handling

The LXT972 offers two options for preamble handling, selected by bit 16.5. In 10T Mode when 16.5 = 0, the LXT972 strips the entire preamble off of received packets. CRS is asserted coincident with SFD. RX_DV is held Low for the duration of the preamble. When RX_DV is asserted, the very first two nibbles driven by the LXT972 are the SFD "5D" hex followed by the body of the packet.

In 10T mode with 16.5 = 1, the LXT972 passes the preamble through the MII and asserts RX_DV and CRS simultaneously. In 10T loopback, the LXT972 loops back whatever the MAC transmits to it, including the preamble.

10T Carrier Sense

For 10T links, CRS assertion is based on reception of valid preamble, and de-assertion on reception of an end-of-frame (EOF) marker. Bit 16.7 allows CRS de-assertion to be synchronized with RX_DV de-assertion. Refer to Table 46 on page 58.

10T Dribble Bits

The LXT972 device handles dribbles bits in all modes. If between 1-4 dribble bits are received, the nibble will be passed across the MII, padded with 1s if necessary. If between 5-7 dribble bits are received, the second nibble will not be sent onto the MII bus.

10T Link Integrity Test

In 10T mode, the LXT972 always transmits link pulses. When the Link Integrity Test function is enabled (the normal configuration), it monitors the connection for link pulses. Once link pulses are detected, data transmission will be enabled and will remain enabled as long as either the link pulses or data transmission continue. If the link pulses stop, the data transmission will be disabled.

If the Link Integrity Test function is disabled, the LXT972 will transmit to the connection regardless of detected link pulses. The Link Integrity Test function can be disabled by setting bit 16.14 = 1.

Link Failure

Link failure occurs if Link Integrity Test is enabled and link pulses or packets stop being received. If this condition occurs, the LXT972 returns to the auto-negotiation phase if auto-negotiation is enabled. If the Link Integrity Test function is disabled by setting 16.14 = 1 in the Configuration Register, the LXT972 will transmit packets, regardless of link status.

10T SQE (Heartbeat)

By default, the Signal Quality Error (SQE) or heartbeat function is disabled on the LXT972. To enable this function, set bit 16.9 = 1. When this function is enabled, the LXT972 will assert its COL output for 5-15 BT after each packet. See Figure 28 on page 44 for SQE timing parameters.

10T Jabber

If a transmission exceeds the jabber timer, the LXT972 will disable the transmit and loopback functions. See Figure 27 on page 44 for jabber timing parameters.

The LXT972 automatically exits jabber mode after the unjabber time has expired. This function can be disabled by setting bit 16.10 = 1.

10T Polarity Correction

The LXT972 automatically detects and corrects for the condition where the receive signal (TPIP/N) is inverted. Reversed polarity is detected if eight inverted link pulses, or four inverted end-of-frame (EOF) markers, are received consecutively. If link pulses or data are not received by the maximum receive time-out period (96-128 ms), the polarity state is reset to a non-inverted state.

Monitoring Operations

Monitoring Auto-Negotiation

Auto-negotiation can be monitored as follows:

- Bit 17.7 is set to 1 once the Auto-Negotiation process is completed.
- Bits 1.2 and 17.10 are set to 1 once the link is established.
- Bits 17.14 and 17.9 can be used to determine the link operating conditions (speed and duplex).

Monitoring Next Page Exchange

The LXT972 offers an Alternate Next Page mode to simplify the next page exchange process. Normally, bit 6.1 (Page Received) remains set until read. When Alternate Next Page mode is enabled (16.1 = 1), bit 6.1 is automatically cleared whenever a new negotiation process takes place. This prevents the user from reading an old value in 6.1 and assuming that Registers 5 and 8 (Partner Ability) contain valid information. Additionally, the LXT972 uses bit 6.5 to indicate when the current received page is the base page. This information is useful for recognizing when next pages must be resent due to a new negotiation process starting. Bits 6.1 and 6.5 are cleared when read.

LED Functions

The LXT972 incorporates three direct LED drivers. On power up all the drivers are asserted for approximately 1 second after reset de-asserts. Each LED driver can be programmed using the LED Configuration Register (refer to Table 50 on page 62) to indicate one the following conditions:

- Operating Speed
- Transmit Activity
- Receive Activity
- Collision Condition
- Link Status
- Duplex Mode

The LED drivers can also be programmed to display various combined status conditions. For example, setting bits 20.15:12 = 1101 produces the following combination of Link and Activity indications:

- If Link is down LED is off.
- If Link is up LED is on.
- If Link is up and activity is detected, the LED will blink at the stretch interval selected by bits 20.3:2 and will continue to blink as long as activity is present.

The LED driver pins also provide initial configuration settings. The LED pins are sensitive to polarity and will automatically pull up or pull down to configure for either open drain or open source circuits (10 mA Max current rating) as required by the hardware configuration. Refer to the discussion of "Hardware Configuration Settings" on page 16 for details.

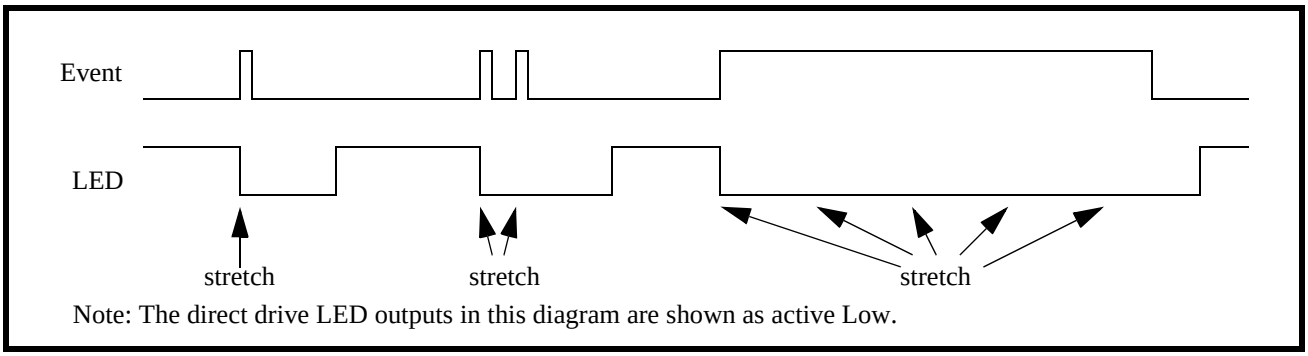
LED Pulse Stretching

The LED Configuration Register also provides optional LED pulse stretching to 30, 60, or 100 ms. If during this pulse stretch period, the event occurs again, the pulse stretch time will be further extended.

When an event such as receiving a packet occurs it will be edge detected and it will start the stretch timer. The LED driver will remain asserted until the stretch timer expires. If another event occurs before the stretch timer expires then the stretch timer will be reset and the stretch time will be extended.

When a long event (such as duplex status) occurs it will be edge detected and it will start the stretch timer. When the stretch timer expires the edge detector will be reset so that a long event will cause another pulse to be generated from the edge detector which will reset the stretch timer and cause the LED driver to remain asserted. Figure 19 shows how the stretch operation functions.

Figure 19: LED Pulse Stretching



Note: The direct drive LED outputs in this diagram are shown as active Low.

Boundary Scan (JTAG1149.1) Functions

LXT972 includes a IEEE 1149.1 boundary scan test port for board level testing. All digital input, output, and input/output pins are accessible. *The BSDL file is available by contacting your local sales office (see the back page) or by accessing the Level One website (www.level1.com).*

Boundary Scan Interface

This interface consists of five pins (TMS, TDI, TDO, $\overline{\text{TRST}}$, and TCK). It includes a state machine, data register array, and instruction register. The TMS and TDI pins are internally pulled up. TCK is internally pulled down. TDO does not have an internal pull-up or pull-down.

State Machine

The TAP controller is a 16 state machine driven by the TCK and TMS pins. Upon reset the TEST_LOGIC_RESET state is entered. The state machine is also reset when TMS and TDI are high for five TCK periods.

Instruction Register

After the state machine resets, the IDCODE instruction is always invoked. The decode logic ensures the correct data flow to the Data registers according to the current instruction. Valid instructions are listed in Table 12.

Boundary Scan Register (BSR)

Each Boundary Scan Register (BSR) cell has two stages. A flip-flop and a latch are used for the serial shift stage and the parallel output stage. There are four modes of operation as listed in Table 11.

Table 11: BSR Mode of Operation

Mode	Description
1	Capture
2	Shift
3	Update
4	System Function

Table 12: Supported JTAG Instructions

Name	Code	Description	Mode	Data Register
EXTEST	0000	External Test	Test	BSR
IDCODE	0001	ID Code Inspection	Normal	ID REG
SAMPLE	0010	Sample Boundary	Normal	BSR
TRIBYP	0011	Force Float	Normal	Bypass
SETBYP	0100	Control Boundary to 1/0	Test	Bypass
BYPASS	1111	Bypass Scan	Normal	Bypass

Table 13: Device ID Register

31:28	27:12	11:8	7:1	0
Version	**Part ID (hex)**	**Jedec Continuation Characters**	**JEDEC ID**[1]	**Reserved**
0001	03CB	1110	111 1110	1

1. The JEDEC IS is an 8-bit identifier. The MSB is for parity and is ignored. Level One's JEDEC ID is FE (1111 1110) which becomes 111 1110

APPLICATION INFORMATION

Magnetics Information

The LXT972 requires a 1:1 ratio for both the receive and transmit transformers. The transformer isolation voltage should be rated at 2 kV to protect the circuitry from static voltages across the connectors and cables. Refer to Table 14 for transformer requirements.

A cross-reference list of magnetic manufacturers and part numbers is available in Application Note 073, Magnetic Manufacturers, which can be found on the Level One web site (www.level1.com). Before committing to a specific component, designers should contact the manufacturer for current product specifications, and validate the magnetics for the specific application.

Table 14: Magnetics Requirements

Parameter	Min	Nom	Max	Units	Test Condition
Rx turns ratio	–	1 : 1	–	–	
Tx turns ratio	–	1 : 1	–	–	
Insertion loss	0.0	0.6	1.1	dB	
Primary inductance	350	–	–	µH	
Transformer isolation	–	1.5	–	kV	
Differential to common mode rejection	40	–	–	dB	.1 to 60 MHz
	35	–	–	dB	60 to 100 MHz
Return Loss	-16	–	–	dB	30 MHz
	-10	–	–	dB	80 MHz

