- **Single-Chip Ethernet™ Adapter for the Peripheral Component Interconnect (PCI) Local Bus**
  - **32-Bit PCI† Glueless Host Interface**
  - **Compliant With PCI Local-Bus Specification (Revision 2.0)**
  - **0-MHz to 33-MHz Operation**
  - **3-V or 5-V Input/Output (I/O) Operation**
  - **Adaptive Performance Optimization™ (APO) by Texas Instruments (TI™) for Highest Available PCI Bandwidth**
  - **High-Performance Bus Master Architecture With Byte-Aligning Direct Memory Access (DMA) Controller for Low Host CPU and Bus Utilization**
  - **Plug-and-Play Compatible**
- **Supports 32-Bit Data Streaming on PCI Bus**
  - **Time Division Multiplexed Static Random-Access Memory (SRAM)**
  - **2-Gbps Internal Bandwidth**
  - **Driver Compatible With All Previous ThunderLAN Components**
- **Switched Ethernet Compatible**
- **Full-Duplex Compatible With Independent Transmit and Receive Channels**
- **No On-Board Memory Required**
- **Auto-Negotiation (N-Way) Compatible**
- **Integrated 10 Base-T and 10 Base-5 Attachment Unit Interface (AUI) Physical Layer Interface**
  - **Single-Chip IEEE 802.3 and Blue Book Ethernet-Compliant Solution**
  - **DSP-Based Digital Phase-Locked Loop (PLL)**
  - **Smart Squelch Allows for Transparent Link Testing**
  - **Transmission Waveshaping**
  - **Autopolarity (Reverse Polarity Correction)**
  - **External/Internal Loopback Including Twisted Pair and AUI**
  - **10 Base-2 Supported Through AUI Interface**
- **Low-Power CMOS Technology**
  - **Green PC Compatible**
  - **Microsoft™ Advanced Power Management**
- **EEPROM Interface Supports Jumperless Design and Autoconfiguration**
- **Hardware Statistics Registers for Management Information Base (MIB)**
- **DMTF (Desktop Management Task Force) Compatible**
- **IEEE Standard 1149.1‡ Test-Access Port**
- **144-Pin Quad Flat Package (PCE Suffix)**

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

† The PCI Local-Bus Specification, Revision 2.0 should be used as a reference with this document.
‡ IEEE Standard 1149.1–1990, IEEE Standard Test-Access Port and Boundary-Scan Architecture
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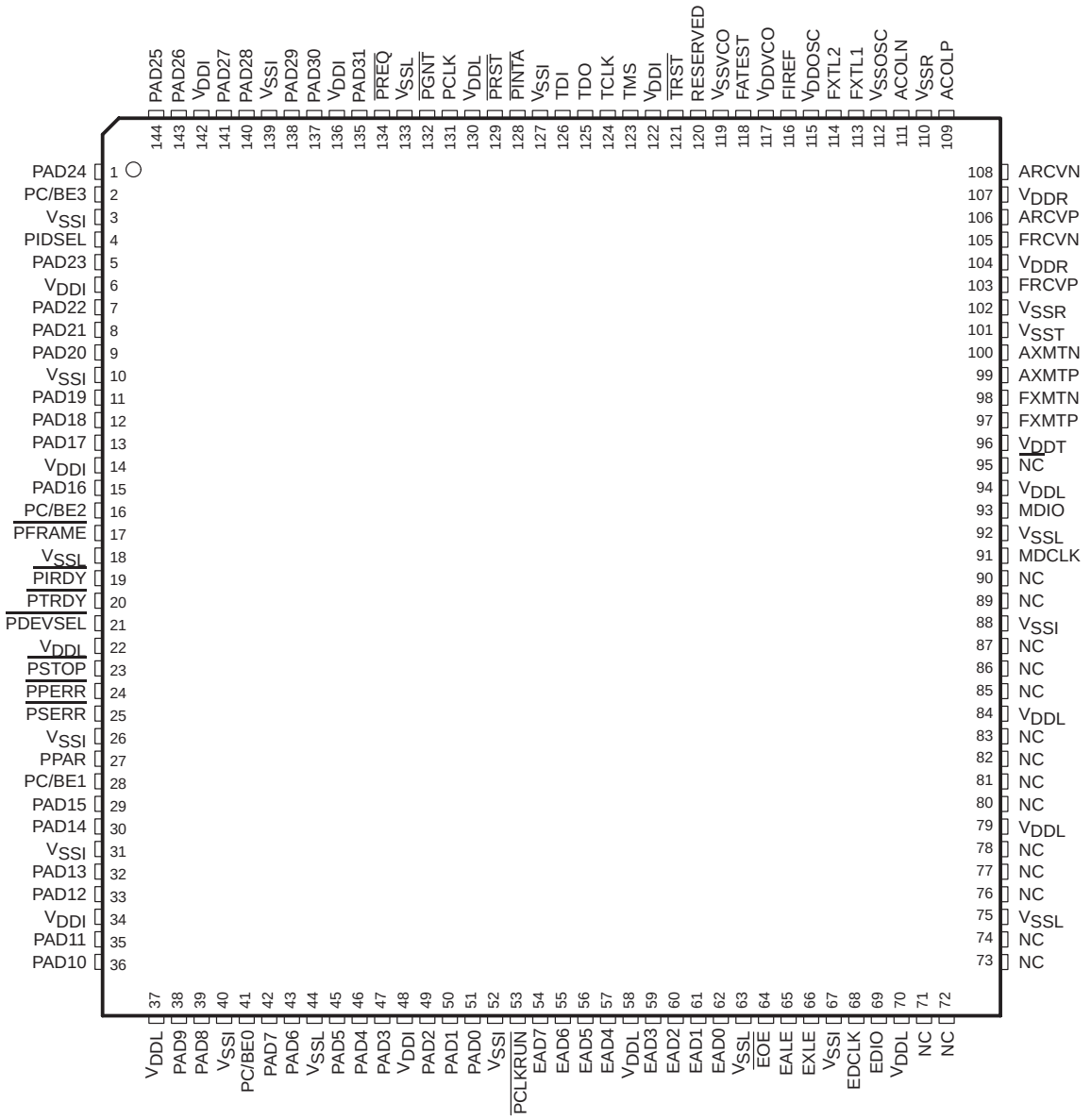
Ethernet is a trademark of Xerox Corporation.
Microsoft is a registered trademark of Microsoft Corp.

pin assignments

PCE PACKAGE†
(TOP VIEW)



† NC = no connection

description

ThunderLAN is a high-speed networking architecture that provides a complete PCI-to-10 Base-T/AUI Ethernet solution. The TNETE110, an implementation of the ThunderLAN architecture, is an intelligent network protocol interface. The ThunderLAN SRAM FIFO-based architecture eliminates the need for external memory and offers a single-chip glueless PCI-to-10 Base-T/AUI (IEEE 802.3) solution with an on-board physical layer interface.

