- **Single-Chip Multi-PHY Solution:**
  - **Four 10BASE-T Physical-Layer (PHY) Interfaces in One Package Minimizing PCB Footprint for Internetworking Applications**
- **Each PHY is Half-Duplex and Full-Duplex Compliant**
  - **Full-Duplex: Independent Transmit and Receive Channels for Operation at 20-Mbit/s Aggregate**
- **Compliant With IEEE Std 802.3 10BASE-T Specification**
- **Management Data Input/Output (MDIO) Serial Compliant With IEEE Std 802.3 Media-Independent Interface (MII)**
- **Integrated Filters on Both Receive and Transmit Circuits**
  - **No External Filters Are Required**
  - **Meets IEEE Std 802.3 (Section 14.3) Electrical Requirements**
- **Implements IEEE Std 802.3u Auto-Negotiation to Establish the Highest Common Protocol**
- **DSP-Based Digital Phase-Locked Loop (PLL)**
- **Interrupt Feature on MDIO**
- **Loopback Mode for Test Operations**
- **Integrated Manchester Encoding/Decoding**
- **Receive-Clock Regeneration for All Input Channels**
- **Smart Squelch**
- **Transmit Pulse Shaping**
- **Collision Detection**
- **Jabber Detection**
- **Link-Pulse Detection**
- **Auto-Polarity Control**
- **Simple Connection for LED Status Indicators**
- **Sufficient Current Drive to Directly Connect LED Status Indicators**
- **CMOS Technology Enables Low Power Consumption**
- **Power-Down Mode**
- **IEEE Std 1149.1 (JTAG)† Test-Access Port (TAP)**
- **Each Serial Network Interface (SNI) Signal Is User Programmable**
- **Package Options Include 120-Pin Plastic Quad Flat Package (PBE) and 128-Pin Plastic Quad Flat Package (PAC)**

description

The TNETE2004 QuadPHY interface device is a single-chip, multi-PHY (four 10BASE-T devices), high-performance solution for designers of 10BASE-T networking systems. The highly integrated TNETE2004 includes a user-programmable SNI signal for each PHY. Each PHY interface on the device provides Manchester encoding/decoding of data via unshielded twisted-pair (UTP) balanced cable through simple isolation transformers requiring no external filtering. Additional TNETE2004 features are smart squelch, jabber detection, auto-polarity correction, transmission wave shaping, and anti-alias filtering capabilities. Each PHY interface on the TNETE2004 is individually addressable within the TNETE2004 via the MDIO.

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.

† IEEE Std 1149.1-1990, IEEE Standard Test-Access Port and Boundary-Scan Architecture

description (continued)

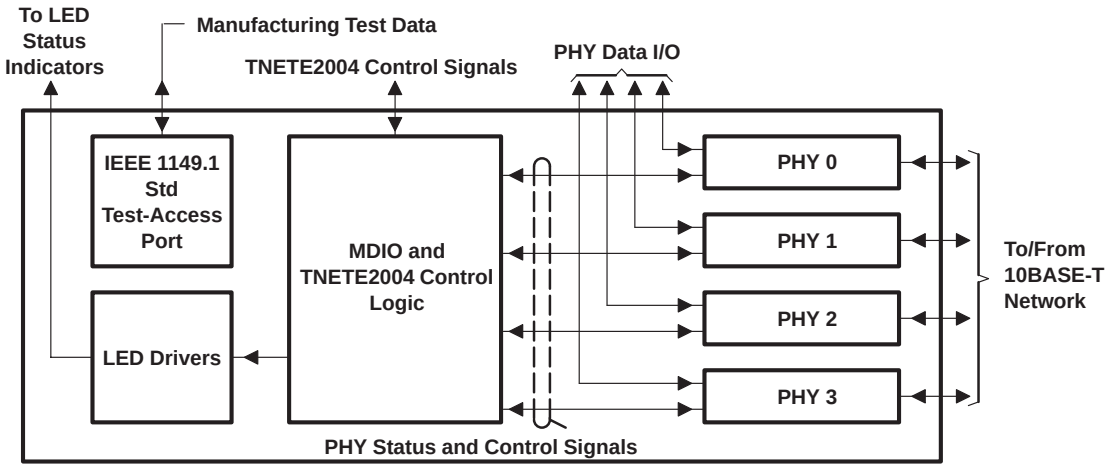


Figure 1. TNETE2004 Architecture

The TNETE2004 provides PHY-interface functions for up to four 10BASE-T half- or full-duplex ports as shown in Figure 1. The TNETE2004 contains four independent 10BASE-T transceivers in a single chip. Each transceiver is compliant with IEEE Std 802.3, Section 14, and a compliant management serial-interface port provides information for network management.

A typical application with external components is shown in Figure 2.

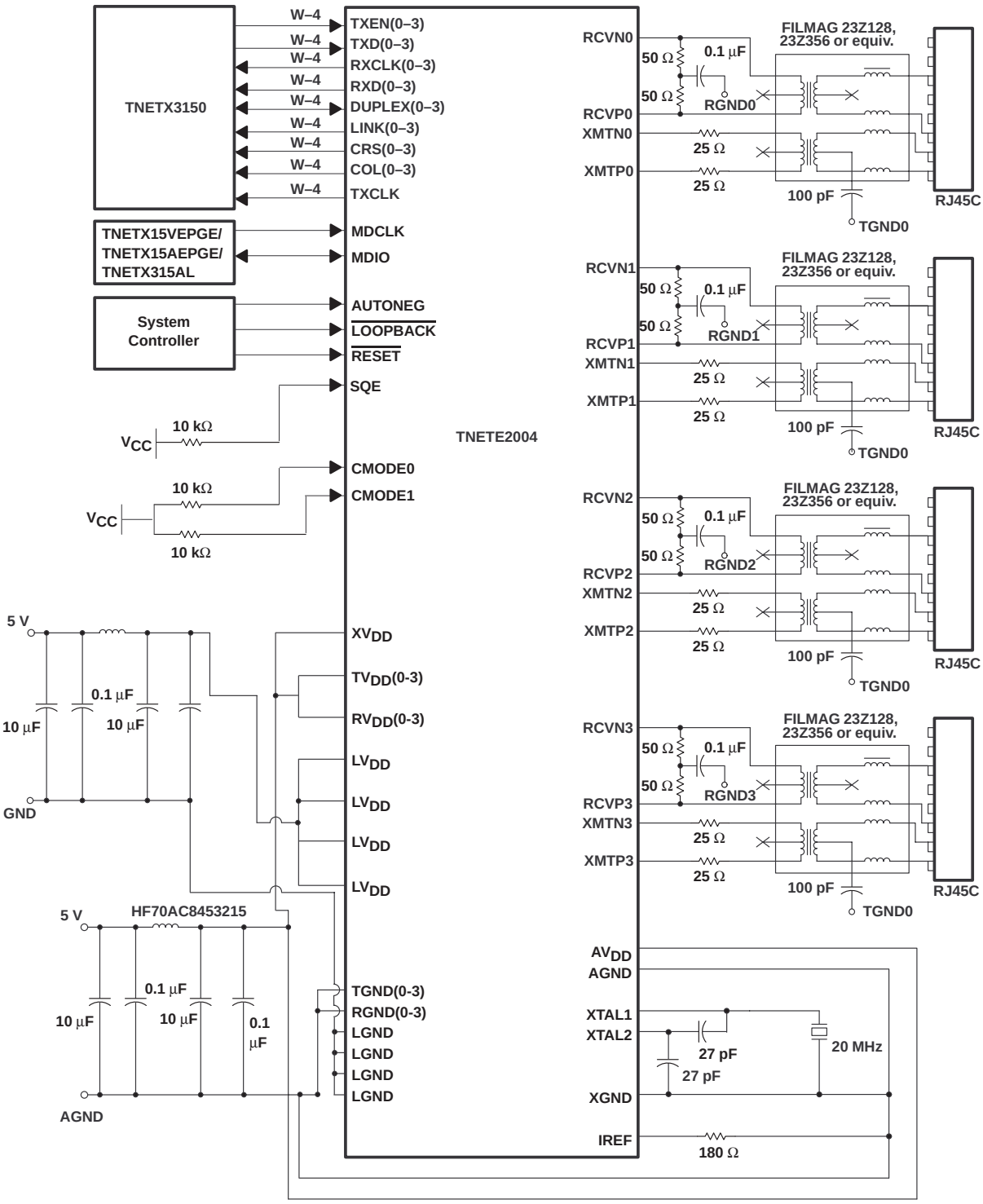
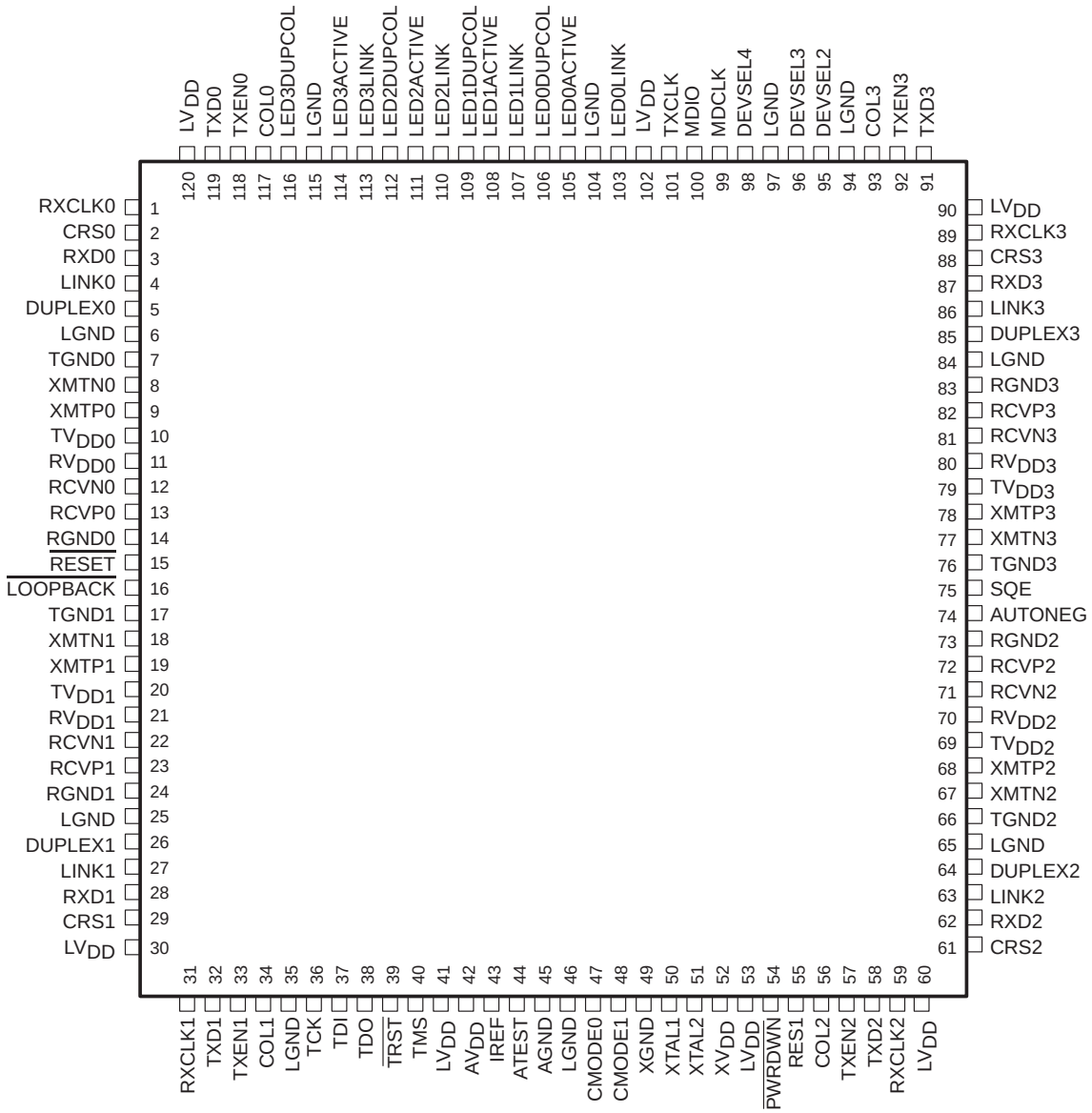


Figure 2. External Components for the TNETE2004

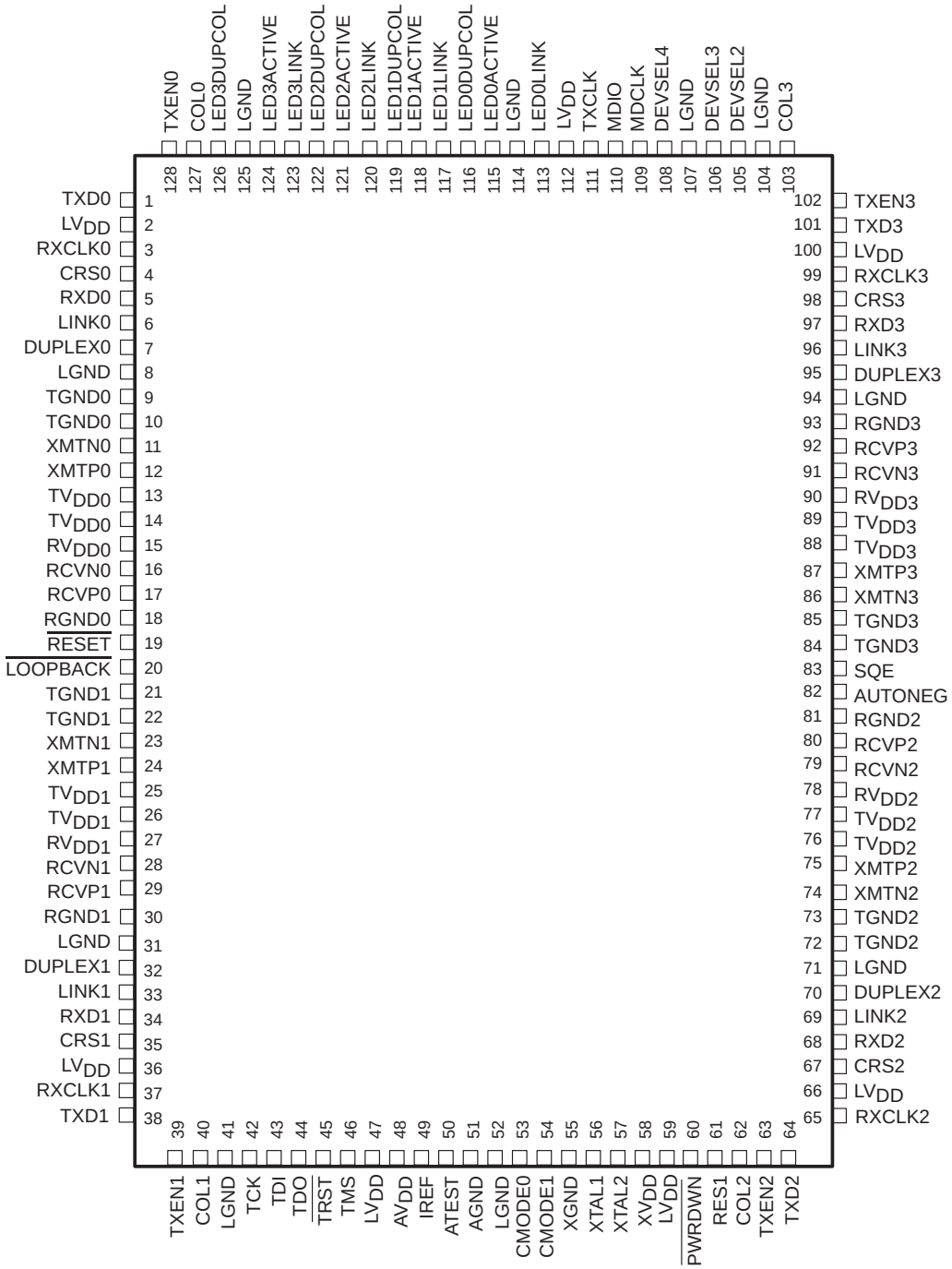
pin assignments

TNETE2004 power supplies are identified according to the section of the device they supply. All power supplies are labeled V_{DD} or V_{SS}, and each has a single-letter prefix indicating which circuit of the device they supply. L indicates a supply for control logic, R is for receiver circuits, T is for transmitter circuits, and A is for analog circuits. Each PHY-specific signal has a suffix, which is the number of the PHY, for example, carrier sense (CRS0), CRS1, and so on. If a signal name does not include a suffix, it is applicable to all PHYs.