Typical Twisted-Pair Interface

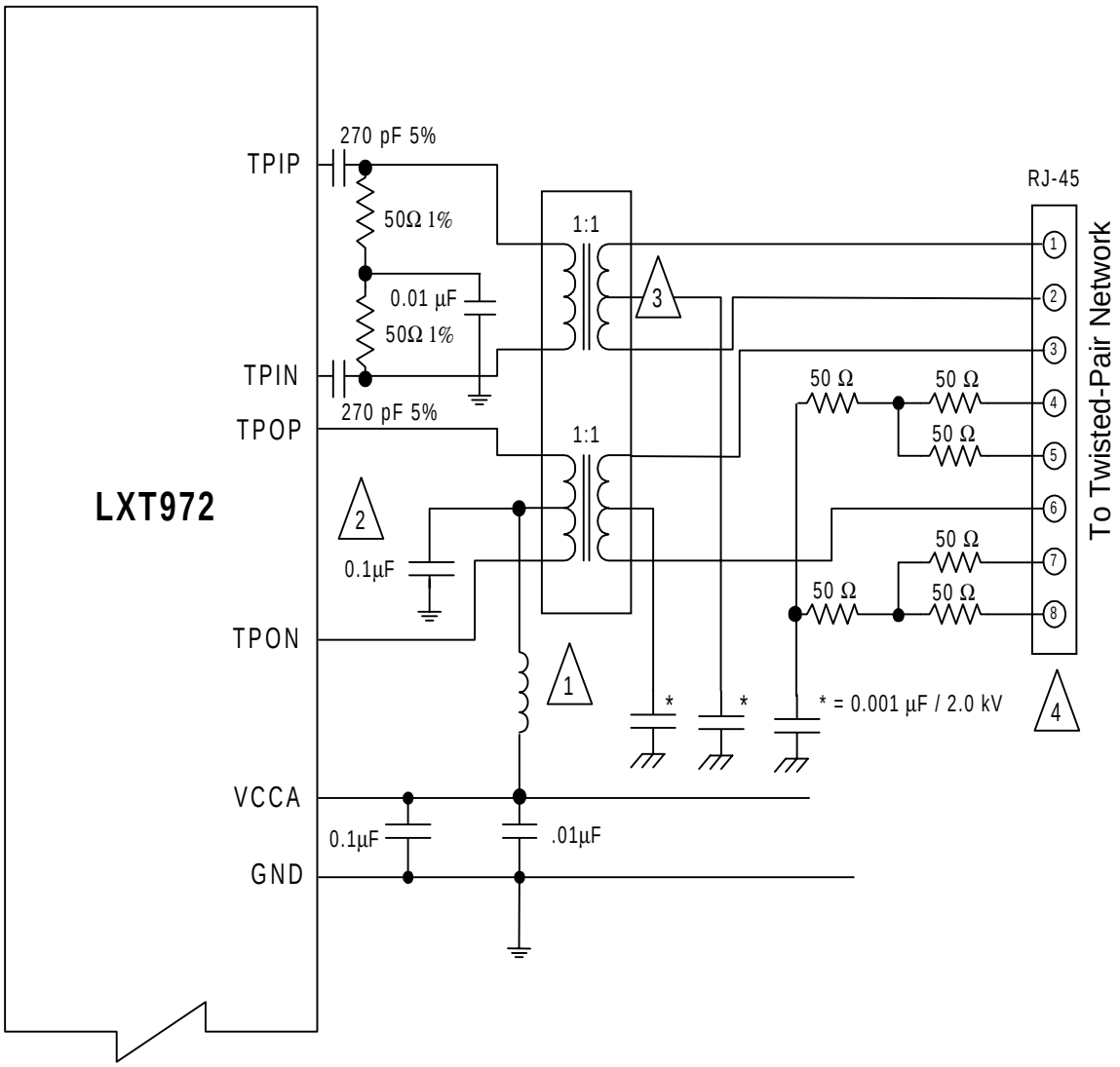
Table 15 provides a comparison of the RJ-45 connections for NIC and switch applications in a typical twisted-pair interface setting.

Figure 20 on page 33 shows a typical twisted-pair interface with the RJ-45 connections crossed over for a switch configuration. Figure 21 on page 34 provides a typical twisted-pair interface with the RJ-45 connections configured for a NIC application.

Table 15: RJ-45 Pin Comparison of NIC and Switch Twisted-Pair Interfaces

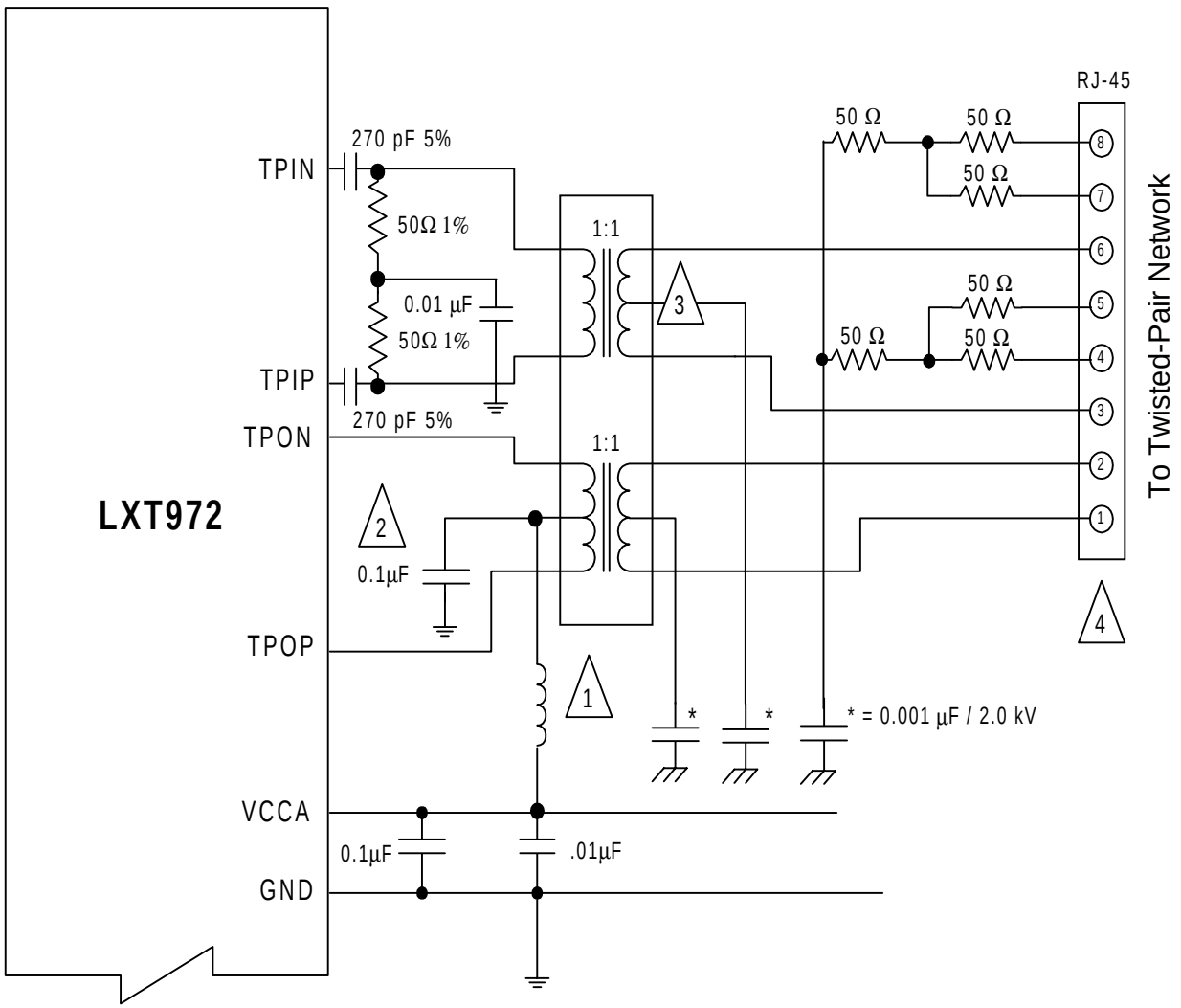
Symbol	RJ-45	
	Switch	NIC
TPIP	1	3
TPIN	2	6
TPOP	3	1
TPON	6	2

Figure 20: Typical Twisted-Pair Interface - Switch



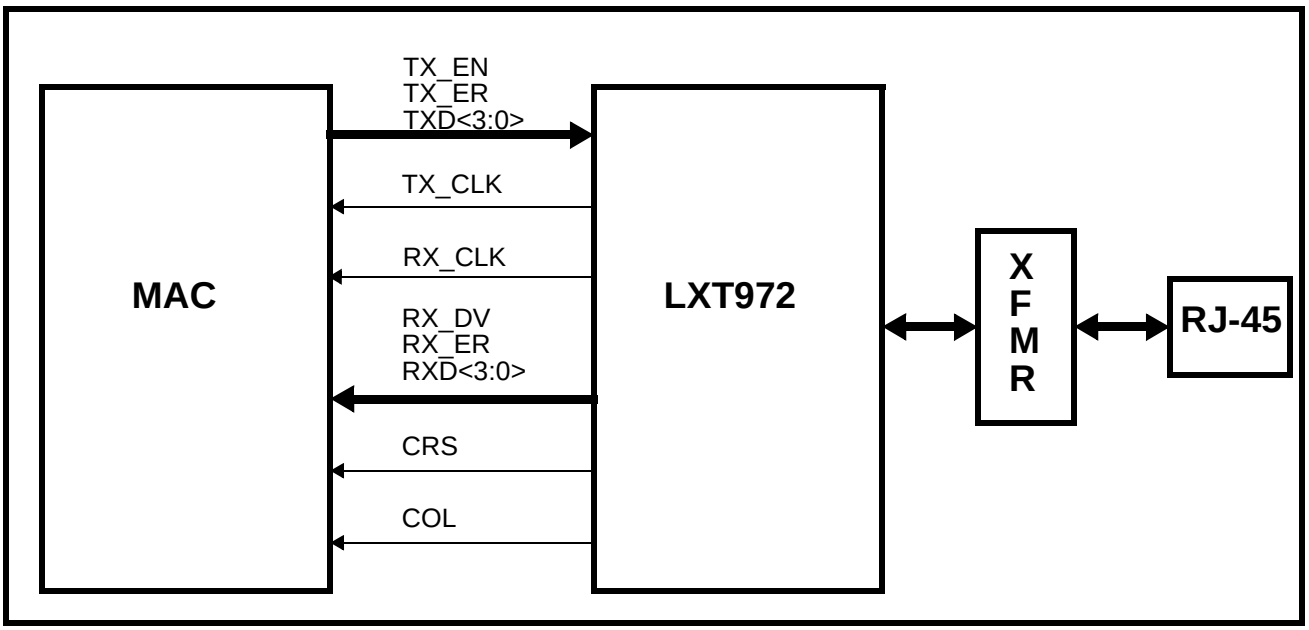
1. Center-tap current may be supplied from 3.3V VCCA as shown. Additional power savings may be realized by supplying the center-tap from a 2.5V current source. A separate ferrite bead (rated at 50 mA) should be used to supply center-tap current.
2. The 100Ω transmit load termination resistor typically required is integrated in the LXT972.
3. Magnetics without a receive pair center-tap do not require a 2 kV termination.
4. RJ-45 connections shown are for a standard switch application. For a standard NIC RJ-45 setup, see Figure 21.

Figure 21: Typical Twisted-Pair Interface - NIC



1. Center-tap current may be supplied from 3.3V VCCA as shown. Additional power savings may be realized by supplying the center-tap from a 2.5V current source. A separate ferrite bead (rated at 50 mA) should be used to supply center-tap current.
2. The 100Ω transmit load termination resistor typically required is integrated in the LXT972.
3. Magnetics without a receive pair center-tap do not require a 2 kV termination.
4. RJ-45 connections shown are for a standard NIC. Tx/Rx crossover may be required for repeater & switch applications..

Figure 22: Typical MII Interface



PRELIMINARY TEST SPECIFICATIONS

NOTE

Tables 16 through 34 and Figures 23 through 34 represent the target specifications of the LXT972. These specifications are guaranteed by test except where noted "by design." Minimum and maximum values listed in Tables 18 through 34 apply over the recommended operating conditions specified in Table 17.

Electrical Parameters

Table 16: Absolute Maximum Ratings

Parameter	Sym	Min	Max	Units
Supply voltage	V_{CC}	-0.3	4.0	V
Operating temperature	T_{OPA}	0	+70	ºC
Storage temperature	T_{ST}	-65	+150	ºC

CAUTION

Exceeding these values may cause permanent damage.
Functional operation under these conditions is not implied.
Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 17: Operating Conditions

Parameter		Sym	Min	Typ[1]	Max	Units
Recommended operating temperature	LXT972_C (Commercial)	T_{OPA}	0	–	70	ºC
Recommended supply voltage[2]	Analog & Digital	V_{CCA}, V_{CCD}	3.14	3.3	3.45	V
	I/O	V_{CCIO}	2.35	–	3.45	V
V_{CC} current	100BASE-TX	I_{CC}	–	–	110	mA
	10BASE-T	I_{CC}	–	–	82	mA
	Power Down	I_{CC}	–	–	1	mA
	Auto-Negotiation	I_{CC}	–	–	110	mA

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. Voltages with respect to ground unless otherwise specified.