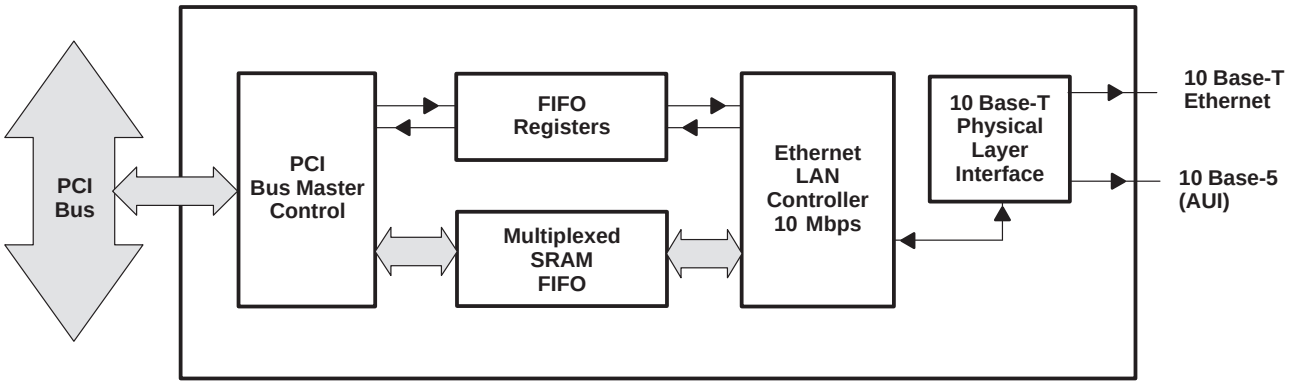


Figure 1. ThunderLAN Architecture

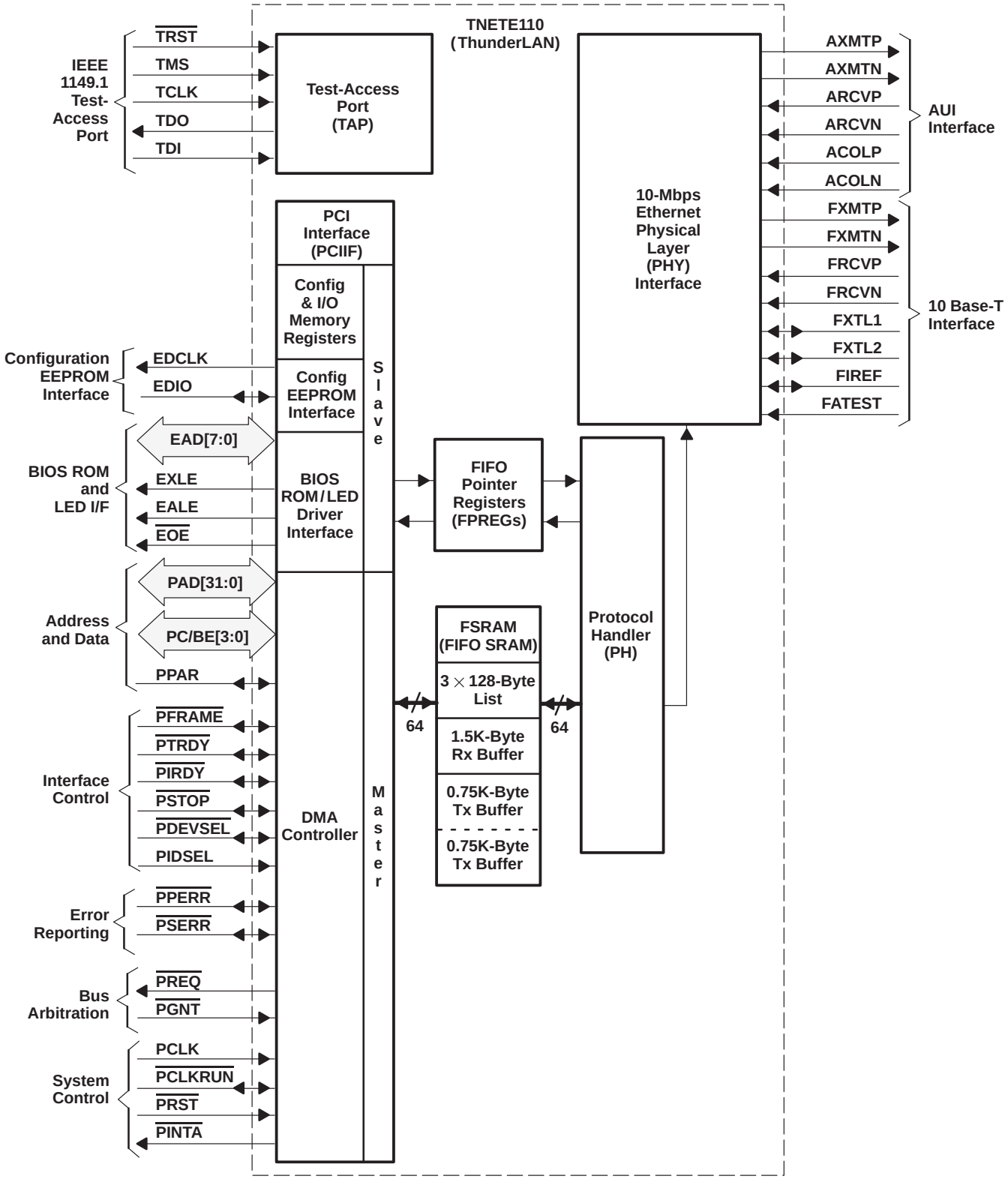
The glueless PCI interface supports 32-bit streaming, operates at speeds up to 33 MHz and is capable of internal data transfer rates up to 2 Gbps, taking full advantage of all available PCI bandwidth. The TNETE110 offers jumperless autoconfiguration using PCI configuration read/write cycles. Customizable configuration registers, which can be autoloaded from an external serial EEPROM, allow designers of TNETE110-based systems to give their systems a unique identification code. The TNETE110 PCI interface, developed in conjunction with other leaders in the semiconductor and computer industries, has been tested vigorously on multiple platforms to ensure compatibility across a wide array of available PCI products. In addition, the ThunderLAN drivers and ThunderLAN architecture use TI's patented Adaptive Performance Optimization (APO) technology to adjust critical parameters dynamically for minimum latency, minimum host CPU utilization, and maximum system performance. This technology ensures that the maximum capabilities of the PCI interface are used by automatically tuning the adapter to the specific system in which it is operating.

An intelligent protocol handler (PH) implements the serial protocols of the network. The PH is designed for minimum overhead related to multiple protocols, using common state machines to implement 95% of the total protocol handler. On transmit, the PH serializes data, adds framing and cyclic redundancy check (CRC) fields, and interfaces to the network physical layer (PHY) chip. On receive, it provides address recognition, CRC and error checking, frame disassembly, and deserialization. Data for multiple channels is passed to and from the PH by way of circular buffer pointers in the FIFO SRAM.

Compliant with IEEE Standard 1149.1, the TNETE110 provides a 5-pin test-access port that is used for boundary-scan testing.

The TNETE110 is available in a 144-pin quad flat package (PCE suffix).

functional block diagram



Pin Functions

PIN NAME	PIN NO.	TYPE†	DESCRIPTION
TEST PORT			
TCLK	124	I	Test clock. TCLK is used to clock state information and test data into and out of the device during operation of the test port.
TDI	126	I	Test data input. TDI is used to shift serially test data and test instructions into the device during operation of the test port.
TDO	125	O	Test data output. TDO is used to shift serially test data and test instructions out of the device during operation of the test port.
TMS	123	I	Test mode select. TMS is used to control the state of the test port controller within TNETE110.
$\overline{\text{TRST}}$	121	I	Test reset. $\overline{\text{TRST}}$ is used for the asynchronous reset of the test port controller.
PCI INTERFACE			
PAD31	135	I/O	PCI address/data bus. Byte 3 (most significant byte, MSByte) of the PCI address/data bus
PAD30	137		
PAD29	138		
PAD28	140		
PAD27	141		
PAD26	143		
PAD25	144		
PAD24	1		
PAD23	5	I/O	PCI address/data bus. Byte 2 of the PCI address/data bus
PAD22	7		
PAD21	8		
PAD20	9		
PAD19	11		
PAD18	12		
PAD17	13		
PAD16	15		
PAD15	29	I/O	PCI address/data bus. Byte 1 of the PCI address/data bus
PAD14	30		
PAD13	32		
PAD12	33		
PAD11	35		
PAD10	36		
PAD9	38		
PAD8	39		

† I = input, O = output, I/O = 3-state input/output

Pin Functions (Continued)