PBE PACKAGE
(TOP VIEW)



PAC PACKAGE
(TOP VIEW)



Terminal Functions

controller interface

TERMINAL NAME	TERMINAL NO. 120	TERMINAL NO. 128	I/O†	DESCRIPTION
AUTONEG	74	82	I	Auto-negotiation. When high, AUTONEG enables auto-negotiation on all four PHYs. Auto-negotiation takes place only after a reset or when a link is reestablished. AUTONEG can be overridden from the MDI.
COL0 COL1 COL2 COL3	117 34 56 93	127 40 62 103	O	Collision sense. When asserted, COL0–COL3 indicates that PHY0–PHY3 sensed a network collision. The active level is set by the compatibility pins (see Table 2) or by setting the correct bits in pin-polarity register 0x16 (see Figure 17). Functions are described in Table 13.
CRS0 CRS1 CRS2 CRS3	2 29 61 88	4 35 67 98	O	Carrier sense. When asserted, CRS0–CRS3 indicates that PHY0–PHY3 is receiving a frame carrier signal. The active level is set by the compatibility pins (see Table 2) or by setting the correct bits in pin-polarity register 0x16 (see Figure 17). Functions are described in Table 13.
DUPLEX0 DUPLEX1 DUPLEX2 DUPLEX3	5 26 64 85	7 32 70 95	O/D	Duplex mode. When DUPLEX0–DUPLEX3 is high, PHY0–PHY3 operates in full-duplex mode. When DUPLEX0–DUPLEX3 is low, PHY0–PHY3 operates in the half-duplex mode. There is an internal weak drive on DUPLEX0–DUPLEX3 that pulls DUPLEX0–DUPLEX3 if auto-negotiation chooses the full-duplex mode, or if full duplex is chosen by writing to an MDI register. By connecting DUPLEX0–DUPLEX3 GND or V_{DD}, this weak drive is overridden, and the type of duplex mode is permanently set, ignoring any auto-negotiation decisions or values written to the appropriate MDI registers. To set duplex mode, connect the auto-negotiation pin low. (This turns off auto-negotiation.)
LINK0 LINK1 LINK2 LINK3	4 27 63 86	6 33 69 96	O	Link status. When LINK0–LINK3 is high, it indicates that PHY0–PHY3 has determined that a valid 10BASE-T link has been established. When low, LINK0–LINK3 indicates that the link has not been established.
$\overline{\text{LOOPBACK}}$	16	20	I	Loopback. When low, $\overline{\text{LOOPBACK}}$ enables internal loopback in all four PHYs. When asserted, data is internally wrapped within each PHY and does not appear on the network. While in the looped-back state, all network lines are placed in a noncontentious state. $\overline{\text{LOOPBACK}}$ can be overridden by the MDI registers.
RXCLK0 RXCLK1 RXCLK2 RXCLK3	1 31 59 89	3 37 65 99	O	Receive clock. Receive clock source for the receive data output RXD0–RXD3. Data is valid on RXD0–RXD3 on the edges of RXCLK0–RXCLK3 specified by the currently set compatibility mode (see Table 2) or by setting the correct bits in pin-polarity register 0x16 (see Figure 17). Functions are described in Table 13.
RXD0 RXD1 RXD2 RXD3	3 28 62 87	5 34 68 97	O	Receive data. Bit-wise serial-data output from PHY0–PHY3.
SQE	75	83	I	Signal quality error. When high, SQE causes each PHY to simulate a collision condition at the end of each frame transmission to test functionality of the collision-detect circuitry. SQE is overridden by SQEEN (see Table 8). SQE must be set high to interface with the TNETX3150.
TXCLK	101	111	O	Transmit clock. TXCLK is shared by all PHYs to clock in transmit data. Data is valid on TXD0-TDX3 on the edges of TXCLK specified by the currently set compatibility mode (see Table 2) or by setting the correct bits in pin-polarity register 0x16 (see Figure 17). Functions are described in Table 13.
TXD0 TXD1 TXD2 TXD3	119 32 58 91	1 38 64 101	I	Transmit data. Serial-data input to PHY0–PHY3.
TXEN0 TXEN1 TXEN2 TXEN3	118 33 57 92	128 39 63 102	I	Transmit enable. Assert TXEN0–TXEN3 active to indicate that valid transmit data is on TXD0–TXD3. The active level is set by the compatibility pins (see Table 2) or by setting the correct pins in pin-polarity register 0x16 (see Figure 17). Functions are described in Table 13.

† I = input, O = output, O/D = open-drain output

Terminal Functions (Continued)

miscellaneous interface

TERMINAL NAME	TERMINAL NO. 120	TERMINAL NO. 128	TYPE†	DESCRIPTION
ATEST	44	50	A	Analog test pin. ATEST provides access to the filter of the reference PLL. When operating correctly, ATEST presents a voltage between 1–2 V.
CMODE0 CMODE1	47 48	53 54	I	Compatibility mode. Eases compatibility with third-party media-access controllers (MACs) (see Table 2).
DEVSEL2 DEVSEL3 DEVSEL4	95 96 98	105 106 108	I	Device select. DEVSEL2–DEVSEL4 specifies the three most-significant bits of a 5-bit number used to address a PHY on the management-data interface. The two least-significant bits are set as 00, 01, 10, and 11 for PHY0–PHY3, respectively.
IREF	43	49	A	Current reference. Used to set a current reference for the analog circuitry. IREF must be connected to ground by a 180 ± 5-Ω resistor.
MDCLK	99	109	I	Management-data clock. MDCLK is used to clock data in and out of the MDIO port.
MDIO	100	110	I/O	Management-data I/O. MDIO is the serial management-data interface.
$\overline{\text{PWRDWN}}$	54	60	I	Power down. When asserted, $\overline{\text{PWRDWN}}$ places all four PHYs in the lower power state. Transmitting and receiving are inhibited in this state.
RES1	55	61	O	Reserved
$\overline{\text{RESET}}$	15	19	I	Global reset. $\overline{\text{RESET}}$ is used to reset all four PHY sections.
XTAL1	50	56	A	Crystal oscillator pins. Connect a 20-MHz crystal across XTAL1 and GND, or drive XTAL1 from a 20-MHz crystal-oscillator module.
XTAL2	51	57	A	Connect a 27-pF capacitor across XTAL2 and XTAL1 and connect a 27-pF capacitor between XTAL2 and GND. If a crystal-oscillator module is used, do not connect anything to XTAL2.

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

JTAG interface

TERMINAL NAME	TERMINAL NO. 120	TERMINAL NO. 128	I/O‡	DESCRIPTION
TCK	36	42	I	Test clock. TCK is used to clock state information and test data into and out of the device during operation of the JTAG.
TDI	37	43	I	Test data input. TDI is used to serially shift test data and test instructions into the device during operation of the JTAG.
TDO	38	44	O	Test data output. TDO is used to serially shift test data and test instructions out of the device during operation of the JTAG.
TMS	40	46	I	Test mode select. TMS controls the operating state of the JTAG.
$\overline{\text{TRST}}$	39	45	I	Test reset. $\overline{\text{TRST}}$ is used for asynchronous reset of the JTAG controller.

‡ I = input, O = output

Terminal Functions (Continued)

LED interface

TERMINAL NAME	TERMINAL NO. 120	TERMINAL NO. 128	I/O†	DESCRIPTION
LED0ACTIVE LED1ACTIVE LED2ACTIVE LED3ACTIVE	105 108 111 114	115 118 121 124	O	LED activity indicator. The LED activity indicator is driven low for 20 ms when PHY0–PHY3 receives or transmits. LED0ACTIVE–LED3ACTIVE can sink a 10-mA current. If it receives or transmits another packet during that 20 ms, the LED does not flash, but stays on. Therefore, if packets are received or transmitted at intervals faster than 20 ms, the LED stays on continuously.
LED0DUPCOL LED1DUPCOL LED2DUPCOL LED3DUPCOL	106 109 112 116	116 119 122 126	O	LED duplex/collision indicator for PHY0–PHY3. This LED status pin has different meaning when in full- or half-duplex mode. In full-duplex mode, LED0DUPCOL–LED3DUPCOL is continuously driven low. In half-duplex mode, it is driven low for 20 ms after a collision. LED0DUPCOL–LED3DUPCOL can sink a 10-mA current.
LED0LINK LED1LINK LED2LINK LED3LINK	103 107 110 113	113 117 120 123	O	LED link indicator. The LED link indicator is driven low when PHY0–PHY3 has established a valid link. LED0LINK–LED3LINK can sink a 10-mA current.

† O = output

10BASE-T interface

TERMINAL NAME	TERMINAL NO. 120	TERMINAL NO. 128	TYPE‡	DESCRIPTION
XMTN0 XMTN1 XMTN2 XMTN3	8 18 67 77	11 23 74 86	A	Transmit pair. Differential line-transmitter outputs from PHY0–PHY3.
XMTP0 XMTP1 XMTP2 XMTP3	9 19 68 78	12 24 75 87		
RCVN0 RCVN1 RCVN2 RCVN3	12 22 71 81	16 28 79 91	A	Receive pair for PHY0–PHY3. Differential line-receiver inputs connect to receive pair through transformer isolation.
RCVP0 RCVP1 RCVP2 RCVP3	13 23 72 82	17 29 80 92		

‡ A = analog

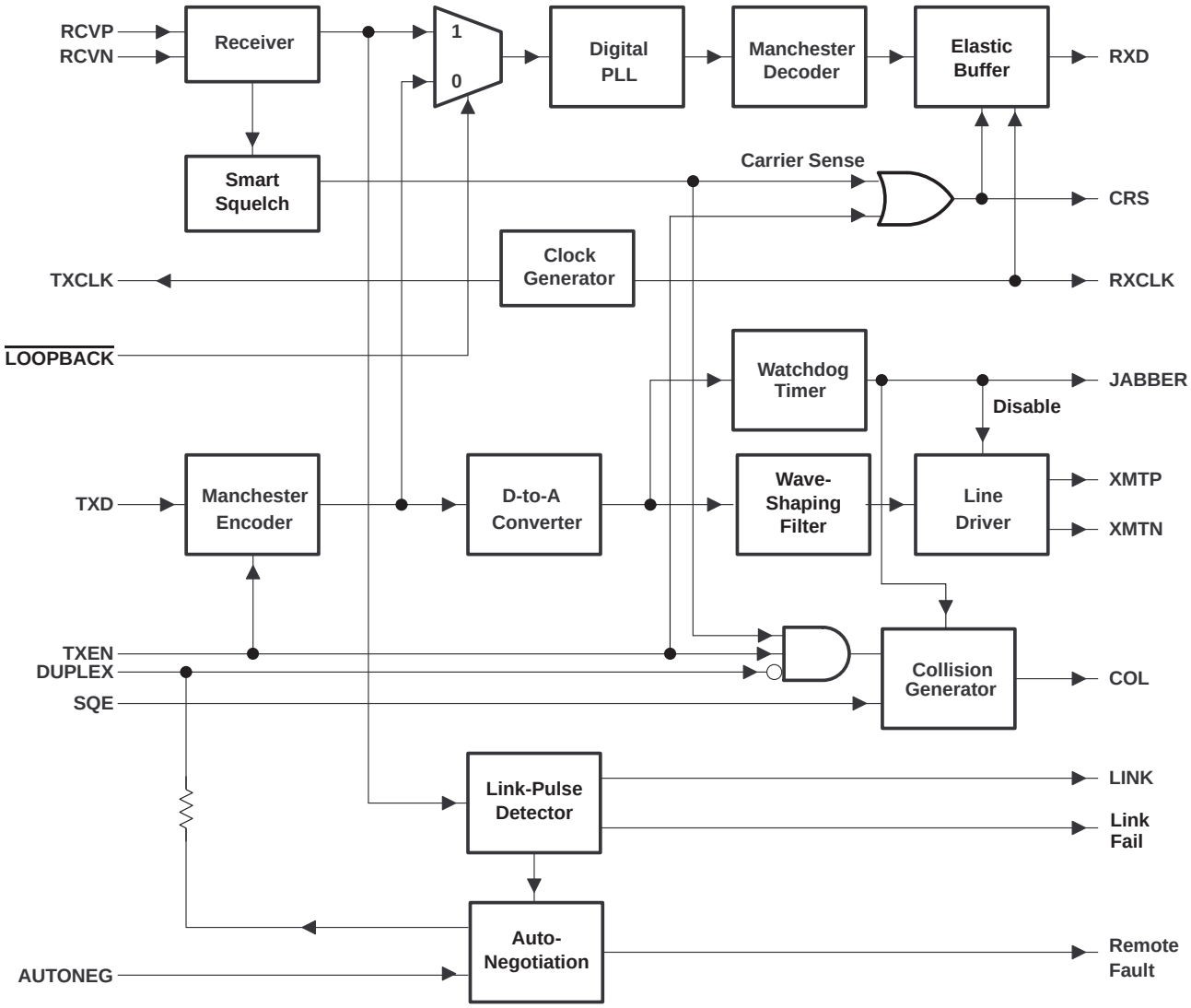
Terminal Functions (Continued)

power interface

NAME	TERMINAL NO. 120	TERMINAL NO. 128	TYPE†	DESCRIPTION
AGND	45	51	GND	Ground pin for analog circuitry
AV_{DD}	42	48	PWR	V_{DD} pin for analog circuitry
LGND	6, 25 35, 46 65, 84 94, 97 104, 115	8, 31 41, 52 71, 94 104, 107 114, 125	GND	Logic ground pin
LV_{DD}	30, 41 53, 60 90, 102 120	36, 47 59, 66 100, 112 2	PWR	Logic V_{DD} pin
RGND0 RGND1 RGND2 RGND3	14 24 73 83	18 30 81 93	GND	Ground pin for receiver circuitry
RV_{DD0} RV_{DD1} RV_{DD2} RV_{DD3}	11 21 70 80	15 27 78 90	PWR	V_{DD} pin for receiver circuitry
TGND0 TGND1 TGND2 TGND3	7 17 66 76	9, 10 21, 22 72, 73 84, 85	GND	Ground pin for transmit circuitry
TV_{DD0} TV_{DD1} TV_{DD2} TV_{DD3}	10 20 69 79	13, 14 25, 26 76, 77 88, 89	PWR	V_{DD} pin for transmit circuitry
XGND	49	55	GND	Ground pin for crystal-oscillator circuitry
XV_{DD}	52	58	PWR	V_{DD} pin for crystal-oscillator circuitry

† GND = ground, PWR = power

functional block diagram



functional description

The TNETE2004 consists of four PHYs, with each PHY having several logical blocks (see the functional block diagram and Table 1).