Table 18: Digital I/O Characteristics [1]

Parameter	Symbol	Min	Typ[2]	Max	Units	Test Conditions
Input Low voltage	V_{IL}	–	–	0.8	V	–
Input High voltage	V_{IH}	2.0	–	–	V	–
Input current	I_I	-10	–	10	µA	$0.0 < V_I < V_{CC}$
Output Low voltage	V_{OL}	–	–	0.4	V	I_{OL} = 4 mA
Output High voltage	V_{OH}	2.4	–	–	V	I_{OH} = -4 mA

1. Applies to all pins except MII , LED and XI/XO pins. Refer to Table 19 for MII I/O Characteristics, Table 20 for XI/XO and Table 21 for LED Characteristics.
2. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.

Table 19: Digital I/O Characteristics - MII Pins

Parameter	Symbol	Min	Typ[1]	Max	Units	Test Conditions
Input Low voltage	V_{IL}	–	–	0.8	V	–
Input High voltage	V_{IH}	2.0	–	–	V	–
Input current	I_I	-10	–	10	µA	$0.0 < V_I <$ VCCIO
Output Low voltage	V_{OL}	–	–	0.4	V	I_{OL} = 4 mA
Output High voltage	V_{OH}	2.2	–	–	V	I_{OH} = -4 mA, VCCIO = 3.3V
	V_{OH}	2.0	–	–	V	I_{OH} = -4 mA, VCCIO = 2.5V
Driver output resistance (Line driver output enabled)	R_O[2]	–	100	–	Ω	VCCIO = 2.5V
	R_O[2]	–	100	–	Ω	VCCIO = 3.3V

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. Parameter is guaranteed by design; not subject to production testing.

Table 20: I/O Characteristics - REFCLK/XI and XO Pins

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Input Low Voltage	V_{IL}	–	–	0.8	V	
Input High Voltage	V_{IH}	2.0	–	–	V	
Input Clock Frequency Tolerance[2]	Δf	–	–	±100	ppm	
Input Clock Duty Cycle[2]	T_{DC}	40	–	60	%	
Input Capacitance	C_{IN}	–	3.0	–	pF	

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. Parameter is guaranteed by design; not subject to production testing.

Table 21: I/O Characteristics - LED/CFG Pins

Parameter	Sym	Min	Typ	Max	Units	Test Conditions
Output Low Voltage	V_{OL}	–	–	0.4	V	I_{OL} = 10 mA
Output High Voltage	V_{OH}	2.4	–	–	V	I_{OH} = -10 mA
Input Current	I_I	-10	–	10	µA	0 < V_I < VCCIO

Table 22: 100BASE-TX Transceiver Characteristics

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Peak differential output voltage	V_P	0.95	–	1.05	V	Note 2
Signal amplitude symmetry	Vss	98	–	102	%	Note 2
Signal rise/fall time	T_{RF}	3.0	–	5.0	ns	Note 2
Rise/fall time symmetry	T_{RFS}	–	–	0.5	ns	Note 2
Duty cycle distortion	D_{CD}	35	50	65	%	Offset from 16ns pulse width at 50% of pulse peak
Overshoot/Undershoot	V_{OS}	–	–	5	%	–
Jitter (measured differentially)	–	–	–	1.4	ns	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. Measured at the line side of the transformer, line replaced by 100Ω(+/-1%) resistor.

Table 23: 10BASE-T Transceiver Characteristics

Parameter	Sym	Min	Typ	Max	Units	Test Conditions
Transmitter						
Peak differential output voltage	V_{OP}	2.2	2.5	2.8	V	With transformer, line replaced by 100 Ω resistor
Transition timing jitter added by the MAU and PLS sections	-	0	2	11	ns	After line model specified by IEEE 802.3 for 10BASE-T MAU
Receiver						
Receive Input Impedance	Z_{IN}	-	-	22	kΩ	
Differential Squelch Threshold	V_{DS}	300	420	585	mV	

Table 24: 10BASE-T Link Integrity Timing Characteristics

Parameter	Sym	Min	Typ	Max	Units	Test Conditions
Time Link Loss Receive	TLL	50	–	150	ms	–
Link Pulse	TLP	2	–	7	Link Pulses	–
Link Min Receive Timer	TLR MIN	2	–	7	ms	–
Link Max Receive Timer	TLR MAX	50	–	150	ms	–
Link Transmit Period	TLT	8	–	24	ms	–
Link Pulse Width	TLPW	60	–	150	ns	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.

Timing Diagrams

Figure 23: 100BASE-TX Receive Timing - 4B Mode

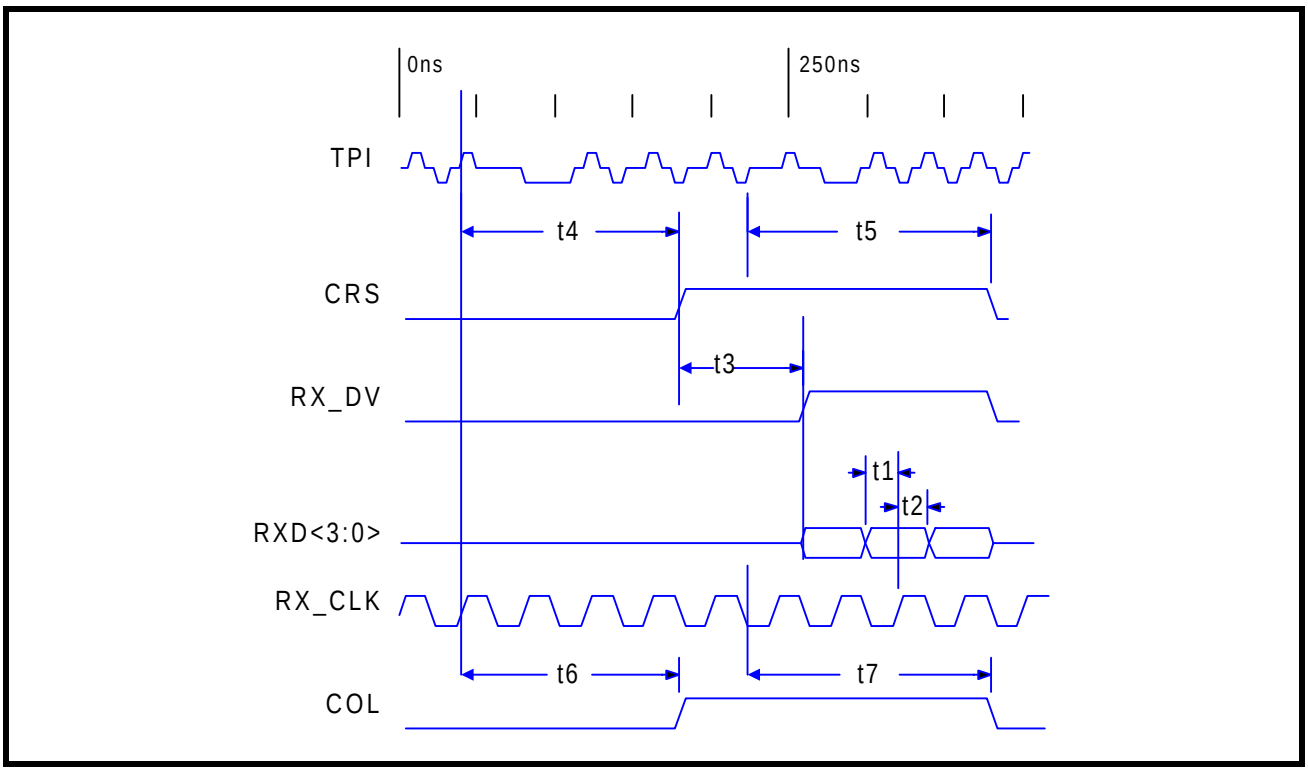


Table 25: 100BASE-TX Receive Timing Parameters - 4B Mode

Parameter	Sym	Min	Typ[1]	Max	Units[2]	Test Conditions
RXD<3:0>, RX_DV, RX_ER setup to RX_CLK High	t1	10	–	–	ns	–
RXD<3:0>, RX_DV, RX_ER hold from RX_CLK High	t2	10	–	–	ns	–
CRS asserted to RXD<3:0>, RX_DV	t3	3	–	5	BT	–
Receive start of “J” to CRS asserted	t4	12	–	16	BT	–
Receive start of “T” to CRS de-asserted	t5	10	–	17	BT	–
Receive start of “J” to COL asserted	t6	16	–	22	BT	–
Receive start of “T” to COL de-asserted	t7	17	–	20	BT	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. BT is the duration of one bit as transferred to and from the MAC and is the reciprocal of the bit rate. 100BASE-T bit time = 10^{-8} s or 10 ns.

Figure 24: 100BASE-TX Transmit Timing - 4B Mode

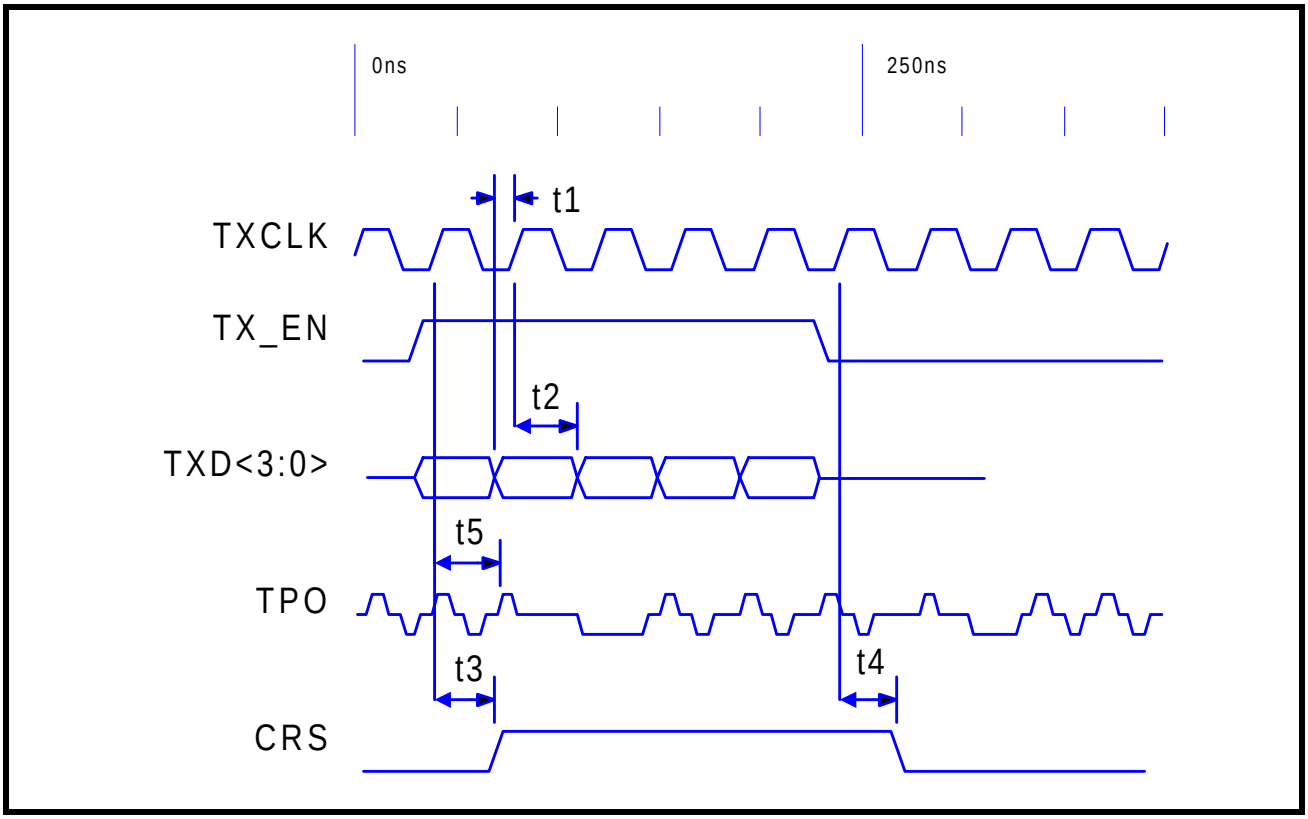


Table 26: 100BASE-TX Transmit Timing Parameters - 4B Mode

Parameter	Sym	Min	Typ[1]	Max	Units[2]	Test Conditions
TXD<3:0>, TX_EN, TX_ER setup to TX_CLK High	t1	12	–	–	ns	–
TXD<3:0>, TX_EN, TX_ER hold from TX_CLK High	t2	0	–	–	ns	–
TX_EN sampled to CRS asserted	t3	20	–	24	BT	–
TX_EN sampled to CRS de-asserted	t4	24	–	28	BT	–
TX_EN sampled to TPO out (Tx latency)	t5	5.3	–	5.7	BT	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. BT is the duration of one bit as transferred to and from the MAC and is the reciprocal of the bit rate. 100BASE-T bit time = 10^{-8} s or 10 ns.