PIN NAME	PIN NO.	TYPE†	DESCRIPTION
PCI INTERFACE (CONTINUED)			
PAD7	42	I/O	PCI address/data bus. Byte 0 (least significant byte, LSByte) of the PCI address/data bus
PAD6	43		
PAD5	45		
PAD4	46		
PAD3	47		
PAD2	49		
PAD1	50		
PAD0	51		
PCLK	131	I	PCI clock. PCLK is the clock reference for all PCI bus operations. All other PCI pins except $\overline{\text{PRST}}$ and $\overline{\text{PINTA}}$ are sampled on the rising edge of PCLK. All PCI bus timing parameters are defined with respect to this edge.
$\overline{\text{PCLKRUN}}$	53	I/O‡	Clock run control. $\overline{\text{PCLKRUN}}$ is the active-low PCI clock request/grant signal that allows the TNETE110 to indicate when an active PCI clock is required. (This is an open drain.)
PC/BE3	2	I/O	PCI bus command and byte enables: PC/BE3 enables byte 3 (MSByte) of the PCI address/data bus.
PC/BE2	16		PC/BE2 enables byte 2 of the PCI address/data bus.
PC/BE1	28		PC/BE1 enables byte 1 of the PCI address/data bus.
PC/BE0	41		PC/BE0 enables byte 0 of the PCI address/data bus.
$\overline{\text{PDEVSEL}}$	21	I/O	PCI device select. $\overline{\text{PDEVSEL}}$ indicates that the driving device has decoded one of its addresses as the target of the current access. The TNETE110 drives $\overline{\text{PDEVSEL}}$ when it decodes an access to one of its registers. As a bus master, the TNETE110 monitors $\overline{\text{PDEVSEL}}$ to detect accesses to illegal memory addresses.
$\overline{\text{PFRAME}}$	17	I/O	PCI cycle frame. $\overline{\text{PFRAME}}$ is driven by the active bus master to indicate the beginning and duration of an access. It is asserted to indicate the start of a bus transaction. $\overline{\text{PFRAME}}$ remains asserted during the transaction, and is deasserted only in the final data phase.
$\overline{\text{PGNT}}$	132	I	PCI bus grant. $\overline{\text{PGNT}}$ is asserted by the system arbiter to indicate that the TNETE110 has been granted control of the PCI bus.
PIDSEL	4	I	PCI initialization device select. PIDSEL is the chip select for access to the PCI configuration registers.
$\overline{\text{PINTA}}$	128	O/D	PCI interrupt. $\overline{\text{PINTA}}$ is the interrupt request from the TNETE110. PCI interrupts are shared, so this is an open-drain (wired-OR) output.
$\overline{\text{PIRDY}}$	19	I/O	PCI initiator ready. $\overline{\text{PIRDY}}$ is driven by the active bus master to indicate that it is ready to complete the current data phase of a transaction. A data phase is not completed until both $\overline{\text{PIRDY}}$ and $\overline{\text{PTRDY}}$ are sampled. When the TNETE110 is a bus master, it uses $\overline{\text{PIRDY}}$ to align incoming data on reads or outgoing data on writes with its internal RAM access synchronization (maximum of one cycle at the beginning of burst). When the TNETE110 is a bus slave, it extends the access appropriately until both $\overline{\text{PIRDY}}$ and $\overline{\text{PTRDY}}$ are asserted.
$\overline{\text{PTRDY}}$	20	I/O	PCI target ready. $\overline{\text{PTRDY}}$ is driven by the selected device (bus slave or target) to indicate that it is ready to complete the current data phase of a transaction. A data phase is not completed until both $\overline{\text{PIRDY}}$ and $\overline{\text{PTRDY}}$ are sampled. ThunderLAN uses $\overline{\text{PTRDY}}$ to ensure every direct I/O (DIO) operation is interlocked correctly.
PPAR	27	I/O	PCI parity. PPAR carries even parity across PAD[0–31] and PC/BE[0–3]. It is driven by the TNETE110 during all address and write cycles as a bus master and during all read cycles as a bus slave.
$\overline{\text{PPERR}}$	24	I/O	PCI parity error. $\overline{\text{PPERR}}$ indicates a data parity error on all PCI transactions except special cycles.

† I = input, I/O = 3-state input/output, O/D = open-drain output
‡ Open drain

Pin Functions (Continued)

PIN NAME	PIN NO.	TYPE†	DESCRIPTION
PCI INTERFACE (CONTINUED)			
$\overline{\text{PREQ}}$	134	I/O	PCI bus request. $\overline{\text{PREQ}}$ is asserted by the TNETE110 to request control of the PCI bus. This is not a shared signal.
$\overline{\text{PRST}}$	129	I	PCI reset signal
$\overline{\text{PSERR}}$	25	O/D	PCI system error. $\overline{\text{PSERR}}$ indicates parity errors or special-cycle data-parity errors.
$\overline{\text{PSTOP}}$	23	I/O	PCI stop. $\overline{\text{PSTOP}}$ indicates the current target is requesting the master to stop the current transaction.
BIOS ROM/LED DRIVER INTERFACE			
EAD7 EAD6 EAD5 EAD4 EAD3 EAD2 EAD1 EAD0	54 55 56 57 59 60 61 62	I/O	EPROM address/data. EAD[0–7] is a multiplexed byte bus that is used to address and to read data from an external BIOS ROM. • On the cycle when EXLE is asserted low, EAD[0–7] is driven with the high byte of the address. • On the cycle when EALE is asserted low, EAD[0–7] is driven with the low byte of the address. • When $\overline{\text{EOE}}$ is asserted, BIOS ROM data should be placed on the bus. These pins can be used also to drive external status LEDs. Low-current (2–5 mA) LEDs can be connected directly through appropriate resistors. High-current LEDs can be driven through buffers or from the BIOS ROM address latches.
EALE	65	O	EPROM address latch enable. EALE is driven low to latch the low (least significant) byte of the BIOS ROM address from EAD[0–7].
$\overline{\text{EOE}}$	64	O	EPROM output enable. When $\overline{\text{EOE}}$ is active (low), EAD[0–7] is 3-stated and the output of the BIOS ROM should be placed on EAD[0–7].
EXLE	66	O	EPROM extended address-latch enable. EXLE is driven low to latch the high (most significant) byte of the BIOS ROM address from EAD[0–7].
CONFIGURATION EEPROM INTERFACE			
EDCLK	68	O	EEPROM data clock. EDCLK transfers serial clocked data to the 2K-bit serial EEPROMs (24C02) (see Note 1).
EDIO	69	I/O	EEPROM data I/O. EDIO is the bidirectional serial data/address line to the 2K-bit serial EEPROM (24C02). EDIO requires an external pullup for EEPROM operation. Tying EDIO to ground disables the EEPROM interface and prevents autoconfiguration of the PCI configuration register.
MANAGEMENT DATA PINS			
MDCLK	91	O	Management data clock. MDCLK is part of the serial management interface to physical-media independent (PMI)/PHY chip.
MDIO	93	I/O	Management data I/O. MDIO is part of the serial management interface to PMI/PHY chip.
NETWORK INTERFACE (10 Base-T AND AUI)			
ACOLN ACOLP	111 109	A	AUI receive pair. ACOLN and ACOLP are differential line receiver inputs and connect to the receive pair through transformer isolation, etc.
ARCVN ARCVP	108 106	A	AUI receive pair. ARCVN and ARCVP are differential line receiver inputs and connect to the receive pair through transformer isolation, etc.
AXMTP AXMTN	99 100	A	AUI transmit pair. AXMTP and AXMTN are differential line transmitter outputs.
FATEST	118	A	Analog test pin. FATEST provides access to the filter of the reference PLL. This pin must be left as a no connect.
FIREF	116	A	Current reference. FIREF is used to set a current reference for the analog circuitry.

† I = input, O = output, I/O = 3-state input/output, O/D = open-drain output, A = analog

NOTE 1: This pin should be tied to V_{DD} with a 4.7-kΩ – 10-kΩ pullup resistor.

Pin Functions (Continued)

PIN NAME	PIN NO.	TYPE†	DESCRIPTION
FXMTP FXMTN	97 98	A	10 Base-T transmit pair. FXMTP and FXMTN are differential line transmitter outputs.
RESERVED	120	I	Reserved. Tie this pin low.
FRCVN FRCVP	105 103	A	10 Base-T receive pair. FRCVN and FRCVP are differential line receiver inputs and connect to the receive pair through transformer isolation, etc.
FXTL1 FXTL2	113 114	A	Crystal oscillator pins. Drive FXTL1 and FXTL2 from a 20-MHz crystal oscillator module
POWER			
V_{DDI}	6, 14, 34, 48, 122, 136, 142	PWR	PCI V_{DD} pins. V_{DDI} pins provide power for the PCI I/O pin drivers. Connect V_{DDI} pins to a 5-V power supply when using 5-V signals on the PCI bus. Connect V_{DDI} pins to a 3-V power supply when using 3-V signals on the PCI bus
V_{DDL}	22, 37, 58, 70 79, 84 94, 130	PWR	Logic V_{DD} pins (5 V). V_{DDL} pins provide power for internal TNETE110 logic and they always should be connected to 5-V power supply.
V_{DDOSC}	115	PWR	Analog power pin. V_{DDOSC} is the 5-V power for the crystal oscillator circuit.
V_{DDR}	104 107	PWR	Analog power pin. V_{DDR} is the 5-V power for the receiver circuitry.
V_{DDT}	96	PWR	Analog power pin. V_{DDT} is the 5-V power for the transmitter circuitry.
V_{DDVCO}	117	PWR	Analog power pin. V_{DDVCO} is the 5-V power for the voltage controller oscillator (VCO) and filter input.
V_{SSI}	3, 10, 26, 31, 40, 52, 67, 88, 127, 139	PWR	PCI I/O ground pins
V_{SSL}	18, 44, 63, 75, 92, 133	PWR	Logic ground pins
V_{SSOSC}	112	PWR	Analog power pin. Ground for crystal oscillator circuit
V_{SSR}	102 110	PWR	Analog power pin. Ground for receiver circuitry
V_{SST}	101	PWR	Analog power pin. Ground for transmitter circuitry
V_{SSVCO}	119	PWR	Analog power pin. Ground for VCO and filter input

† I = input, A = analog, PWR = power

architecture

The major blocks of the TNETE110 include the PCI interface (PCIIF), the protocol handler (PH), the physical layer (PHY), the FIFO pointer registers (FPREGS), the FIFO SRAM (FSRAM), and a test-access port (TAP). The functionality of these blocks is described in the following sections.