Table 1. Logical Blocks

LOGICAL BLOCKS	FUNCTION
Transmitter function	Accepts data from the data terminal equipment (DTE) and transmits it onto the network
Receiver function	Receives data from the network and sends it to the DTE
Collision/signal-quality error detection	Indicates to the DTE any collision on the network/transmitter with valid link
Jabber detection	Indicates to the DTE if a packet transmission exceeds 20-ms minimum
Auto-negotiation	Negotiate to establish the highest common protocol
Management-data interface	To allow register-based management operations for each PHY module
Link test	A link pulse is sent to indicate a valid connection.
LED status indicator	Indication for link, activity, and collision
Test port	IEEE Std 1149.1 test-access port and boundary-scan testing
Loopback test mode	Loopback capabilities are provided to allow certain tests to be performed to validate operation of the TNETE2004.
Compatibility modes	Ease connection to third-party MACs

10BASE-T differential line-transmitter function

Each differential line driver of the TNETE2004 drives a balanced, properly terminated twisted-pair transmission line with a characteristic impedance of 85 Ω to 111 Ω (see Figure 2). In the idle state, the driver maintains a minimum differential output voltage, while staying within the required common-mode voltage range.

The driver incorporates an on-chip wave-shaping stage and a high-frequency filtering stage to allow the outputs to be connected directly to isolation transformers through serial termination resistors. No external filters are required.

Serial data for transmission by a PHY is presented to the appropriate transmit data (TXD) input of the TNETE2004. To be valid, data must be synchronized on the appropriate edges of the transmit clock (TXCLK) signal, which depends on the compatibility-mode setting.

Once the transmit-enable (TXEN) pin is deasserted for a PHY, the driver maintains full differential outputs for a minimum of 250 ns, which then begins to decay to minimum differential levels.

The PHY also transmits regular link pulses in compliance with IEEE Std 802.3.

10BASE-T differential line-receiver function

The line-receiver pins of each PHY must be connected to a properly terminated transmission line by an external isolation transformer. The receiver establishes its own common-mode input-bias voltage. Data received from the network is output on RXD of the appropriate PHY and synchronized by the appropriate edges of the corresponding RXCLK signal, which depends on the compatibility-mode setting.

The receiver incorporates a squelch function to pass incoming data. This smart squelch function passes data only if the input amplitude is greater than a minimum signal threshold and if a specific pulse sequence is received. This protects input data from impulse line noise being mistaken for signal or link activity. The squelch circuits quickly deactivate if received pulses exceed the specifications; thus, overly long pulses are not mistaken as link pulses.

Carrier sense (CRS) is driven high while the squelch function is active to indicate that the circuit is allowing data to pass from the twisted pair. CRS is driven low when the squelch circuit is disabling data low.

collision/signal-quality error detection

When not in full-duplex mode, collisions are detected by sensing simultaneous activity on both the transmit and the receive pins. A collision detection is signified by COL on the respective PHY being driven high for the duration of the condition and for a specified time afterwards.

The TNETE2004 device also provides a signal-quality error (SQE) function. This function can be enabled or disabled only for the whole device and not for individual PHYs. When SQE is enabled, following transmission, a simulated collision is presented to a PHY. PHY tests as much of the collision-detect circuitry as possible without affecting the attached twisted-pair channels. Each PHY asserts its COL output signal high for a defined time interval relative to the last positive data edge of its transmit data input. SQE is invoked by driving SQE high or by using the TNETE2004 registers.

jabber detection

Each PHY monitors the length of the packet being transmitted. If a single packet exceeds 20 ms, a jabber condition is detected. The output is disabled, and CRS is driven low. The TNETE2004 device asserts COL, while attempts are made to transmit data, and signals link-fail for the duration of the attempts. The device also asserts COL (for half-duplex mode only) when it has detected that the transmitter has entered jabber mode. To clear the jabber function, transmission must cease for a minimum of 500 ms.

auto-negotiation

Each PHY on the device is capable of auto-negotiation as defined in IEEE Std 802.3. When enabled, this feature allows a PHY to negotiate with another PHY on the link to establish their highest common protocol. Until a PHY has completed its negotiation, it cannot assert LINK.

The only two protocols possible for the TNETE2004 are half- or full-duplex 10BASE-T. When auto-negotiation indicates that full-duplex operation is possible, a weak pullup resistor is applied to DUPLEX on the device, allowing full-duplex operation, unless the pin is pulled low externally.

link-partner register

This register contains the information for the link partner. Refer to Table 6 for the link partner's ability-register bit functions.

expansion register

Refer to Table 7 for the bit definition on the expansion register.

next_page transmit

After exchanging the base page, which contains the information to make connection automatically, if both ends of the link indicate support for the next_page function, additional data can be exchanged. This allows extensions to the standard and proprietary extensions to exist without affecting interoperability. Refer to Figure 11 for the next_page transmit register.

management-data interface

The TNETE2004 incorporates a management-data interface to allow register-based management operations for each PHY module. Operation of the TNETE2004 is possible without use of the management-data interface, since all the signals necessary for complete functionality are accessible by way of the device pins; however, some additional features are accessible only through the management-data interface.

interrupt enable cycle

The TNETE2004 can generate interrupts via the MDIO interface after the quiescent cycle. The quiescent cycle is the cycle following the data transfer in which neither the external MAC nor the PHYs drive MDIO. The TNETE2004 indicates to the host that an interrupt is pending by driving MDIO low. This happens one clock cycle after the quiescent cycle, while MDCLK is high. When MDCLK goes low, TNETE2004 stops driving MDIO so the host can determine what caused the interrupt.

link test

When not in auto-negotiation mode, the PHY sends link pulses, separated by an interval of 16 ms, on the data-out (DO) circuit. The receiver looks for valid link pulses on the input pair. If a link pulse is not received within a given time interval, the device enters a link-fail state. In this state, link pulses continue to be generated, and the receiver constantly looks for the link-pulse pattern. The device remains in this state until a valid receive packet or multiple legal link-test pulses are received.

loopback test mode

By asserting the $\overline{\text{LOOPBACK}}$ pin on the device or by setting the LOOPBACK bit in the PHY generic control register, the transmit circuit of each PHY is looped to the corresponding receive circuit closest to the twisted-pair I/O pins. Thereafter, transmit drivers do not forward any further packet data but continue to send link-test pulses.

When accessing loopback test mode from the package pins, since there is only one $\overline{\text{LOOPBACK}}$ pin on the package, all four PHYs are placed in LOOPBACK mode simultaneously. Individual PHYs can be placed in LOOPBACK mode by means of the TNETE2004 registers. While in LOOPBACK mode, all receive activities, other than link-test pulses, are ignored. However, squelch information is still processed, allowing the link status to be maintained under momentary loopback self-test.

LED status indication

The TNETE2004 has 12 pins that drive LEDs. Each PHY has the following three status LEDs:

Note: The LEDs are all off when reset is active. Once reset is inactive, all the LEDs turn on for 100ms, then turn off, and then function in the normal way. The following signals are active low.

LEDxLINK – illuminates when PHYx has established a valid link

LEDxACTIVE – illuminates when PHYx is transmitting or receiving data. This LED illuminates for a minimum duration of 20 ms for each activity, but if packets are being received or transmitted faster than 20 ms, it stays on continuously.

LEDxDUPCOL – illuminates continuously when PHYx is in full-duplex mode. Illuminates for a minimum duration of 20 ms when collisions occur in half-duplex mode. Additionally, in half-duplex mode, LED0DUPCOL–LED3DUPCOL flashes when a jabber condition is detected. This feature is not available in full-duplex mode.

IEEE Std 1149.1 (JTAG) test port

Compliant with the IEEE Std 1149.1, the test-access port is composed of five pins. These pins interface serially with the device and the board on which the device is installed for boundary-scan testing. The TNETE2004 implements the following JTAG instructions:

000	EXTEST	External boundary-scan test
001	SAMPLE/PRELOAD	Initialization for boundary-scan test
100	IDCODE	Scans out TNETE2004 identification code
101	HIGHZ	Sets all digital output pins on the TNETE2004 to high impedance
111	BYPASS	Connects 1-bit bypass register between TDI and TDO

autopolarity

The TNETE2004 can sense and detect reversed polarity of its receiver inputs (e.g., due to incorrect cable wiring). If, at any time, seven consecutive inverted link pulses are detected, then reversed polarity is assumed and flagged by the POLOK bit in the TNETE2004_sts register (see Table 9). If automatic polarity correction is selected by the SWAPPOLEN bit in the TNETE2004_ctl register (see Table 8), the TNETE2004 swaps its RCVP and RCVN input for the affected PHY. Once a single correct link pulse is received, good polarity is assumed, and the POLOK bit is set.

Automatic polarity correction is enabled by default after power on or reset. The polarity detect circuit must see link pulses to detect the polarity of the receive pair, so, in instances of high network activity where link pulses are sparse, there may be a slight delay before the correct polarity is established.

compatibility modes

To ease connection to third-party MACs, the TNETE2004 provides options to reverse the polarity of some device pins. The compatibility mode is selected by the CMODE0 and CMODE1 pins, as defined in Table 2. The TNETE2004 can be programmed through the MDIO to change the polarity of each SNI (like COL or RXCLK, etc.) signal. Refer to Table 13 for more details on this function.

Table 2. Compatibility Mode Options

CMODE	PIN SIGNIFICANCE
Mode 1: CMODE0 = Low CMODE1 = Low	CRS high to indicate carrier detected COL high to indicate collision TXEN high to indicate valid data on TXD Data on RXD valid on rising edge of RXCLK Data on TXD valid on rising edge of TXCLK RXD high when no data is being received RXCLK is continuously running.
Mode 2: CMODE0 = High CMODE1 = Low	CRS low to indicate carrier detected COL low to indicate collision TXEN low to indicate valid data on TXD Data on RXD valid on falling edge of RXCLK Data on TXD valid on falling edge of TXCLK RXD high when no data is being received RXCLK runs for seven clocks after CRS is high, then it stays high.
Mode 3: CMODE0 = Low CMODE1 = High	CRS high to indicate carrier detected COL low to indicate collision TXEN high to indicate valid data on TXD Data on RXD valid on falling edge of RXCLK Data on TXD valid on falling edge of TXCLK RXD low when no data is being received RXCLK runs for seven clocks after CRS is low, then it stays high.
Mode 4: CMODE0 = High CMODE1 = High	CRS high to indicate carrier detected COL high to indicate collision TXEN high to indicate valid data on TXD Data on RXD valid on rising edge of RXCLK Data on TXD valid on rising edge of TXCLK RXD low when no data is being received RXCLK is continuously running.

TNETE2004 registers

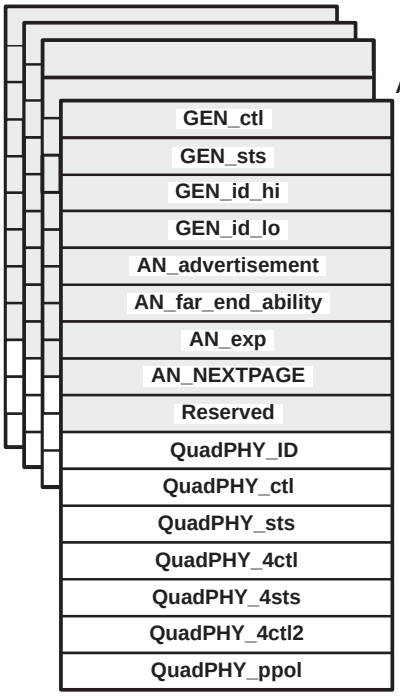
The TNETE2004 incorporates management-data interface to allow register-based management operations for each PHY module. Normal operation of the TNETE2004 is possible without use of management-data interface since all the essential signals for operation are accessible through the device pins; however, some additional features are accessible only through the management-data interface. If management-data interface is not being used, DEVSEL, MDCLK, and MDIO all can be tied low.

Some features are controllable by both pins and registers. A feature is controlled by the pin until a write operation is performed on the register controlling the feature. From then until the device is reset, the value on the pin is ignored.

The TNETE2004 registers are accessible through the Mll-management interface. The IEEE Std 802.3 Mll serial protocol allows for up to 32 different PHYs, with up to 32 (16-bit-wide) internal registers in each device.

The TNETE2004 implements 11 registers (three of which are hardwired) on each PHY and three additional overview registers that allow software drivers to access all four PHYs in a single operation. User programming of the SNI is implemented through the pin-polarity register. These all-PHY registers are mapped into the addressing space on PHY0.

Figure 3 shows the TNETE2004 device register map. The registers, shown shaded, are the generic registers mandated by the Mll specification. The unshaded registers are TI-specific registers.