Figure 25: 10BASE-T Receive Timing

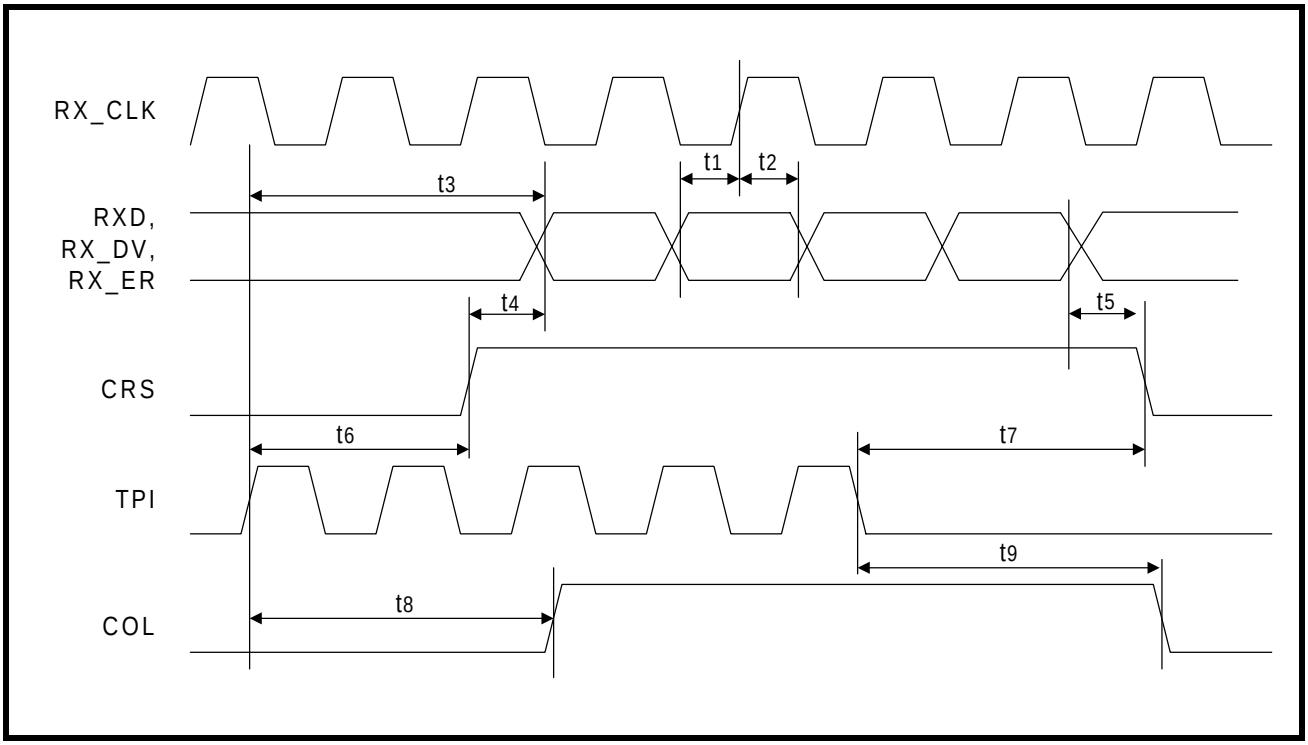


Table 27: 10BASE-T Receive Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units[2]	Test Conditions
RXD, RX_DV, RX_ER Setup to RX_CLK High	t1	10	–	–	ns	–
RXD, RX_DV, RX_ER Hold from RX_CLK High	t2	10	–	–	ns	–
TPIP/N in to RXD out (Rx latency)	t3	5.8	–	6.0	BT	–
CRS asserted to RXD, RX_DV, RX_ER asserted	t4	5	–	32	BT	–
RXD, RX_DV, RX_ER de-asserted to CRS de-asserted	t5	0.3	–	0.5	BT	–
TPI in to CRS asserted	t6	2	–	28	BT	–
TPI quiet to CRS de-asserted	t7	6	–	10	BT	–
TPI in to COL asserted	t8	1	–	31	BT	–
TPI quiet to COL de-asserted	t9	5	–	10	BT	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. BT is the duration of one bit as transferred to and from the MAC and is the reciprocal of the bit rate. 10BASE-T bit time = 10^{-7} s or 100 ns.

Figure 26: 10BASE-T Transmit Timing

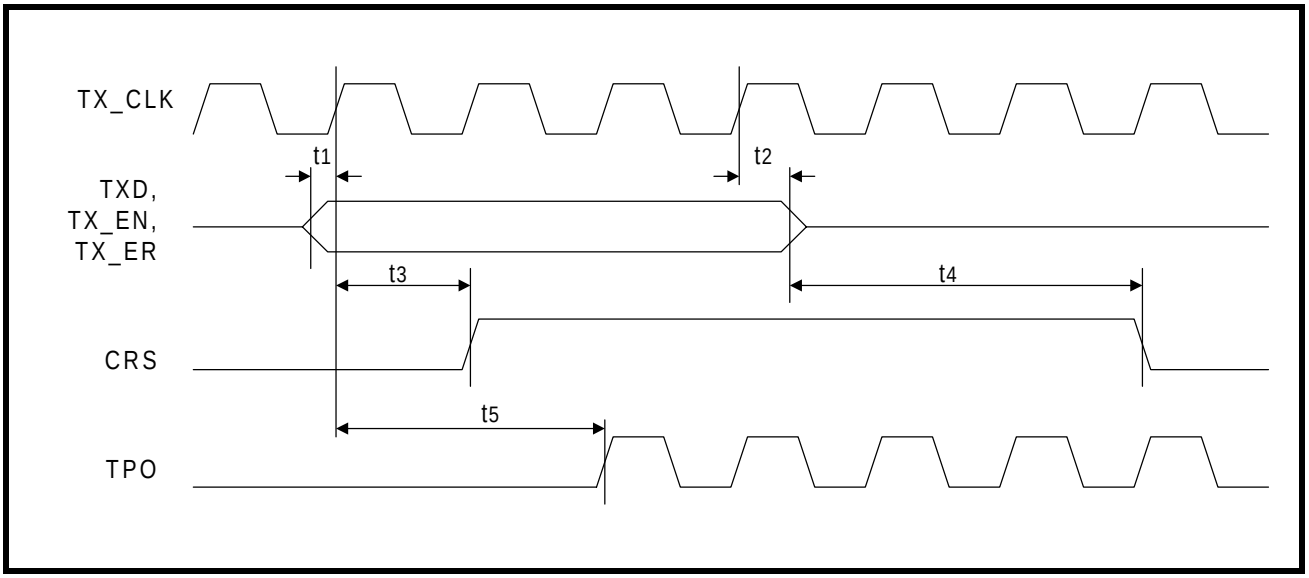


Table 28: 10BASE-T Transmit Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units[2]	Test Conditions
TXD, TX_EN, TX_ER setup to TX_CLK High	t1	10	–	–	ns	–
TXD, TX_EN, TX_ER hold from TX_CLK High	t2	0	–	–	ns	–
TX_EN sampled to CRS asserted	t3	–	2	–	BT	–
TX_EN sampled to CRS de-asserted	t4	–	1	–	BT	–
TX_EN sampled to TPO out (Tx latency)	t5	–	72.5	–	BT	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.
2. BT is the duration of one bit as transferred to and from the MAC and is the reciprocal of the bit rate. 10BASE-T bit time = 10^{-7} s or 100 ns.

Figure 27: 10BASE-T Jabber and Unjabber Timing

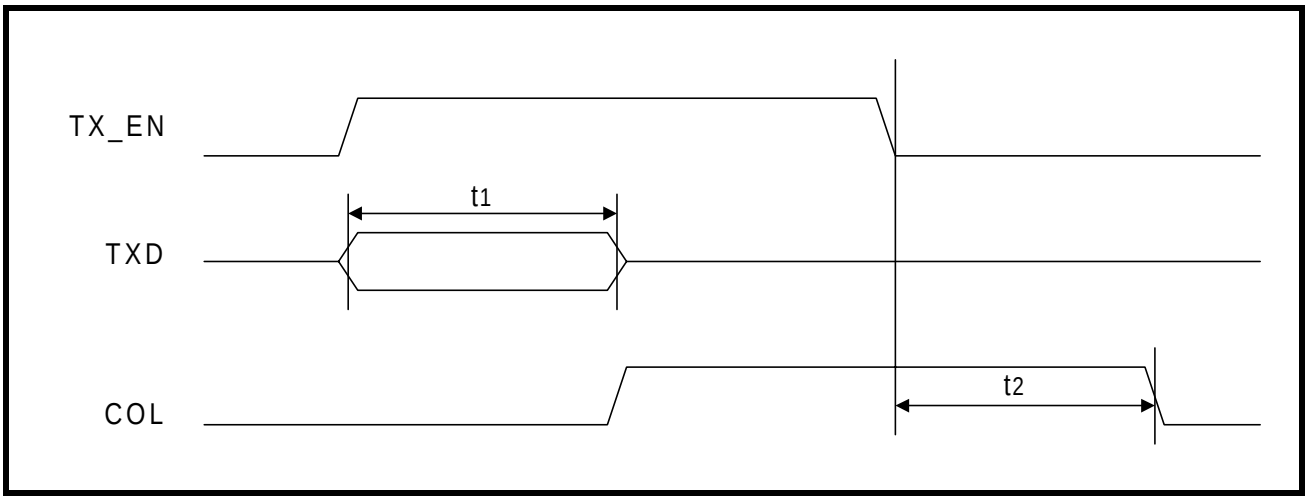


Table 29: 10BASE-T Jabber and Unjabber Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Maximum transmit time	t1	20	–	150	ms	–
Unjab time	t2	250	–	750	ms	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.