PCI interface (PCIIF)

The TNETE110 PCIIF contains a byte-aligning DMA controller that allows frames to be fragmented into any byte length and transferred to any byte address while supporting 32-bit data streaming. For multipriority networks, it can provide multiple data channels, each with separate lists, commands, and status. Data for the channels is passed to and from the PH by way of circular buffer FIFOs in the SRAM, which are controlled through FIFO

registers. The configuration EEPROM interface, BIOS ROM/LED driver interface, configuration and I/O memory registers, and DMA controller are subblocks of the PCIIF. The features of these subblocks are described in the following sections.

configuration EEPROM interface (CEI)

The CEI provides a means for autoconfiguration of the PCI configuration registers. Certain registers in the PCI configuration space can be loaded using the CEI. Autoconfiguration allows builders of TNETE110-based systems to customize the contents of these registers to identify their own system, rather than to use the TI defaults. The EEPROM is read at power up and can then be read from, and written to, under program control.

BIOS ROM/LED driver interface (BRI)

The BRI addresses and reads data from an external BIOS ROM through a multiplexed byte-wide bus. The ROM address/data pins also can be multiplexed to drive external status LEDs.

configuration and I/O memory registers (CIOREGS)

The CIOREGS reside in the configuration space, which is 256 bytes in length. The first 64 bytes of the configuration space is the header region, which is defined explicitly by the PCI standard.

DMA controller (DMAC)

The DMAC is responsible for coordinating TNETE110 requests for mastership of the PCI bus. The DMAC provides byte-aligning DMA control, allowing byte-size fragmented frames to be transferred to any byte address while supporting 32-bit data streaming.

protocol handler (PH)

The PH implements the serial protocols of the network. On transmit, it serializes data, adds framing and CRC fields, and interfaces to the network PHY. On receive, it provides address recognition, CRC and error checking, frame disassembly, and deserialization. Data for multiple channels is passed to and from the PH by way of circular buffer FIFOs in the FSRAM, which are controlled through FPREGS.

10 Base-T physical layer (PHY)

The PHY acts as an on-chip front-end providing physical layer functions for both 10 Base-5 (AUI) and 10 Base-T (twisted pair). The PHY provides Manchester encoding/decoding from smart squelch, jabber detection, link pulse detection, autopolarity control, 10 Base-T transmission waveshaping, and antialiasing filtering. Connection to the AUI drop cable for the 10 Base-T twisted pair is made through simple isolation transformers (see Figure 2) and no external filter networks are required. Suitable external termination components allow the use of either shielded or unshielded twisted-pair cable (150 Ω or 100 Ω). Some of the key features of the on-chip PHY are listed below.

- Integrated filters
- 10 Base-T transceiver
- AUI transceiver
- Autopolarity (reverse polarity correction)
- Loopback for twisted pair and AUI
- Full-duplex mode for simultaneous 10 Base-T transmission and reception
- Low power

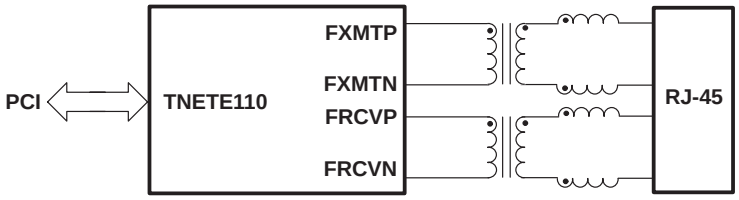


Figure 2. Schematic for 10 Base-T Network Interface Using TNETE110

FIFO pointer registers (FPREGS)

The FPREGS are used to implement circular buffer FIFOs in the SRAM. They are a collection of pointer and counter registers used to maintain the FIFO operation. Both the PCIIF and PH use FPREGS to determine where to read or write data in the SRAM and to determine how much data the FIFO contains.

FIFO SRAM (FSRAM)

The FSRAM is a conventional SRAM array accessed synchronously to the PCI bus clock. Access to the RAM is allocated on a time-division multiplexed (TDM) basis, rather than through a conventional shared bus. This removes the need for bus arbitration and provides guaranteed bandwidth. Half the RAM accesses (every other cycle) are allocated to the PCI controller. It has a 64-bit access port to the RAM, giving it 1 Gbps of bandwidth, sufficient to support 32-bit data streaming on the PCI bus. The PH has one-quarter the RAM accesses, and its port can be up to 64 bits wide. A 64-bit port for the PH provides 512 Mbps of bandwidth, more than sufficient for a full-duplex 100-Mbps network. The remaining RAM accesses can be allocated toward providing even more PH bandwidth. The RAM is also accessible (for diagnostic purposes) from the TNETE110 internal data bus. Host DIO accesses are used by the host to access internal TNETE110 registers and for adapter test.

- 3.375K bytes of FSRAM
  - One 1.5K-byte FIFO for receive channel
  - One 1.5K-byte FIFO for transmit channel
  - Three 128-byte lists

Supporting 1.5K bytes of FIFO per channel allows full frame buffering of Ethernet frames.

test-access port (TAP)

Compliant with IEEE Standard 1149.1, the TAP is comprised of five pins that are used to interface serially with the device and with the board on which it is installed for boundary-scan testing.

absolute maximum ratings over operating case temperature range (unless otherwise noted)†

Supply voltage range, V_{DD} (see Note 2) . . . . . – 0.5 V to 7 V
Input voltage range (see Note 2) . . . . . – 0.5 V to 7 V
Output voltage range . . . . . – 0.5 V to 7 V
Power dissipation . . . . . 1.6 W
Operating case temperature range, T_C . . . . . 0°C to 95°C
Junction-to-ambient package thermal impedance, airflow = 0 lfpm, $T_{JA(0)}$ . . . . . 28.8°C/W
Junction-to-ambient package thermal impedance, airflow = 100 lfpm, $T_{JA(100)}$ . . . . . 24.8°C/W
Junction-to-case package thermal impedance, T_{JC} . . . . . 2°C/W
Storage temperature range, T_{stg} . . . . . – 65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 2: Voltage values are with respect to V_{SS}; all V_{SS} pins should be routed so as to minimize inductance to system ground.

The recommended operating conditions and the electrical characteristics tables are divided into groups, depending on pin function:

- PCI interface pins
- Logic pins
- Physical layer pins

The PCI signal pins can be operated in one of two modes shown in the PCI tables.

- 5-V signal mode
- 3-V signal mode

recommended operating conditions (PCI interface pins) (see Note 3)

			3-V SIGNALING OPERATION			5-V SIGNALING OPERATION			UNIT
			MIN	NOM	MAX	MIN	NOM	MAX	
V_{DD}	Supply voltage (PCI)		3	3.3	3.6	4.75	5	5.25	V
V_{IH}	High-level input voltage		$0.5 \times V_{DD}$		$V_{DD}+0.5$	2.0		$V_{DD}+0.5$	V
V_{IL}	Low-level input voltage, TTL-level signal (see Note 4)		–0.5		$0.3 \times V_{DD}$	–0.5		0.8	V
I_{OH}	High-level output current	TTL outputs			–0.5			–2	mA
I_{OL}	Low-level output current (see Note 5)	TTL outputs			1.5			6	mA
T_C	Operating case temperature		0		95	0		95	°C

NOTES: 3. PCI interface pins include V_{DD}, $\overline{\text{PCLKRUN}}$, $\overline{\text{PFRAME}}$, $\overline{\text{PTRDY}}$, $\overline{\text{PIRDY}}$, $\overline{\text{PSTOP}}$, $\overline{\text{PDEVSEL}}$, PIDSEL, $\overline{\text{PPERR}}$, $\overline{\text{PSERR}}$, $\overline{\text{PREQ}}$, $\overline{\text{PGNT}}$, PCLK, PPAR, $\overline{\text{PRST}}$, $\overline{\text{PINTA}}$, PAD[31:0], and PC/$\overline{\text{BE}}$[3:0].

4. The algebraic convention, where the more negative (less positive) limit is designated as a minimum, is used for logic levels only.