	Address	Register
GEN_ctl	0x00	PHY Generic Control Register (see Figure 6, Table 3)
GEN_sts	0x01	PHY Generic Status Register (see Figure 7, Table 4)
GEN_id_hi	0x02	PHY Generic Identifier (high), hardwired 0x4000
GEN_id_lo	0x03	PHY Generic Identifier (low), hardwired 0x5051
AN_advertisement	0x04	Auto-Negotiation Advertisement (see Figure 8, Table 5)
AN_far_end_ability	0x05	Auto-Negotiation Link-Partner Ability (see Figure 9, Table 6)
AN_exp	0x06	Auto-Negotiation Expansion (see Figure 10, Table 7)
AN_NEXTPAGE	0x07	Auto-Negotiation Next-Page Transmit (see Figure 11)
Reserved	0x08 to 0x0f	Reserved by IEEE Std 802.3
QuadPHY_ID	0x10	TNETE2004 Identification, Hardwired
QuadPHY_ctl	0x11	TNETE2004 Control Register (see Figure 12, Table 8)
QuadPHY_sts	0x12	TNETE2004 Status Register (see Figure 13, Table 9)
QuadPHY_4ctl	0x13	TNETE2004 Nibble-Based Control Register, Overview (see Figure 14, Table 10)
QuadPHY_4sts	0x14	TNETE2004 Nibble-Based Status Register, Overview (see Figure 15, Table 11)
QuadPHY_4ctl2	0x15	TNETE2004 Nibble-Based Control Register 2, Overview (see Figure 16, Table 12)
QuadPHY_ppol	0x16	TNETE2004 Pin-Polarity Register (see Figure 17, Table 13)

Figure 3. TNETE2004 Registers

The default or IDLE state of the two-wire Mll is a logic 1. All 3-state drivers are disabled, and the TNETE2004 pullup resistor pulls the MDIO line to a logic 1. Before initiating any other transaction, the station management entity sends a sequence of 32 contiguous logic 1 bits on MDIO and 32 corresponding contiguous logic 1 bits on MDCLK. This sequence provides the TNETE2004 with a pattern that it can use to establish synchronization. The TNETE2004 responds to no other transactions until it recognizes a sequence of 32 contiguous logic 1 bits on MDIO with 32 contiguous logic 1 bits on MDCLK.

Frame format of the generic registers is in accordance with Mll specifications as shown in Figures 4 and 5.

Start Delimiter	Operation Code	PHY Address	Register Address	Turnaround	Data
01	10	AAAAA	RRRRR	Z0	DDDD.DDDD.DDDD.DDDD

Figure 4. MII Frame Format: Reads

Start Delimiter	Operation Code	PHY Address	Register Address	Turnaround	Data
01	01	AAAAA	RRRRR	10	DDDD.DDDD.DDDD.DDDD

Figure 5. MII Frame Format: Writes

start delimiter

The start of a frame is indicated by a 01 pattern. This pattern ensures transitions from the default logic 1 line state to 0 and back to 1.

operation code

The operation code for a read is 10, while the code for a write is 01.

PHY address

The PHY address is five bits wide, which allows 32 unique PHY addresses. The first PHY address bit transmitted and received is the most-significant bit (MSB) of the address. The two least-significant bits (LSBs) represent the PHY number within the package. The upper three bits for each internal PHY are read from the DEVSEL pins.

register address

The register address is five bits wide, allowing 32 individual registers to be addressed within each PHY. Refer to the address maps (Figures 4 and 5) for the addresses of individual registers.

turn around

An idle-bit time, during which no device actively drives the MDIO signal, must be inserted between the register address field and the data field of a read frame, to avoid contention. During a read frame, the PHY drives a 0 bit onto MDIO for the bit time following the idle bit and preceding the data field. During a write frame, this field must consist of a 1 bit followed by a 0 bit.

data

The data field is composed of 16 bits. The first data bit transmitted and received is the MSB of the data payload.

PHY generic control register – GEN_ctl at 0x0

BYTE 1								BYTE 0							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RESET	LOOPBACK	0	ANENABLE	PDOWN	ISOLATE	ANRESTART	DUPLEX	COLTEST	RESERVED						

Figure 6. PHY Generic Control Register

Table 3. PHY Generic Control Register Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†	DEFAULT
15	RESET‡	Reset a PHY. Writing a 1 RESET resets the whole device, and all registers revert to their default values. RESET is self clearing. It is always read as 0. It is not possible to reset one PHY separately from the others. Operation of the device is not ensured for a duration of 50 ms after a software reset.	R/W	0
14	LOOPBACK	Internal loopback mode. LOOPBACK enables the internal loopback within the individual PHY. When LOOPBACK is set to 1, data is wrapped internally within the PHY and does not appear on the network. Collision detection is disabled, and data transmitted appears at the receive pins. While in loopback mode, the device pins are placed in noncontentious states.	R/W	Pin
13		Reserved	RO	0
12	ANENABLE	Auto-negotiation enable. When set, ANENABLE allows auto-negotiation to take place.	R/W	Pin
11	PDOWN	Power-down mode. When set, PDOWN places the PHY in a power-down mode. In this mode, it is not possible to receive or transmit data, although it is possible to continue to process management-data frames. IEEE Std 802.3 states that the PHY must be allowed 500 ms of initialization time after it is taken out of power-down state before data transmission and reception can be started. See Note 1.	R/W	0
10	ISOLATE	PHY pin isolation. When set, the PHY electrically isolates itself from the pins. In the ISOLATE state, the PHY does not respond to TXD or TXEN but presents a high impedance on RXD, RXCLK, and COL. However, it still responds to MII data frames.	R/W	0
9	ANRESTART	Auto-negotiation restart. Setting ANRST causes auto-negotiation to be restarted.	R/W	0
8	DUPLEX	Full-duplex mode select. Setting DUPLEX forces this PHY into full-duplex mode. Resetting it forces half-duplex. For DUPLEX to have any effect, the DUPLEX pin on the package must not be driven externally.	R/W	Pin
7	COLTEST	Collision-test enable. Setting COLTEST causes this PHY to assert COL when TXEN is asserted.	R/W	0
6–0	RESERVED	Reserved		0

† RO = read only, R/W = read/write
‡ This bit is set for the TNETE2004, not for each PHY.
NOTE 1: If all four PHYs are in power-down mode simultaneously, then reset must be used to power up the device. It is not possible to power up an individual PHY if all four PHYs are in power-down mode.

PHY generic status register – GEN_sts at 0x1

BYTE 1										BYTE 0					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	1	1	RESERVED					ACOMPLETE	RFAULT	1	LINK	JABBER	1

Figure 7. PHY Generic Status Register

Table 4. PHY Generic Status Register Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15		100Base-T4 capable. Not supported, read as 0	RO
14		100Base-T4 full-duplex capable. Not supported, read as 0	RO
13		100Base-T4 half-duplex capable. Not supported, read as 0	RO
12		10BASE-TX full-duplex capable. Supported, read as 1	RO
11		10BASE-TX half-duplex capable. Supported, read as 1	RO
10–6	RESERVED	Reserved. Read as 0.	RO
5	ACOMPLETE	Auto-negotiation complete. When set, ACOMPLETE indicates that auto-negotiation has been completed.	RO
4	RFAULT	Remote fault detected. When set, RFAULT indicates that the link partner has indicated a fault condition by way of auto-negotiation.	RO
3		Auto-negotiation capable. Set to indicate this PHY is capable of auto-negotiation	RO
2	LINK	Link status. When set, LINK indicates that the PHY is receiving valid link pulses.	RO
1	JABBER	Jabber detected. When set, JABBER indicates the PHY has entered jabber mode. JABBER is cleared after a reset or after TXEN is deasserted for 500 ms.	RO
0		Extended capability. This bit is hardwired to 1 to indicate that the PHY supports extensions to the IEEE Std 802.3u.	RO

† RO = read only

PHY generic identifier, GEN_id_hi, and GEN_id_lo at 0x2 and 0x3

These two registers are hardwired to constant values. GEN_id_hi is fixed at 0x4000, and GEN_id_lo is fixed at 0x5051.

auto-negotiation advertisement register at 0x4

BYTE 1											BYTE 0				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NXTPAGE	RESERVED	RFLT	TECHNOLOGY ABILITY FIELD								SELECTOR FIELD				

Figure 8. Auto-Negotiation Advertisement Register

Table 5. Auto-Negotiation Advertisement-Register Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†	DEFAULT
15	NXTPAGE	Auto-negotiation next page. NXTPAGE should be set when there is a next page to transmit. The next page is set by writing to AN_NEXTPAGE.	RO	0
14	RESERVED	Reserved	RO	0
13	RFLT	Remote fault. RFLT enabled indicates to the link partner that there is a fault condition on the TNETE2004. RFLT can be set only by a management entity. This bit does not imply an internal test mode.	R/W	0
12–5	TECHNOLOGY ABILITY FIELD‡	This field indicates the technology abilities advertised to the link partner. Unsupported technologies cannot be transmitted, hence, only two bits have significance. Bit 6: Full-duplex 10BASE-T Bit 5: Half-duplex 10BASE-T All other bits are hardwired to 0.	R/W	Bits 5 and 6 are set to 1, all others are set to 0.
4–0	SELECTOR FIELD	This field specifies the format of the page to be transmitted. This PHY supports only standard IEEE Std 802.3u base pages, so this field is hardwired to 00001.	RO	

† RO = read only, R/W = read/write
‡ After a reset, the PHY attempts to drive the duplex pin. If the pin can be driven high, then bit 6 is set. If the pin can be driven low, then bit 5 is set.

auto-negotiation link-partner ability register at 0x5

This register contains the most recently received link control word from the remote PHY. Writing to this register has no effect. The contents of this register are undefined unless either ACOMPLETE (bit 5, register 1) or PAGERX (bit 1, register 6) are set.

When ACOMPLETE is set, the bits in this register are as described in Table 6.

BYTE 1											BYTE 0				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LPNXTPAGE	RESERVED	LPRFLT	LINK-PARTNER TECHNOLOGY ABILITY FIELD								LINK-PARTNER SELECTOR FIELD				

Figure 9. Auto-Negotiation Link-Partner Ability Register

auto-negotiation link-partner ability register at 0x5 (continued)

Table 6. Auto-Negotiation Link-Partner Ability Register Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15	LPNXTPAGE	Link-partner auto-negotiation next page. LPNXTPAGE indicates that the link partner has another page to send.	RO
14	RESERVED	Reserved	RO
13	LPRFLT	Link-partner remote fault. LPRRFLT indicates that the link partner is reporting a fault condition.	RO
12	RESERVED	Reserved for future abilities. Read as 0.	RO
11	RESERVED	Reserved for future abilities. Read as 0.	RO
10	RESERVED	Reserved for future abilities. Read as 0.	RO
9	100BASE-T4	100Base-T4 is supported by the link partner.	RO
8	100BASE-TXFD	100Base-TX full-duplex is supported by the link partner.	RO
7	100BASE-TXHD	100Base-TX half-duplex is supported by the link partner.	RO
6	10BASE-TFD	10BASE-T full-duplex is supported by the link partner.	RO
5	10BASE-THD	10BASE-T half-duplex is supported by the link partner.	RO
4–0	LINK-PARTNER SELECTOR FIELD	Identifies the format of this register. The IEEE Std 802.3u base page is indicated by code 00001.	RO

† RO = read only

When PAGERX is set, this register contains a direct copy of the next page received. PAGERX is cleared on a read from this register.

auto-negotiation expansion register – AN_exp at 0x6

BYTE 1											BYTE 0				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RESERVED											PARDETFLT	LPNPABLE	NPABLE	PAGERX	LPANABLE

Figure 10. Auto-Negotiation Expansion Register

expansion register

Refer to Table 7 for the bit definition of the expansion register.

Table 7. Auto-Negotiation Expansion-Register Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15–5	RESERVED	Reserved. Read as 0.	RO
4	PARDETFLT	Parallel detection fault. PARDETFLT indicates multiple links established. This is not supported by this PHY; hence, PARDETFLT is always read as the inverse of LINK.	RO
3	LPNPABLE	Link-partner next-page able. LPNPABLE indicates that the link partner is next-page capable.	RO
2	NPABLE	Next-page able. This PHY is capable of exchanging next pages, so NPABLE is hardwired to 1.	RO
1	PAGERX	Page received. PAGERX is set after three identical and consecutive link code words have been received from the link partner. PAGERX is cleared when the link-partner ability register is read.	RO
0	LPANABLE	Link-partner auto-negotiation able. LPANABLE is set to 1 when the PHY has received fast link pulses from the link partner.	RO

† RO = read only

auto-negotiation next_page transmit register – AN_NEXTPAGE at 0x07

Figure 11. Auto-Negotiation Next_Page Transmit Register

When written to, this register sets the next page to be transmitted by way of auto-negotiation. Writing to this register instructs the auto-negotiation system to transmit a next page.

TNETE2004 identification register, QUADB_ID at 0x10

This register is hardwired to the value 0x0005. Writing to this register has no effect.

TNETE2004 control register – QuadPHY_ctl at 0x11

Byte 1												Byte 0			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IGLINK	SWAPPOLEN	SWAPPOL	SQEEN	MTEST	LINKJAB	RESERVED						NOLINKP	RESERVED	INTEN	TINT

Figure 12. TNETE2004 Control Register

Table 8. TNETE2004 Control Register Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†	DEFAULT
15	IGLINK	Ignore link. When IGLINK is 0, the 10BASE-T PHY expects to receive link pulses and sets the LINK bit in the GEN_sts register to 0 if they are not present. When IGLINK is set to 1, link pulses are ignored, and the LINK bit always is set to 1.	R/W	0
14	SWAPPOLEN	Swap polarity enable. When set, SWAPPOLEN enables the PHY to reverse the polarity of received signals after reception of seven inverted link pulses.	R/W	1
13	SWAPPOL	Swap polarity. When set, SWAPPOL forces the PHY to reverse the polarity of received signals. Writing to SWAPPOL has no effect when SWAPPOLEN is set to 1. However, when read, SWAPPOL always reflects the current polarity setting.	R/W	0
12	SQEEN	SQE enable. Writing a 1 to SQEEN causes the 10BASE-T PHY to perform the SQE test function at the end of packet transmission.	R/W	Pin
11	MTEST	Manufacturing test. When MTEST is set to 1, the PHYs are placed in manufacturing test mode. Manufacturing test mode is reserved for Texas Instruments manufacturing test only. Operation of the device with this bit set is undefined. MTEST is common to all PHYs.	R/W	0
10	LINKJAB	Link jabber indication for all PHYs. When LINKJAB is set to a 1, each PHY deasserts the LINK pin when in JABBER mode. When set to 0, JABBER has no effect on link status. Setting this bit has no effect on the value of the LINK bit in GEN_STS register.	R/W	1
9–4	RESERVED	Reserved. Read as 0	RO	0
3	NOLINKP	When NOLINKP is asserted and IGLINK is set to 1, the PHYs do not transmit link pulses.	R/W	0
2	RESERVED	Reserved. Read as 0	RO	0
1	INTEN	Interrupt enable. Writing a 1 to INTEN allows the TNETE2004 to generate interrupts on the MII when the MINT bit is set to 1. INTEN does not affect test interrupts. INTEN is common to all PHYs; changing it on one PHY changes it on all PHYs.	R/W	0
0	TINT	Test interrupt. Writing a 1 to TINT causes the PHY to generate an interrupt on the MII. Writing a 0 to TINT causes the PHY to stop generating an interrupt on the MII. This test function is totally independent of INTEN and the MINT bit. TINT is used for diagnostic test of the MII-interrupt function. TINT is common to all PHYs.	R/W	0