Figure 28: 10BASE-T SQE (Heartbeat) Timing

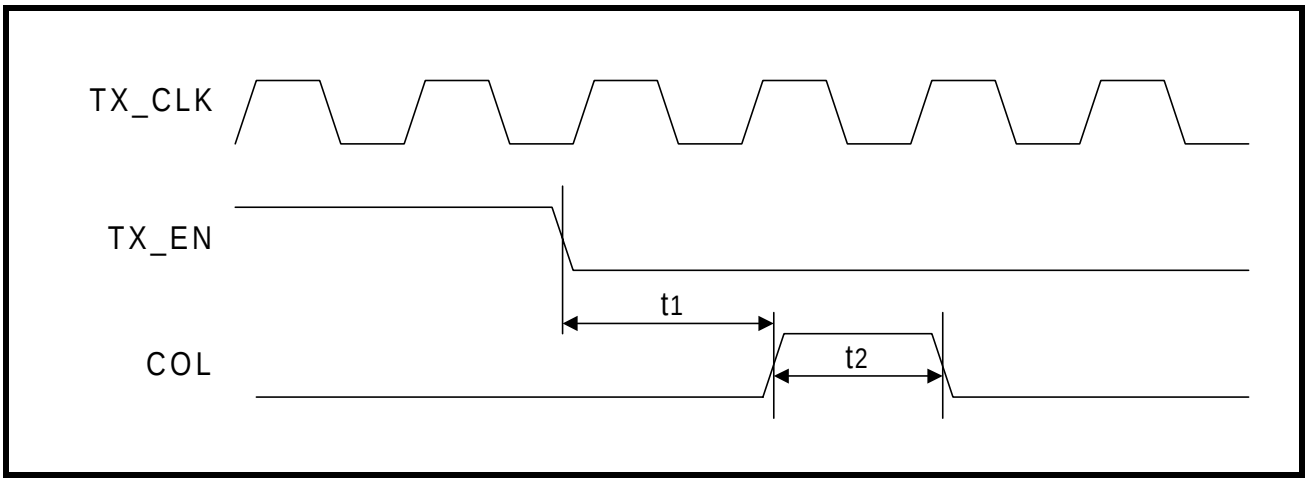


Table 30: 10BASE-T SQE Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
COL (SQE) Delay after TX_EN off	t1	0.65	–	1.6	us	–
COL (SQE) Pulse duration	t2	0.5	–	1.5	us	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.

Figure 29: Auto Negotiation and Fast Link Pulse Timing

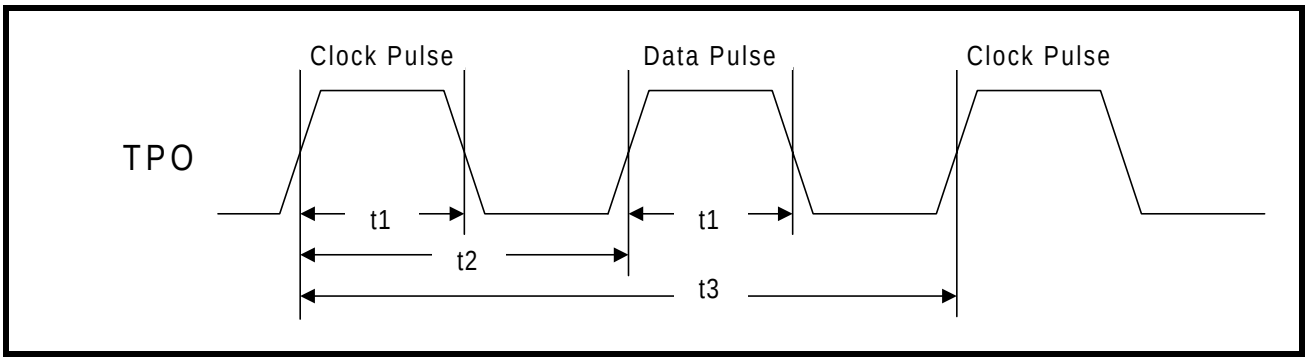


Figure 30: Fast Link Pulse Timing

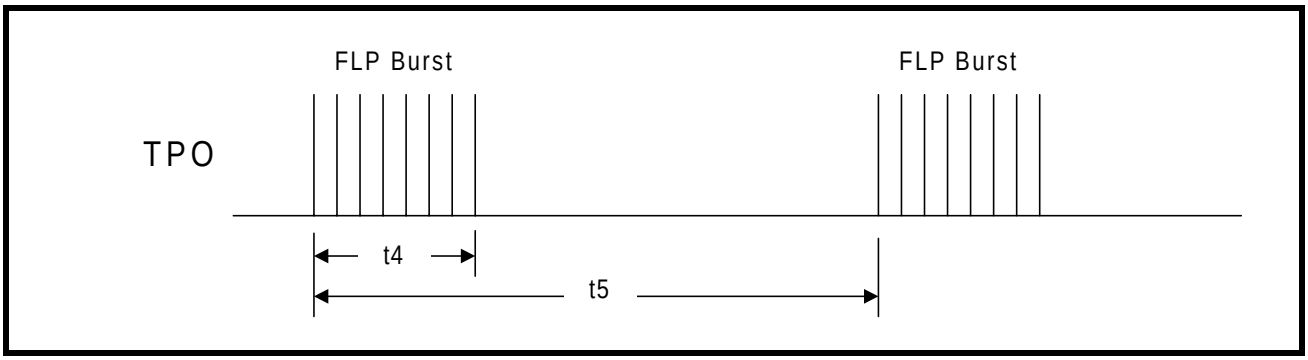


Table 31: Auto Negotiation and Fast Link Pulse Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Clock/Data pulse width	t1	–	100	–	ns	–
Clock pulse to Data pulse	t2	55.5	–	63.8	µs	–
Clock pulse to Clock pulse	t3	123	–	127	µs	–
FLP burst width	t4	–	2	–	ms	–
FLP burst to FLP burst	t5	8	12	24	ms	–
Clock/Data pulses per burst	–	17	–	33	ea	–

1. Typical values are at 25 °C and are for design aid only; not guaranteed and not subject to production testing.

Figure 31: MDIO Input Timing

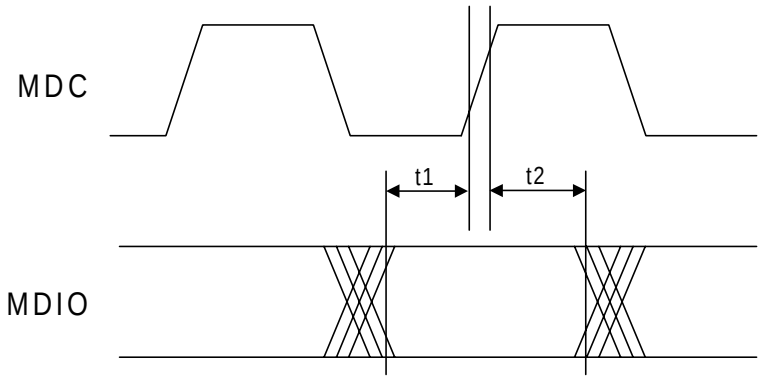


Figure 32: MDIO Output Timing

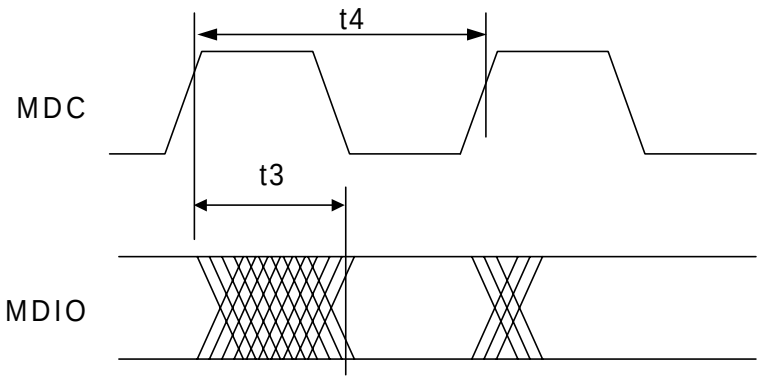


Table 32: MDIO Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
MDIO setup before MDC, sourced by STA	t1	10	–	–	ns	–
MDIO hold after MDC, sourced by STA	t2	5	–	–	ns	–
MDC to MDIO output delay, source by PHY	t3	–	–	150	ns	–
MDC period	t4	125	–	–	ns	MDC = 8 MHz

1. Typical values are at 25° C and are for design aid only; not guaranteed and not subject to production testing.

Figure 33: Power-Up Timing

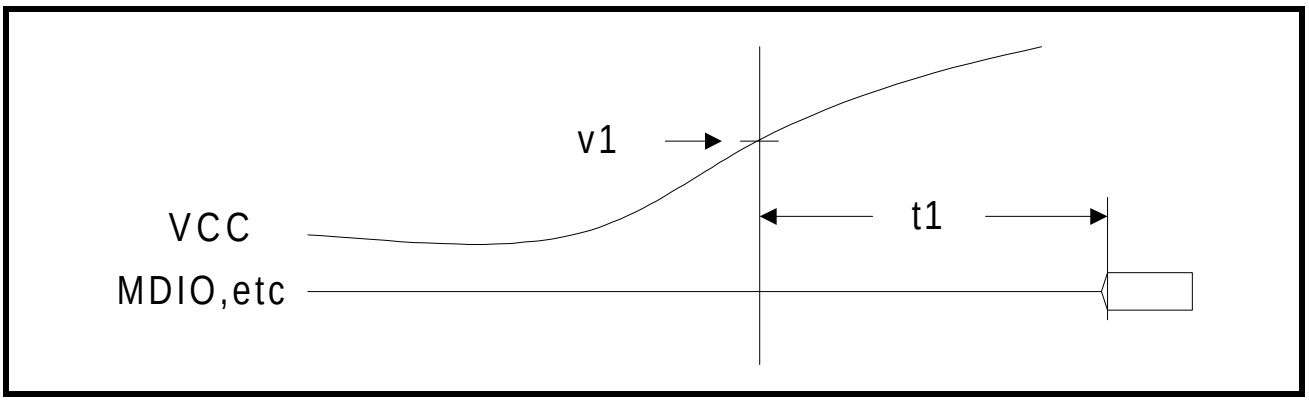


Table 33: Power-Up Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Voltage threshold	v1	–	2.9	–	V	–
Power Up delay[2]	t1	–	–	300	µs	–

1. Typical values are at 25° C and are for design aid only; not guaranteed and not subject to production testing.
2. Power Up Delay is specified as a maximum value because it refers to the PHY's guaranteed performance - the PHY will come out of reset after a delay of No MORE Than 300 µs. System designers should consider this as a minimum value - After threshold v1 is reached, the MAC should delay No LESS Than 300 µs before accessing the MDIO port.

Figure 34: $\overline{\text{RESET}}$ Pulse Width and Recovery Timing

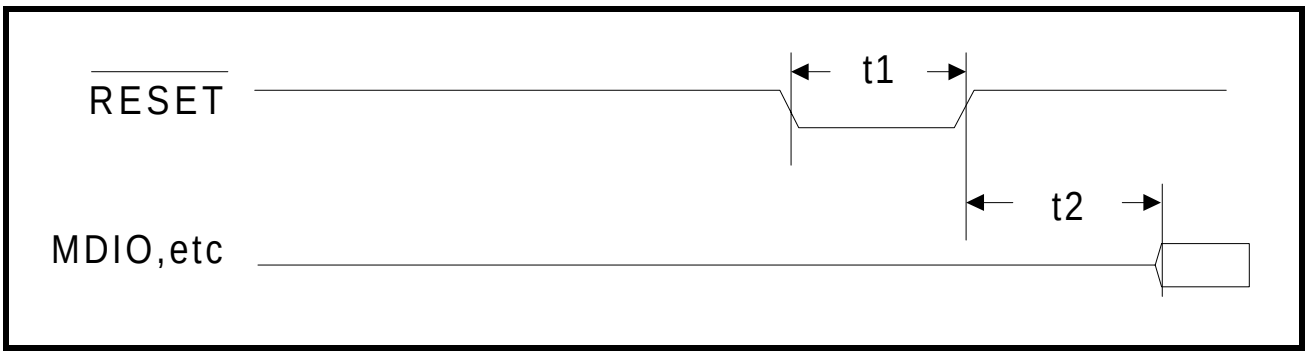


Table 34: $\overline{\text{RESET}}$ Pulse Width and Recovery Timing Parameters

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
$\overline{\text{RESET}}$ pulse width	t1	10	–	–	ns	–
$\overline{\text{RESET}}$ recovery delay[2]	t2	–	–	300	µs	–

1. Typical values are at 25° C and are for design aid only; not guaranteed and not subject to production testing.
2. Reset Recovery Delay is specified as a maximum value because it refers to the PHY's guaranteed performance - the PHY will come out of reset after a delay of No MORE Than 300 µs. System designers should consider this as a minimum value - After de-asserting RESET*, the MAC should delay No LESS Than 300 µs before accessing the MDIO port.