5. Output current of 2 mA is sufficient to drive five low-power Schottky TTL loads or ten advanced low-power Schottky TTL loads (worst case).

electrical characteristics over recommended ranges of supply voltage (unless otherwise noted) (PCI interface pins)

PARAMETER		TEST CONDITIONS †		3-V SIGNALING OPERATION		5-V SIGNALING OPERATION		UNIT
				MIN	MAX	MIN	MAX	
V_{OH}	High-level output voltage, TTL-level signal (see Note 6)	V_{DD} = MIN,	I_{OH} = MAX	2.4		2.4		V
V_{OL}	Low-level output voltage, TTL-level signal	V_{DD} = MAX,	I_{OL} = MAX		0.45		0.5	V
I_{OZ}	High-impedance output current	V_{DD} = MAX,	V_O = 0 V		10		10	µA
		V_{DD} = MAX,	V_O = V_{DD}		–10		– 10	
I_I	Input current, any input or input/output	V_I = V_{SS} to V_{DD}			± 10		± 10	µA
C_i	Input capacitance, any input	f = 1 MHz,	Others at 0 V		10		10	pF
C_o	Output capacitance, any output or input/output	f = 1 MHz,	Others at 0 V		10		10	pF

† For conditions shown as MIN/MAX, use the appropriate value specified under the recommended operating conditions.
NOTE 6: The following signals require an external pullup resistor: $\overline{\text{PSERR}}$, $\overline{\text{PINTA}}$.

recommended operating conditions (logic pins) (see Note 7)

			MIN	NOM	MAX	UNIT
V_{DD}	Supply voltage (5 V only)		4.75	5	5.25	V
V_{IH}	High-level input voltage		2		V_{DD} + 0.3	V
V_{IL}	Low-level input voltage, TTL-level signal (see Note 4)		–0.3		0.8	V
I_{OH}	High-level output current	TTL outputs			–4	mA
I_{OL}	Low-level output current (see Note 5)	TTL outputs			4	mA
T_C	Operating case temperature		0		95	°C

NOTES: 4. The algebraic convention, where the more negative (less positive) limit is designated as a minimum, is used for logic levels only.
5. Output current of 2 mA is sufficient to drive five low-power Schottky TTL loads or ten advanced low-power Schottky TTL loads (worst case).
7. Logic pins include V_{DDL}, EAD[7:0], EXLE, EALE, $\overline{\text{EOE}}$, EDCLK, EDIO.

electrical characteristics over recommended ranges of supply voltage (unless otherwise noted) (logic pins)

PARAMETER		TEST CONDITIONS †		MIN	MAX	UNIT
V_{OH}	High-level output voltage, TTL-level signal	V_{DD} = MIN,	I_{OH} = MAX	2.4		V
V_{OL}	Low-level output voltage, TTL-level signal	V_{DD} = MAX,	I_{OL} = MAX		0.5	V
I_{OZ}	High-impedance output current	V_{DD} = MIN,	V_O = V_{DD}		10	µA
		V_{DD} = MIN,	V_O = 0 V		–10	
I_I	Input current	V_I = V_{SS} to V_{DD}			± 1	µA
I_{DD}	Supply current	V_{DD} = MAX			320	mA
C_i	Input capacitance, any input	f = 1 MHz,	Others at 0 V		10	pF
C_o	Output capacitance, any output or input/output	f = 1 MHz,	Others at 0 V		10	pF

† For conditions shown as MIN/MAX, use the appropriate value specified under the recommended operating conditions.

recommended operating conditions (physical layer pins) (see Note 8)

		JEDEC SYMBOL	MIN	NOM	MAX	UNIT
V_{DD}	Supply voltage		4.75	5	5.25	V
T_C	Operating case temperature		0		95	°C

NOTES: 8. Physical layer pins include V_{DDOSC}, V_{DDR}, V_{DDT}, V_{DDVCO}, ACOLN, ACOLP, ARCVN, ARCVP, AXMTP, AXMTN, FATEST, FIREF, FRCVN, FRCVP, FXTL1, FXTL2, FXMTP, and FXMTN.

recommended operating conditions (10 Base-T receiver input pins)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{I(DIFF)}$	Differential input voltage	V_{ID}		0.6	2.8	V
$I_{(CM)}$	Common-mode current	I_{IC}			4	mA

recommended operating conditions (AUI receiver input pins)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{I(DIFF)1}$	Differential input voltage 1	$V_{ID(1)}$	See Note 9	0	3	V
$V_{I(DIFF)2}$	Differential input voltage 2	$V_{ID(2)}$	See Note 10	0	100	mV

9. Common-mode frequency range: 10 Hz to 40 kHz
10. Common-mode frequency range: 40 kHz to 10 MHz

electrical characteristics over recommended ranges of supply voltage (unless otherwise noted) (physical layer pins)

10 Base-T receiver input (FRCVP, FRCVN)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
V_{SQ+}	Rising input pair squelch threshold		$V_{CM} = V_{SB}$, See Note 11		270	mV
V_{SQ-}	Falling input pair squelch threshold		$V_{CM} = V_{SB}$, See Note 11	–270		mV

NOTE 11: V_{SB} is the self-bias voltage of the input pins FRCVP and FRCVN.

10 Base-T transmitter drive characteristics (FXMTP, FXMTN)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
V_{SLW}	Differential voltage at specified slew rate	$V_{OD(SLEW)}$		±2.2	±2.8	V
$V_{O(CM)}$	Common-mode output voltage	V_{OC}	See Figure 3(d) & 3(e)	0	4	V
$V_{O(DIFF)}$	Differential output voltage	V_{OD}	Into open circuit		5.25	V
$V_{O(I)}$	Output idle differential voltage	$V_{OD(IDLE)}$			±50	mV
$I_{O(FC)}$	Output current, fault condition	$I_{O(FC)}$			300†	mA

† Assured by design

electrical characteristics over recommended ranges of supply voltage (unless otherwise noted) (physical layer pins) (continued)

AUI receiver input (ARCVP, ARCVN, ACOLP, ACOLN)

PARAMETER			JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{(SQ)}$	Input squelch threshold	To activate		See Note 12, 20 ns < X < 35 ns	–325	–100	mV
		Not to activate			–100	0	mV

NOTES: 12. This parameter is a range that is allowed to vary over operating conditions. The reference point for the timing period is from the input pair reaching –175 mV on the falling edge to reaching –175 mV on the rising edge.

AUI transmitter drive characteristics (AXMTP, AXMTN)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{O(DIFF)1}$	Differential output voltage	$V_{OD(1)}$	See Note 13	±500	±1315	mV
$V_{OI(DIFF)}$	Output idle differential voltage	$V_{OD(IDLE)}$			±40†	mV
$V_{OI(DIFF)U}$	Output differential undershoot	$V_{OD(IDLE)U}$			100‡	mV
$I_{O(FC)}$	Output current, fault condition	$I_{O(FC)}$			150‡	mA

† Assured by design
‡ Characterized but not tested
NOTE 13: The differential voltage is measured as per Figure 3(b) on page 16.

phase-locked loop (PLL) characteristics

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
V_{FILT}	Reference PLL operating filter voltage	$t_{c(FXTL1)}$ = 50 ns	0.8	2	V

crystal oscillator characteristics

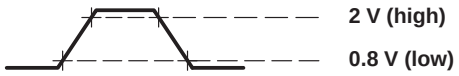
PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{SB(FXTL1)}$	Input self-bias voltage	V_{IB}		1.8	4	V
$I_{OH(FXTL2)}$	High-level output current	I_{OH}	$V_{(FXTL2)} = V_{SB(FXTL1)}$ $V_{(FXTL1)} = V_{SB(FXTL1)} + 0.5$ V	– 2.5	– 6.5	mA
$I_{OL(FXTL2)}$	Low-level output current	I_{OL}	$V_{(FXTL2)} = V_{SB(FXTL1)}$ $V_{(FXTL1)} = V_{SB(FXTL1)} - 0.5$ V	0.4	1.3	mA

PARAMETER MEASUREMENT INFORMATION

Outputs are driven to a minimum high-logic level of 2.4 V and to a maximum low-logic level of 0.6 V. These levels are compatible with TTL devices.

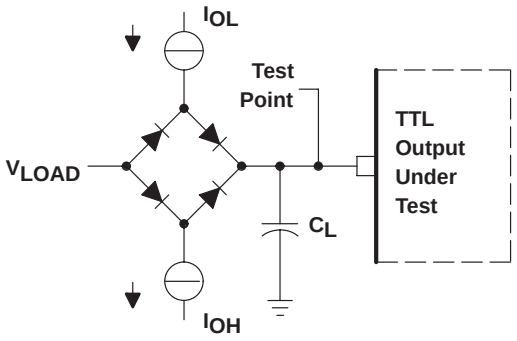
Output transition times are specified as follows: For a high-to-low transition on either an input or output signal, the level at which the signal is said to be no longer high is 2 V and the level at which the signal is said to be low is 0.8 V. For a low-to-high transition, the level at which the signal is said to be no longer low is 0.8 V and the level at which the signal is said to be high is 2 V, as shown below.