† RO = read only, R/W = read/write

TNETE2004 status register – QuadPHY_sts at 0x12

BYTE 1															BYTE 0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MINT	PHOK	POLOK	RESERVED												

Figure 13. TNETE2004 Status Register – QuadPHY_sts at 0x12

Table 9. TNETE2004 Status Register (QuadPHY_sts at 0x12) Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15	MINT	MII interrupt. MINT indicates an MII-interrupt condition. The MII-interrupt request is activated (held) until the register causing the interrupt is read. Writing a 0 to MINT has no effect. MINT is set to 1 when: • PHOK is set to 1. • LINK has changed since it was read last. • RFLT is set to 1. • JABBER is set to 1. • POLOK is set to 1. • PAGERX is set to 1. • ACOMPLETE is set to 1.	RO
14	PHOK	Power high OK. PHOK indicates that the PHY reference oscillator has started up correctly. PHY-sourced clocks (RXCLK and TXCLK) are not valid until PHOK is asserted. PHOK is common to all PHYs.	RO
13	POLOK	Polarity OK. When POLOK is high (default), the 10BASE-T PHY is receiving valid (noninverted) link pulses. If POLOK goes low, it indicates that a sequence of seven inverted link pulses has been detected.	RO
12–0	RESERVED	Reserved. Read as 0	RO

† RO = read only

TNETE2004 all-PHY control register – QuadPHY_4ctl at 0x13

BYTE 1															BYTE 0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LOOPBACK3	LOOPBACK2	LOOPBACK1	LOOPBACK0	PDOWN3	PDOWN2	PDOWN1	PDOWN0	ISOLATE3	ISOLATE2	ISOLATE1	ISOLATE0	DUPLEX3	DUPLEX2	DUPLEX1	DUPLEX0

Figure 14. TNETE2004 All-PHY Control Register – QuadPHY_4ctl at 0x13

Table 10. TNETE2004 All-PHY Control Register (QuadPHY_4ctl at 0x13) Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15	LOOPBACK3	Loopback mode. Writing a 1 to LOOPBACK3 sets PHY3 into loopback mode.	R/W
14	LOOPBACK2	Loopback mode. Writing a 1 to LOOPBACK2 sets PHY2 into loopback mode.	R/W
13	LOOPBACK1	Loopback mode. Writing a 1 to LOOPBACK1 sets PHY1 into loopback mode.	R/W
12	LOOPBACK0	Loopback mode. Writing a 1 to LOOPBACK0 sets PHY0 into loopback mode.	R/W
11	PDOWN3	Power-down mode. When set, PDOWN3 places PHY3 in a power-down mode. In this mode, it is not possible to receive or transmit data. See Note 1.	R/W
10	PDOWN2	Power-down mode. When set, PDOWN2 places PHY2 in a power-down mode. In this mode, it is not possible to receive or transmit data. See Note 1.	R/W
9	PDOWN1	Power-down mode. When set, PDOWN1 places PHY1 in a power-down mode. In this mode, it is not possible to receive or transmit data. See Note 1.	R/W
8	PDOWN0	Power-down mode. When set, PDOWN0 places PHY0 in a power-down mode. In this mode, it is not possible to receive or transmit data. See Note 1.	R/W
7	ISOLATE3	PHY pin isolation. When set, PHY3 electrically isolates itself from the pins. In this state, it does not respond to TXD or TXEN and presents a high impedance on RXD, RXCLK, and COL. It still responds to MII data frames, however.	R/W
6	ISOLATE2	PHY pin isolation. When set, PHY2 electrically isolates itself from the pins. In this state, it does not respond to TXD or TXEN and presents a high impedance on RXD, RXCLK, and COL. It still responds to MII data frames, however.	R/W
5	ISOLATE1	PHY pin isolation. When set, PHY1 electrically isolates itself from the pins. In this state, it does not respond to TXD or TXEN and presents a high impedance on RXD, RXCLK, and COL. It still responds to MII data frames, however.	R/W
4	ISOLATE0	PHY pin isolation. When set, PHY0 electrically isolates itself from the pins. In this state, it does not respond to TXD or TXEN and presents a high impedance on RXD, RXCLK, and COL. It still responds to MII data frames, however.	R/W
3	DUPLEX3	Set full-duplex mode. Setting DUPLEX3 forces PHY3 into full-duplex mode. Resetting forces half-duplex mode.	R/W
2	DUPLEX2	Set full-duplex mode. Setting DUPLEX2 forces PHY2 into full-duplex mode. Resetting forces half-duplex mode.	R/W
1	DUPLEX1	Set full-duplex mode. Setting DUPLEX1 forces PHY1 into full-duplex mode. Resetting forces half-duplex mode.	R/W
0	DUPLEX0	Set full-duplex mode. Setting DUPLEX0 forces PHY0 into full-duplex mode. Resetting forces half-duplex mode.	R/W

† R/W = read/write

NOTE 1. If all four PHYs are in power-down mode simultaneously, then reset must be used to power up the device. It is not possible to power up an individual PHY if all four PHYs are in power-down mode.

TNETE2004 all-PHY status register – QuadPHY_4sts at 0x14

BYTE 1															BYTE 0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ACOMPLETE3	ACOMPLETE2	ACOMPLETE1	ACOMPLETE0	MINT3	MINT2	MINT1	MINT0	LINK3	LINK2	LINK1	LINK0	JABBER3	JABBER2	JABBER1	JABBER0

Figure 15. TNETE2004 All-PHY Status Register – QuadPHY_4sts at 0x14

Table 11. TNETE2004 All-PHY Status Register (QuadPHY_4sts at 0x14) Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15	ACOMPLETE3	Auto-negotiation complete. Auto-negotiation complete on PHY3.	RO
14	ACOMPLETE2	Auto-negotiation complete. Auto-negotiation complete on PHY2.	RO
13	ACOMPLETE1	Auto-negotiation complete. Auto-negotiation complete on PHY1.	RO
12	ACOMPLETE0	Auto-negotiation complete. Auto-negotiation complete on PHY0.	RO
11	MINT3	MII interrupt. PHY3 indicates an interrupt condition.	RO
10	MINT2	MII interrupt. PHY2 indicates an interrupt condition.	RO
9	MINT1	MII interrupt. PHY1 indicates an interrupt condition.	RO
8	MINT0	MII interrupt. PHY0 indicates an interrupt condition.	RO
7	LINK3	Link status. When set, LINK3 indicates that PHY3 is receiving valid link pulses.	RO
6	LINK2	Link status. When set, LINK2 indicates that PHY2 is receiving valid link pulses.	RO
5	LINK1	Link status. When set, LINK1 indicates that PHY1 is receiving valid link pulses.	RO
4	LINK0	Link status. When set, LINK0 indicates that PHY0 is receiving valid link pulses.	RO
3	JABBER3	Jabber detected. When set, JABBER3 indicates that PHY3 has entered jabber mode. This can be cleared only by reset.	RO
2	JABBER2	Jabber detected. When set, JABBER2 indicates that PHY2 has entered jabber mode. This can be cleared only by reset.	RO
1	JABBER1	Jabber detected. When set, JABBER1 indicates that PHY1 has entered jabber mode. This can be cleared only by reset.	RO
0	JABBER0	Jabber detected. When set, JABBER0 indicates that PHY0 has entered jabber mode. This can be cleared only by reset.	RO

† RO = read only

TNETE2004 all-PHY control register 2 – QuadPHY_4ctl2 at 0x15

BYTE 1															BYTE 0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IGLINK3	IGLINK2	IGLINK1	IGLINK0	SWAPPOLEN3	SWAPPOLEN2	SWAPPOLEN1	SWAPPOLEN0	SWAPPOL3	SWAPPOL2	SWAPPOL1	SWAPPOL0	SQEEN3	SQEEN2	SQEEN1	SQEEN0

Figure 16. TNETE2004 All-PHY Control Register 2 – QuadPHY_4ctl2 at 0x15

Table 12. TNETE2004 All-PHY Control Register 2 (QuadPHY_4ctl2 at 0x15) Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15	IGLINK3	Ignore link. Ignore link pulses on PHY3.	R/W
14	IGLINK2	Ignore link. Ignore link pulses on PHY2.	R/W
13	IGLINK1	Ignore link. Ignore link pulses on PHY1.	R/W
12	IGLINK0	Ignore link. Ignore link pulses on PHY0.	R/W
11	SWAPPOLEN3	Automatic polarity correction. Enable automatic polarity correction on PHY3.	R/W
10	SWAPPOLEN2	Automatic polarity correction. Enable automatic polarity correction on PHY2.	R/W
9	SWAPPOLEN1	Automatic polarity correction. Enable automatic polarity correction on PHY1.	R/W
8	SWAPPOLEN0	Automatic polarity correction. Enable automatic polarity correction on PHY0.	R/W
7	SWAPPOL3	Swap polarity. Swap polarity on PHY3.	R/W
6	SWAPPOL2	Swap polarity. Swap polarity on PHY2.	R/W
5	SWAPPOL1	Swap polarity. Swap polarity on PHY1.	R/W
4	SWAPPOL0	Swap polarity. Swap polarity on PHY0.	R/W
3	SQEEN3	Signal quality error. Enable SQE on PHY3.	R/W
2	SQEEN2	Signal quality error. Enable SQE on PHY2.	R/W
1	SQEEN1	Signal quality error. Enable SQE on PHY1.	R/W
0	SQEEN0	Signal quality error. Enable SQE on PHY0.	R/W

† R/W = read/write

TNETE2004 pin-polarity register – QuadPHY_ppol at 0x16

BYTE 1															BYTE 0
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
INV_CRS	INV_COL	INV_RXCLK	INV_TXCLK	INV_TXEN	RXD_POL	RXCLK_OFF	RESERVED								

Figure 17. TNETE2004 Pin-Polarity Register – QuadPHY_ppol at 0x16

Table 13. TNETE2004 Pin-Polarity Register (QuadPHY_ppol at 0x16) Bit Functions

BIT NO.	BIT NAME	FUNCTION	DIRECTION†
15	INV_CRS	Invert carrier sense. When INV_CRS is set to 1, carrier sense is indicated by a low voltage on the appropriate CRSx pin. When INV_CRS is 0, carrier sense is indicated by a high voltage level.	R/W
14	INV_COL	Invert collision. When INV_COL is set to 1, a collision is indicated by a low voltage on the appropriate COLx pin. When INV_COL is 0, collision is indicated by a high voltage level.	R/W
13	INV_RXCLK	Invert RXCLK. When INV_RXCLK is set to 1, the MAC samples RXD data on the falling edge of RXCLK. When INV_RXCLK is 0, data is sampled on the rising edge of RXCLK.	R/W
12	INV_TXCLK	Invert TXCLK. When INV_TXCLK is set to 1, the TNETE2004 samples data on its TXD pins on the falling edges of TXCLK. When INV_TXCLK is set to 0, the data is sampled on the rising edges of TXCLK.	R/W
11	INV_TXEN	Invert TXEN. When INV_TXEN is set to 1, the MAC indicates that data is to be transmitted by forcing the appropriate TXENx pin low. When INV_TXEN is 0, valid data is indicated by a high voltage level.	R/W
10	RXD_POL	Receive data active-low. When RXD_POL is set to 1, RXD is driven low when no data is being received by the PHY. When RXD_POL is set to 0, RXD is driven high when no data is being received.	R/W
9	RXCLK_OFF	Receive clock off when inactive. When RXCLK_OFF is set to 1, RXCLK outputs seven more clock cycles after CRS is inactive and then RXCLK is held high. Otherwise, RXCLK continuously outputs a 10-MHz clock signal.	R/W
8–0	RESERVED	Reserved. Read as 0.	RO

† RO = read only, R/W = read/write

After power on or a reset prior to writing to this register, the polarity of CRS, COL, TXEN, RXCLK, and TXCLK is determined by CMODE0 and CMODE1. After this register has been written to, CMODE has no effect on the polarity. This register is always read as 0 until it has been written to.

timing characteristics

reset and power up

At initial power up, the TNETE2004 performs an internal reset. No external reset circuitry is required. However, operation of the TNETE2004 is not specified for 50 ms after power up.

During operation, a full reset of the device can be performed by taking RESET low for a duration of not less than 50 μs. Operation of the device is not ensured for a duration of 5 ms after reset.

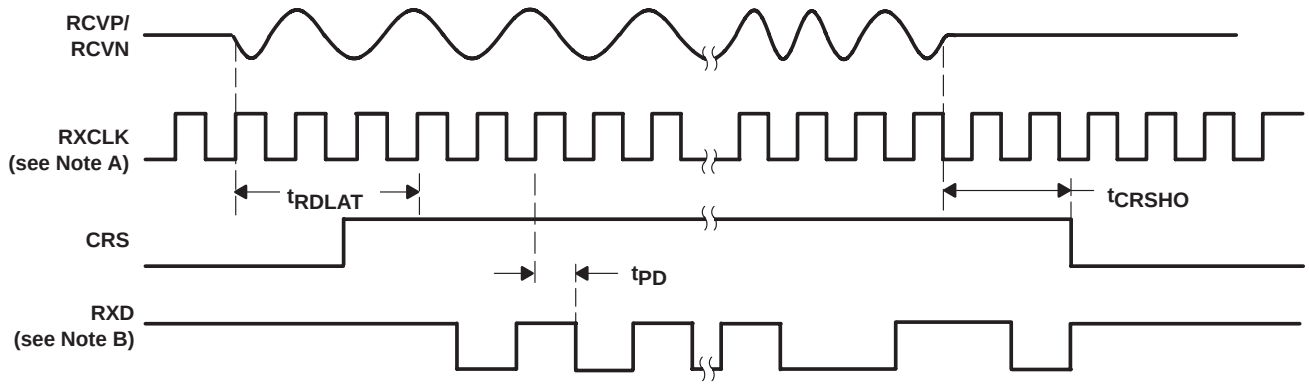
receive-data timing

The TNETE2004 buffers have received data in an elastic first-in, first-out (FIFO) buffer so that it can be synchronous to the TNETE2004 10-MHz clock. At the start of packet reception on the RCVP/RCVN pair, no more than five bits can be received and not be forwarded to RXD.