REGISTER DEFINITIONS

The LXT972 register set includes multiple 16-bit registers. Refer to Table 35 for a complete register listing.

- Base registers (0 through 8) are defined in accordance with the "Reconciliation Sublayer and Media Independent Interface" and "Physical Layer Link Signaling for 10/100 Mbps Auto-Negotiation" sections of the IEEE 802.3 standard.
- Additional registers are defined in accordance with the IEEE 802.3 standard for adding unique chip functions.

Table 35: Register Set

Address	Register Name	Bit Assignments
0	Control Register	Refer to Table 37 on page 51
1	Status Register #1	Refer to Table 38 on page 52
2	PHY Identification Register 1	Refer to Table 39 on page 53
3	PHY Identification Register 2	Refer to Table 40 on page 53
4	Auto-Negotiation Advertisement Register	Refer to Table 41 on page 54
5	Auto-Negotiation Link Partner Base Page Ability Register	Refer to Table 42 on page 55
6	Auto-Negotiation Expansion Register	Refer to Table 43 on page 56
7	Auto-Negotiation Next Page Transmit Register	Refer to Table 44 on page 57
8	Auto-Negotiation Link Partner Received Next Page Register	Refer to Table 45 on page 57
9	1000BASE-T/100BASE-T2 Control Register	Not Implemented
10	1000BASE-T/100BASE-T2 Status Register	Not Implemented
15	Extended Status Register	Not Implemented
16	Port Configuration Register	Refer to Table 46 on page 58
17	Status Register #2	Refer to Table 47 on page 59
18	Interrupt Enable Register	Refer to Table 48 on page 60
19	Interrupt Status Register	Refer to Table 49 on page 61
20	LED Configuration Register	Refer to Table 50 on page 62
21- 29	Reserved	
30	Transmit Control Register	Refer to Table 51 on page 64

Table 36: Register Bit Map

Reg Title	Bit Fields																Addr
	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0	
Control Register																	
Control	Reset	Loopback	Speed Select	A/N Enable	Power Down	Isolate	Re-start A/N	Duplex Mode	COL Test	Speed Select	Reserved						**0**
Status Register																	
Status	100Base-T4	100Base-X Full Duplex	100Base-X Half Duplex	10Mbps Full Duplex	10Mbps Half Duplex	100Base-T2 Full Duplex	100Base-T2 Half Duplex	Extended Status	Reserved	MF Preamble Suppress	A/N Complete	Remote Fault	A/N Ability	Link Status	Jabber Detect	Extended Capability	**1**
PHY ID Registers																	
PHY ID 1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	**2**
PHY ID2	PHY ID No						MFR Model No						MFR Rev No				**3**
Auto-Negotiation Advertisement Register																	
A/N Advertise	Next Page	Reserved	Remote Fault	Reserved	Asymm Pause	Pause	100Base-T4	100Base-TX Full Duplex	100Base-TX	10Base-T Full Duplex	10Base-T	IEEE Selector Field					**4**
Auto-Negotiation Link Partner Base Page Ability Register																	
A/N Link Ability	Next Page	Ack	Remote Fault	Reserved	Asymm Pause	Pause	100Base-T4	100Base-TX Full Duplex	100Base-TX	10Base-T Full Duplex	10Base-T	IEEE Selector Field					**5**
Auto-Negotiation Expansion Register																	
A/N Expansion	Reserved										Base Page	Parallel Detect Fault	Link Partner Next Page Able	Next Page Able	Page Received	Link Partner A/N Able	**6**
Auto-Negotiation Next Page Transmit Register																	
A/N Next Page Txmit	Next Page	Reserved	Message Page	Ack 2	Toggle	Message / Unformatted Code Field											**7**
Auto-Negotiation Link Partner Next Page Receive Register																	
A/N Link Next Page	Next Page	Ack	Message Page	Ack 2	Toggle	Message / Unformatted Code Field											**8**
Configuration Register																	
Port Config	Reserved	Force Link Pass	Txmit Disable	Bypass Scrambler (100TX)	Reserved)	Jabber (10T)	SQE (10T)	TP Loopback (10T)	CRS Select (10T)	Reserved	PRE_EN	Reserved		Reserved	Alternate Next Page	Reserved	**16**

Table 36: Register Bit Map – continued

Reg Title	Bit Fields																Addr
	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0	
Status Register #2																	
Status Register #2	Reserved	10/100 Mode	Transmit Status	Receive Status	Collision Status	Link	Duplex Mode	Auto-Neg	Auto-Neg Complete	Reserved	Polarity	Pause	Error	Reserved	Reserved		**17**
Interrupt Enable Register																	
Interrupt Enable	Reserved							Reserved	Auto-Neg Mask	Speed Mask	Duplex Mask	Link Mask	Reserved	Reserved	Interrupt Enable	Test Interrupt	**18**
Interrupt Status Register																	
Interrupt Status	Reserved							Reserved	Auto-Neg Done	Speed Change	Duplex Change	Link Change	Reserved	MD Interrupt	Reserved	Reserved	**19**
LED Configuration Register																	
LED Config	LED1				LED2				LED3				LED Freq		Pulse Stretch	Reserved	**20**
Transmit Control Register																	
Trans. Control	Reserved			Transmit Low Pwr	Port Rise Time Control		Reserved										**30**

Table 37: Control Register (Address 0)

Bit	Name	Description			Type [1]	Default
0.15	Reset	1 = PHY reset 0 = Normal operation			R/W SC	0
0.14	Loopback	1 = Enable loopback mode 0 = Disable loopback mode			R/W	0
0.13	Speed Selection	**0.6**	**0.13**	**Speed Selected**	R/W	Note 2
		1	1	Reserved		
		1	0	1000 Mbps (not supported)		
		0	1	100 Mbps		
		0	0	10 Mbps		
0.12	Auto-Negotiation Enable	1 = Enable Auto-Negotiation Process 0 = Disable Auto-Negotiation Process			R/W	Note 2
0.11	Power-Down	1 = Power-down 0 = Normal operation			R/W	0
0.10	Isolate	1 = Electrically isolate PHY from MII 0 = Normal operation			R/W	0
0.9	Restart Auto-Negotiation	1 = Restart Auto-Negotiation Process 0 = Normal operation			R/W SC	0
0.8	Duplex Mode	1 = Full Duplex 0 = Half Duplex			R/W	Note 2
0.7	Collision Test	1 = Enable COL signal test 0 = Disable COL signal test			R/W	0
0.6	Speed Selection	**0.6**	**0.13**	**Speed Selected**	R/W	0
		1	1	Reserved		
		1	0	1000 Mbps (not supported)		
		0	1	100 Mbps		
		0	0	10 Mbps		
0.5:0	Reserved	Write as 0, ignore on Read			R/W	00000

1. R/W = Read/Write
   RO = Read Only
   SC = Self Clearing
2. Default value of bits 0.12, 0.13 and 0.8 are determined by the LED/CFG pins (refer to Table 8 on page 16).

Table 38: MII Status Register #1 (Address 1)

Bit	Name	Description	Type [1]	Default
1.15	100BASE-T4 ***Not Supported***	1 = PHY able to perform 100BASE-T4 0 = PHY not able to perform 100BASE-T4	RO	0
1.14	100BASE-X Full-Duplex	1 = PHY able to perform full-duplex 100BASE-X 0 = PHY not able to perform full-duplex 100BASE-X	RO	1
1.13	100BASE-X Half-Duplex	1 = PHY able to perform half-duplex 100BASE-X 0 = PHY not able to perform half-duplex 100BASE-X	RO	1
1.12	10 Mbps Full-Duplex	1 = PHY able to operate at 10 Mbps in full-duplex mode 0 = PHY not able to operate at 10 Mbps full-duplex mode	RO	1
1.11	10 Mbps Half-Duplex	1 = PHY able to operate at 10 Mbps in half-duplex mode 0 = PHY not able to operate at 10 Mbps in half-duplex	RO	1
1.10	100BASE-T2 Full-Duplex ***Not Supported***	1 = PHY able to perform full-duplex 100BASE-T2 0 = PHY not able to perform full-duplex 100BASE-T2	RO	0
1.9	100BASE-T2 Half-Duplex ***Not Supported***	1 = PHY able to perform half duplex 100BASE-T2 0 = PHY not able to perform half-duplex 100BASE-T2	RO	0
1.8	Extended Status	1 = Extended status information in register 15 0 = No extended status information in register 15	RO	0
1.7	Reserved	1 = ignore when read	RO	0
1.6	MF Preamble Suppression	1 = PHY will accept management frames with preamble suppressed 0 = PHY will not accept management frames with preamble suppressed	RO	0
1.5	Auto-Negotiation Complete	1 = Auto-negotiation complete 0 = Auto-negotiation not complete	RO	0
1.4	Remote Fault	1 = Remote fault condition detected 0 = No remote fault condition detected	RO/LH	0
1.3	Auto-Negotiation Ability	1 = PHY is able to perform Auto-Negotiation 0 = PHY is not able to perform Auto-Negotiation	RO	1
1.2	Link Status	1 = Link is up 0 = Link is down	RO/LL	0
1.1	Jabber Detect	1 = Jabber condition detected 0 = Jabber condition not detected	RO/LH	0
1.0	Extended Capability	1 = Extended register capabilities 0 = Basic register capabilities	RO	1

1. RO = Read Only
   LL = Latching Low
   LH = Latching High

Table 39: PHY Identification Register 1 (Address 2)

Bit	Name	Description	Type [1]	Default
2.15:0	PHY ID Number	The PHY identifier composed of bits 3 through 18 of the OUI.	RO	0013 hex

1. RO = Read Only

Table 40: PHY Identification Register 2 (Address 3)

Bit	Name	Description	Type [1]	Default
3.15:10	PHY ID number	The PHY identifier composed of bits 19 through 24 of the OUI.	RO	011110
3.9:4	Manufacturer's model number	6 bits containing manufacturer's part number.	RO	001110
3.3:0	Manufacturer's revision number	4 bits containing manufacturer's revision number.	RO	0001