The rise and fall times are not specified but are assumed to be those of standard TTL devices, which are typically 1.5 ns.

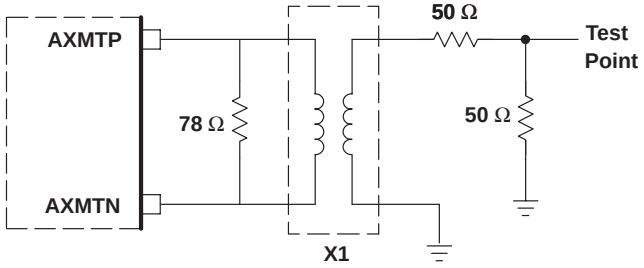


test measurement

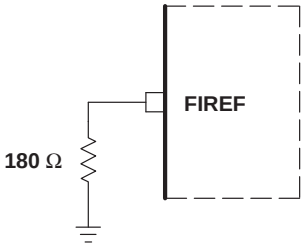
The test-load circuit shown in Figure 3 represents the programmable load of the tester pin electronics that are used to verify timing parameters of the TNETE110 output signals.



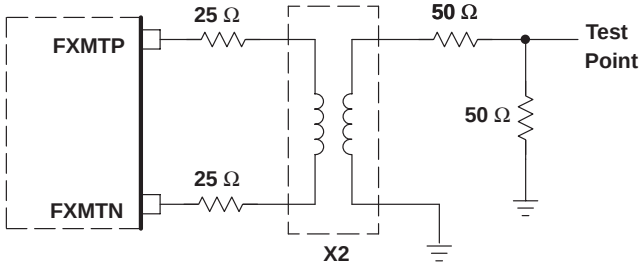
(a) TTL OUTPUT TEST LOAD



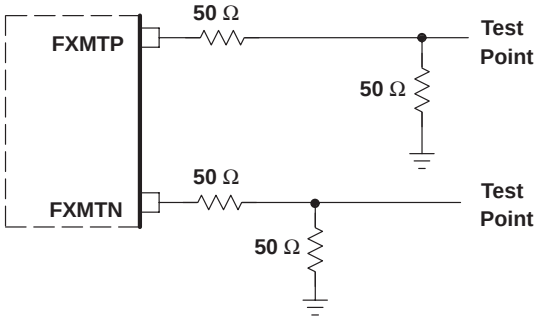
(b) AXMTP AND AXMTN TEST LOAD (AC TESTING)
X1 – Fil – Mag 23Z90 (1:1)



(c) FIREF TEST CIRCUIT



(d) FXMTP AND FXMTN TEST LOAD (AC TESTING)
X2 – Fil – Mag 23Z128 (1: √2)



(e) FXMTP AND FXMTN TEST LOAD (DC TESTING)

Where: I_{OL} = Refer to I_{OL} in recommended operating conditions
I_{OH} = Refer to I_{OH} in recommended operating conditions
V_{LOAD} = 1.5 V, typical dc-level verification or 0.7 V, typical timing verification
C_L = 18 pF, typical load-circuit capacitance

Figure 3. Test and Load Circuit

switching characteristics of PCI 5 V and 3.3 V (see Note 14 and Figure 4)

PARAMETER		MIN	MAX	UNIT
t_{VAL}	Delay time, PCLK to bused signals valid (see Notes 15 and 16)	2	11	ns

$t_{VAL(PTP)}$	Delay time, PCLK to bused signals valid point-to-point (see Notes 15 and 16)	2	12	ns
t_{on}	Float to active delay	2		ns
t_{off}	Active to float delay		28	ns

NOTES: 14. Some of the timing symbols in this table currently are not listed with EIA or JEDEC standards for semiconductor symbology, but are consistent with the PCI Local-Bus Specification, Revision 2.0.
15. Minimum times are measured with a 0-pF equivalent load; maximum times are measured with a 50-pF equivalent load. Actual test capacitance can vary, but results should be correlated to these specifications.
16. $\overline{\text{PREQ}}$ and $\overline{\text{PGNT}}$ are point-to-point signals, and have different output valid delay and input setup times than do bused signals. $\overline{\text{PGNT}}$ has a setup time of 10 ns; $\overline{\text{PREQ}}$ has a setup time of 12 ns. All other signals are bused.

timing requirements of PCI 5 V and 3.3 V (see Note 14 and Figure 4)

		MIN	MAX	UNIT
t_{su}	Setup time, bused signals valid to PCLK (see Note 16)	7		ns
$t_{su(PTP)}$	Setup time to PCLK—point-to-point (see Note 16)	10, 12		ns
t_h	Hold time, input from PCLK	0		ns
t_c	Cycle time, PCLK (see Note 17)	30	500	ns
$t_{w(H)}$	Pulse duration, PCLK high	12		ns
$t_{w(L)}$	Pulse duration, PCLK low	12		ns
t_{slew}	Slew rate, PCLK (see Note 18)	1	4	V/ns

NOTES: 14. Some of the timing symbols in this table currently are not listed with EIA or JEDEC standards for semiconductor symbology, but are consistent with the PCI Local-Bus Specification, Revision 2.0.
16. $\overline{\text{PREQ}}$ and $\overline{\text{PGNT}}$ are point-to-point signals, and have different output valid delay and input setup times than do bused signals. $\overline{\text{PGNT}}$ has a setup time of 10 ns; $\overline{\text{PREQ}}$ has a setup time of 12 ns. All other signals are bused.
17. As a requirement for frame transmission/reception, the minimum PCLK frequency varies with network speed. The clock can only be stopped in a low state.
18. Rise and fall times are specified in terms of the edge rate measured in V/ns. This slew rate must be met across the minimum peak-to-peak portion of the clock waveform.

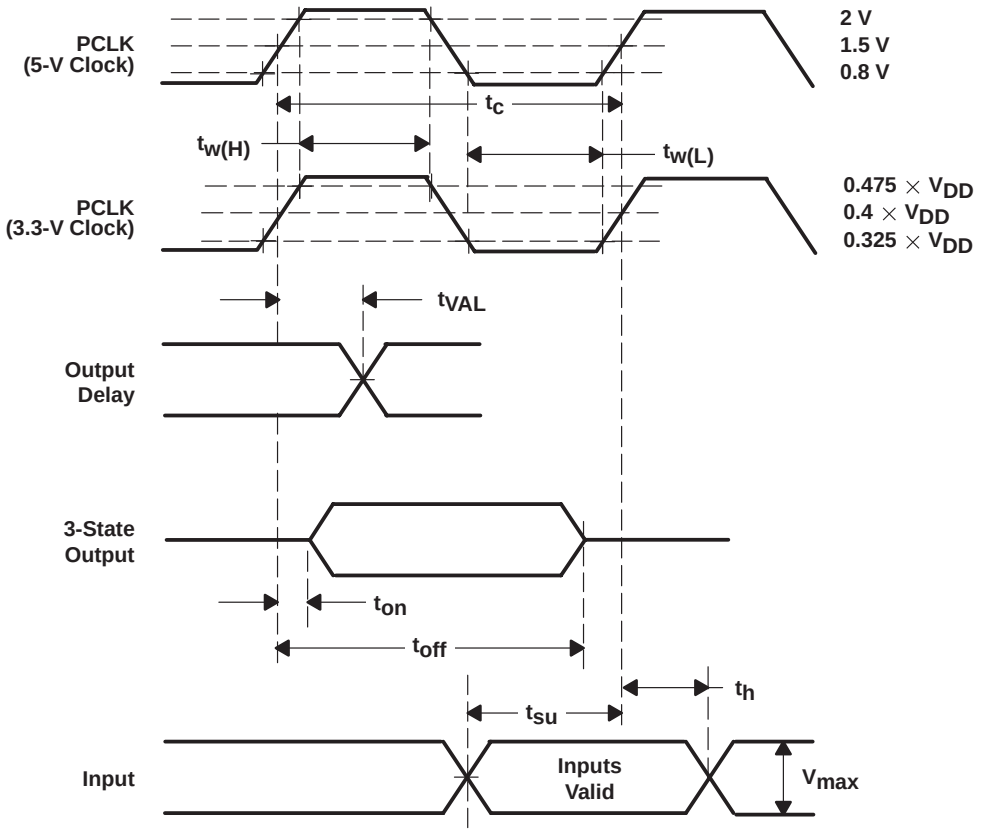


Figure 4. PCI 5-V and 3.3-V Timing

timing requirements of management data I/O (MDIO) (see Figure 5)

		MIN	MAX	UNIT
$t_{a(MDCLKH-MDIOV)}$	Access time, MDIO valid from MDCLK high (see Note 19)	0	300	ns

NOTE 19: When the MDIO signal is sourced by the PMI/PHY, it is sampled by TNETE110 synchronous to the rising edge of MDCLK.

switching characteristics of MDIO (see Figure 6)

PARAMETER		MIN	MAX	UNIT
$t_{su(MDIOV-MDCLKH)}$	Setup time, MDIO valid to MDCLK high (see Note 20)	10		ns
$t_{h(MDCLKH-MDIOX)}$	Hold time, MDCLK high to MDIO changing (see Note 20)	10		ns

NOTE 20: MDIO is a bidirectional signal that can be sourced by TNETE110 or by the PMI/PHY. When TNETE110 sources the MDIO signal, TNETE110 asserts MDIO synchronous to the rising edge of MDCLK.