The selected compatibility mode (see Table 2) of the PHY affects on which clock edge (rising or falling) the received data is valid. Figure 18 through Figure 21 show the receive timing for compatibility modes of operation, and the respective receive-data timing tables show the setup and hold timings. The only differences between modes are the polarity changes in RXCLK, CRS, and RXD during idle periods.

mode 1 receive-data timing

		MIN	TYP	MAX	UNIT
t_{RDLAT}	Receive-data latency		500		ns
t_{PD}	Receive data	40		60	ns
t_{CRSHO}	Time from receiver idle to carrier sense off		200		ns

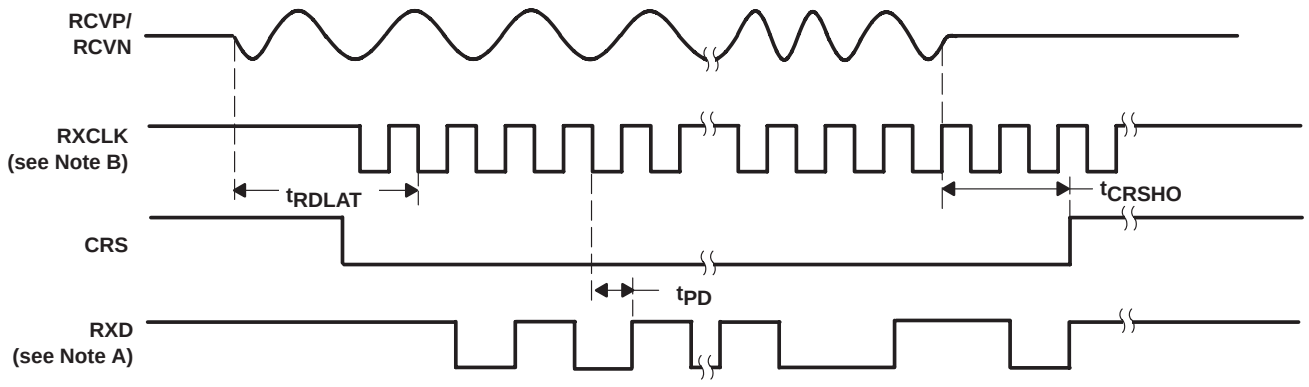


NOTES: A. RXCLK is continuous.
B. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.

Figure 18. Mode 1 Receive Timing

mode 2 receive-data timing

		MIN	TYP	MAX	UNIT
t_{RDLAT}	Receive-data latency		500		ns
t_{PD}	Receive data	40		60	ns
t_{CRSHO}	Time from receiver idle to carrier sense off		200		ns

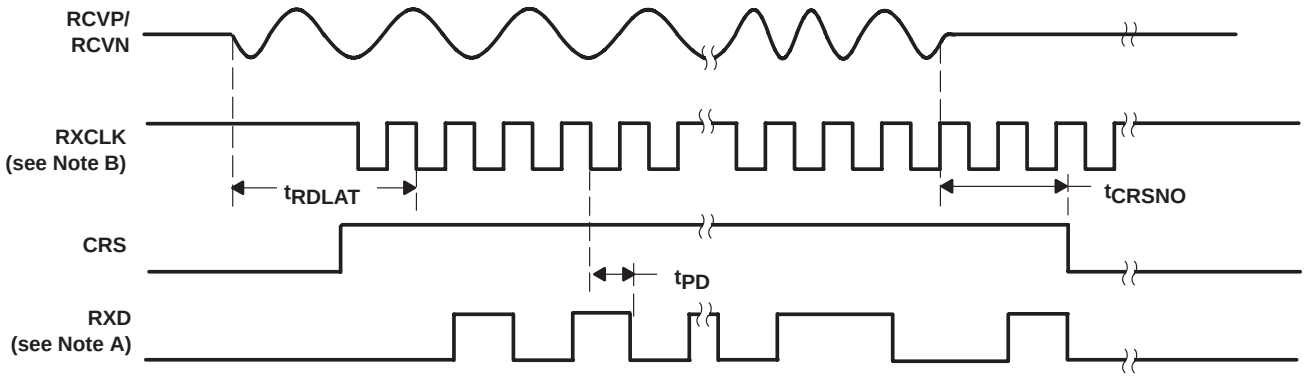


NOTES: A. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.
B. RXCLK goes high seven clock cycles after CRS goes high.

Figure 19. Mode 2 Receive Timing

mode 3 receive-data timing

		MIN	TYP	MAX	UNIT
t_{RDLAT}	Receive-data latency		500		ns
t_{PD}	Receive data	40		60	ns
t_{CRSHO}	Time from receiver idle to carrier sense off		200		ns

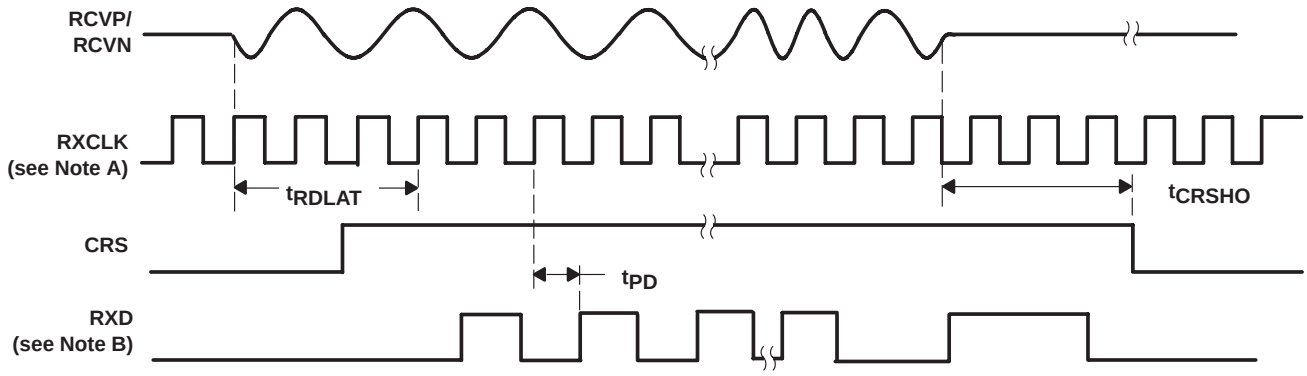


NOTES: A. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.
B. RXCLK goes high seven clock cycles after CRS goes low.

Figure 20. Mode 3 Receive Timing

mode 4 receive-data timing

		MIN	TYP	MAX	UNIT
t_{RDLAT}	Receive-data latency		500		ns
t_{PD}	Receive data	40		60	ns
t_{CRSHO}	Time from receive idle to carrier sense off		200		ns



NOTES: A. RXCLK is continuous.
B. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.

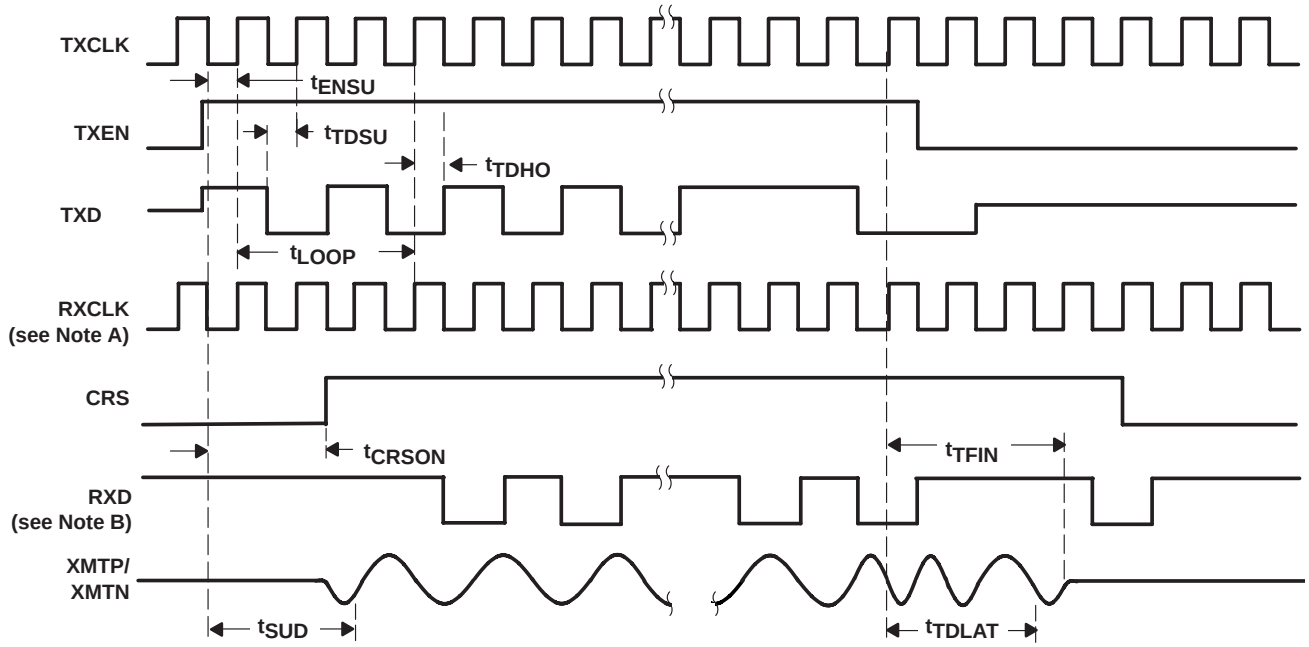
Figure 21. Mode 4 Receive Timing

transmit-data timings

To be transmitted, data must be valid and synchronized with the appropriate edge of TXCLK according to the selected compatibility mode (see Table 2). Figure 22 through Figure 25 show timing for modes of operation. The only differences in modes are the polarity changes in RXD (during CRS deasserted), TXEN, RXCLK, and CRS. In half-duplex operation, transmit data is internally looped back to the receive data pins through the receiver circuitry. The following timing table shows transmit data timing.

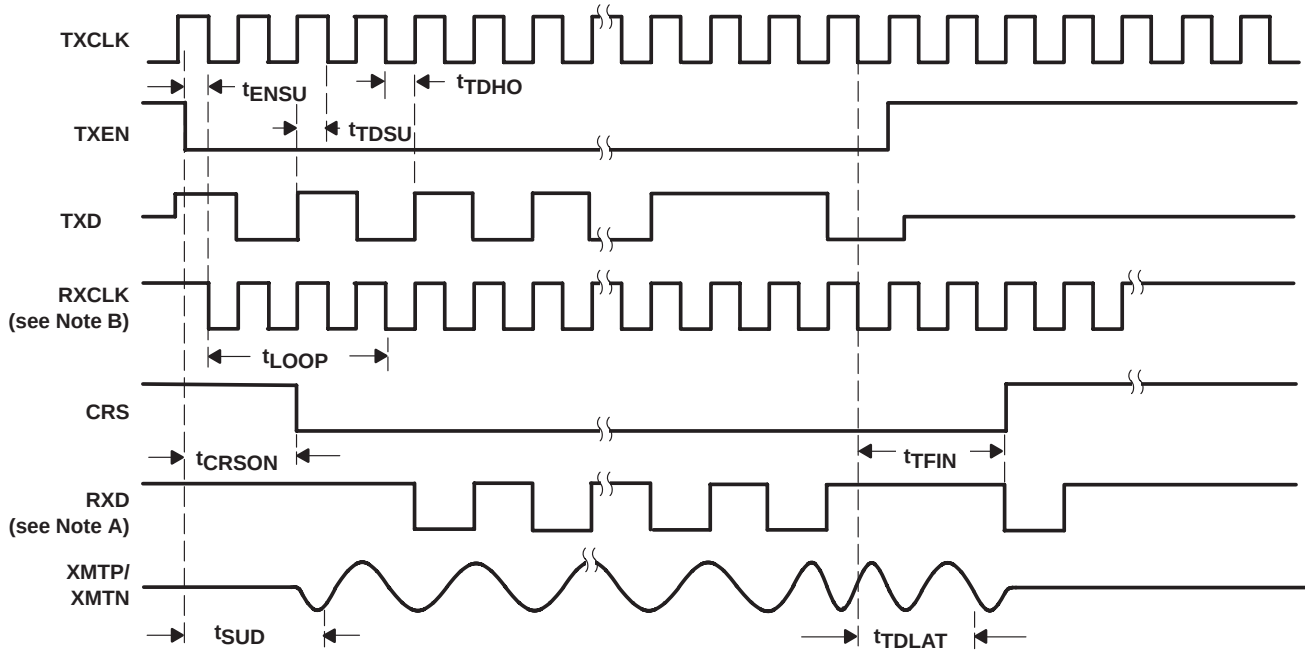
modes 1–4 transmit-data timing

		MIN	TYP	MAX	UNIT
t_{ENSU}	Setup time, transmit enable		50		ns
t_{SUD}	Transmit startup delay		150		ns
t_{CRSON}	Time to CRS assertion		150		ns
t_{TDSU}	Setup time, transmit data	25			ns
t_{TDHO}	Hold time, transmit data	2.5			ns
t_{TDLAT}	Transmit-data latency		100		ns
t_{TFIN}	Time to transmit idle		400		ns
t_{LOOP}	Loopback latency		500		ns



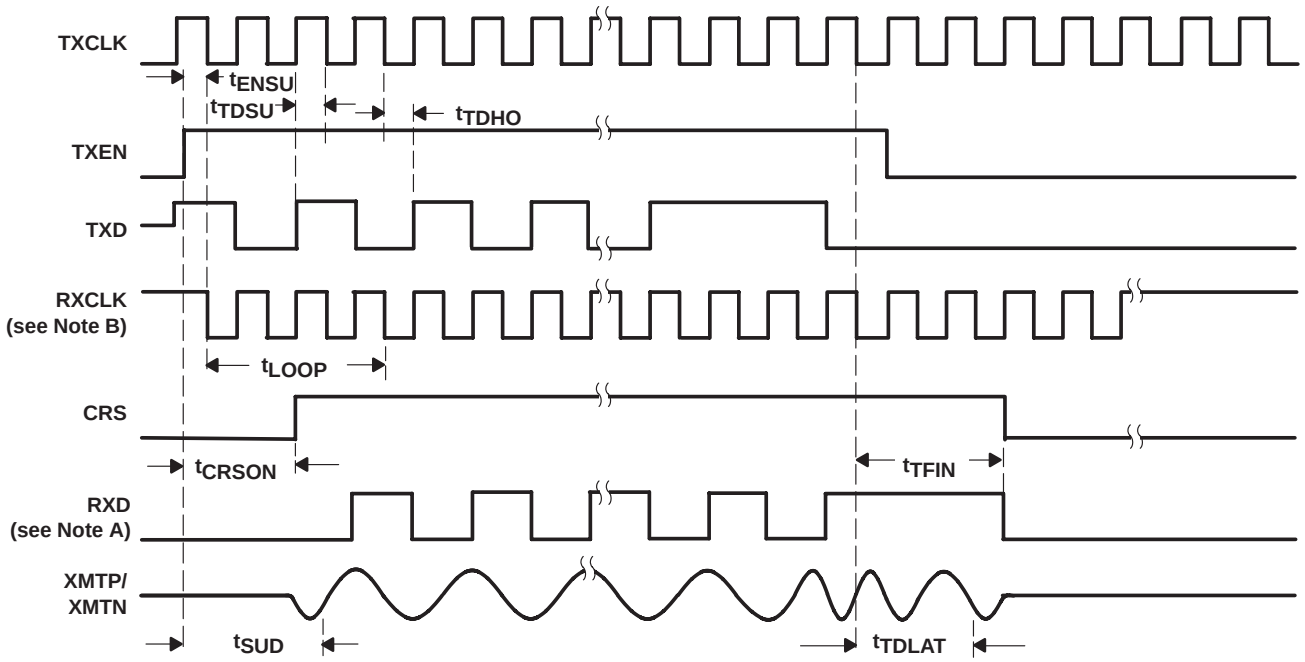
NOTES: A. RXCLK is continuous.
B. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.