1. RO = Read Only

Figure 35: PHY Identifier Bit Mapping

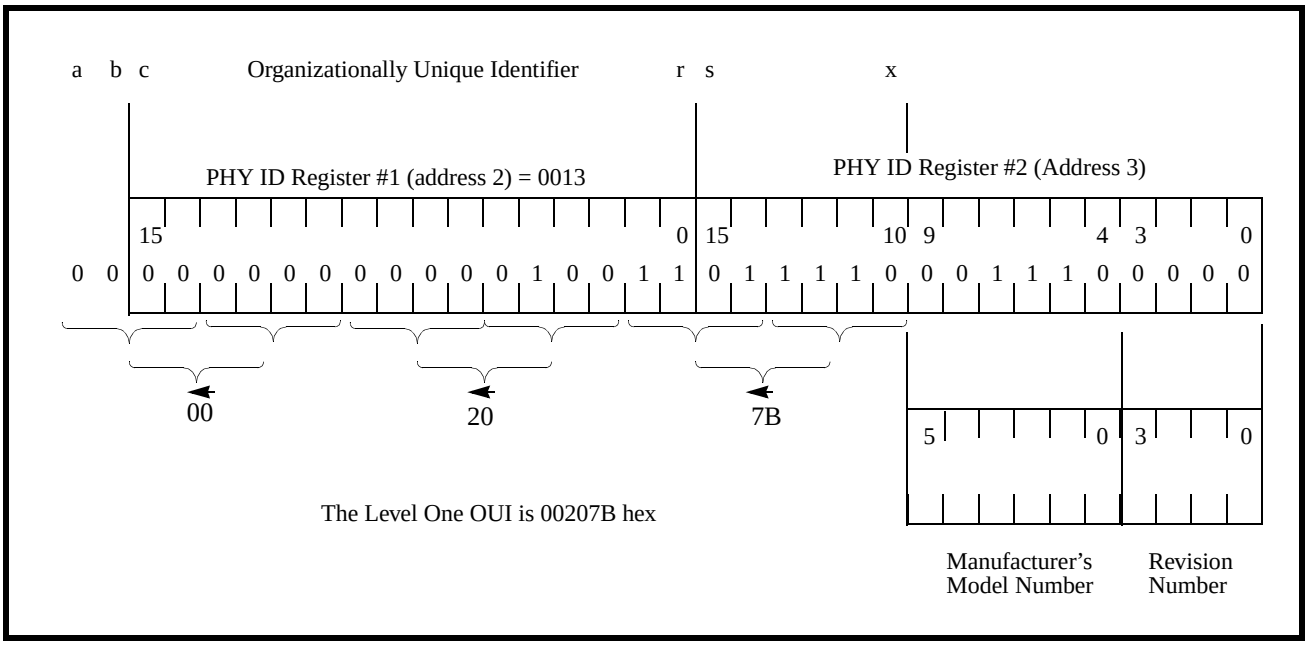


Table 41: Auto Negotiation Advertisement Register (Address 4)

Bit	Name	Description	Type [1]	Default
4.15	Next Page	1 = Port has ability to send multiple pages. 0 = Port has no ability to send multiple pages.	R/W	0
4.14	Reserved	Ignore.	RO	0
4.13	Remote Fault	1 = Remote fault. 0 = No remote fault.	R/W	0
4.12	Reserved	Ignore.	R/W	0
4.11	Asymmetric Pause	Pause operation defined in Clause 40 and 27.	R/W	0
4.10	Pause	1 = Pause operation enabled for full-duplex links. 0 = Pause operation disabled.	R/W	Note 2
4.9	100BASE-T4	1 = 100BASE-T4 capability is available. 0 = 100BASE-T4 capability is not available. (The LXT972 does not support 100BASE-T4 but allows this bit to be set to advertise in the Auto-Negotiation sequence for 100BASE-T4 operation. An external 100BASE-T4 transceiver could be switched in if this capability is desired.)	R/W	0
4.8	100BASE-TX full-duplex	1 = Port is 100BASE-TX full-duplex capable. 0 = Port is not 100BASE-TX full-duplex capable.	R/W	Note 3
4.7	100BASE-TX	1 = Port is 100BASE-TX capable. 0 = Port is not 100BASE-TX capable.	R/W	Note 3
4.6	10BASE-T full-duplex	1 = Port is 10BASE-T full-duplex capable. 0 = Port is not 10BASE-T full-duplex capable.	R/W	Note 3
4.5	10BASE-T	1 = Port is 10BASE-T capable. 0 = Port is not 10BASE-T capable.	R/W	Note 3
4.4:0	Selector Field, S<4:0>	<00001> = IEEE 802.3. <00010> = IEEE 802.9 ISLAN-16T. <00000> = Reserved for future Auto-Negotiation development. <11111> = Reserved for future Auto-Negotiation development. Unspecified or reserved combinations should not be transmitted.	R/W	00001

1. R/W = Read/Write
   RO = Read Only
2. Default value of bit 4.10 is determined by pin 33/H8.
3. Default values of bits 4.5, 4.6, 4.7, and 4.8 are determined by LED/CFG*n* pins at reset. Refer to Table 8 for details.

Table 42: Auto Negotiation Link Partner Base Page Ability Register (Address 5)

Bit	Name	Description	Type [1]	Default
5.15	Next Page	1 = Link Partner has ability to send multiple pages. 0 = Link Partner has no ability to send multiple pages.	RO	N/A
5.14	Acknowledge	1 = Link Partner has received Link Code Word from LXT972. 0 = Link Partner has not received Link Code Word from the LXT972.	RO	N/A
5.13	Remote Fault	1 = Remote fault. 0 = No remote fault.	RO	N/A
5.12	Reserved	Ignore.	RO	N/A
5.11	Asymmetric Pause	Pause operation defined in Clause 40 and 27. 1 = Link Partner is Pause capable. 0 = Link Partner is not Pause capable.	RO	N/A
5.10	Pause	1 = Link Partner is Pause capable. 0 = Link Partner is not Pause capable.	RO	N/A
5.9	100BASE-T4	1 = Link Partner is 100BASE-T4 capable. 0 = Link Partner is not 100BASE-T4 capable.	RO	N/A
5.8	100BASE-TX full-duplex	1 = Link Partner is 100BASE-TX full-duplex capable. 0 = Link Partner is not 100BASE-TX full-duplex capable.	RO	N/A
5.7	100BASE-TX	1 = Link Partner is 100BASE-TX capable. 0 = Link Partner is not 100BASE-TX capable.	RO	N/A
5.6	10BASE-T full-duplex	1 = Link Partner is 10BASE-T full-duplex capable. 0 = Link Partner is not 10BASE-T full-duplex capable.	RO	N/A
5.5	10BASE-T	1 = Link Partner is 10BASE-T capable. 0 = Link Partner is not 10BASE-T capable.	RO	N/A
5.4:0	Selector Field S<4:0>	<00001> = IEEE 802.3. <00010> = IEEE 802.9 ISLAN-16T. <00000> = Reserved for future Auto-Negotiation development. <11111> = Reserved for future Auto-Negotiation development. Unspecified or reserved combinations shall not be transmitted.	RO	N/A

1. RO = Read Only

Table 43: Auto Negotiation Expansion (Address 6)

Bit	Name	Description	Type [1]	Default
6.15:6	Reserved	Ignore on read.	RO	0
6.5	Base Page	This bit indicates the status of the Auto-Negotiation variable, base page. It flags synchronization with the Auto-Negotiation state diagram allowing detection of interrupted links. This bit is only used if bit 16.1 (Alternate NP feature) is set. 1 = basepage = true 0 = basepage = false	RO/ LH	0
6.4	Parallel Detection Fault	1 = Parallel detection fault has occurred. 0 = Parallel detection fault has not occurred.	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	1
6.1	Page Received	1 = Indicates that a new page has been received and the received code word has been loaded into register 5 (base pages) or register 8 (next pages) as specified in clause 28 of 802.3. This bit will be cleared on read. If bit 16.1 is set, the Page Received bit will also be cleared when mr_page_rx = false or transmit_disable = true.	RO LH	0
6.0	Link Partner A/N Able	1 = Link partner is auto-negotiation able. 0 = Link partner is not auto-negotiation able.	RO	0

1. RO = Read Only LH = Latching High

Table 44: Auto Negotiation Next Page Transmit Register (Address 7)

Bit	Name	Description	Type [1]	Default
7.15	Next Page (NP)	1 = Additional next pages follow 0 = Last page	R/W	0
7.14	Reserved	Write as 0, ignore on read	RO	0
7.13	Message Page (MP)	1 = Message page 0 = Unformatted page	R/W	1
7.12	Acknowledge 2 (ACK2)	1 = Will comply with message 0 = Can not comply with message	R/W	0
7.11	Toggle (T)	1 = Previous value of the transmitted Link Code Word equalled logic zero 0 = Previous value of the transmitted Link Code Word equalled logic one	R/W	0
7.10:0	Message/Unformatted Code Field		R/W	00000000001

1. RO = Read Only. R/W = Read/Write

Table 45: Auto Negotiation Link Partner Next Page Receive Register (Address 8)

Bit	Name	Description	Type [1]	Default
8.15	Next Page (NP)	1 = Link Partner has additional next pages to send 0 = Link Partner has no additional next pages to send	RO	0
8.14	Acknowledge (ACK)	1 = Link Partner has received Link Code Word from LXT972 0 = Link Partner has not received Link Code Word from LXT972	RO	0
8.13	Message Page (MP)	1 = Page sent by the Link Partner is a Message Page 0 = Page sent by the Link Partner is an Unformatted Page	RO	0
8.12	Acknowledge 2 (ACK2)	1 = Link Partner complies with the message 0 = Link Partner can not comply with the message	RO	0
8.11	Toggle (T)	1 = Previous value of the transmitted Link Code Word equalled logic zero 0 = Previous value of the transmitted Link Code Word equalled logic one	RO	0
8.10:0	Message/Unformatted Code Field	User definable	RO	0

1. RO = Read Only.

Table 46: Configuration Register (Address 16, Hex 10)

Bit	Name	Description	Type [1]	Default
16.15	Reserved	Write as zero, ignore on read.	R/W	0
16.14	Force Link Pass	1 = Force Link pass 0 = Normal operation	R/W	0
16.13	Transmit Disable	1 = Disable Twisted Pair transmitter 0 = Normal Operation	R/W	0
16.12	Bypass Scrambler (100BASE-TX)	1 = Bypass Scrambler and Descrambler 0 = Normal Operation	R/W	0
16.11	Reserved	Ignore	R/W	0
16.10	Jabber (10BASE-T)	1 = Disable Jabber Correction 0 = Normal operation	R/W	0
16.9	SQE (10BASE-T)	1 = Enable Heart Beat 0 = Disable Heart Beat	R/W	0
16.8	TP Loopback (10BASE-T)	1 = Disable TP loopback during half-duplex operation 0 = Normal Operation	R/W	0
16.7	CRS Select (10BASE-T)	1 = CRS deassert extends to RX_DV deassert 0 = Normal Operation	R/W	1
16.6	Reserved	Write as zero, ignore on read.	R/W	0
16.5	PRE_EN	Preamble Enable. 0 = Set RX_DV high coincident with SFD. 1 = Set RX_DV high and RXD = preamble when CRS is asserted.	R/W	0
16.4:3	Reserved	Write as zero, ignore on read.	R/W	00
16.2	Reserved	Write as zero, ignore on read.	R/W	0
16.1	Alternate NP feature	1 = Enable alternate auto negotiate next page feature. 0 = Disable alternate auto negotiate next page feature	R/W	0
16.0	Reserved	Write as zero, ignore on read.	R/W	0

1. R/W = Read /Write, LHR = Latches High on Reset

Table 47: Status Register #2 (Address 17)

Bit	Name	Description	Type [1]	Default
17.15	Reserved	Always 0.	RO	0
17.14	10/100 Mode	1 = LXT972 is operating in 100BASE-TX mode. 0 = LXT972 is not operating 100BASE-TX mode.	RO	0
17.13	Transmit Status	1 = LXT972 is transmitting a packet. 0 = LXT972 is not transmitting a packet.	RO	0
17.12	Receive Status	1 = LXT972 is receiving a packet. 0 = LXT972 is not receiving a packet.	RO	0
17.11	Collision Status	1 = Collision is occurring. 0 = No collision.	RO	0
17.10	Link	1 = Link is up. 0 = Link is down.	RO	0
17.9	Duplex Mode	1 = Full-duplex. 0 = Half-duplex.	RO	0
17.8	Auto-Negotiation	1 = LXT972 is in Auto-Negotiation Mode. 0 = LXT972 is in manual mode.	RO	0
17.7	Auto-Negotiation Complete	1 = Auto-negotiation process completed. 0 = Auto-negotiation process not completed. This bit is only valid when auto negotiate is enabled, and is equivalent to bit 1.5.	RO	0
17.6	Reserved	Reserved.	RO	0
17.5	Polarity	1 = Polarity is reversed. 0 = Polarity is not reversed.	RO	0
17.4	Pause	1 = Device Pause capable. 0 = Device Not Pause capable.	RO	0
17:3	Error	1 = Error Occurred (Remote Fault, X,Y,Z). 0 = No error occurred.	RO	0
17:2	Reserved	Always 0.	RO	0
17:1	Reserved	Always 0.	RO	0
17.0	Reserved	Always 0.	RO	0