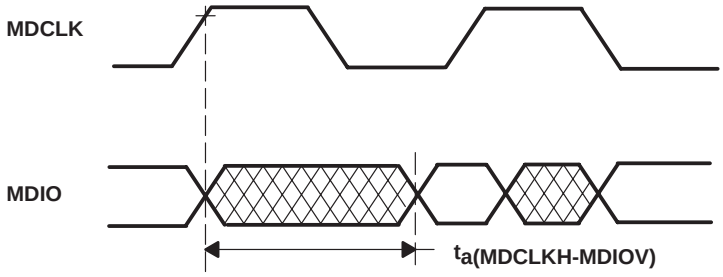


Figure 5. Management Data I/O Timing (Sourced by PHY)

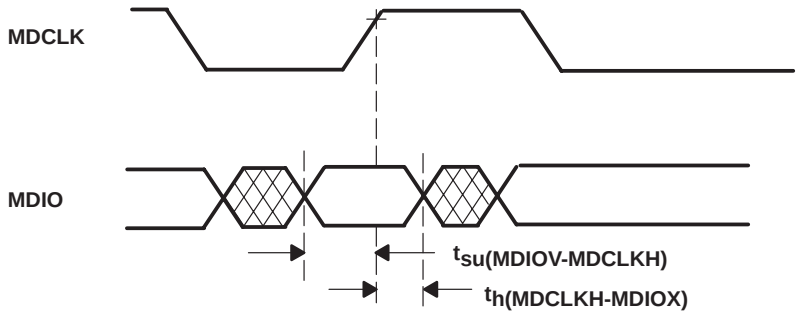


Figure 6. Management Data I/O Timing (Sourced by TNETE110)

timing requirements of BIOS ROM and LED interface (see Figure 7)†

		MIN	MAX	UNIT
t_{su}	Setup time, data		250	ns
t_h	Hold time, data	0		ns

switching characteristics of BIOS ROM and LED interface (see Figure 7)†

PARAMETER		MIN	MAX	UNIT
$t_{d(EADV-EXLEL)}$	Delay time, address high byte valid to EXLE low (address high byte setup time for external latch)	0		ns
$t_{d(EXLEL-EADZ)}$	Delay time, EXLE low to address high byte invalid (address high byte hold time for external latch)	10		ns
$t_{d(EADV-EALEL)}$	Delay time, address low byte valid to EALE low (address low byte setup time for external latch)	0		ns
$t_{d(EALEL-EADZ)}$	Delay time, EALE low to address low byte invalid (address low byte hold time for external latch)	10		ns
t_a	Access time, data valid after EALE goes low	288		ns

† The EPROM interface, consisting of 11 pins, requires only two TTL '373 latches to latch the high and low addresses.

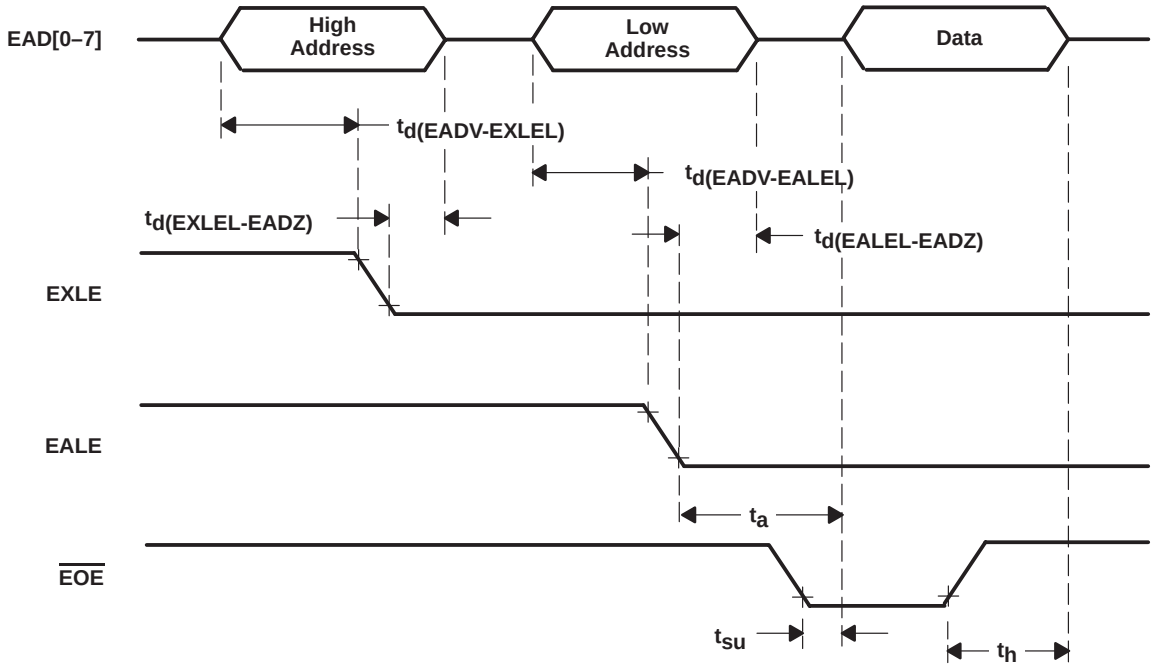


Figure 7. BIOS ROM and LED Interface Timing

switching characteristics of configuration EEPROM interface (see Figure 8)

PARAMETER		MIN	MAX	UNIT
$f_{CLK(EDCLK)}$	Clock frequency, EDCLK	0	100	kHz
$t_{d(EDCLKL-EDIOV)}$	EDCLK low to EDIO (In) data in valid	0.3	3.5	µs
$t_{d(EDIO\ free)}$	Time the bus must be free before a new transmission can start	4.7		µs
$t_{d(EDIOV-EDCLKL)}$	Delay time, EDIO (out) valid after EDCLK low (start condition hold time for EEPROM)	4		µs
$t_{w(L)}$	Pulse duration, EDCLK low	4.7		µs
$t_{w(H)}$	Pulse duration, EDCLK high	4		µs
$t_{d(EDCLKH-EDIOV)}$	Delay time, EDCLK high to EDIO valid (start condition setup time)	4.7		µs
$t_{d(EDCLKL-EDIOX)}$	Delay time, EDCLK low to EDIO (out) changing (data out hold time)	0		µs
$t_{d(EDIOV-EDCLKH)}$	Delay time, EDIO (out) valid to EDCLK high (data out setup time)	250		ns
t_r	Rise time, EDIO (out) and EDCLK		1	µs
t_f	Fall time, EDIO and EDCLK		300	ns
$t_{d(EDCLKH-EDIOH)}$	Delay time, EDCLK high to EDIO (out) high (stop condition setup time)	4.7		µs
$t_{d(EDCLKL-EDIOX)}$	Delay time, EDCLK low to EDIO (in) changing (data in hold time)	300		ns