Figure 22. Mode 1 Transmit Timing



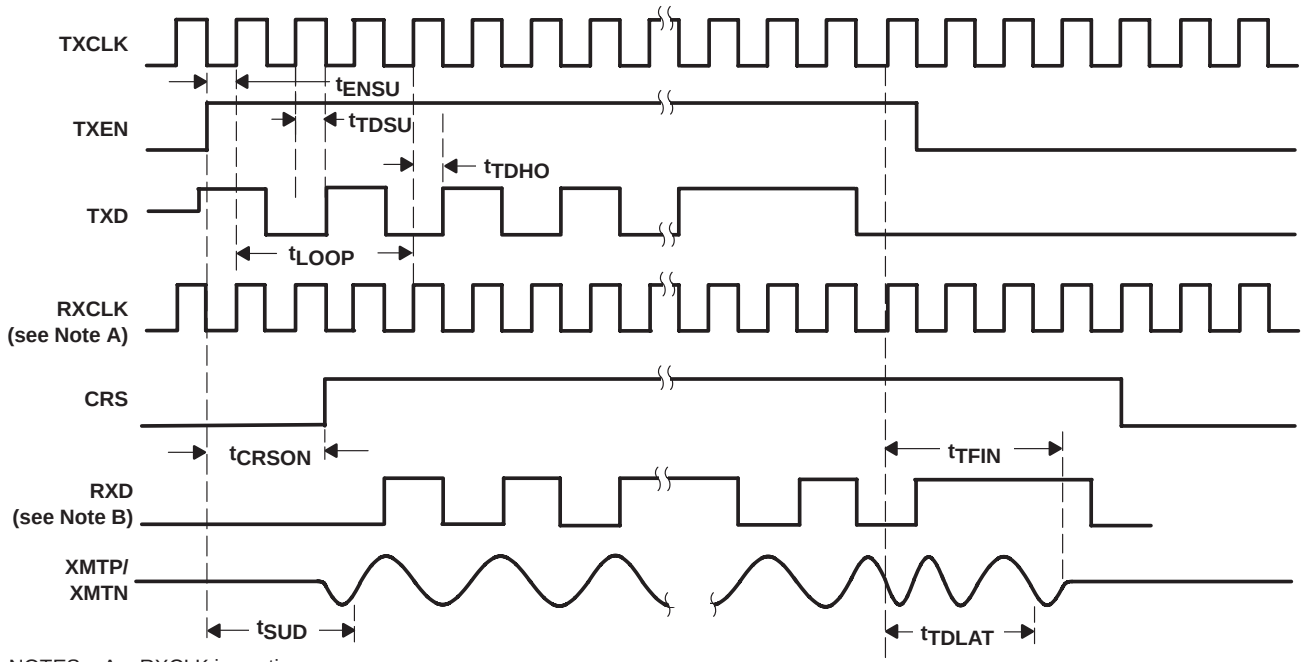
NOTES: A. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.
B. RXCLK goes high seven clock cycles after CRS goes high.

Figure 23. Mode 2 Transmit Timing



NOTES: A. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.
B. RXCLK goes high seven clock cycles after CRS goes low.

Figure 24. Mode 3 Transmit Timing



NOTES: A. RXCLK is continuous.
B. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.

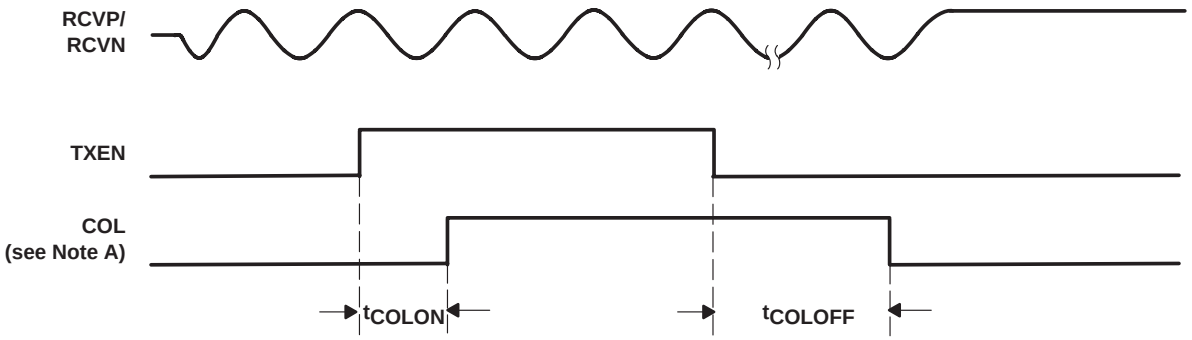
Figure 25. Mode 4 Transmit Timing

collision-detection timing

COL is asserted for a minimum of 600 ns when transmission and reception of data occur simultaneously. COL is not active during link_fail or in full-duplex mode. Figure 26 through Figure 29 and the collision-detect timing table show timing for modes of operation. Operation in all modes is identical except for polarity changes to TXEN and COL. During a collision, the data output on RXD is not valid received data (or looped-back transmit data) since the digital PLL is acquiring lock to a different source of incoming data.

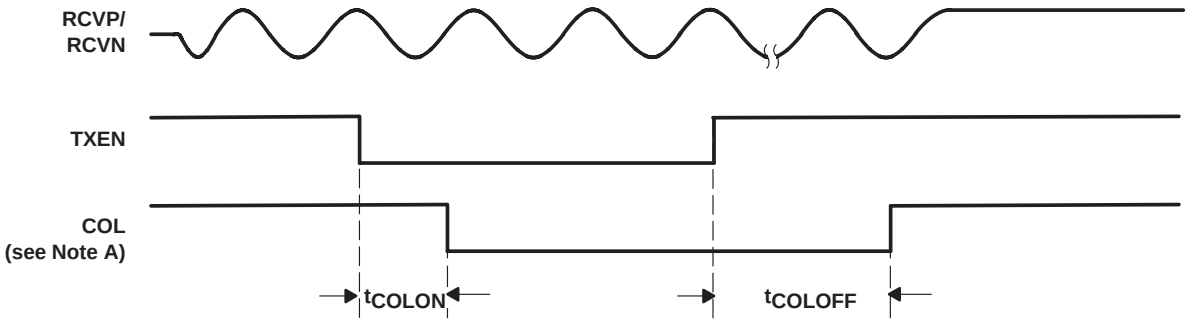
collision-detect timing

		MIN	TYP	MAX	UNIT
t_{COLON}	Collision-detect delay		50		ns
t_{COLOFF}	Collision-off time		325		ns



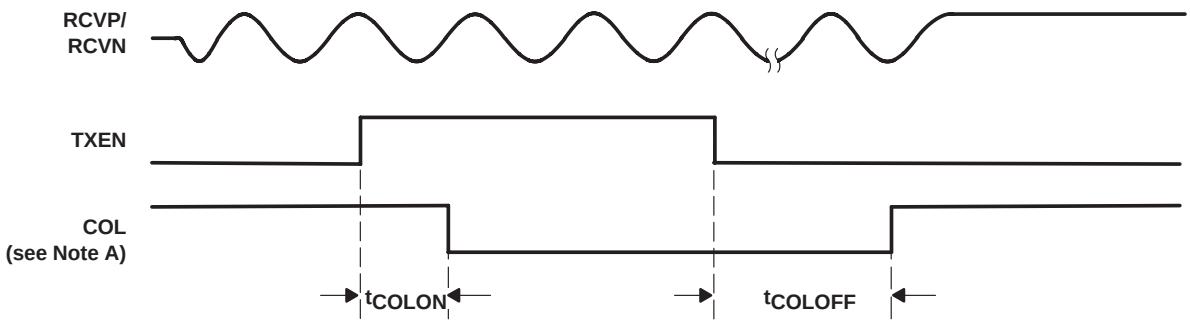
NOTE A: COL high in mode 1 asserts collision.

Figure 26. Mode 1 Collision



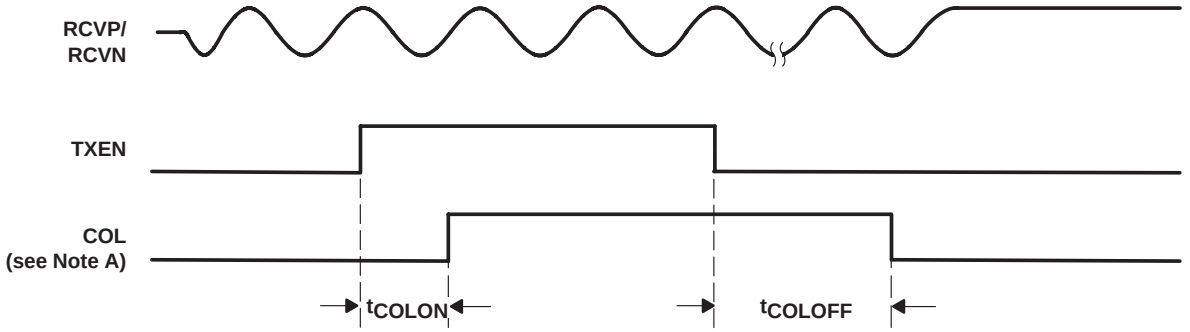
NOTE A: COL low in mode 2 asserts collision.

Figure 27. Mode 2 Collision



NOTE A: COL low in mode 3 asserts collision.

Figure 28. Mode 3 Collision



NOTE A: COL high in mode 4 asserts collision.

Figure 29. Mode 4 Collision

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Normal power-supply voltage	5.0 V ± 5%
Power-supply current draw (see Note 2)	510 mA
Power-supply current draw (see Note 3)	240 mA
dc voltage applied to logic outputs	–0.05 V to V_{CC}MAX
dc voltage applied to logic input	5.25 V
dc differential voltage at receiver pins	± 5 V
Input voltage range (see Note 4)	–0.5 V to 5.25 V
Operating case temperature range, T_C	0°C to 95°C
$R_{\theta JA}$ (see Note 5)	22°C/W
$R_{\theta JA}$ (see Note 6)	27°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.

NOTES: 2. With all PHYs transmitting and receiving (full duplex) into correctly terminated loads and inter-frame gaps of 9.6 μs
3. With all PHYs transmitting and receiving (full duplex) into correctly terminated loads and inter-frame gaps of 10 ms
4. Voltage values are with respect to GND, and all GND pins should be routed to minimize inductance to system ground.
5. 120 pin
6. 128 pin, 2.7-mm thickness

recommended operating conditions

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage		4.75	5	5.25	V
V_{SS}	Supply voltage			0		V
V_{IH}	High-level input voltage	All inputs except XTAL1	2		V_{CC} +0.3	V
		XTAL1	2.8		V_{CC} +0.3	
V_{IL}	Low-level input voltage		–0.3		0.8	V

recommended operating conditions crystal oscillator

		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{SB(XTL1)}$	Input self-bias voltage	V_{IB}		1.7	2.8	V
$I_{OH(XTL2)}$	High-level output current	I_{OH}	$V_{(XTL2)} = V_{SB(XTL1)}$ $V_{(XTL1)} = V_{SB(XTL1)} + 0.5$ V	–1.3	–5.0	mA
$I_{OL(XTL2)}$	Low-level output current	I_{OL}	$V_{(XTL2)} = V_{SB(XTL1)}$ $V_{(XTL1)} = V_{SB(XTL1)} – 0.5$ V	0.4	1.5	mA

recommended operating conditions oscillator requirements

	MIN	TYP	MAX	UNIT
Oscillator, parallel resonant frequency		20		MHz
Oscillator, resonant frequency error	–100		100	ppm
Oscillator, duty cycle	40		60	%

dc electrical characteristics over recommended ranges of supply voltage and operating free-air temperature (see Figure 30)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
V_{OH}	High-level output voltage	V_{OH}	V_{DD} = min, I_{OH} = –300μA	2.4		V
V_{OL}	Low-level output voltage	V_{OL}	V_{DD} = max, I_{OL} = 2mA		0.5	V
V_{OL}, see Note 7	High-level output voltage	V_{OL}	V_{DD} = max, I_{OL} = 10mA		0.5	V
V_{OL}, see Note 8	Low-level output voltage	V_{OL}	V_{DD} = max, I_{OL} = 5μA		0.5	V
I_{OZ}		I_{OZ}	V_{DD} = max, V_O = V_{DD}/V_{SS}	0	10	μA
I_I		I_I	V_{DD} = max, V_O = V_{DD}/V_{SS}		10	μA
C_i			f = 1MHz	10		pF
C_o			f = 1MHz	10		pF
I_{CCQ}			V_{DD} = max		100	μA

NOTES: 7. Maximum with LEDs on
8. Duplex pin

10BASE-T receiver input (RCVP, RCVN)

PARAMETER		JEDEC SYMBOL	TEST CONDITIONS	MIN	MAX	UNIT
$V_{(CM)}$	Common-mode input voltage	V_{IC}		1.8	3.2	V
$V_{I(DIFF)}$	Differential input voltage	V_{ID}		0.6	2.8	V
$I_{(CM)}$	Common-mode current	I_{IC}			4	mA
V_{SQ+}	Rising input-pair squelch threshold		V_{CM} = V_{SB}, See Note 9		270	mV
$V_{SQ–}$	Falling input-pair squelch threshold		V_{CM} = V_{SB}, See Note 9	–270		mV

NOTE 9: V_{SB} is the self bias of the inputs RCVP and RCVN.

PLL characteristics

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
V_{FILT}	Reference PLL operating filter voltage	$t_{c(XTL1)}$ = 50 ns	0.8	2	V

PARAMETER MEASUREMENT INFORMATION

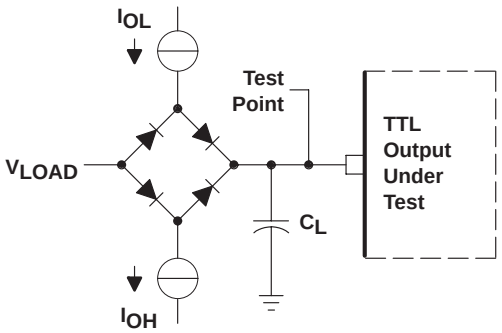
Outputs are driven to a minimum high-logic level of 2.4 V and to a maximum low-logic level of 0.6 V. These levels are compatible with TTL devices.