1. RO = Read Only. R/W = Read/Write

Table 48: Interrupt Enable Register (Address 18)

Bit	Name	Description	Type [1]	Default
18.15:9	Reserved	Write as 0; ignore on read.	R/W	N/A
18.8	Reserved	Write as 0; ignore on read.	R/W	0
18.7	ANMSK	Mask for Auto Negotiate Complete 1 = Enable event to cause interrupt. 0 = Do not allow event to cause interrupt.	R/W	0
18.6	SPEEDMSK	Mask for Speed Interrupt 1 = Enable event to cause interrupt. 0 = Do not allow event to cause interrupt.	R/W	0
18.5	DUPLEXMSK	Mask for Duplex Interrupt 1 = Enable event to cause interrupt. 0 = Do not allow event to cause interrupt.	R/W	0
18.4	LINKMSK	Mask for Link Status Interrupt 1 = Enable event to cause interrupt. 0 = Do not allow event to cause interrupt.	R/W	0
18.3	Reserved	Write as 0, ignore on read.	R/W	0
18.2	Reserved	Write as 0, ignore on read.	R/W	0
18.1	INTEN	1 = Enable interrupts. 0 = Disable interrupts.	R/W	0
18.0	TINT	1 = Force interrupt on $\overline{\text{MDINT}}$. 0 = Normal operation.	R/W	0

1. R/W = Read /Write

Table 49: Interrupt Status Register (Address 19, Hex 13)

Bit	Name	Description	Type [1]	Default
19.15:9	Reserved	Ignore	RO	N/A
19.8	Reserved	Ignore	RO	0
19.7	ANDONE	Auto Negotiation Status 1 = Auto Negotiation has completed. 0 = Auto Negotiation has not completed.	RO/SC	N/A
19.6	SPEEDCHG	Speed Change Status 1 = A Speed Change has occurred since last reading this register. 0 = A Speed Change has not occurred since last reading this register.	RO/SC	0
19.5	DUPLEXCHG	Duplex Change Status 1 = A Duplex Change has occurred since last reading this register. 0 = A Duplex Change has not occurred since last reading this register.	RO/SC	0
19.4	LINKCHG	Link Status Change Status 1 = A Link Change has occurred since last reading this register. 0 = A Link Change has not occurred since last reading this register.	RO/SC	0
19.3	Reserved	Ignore	RO	0
19.2	MDINT	1 = MII interrupt pending. 0 = No MII interrupt pending.	RO	
19.1	Reserved	Ignore.	RO	N/A
19.0	Reserved	Ignore	RO	0

1. R/W = Read/Write, SC = Self Clearing.

Table 50: LED Configuration Register (Address 20, Hex 14)

Bit	Name	Description	Type [1]	Default
20.15:12	LED1 Programming bits	0000 = Display Speed Status (Continuous, Default) 0001 = Display Transmit Status (Stretched) 0010 = Display Receive Status (Stretched) 0011 = Display Collision Status (Stretched) 0100 = Display Link Status (Continuous) 0101 = Display Duplex Status (Continuous) 0110 = Unused 0111 = Display Receive or Transmit Activity (Stretched) 1000 = Test mode- turn LED on (Continuous) 1001 = Test mode- turn LED off (Continuous) 1010 = Test mode- blink LED fast (Continuous) 1011 = Test mode- blink LED slow (Continuous) 1100 = Display Link and Receive Status combined [2] (Stretched)[3] 1101 = Display Link and Activity Status combined [2] (Stretched)[3] 1110 = Display Duplex and Collision Status combined [4] (Stretched)[3] 1111 = Unused	R/W	0000
20.11:8	LED2 Programming bits	0000 = Display Speed Status 0001 = Display Transmit Status 0010 = Display Receive Status 0011 = Display Collision Status 0100 = Display Link Status (Default) 0101 = Display Duplex Status 0110 = Unused 0111 = Display Receive or Transmit Activity 1000 = Test mode- turn LED on 1001 = Test mode- turn LED off 1010 = Test mode- blink LED fast 1011 = Test mode- blink LED slow 1100 = Display Link and Receive Status combined [2] (Stretched)[3] 1101 = Display Link and Activity Status combined [2] (Stretched)[3] 1110 = Display Duplex and Collision Status combined [4] (Stretched)[3] 1111 = Unused	R/W	0100

1. R/W = Read /Write
   RO = Read Only
   LH = Latching High
2. Link status is the primary LED driver. The LED is asserted (solid ON) when the link is up.
   The secondary LED driver (Receive or Activity) causes the LED to change state (blink).
3. Combined event LED settings are not affected by Pulse Stretch bit 20.1. These display settings are stretched regardless of the value of 20.1.
4. Duplex status is the primary LED driver. The LED is asserted (solid ON) when the link is full duplex.
   Collision status is the secondary LED driver. The LED changes state (blinks) when a collision occurs.
5. Values are relative approximations. Not guaranteed or production tested.

Table 50: LED Configuration Register (Address 20, Hex 14) – continued

Bit	Name	Description	Type [1]	Default
20.7:4	LED3 Programming bits	0000 = Display Speed Status 0001 = Display Transmit Status 0010 = Display Receive Status (Default) 0011 = Display Collision Status 0100 = Display Link Status 0101 = Display Duplex Status 0110 = Unused 0111 = Display Receive or Transmit Activity 1000 = Test mode- turn LED on 1001 = Test mode- turn LED off 1010 = Test mode- blink LED fast 1011 = Test mode- blink LED slow 1100 = Display Link and Receive Status combined [2] (Stretched)[3] 1101 = Display Link and Activity Status combined [2] (Stretched)[3] 1110 = Display Duplex and Collision Status combined [4] (Stretched)[3] 1111 = Unused	R/W	0010
20.3:2	LEDFREQ[5]	00 = Stretch LED events to 30 ms. 01 = Stretch LED events to 60 ms. 10 = Stretch LED events to 100 ms. 11 = Reserved.	R/W	00
20.1	PULSE-STRETCH	0 = Disable pulse stretching of all LEDs. 1 = Enable pulse stretching of all LEDs.	R/W	1
20.0	Reserved	Ignore.	R/W	N/A

1. R/W = Read /Write
   RO = Read Only
   LH = Latching High
2. Link status is the primary LED driver. The LED is asserted (solid ON) when the link is up.
   The secondary LED driver (Receive or Activity) causes the LED to change state (blink).
3. Combined event LED settings are not affected by Pulse Stretch bit 20.1. These display settings are stretched regardless of the value of 20.1.
4. Duplex status is the primary LED driver. The LED is asserted (solid ON) when the link is full duplex.
   Collision status is the secondary LED driver. The LED changes state (blinks) when a collision occurs.
5. Values are relative approximations. Not guaranteed or production tested.

Table 51: Transmit Control Register #2 (Address 30)

Bit	Name	Description	Type[2]	Default
30.15:11	Reserved	Ignore	R/W	0
30.12	Transmit Low Power	1 = Forces the transmitter into low power mode. Also forces a zero-differential transmission. 0 = Normal transmission.	R/W	0
30.11:10	Port Rise Time Control[1]	00 = 2.7 ns (default is pins TXSLEW<1:0>) 01 = 3.5 ns 10 = 2.3 ns 11 = 2.0 ns	R/W	N/A
30.9:0	Reserved	Ignore	R/W	0

1. Values are relative approximations. Not guaranteed or production tested.
2. R/W = Read/Write

PACKAGE SPECIFICATION

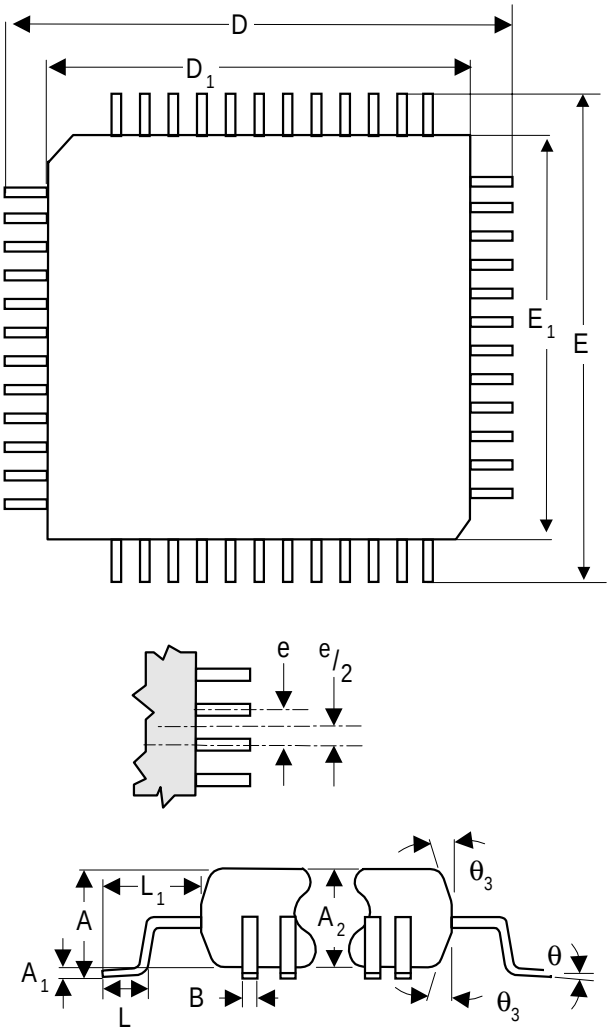
Figure 36: LXT972 LQFP Package Specifications

64-Pin Low Profile Quad Flat Pack

• Part Number - LXT972LC Commercial Temperature Range (0ºC to +70ºC)

Dim	Millimeters	
	Min	Max
A	–	1.60
A_1	0.05	0.15
A_2	1.35	1.45
B	0.17	0.27
D	11.85	12.15
D_1	9.9	10.1
E	11.85	12.15
E1	9.9	10.1
e	0.50 BSC[1]	
L	0.45	0.75
L_1	1.00 REF	
θ_3	11^o	13^o
θ	0^o	7^o

1. Basic Spacing between Centers



REVISION HISTORY

Table 52: Changes from Rev 1.0 to Rev 1.1 (02/00)

Section	Page	Type	Description
Table 2 LXT972 MII Signal Description	6	Modify	Change first sentence under MDDIS to read: “When MDDIS is High, the MDIO is disabled from read and write operations.”
Twisted-Pair Interface	11	Modify	Modify first and third paragraphs for greater clarify.
MDIO Management Interface	12	Add	Add third paragraph regarding MDIO and MDDIS operation in Hardware Control Mode.
Figure 5 Initialization Sequence	14	Modify	Modify figure to reflect change in MDIO operation in the Hardware Control Mode when MDDIS is set High.
Figure 8 10BASE-T Clocking	19	Modify	Remove (Externally Sourced) from figure.
Figure 9 10BASE-X Clocking	19	Modify	Remove (Externally Sourced) from figure.
Figure 21 Typical TP Interface - Switch	20	Modify	Add bypass cap to output transformer center tap.
Figure 22 Typical TP Interface - NIC	21	Modify	Add bypass cap to output transformer center tap.
Table 27 10BASE-T Receive Timing Parameters	42	Modify	Change Min, Typ, and Max values for t3.
Table 28 10BASE-T Transmit Timing Parameters	43	Modify	Change Typ value for t5.

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Revision	Date	Status
1.1	02/00	Technical Update.

IS972DS-R1.1-0200