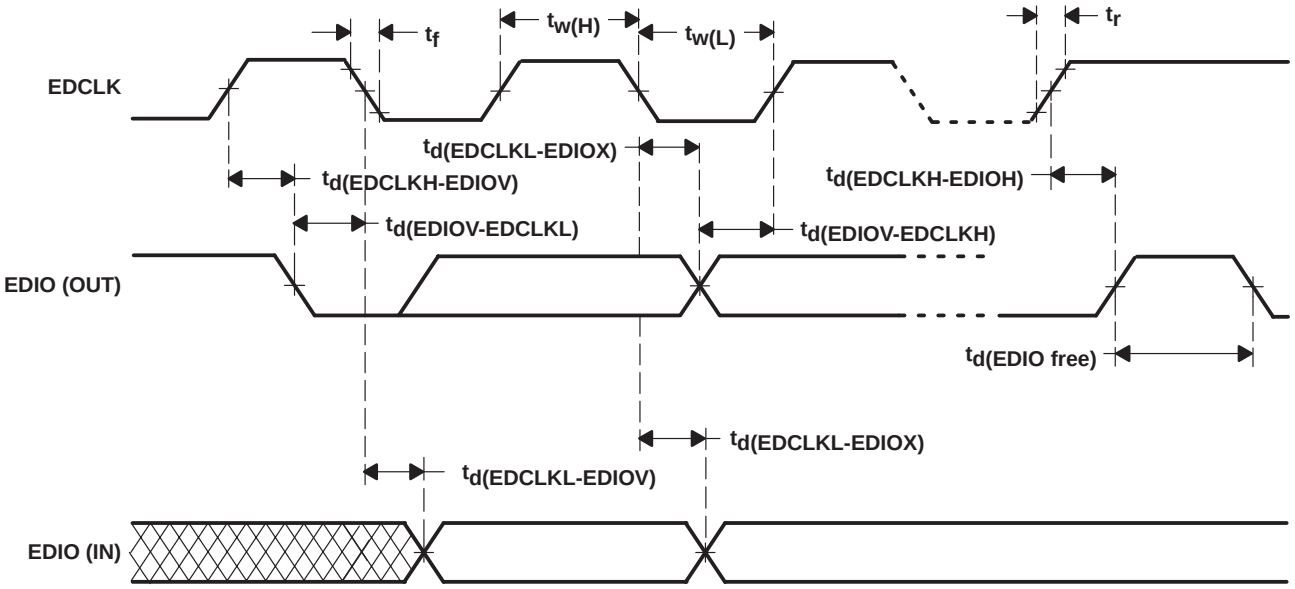


Figure 8. Configuration EEPROM Interface Timing

timing requirements of crystal oscillator (see Figure 9)†

		MIN	TYP	MAX	UNIT
$t_{d(VDDH-FXTL1V)}$	Delay time, minimum V_{DD} high level to first valid FXTL1 full swing period (see Note 21)			100	ms
$t_{w(H)}$	Pulse duration, FXTL1 high	13			ns
$t_{w(L)}$	Pulse duration, FXTL1 low	13			ns
t_t	Transition time, FXTL1		7		ns
t_c	Cycle time, FXTL1		50		ns
	Tolerance of FXTL1 input frequency		±0.01		%

† The FXTL signal can be implemented by either connecting a 20-MHz crystal using the FXTL1 and FXTL2 pins or by driving the FXTL1 from a 20-MHz crystal oscillator module.

NOTE 21: This specification is provided as an aid to board design. This specification is not assured during manufacturing testing.

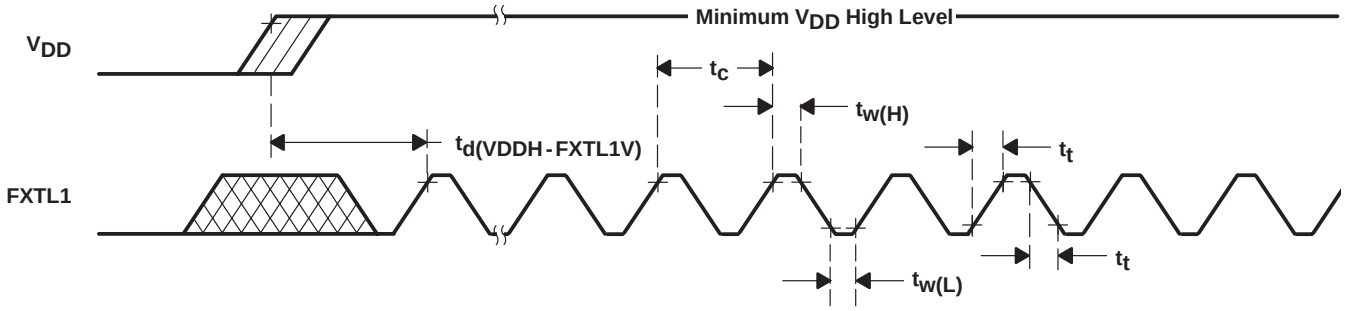
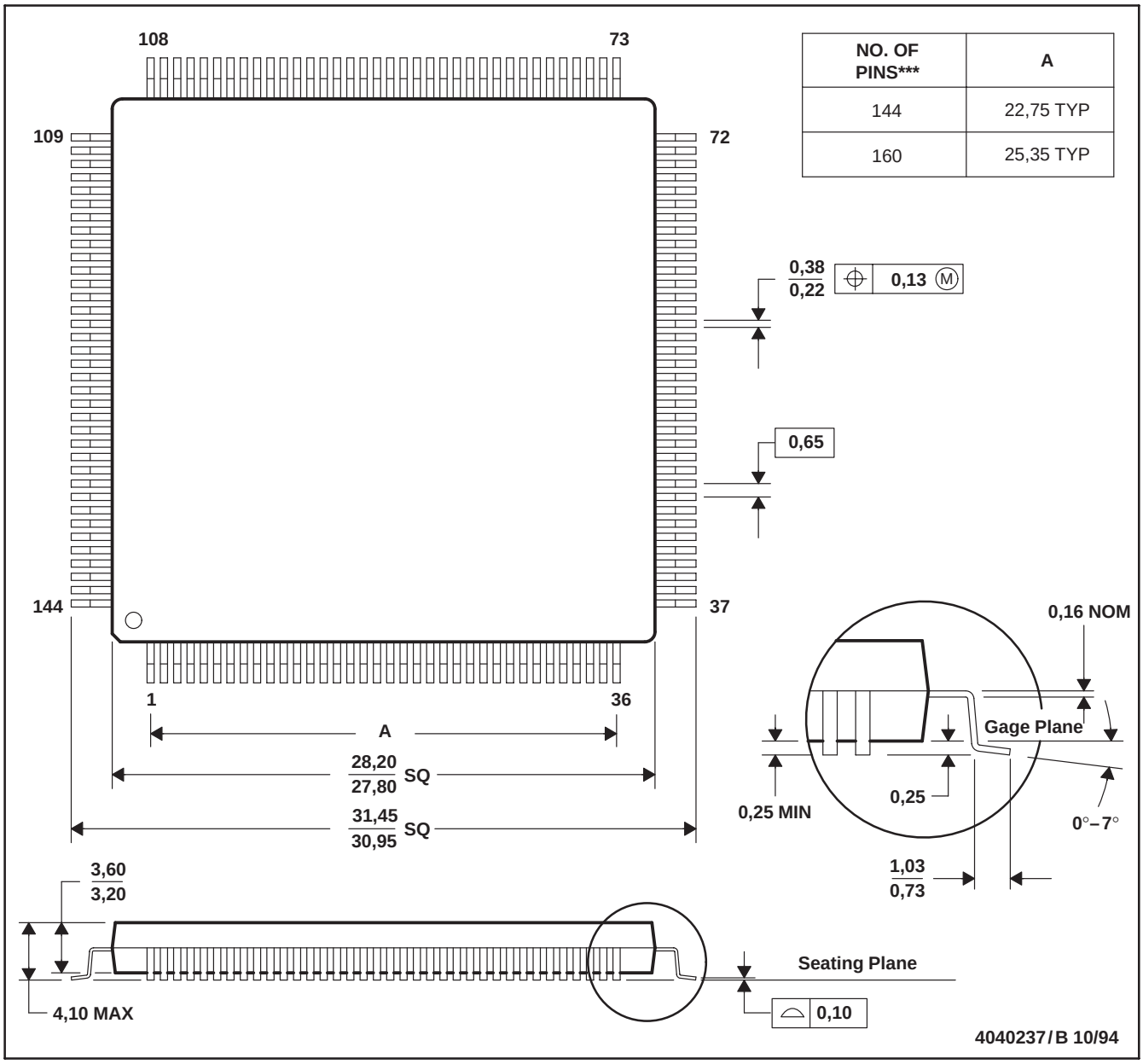


Figure 9. Crystal Oscillator Timing

MECHANICAL DATA

PCE (S-PQFP-G*)** **PLASTIC QUAD FLATPACK**

144 PIN SHOWN



NO. OF PINS***	A
144	22,75 TYP
160	25,35 TYP

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Thermally enhanced molded plastic package with a heat spreader (HSP)
D. Falls within JEDEC MS-022
E. The 144 PCE is identical to the 160 PCE except that four leads per corner are removed.

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