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 no longer is considered high is 2 V. The level at which the signal is considered low is 0.8 V. For a low-to-high transition, the level at which the signal no longer is considered low is 0.8 V, and the level at which the signal is considered high is 2 V, as shown in the following diagram.

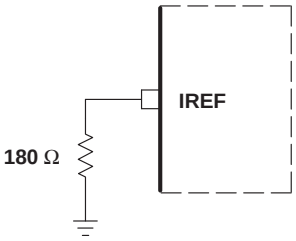
The rise and fall times are not specified but are assumed to be those of standard TTL devices, which are typically 1.5 ns.

test measurement

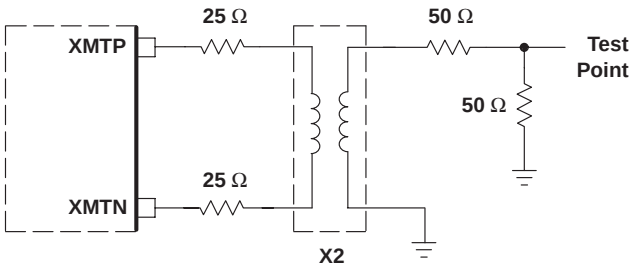
The test and load circuits shown in Figure 30 represent the programmable load of the tester-pin electronics used to verify timing parameters of the TNETE2004 output signals.



(a) TTL OUTPUT TEST LOAD

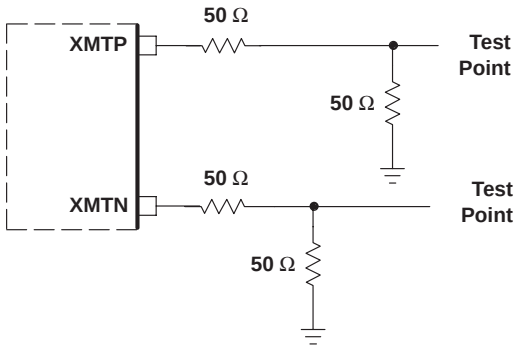


(b) IREF TEST CIRCUIT



(c) XMTP AND XMTN TEST LOAD (ac TESTING)

X2–Fil–Mag 23Z128 $\left(1:\sqrt{2}\right)$



(d) XMTP AND XMTN TEST LOAD (dc TESTING)

Where: I_{OH} = Refer to I_{OH} in dc electrical characteristics.
I_{OL} = Refer to I_{OL} in dc electrical characteristics.
V_{LOAD} = 1.5 V, typical dc-level verification or 0.7 V, typical timing verification
C_L = 22 pF, typical load-circuit capacitance

Figure 30. Test and Load Circuit

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APPLICATION INFORMATION

Interface of the TNETE2004 with the TNETX3150 and TNETX15VEPGE is shown in Figure 2. Details of that interface are shown in Figure 31. Numbers and functions illustrated are for the 120-pin (PBE) device. Refer to *Terminal Functions* table for corresponding pin numbers and functions for the 128-pin (PAC) device.

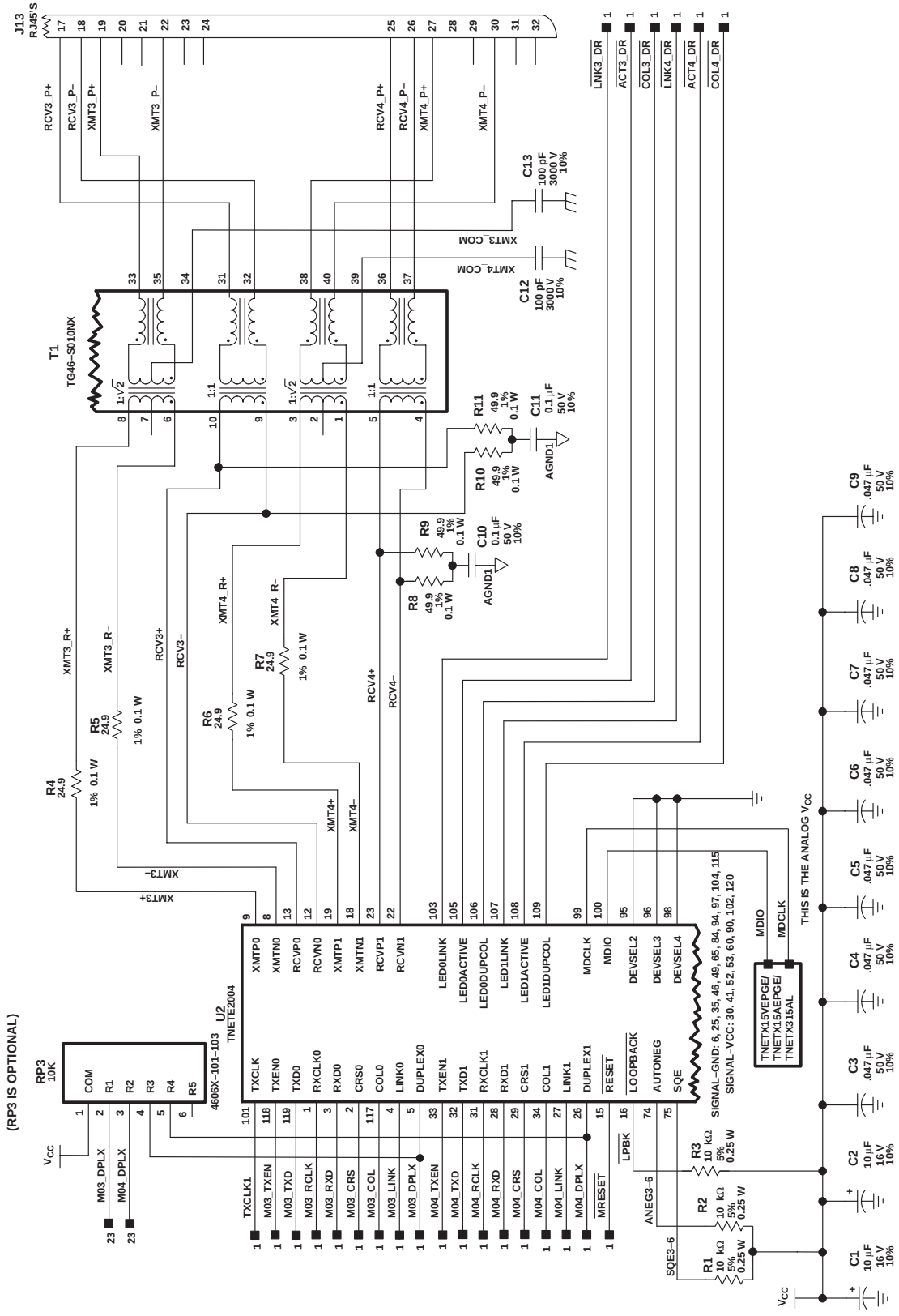


Figure 31. QuadPHY-to-TNETX3150 Interface Diagrams

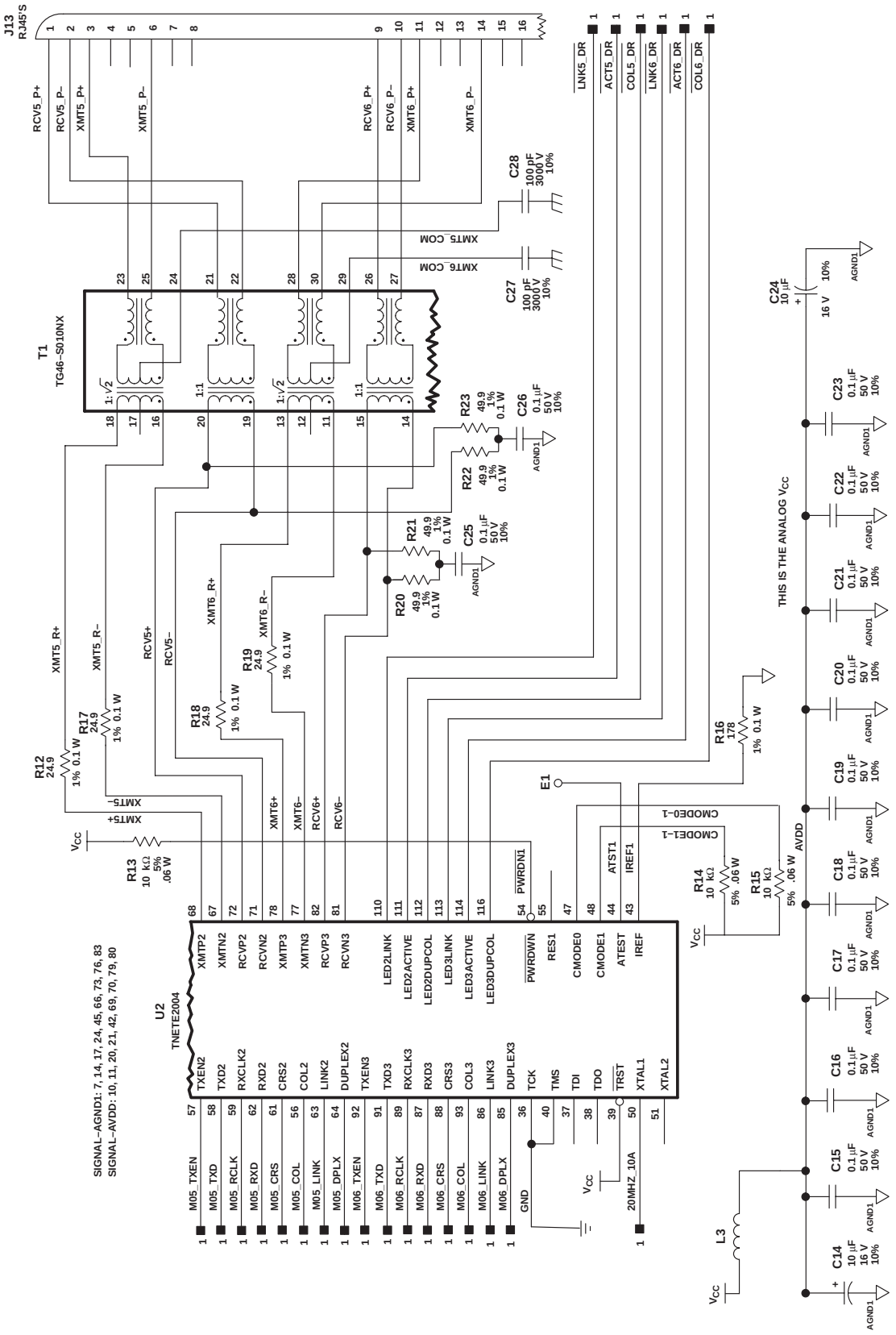


Figure 31. QuadPHY-to-TNETX3150 Interface Diagrams (Continued)

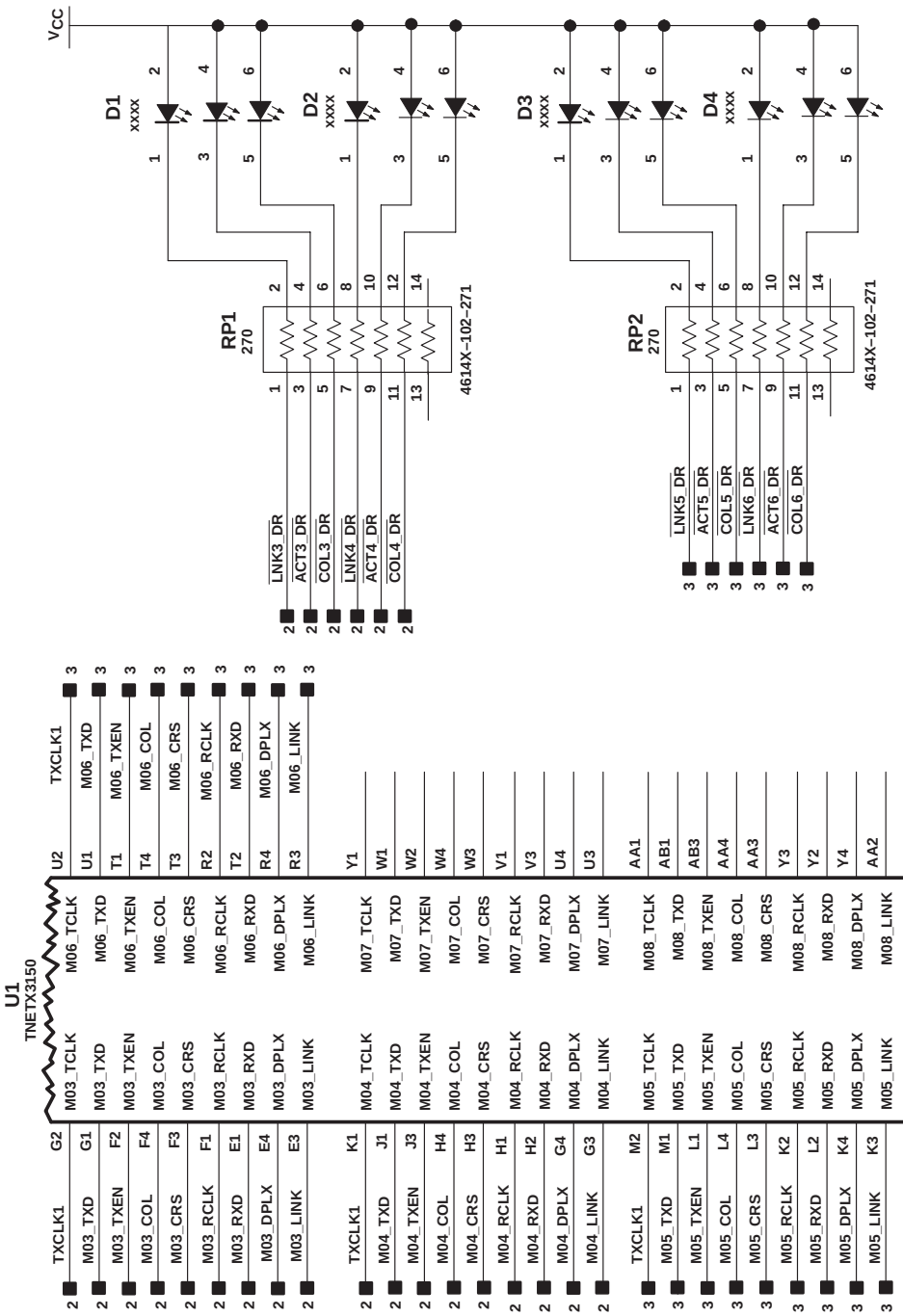
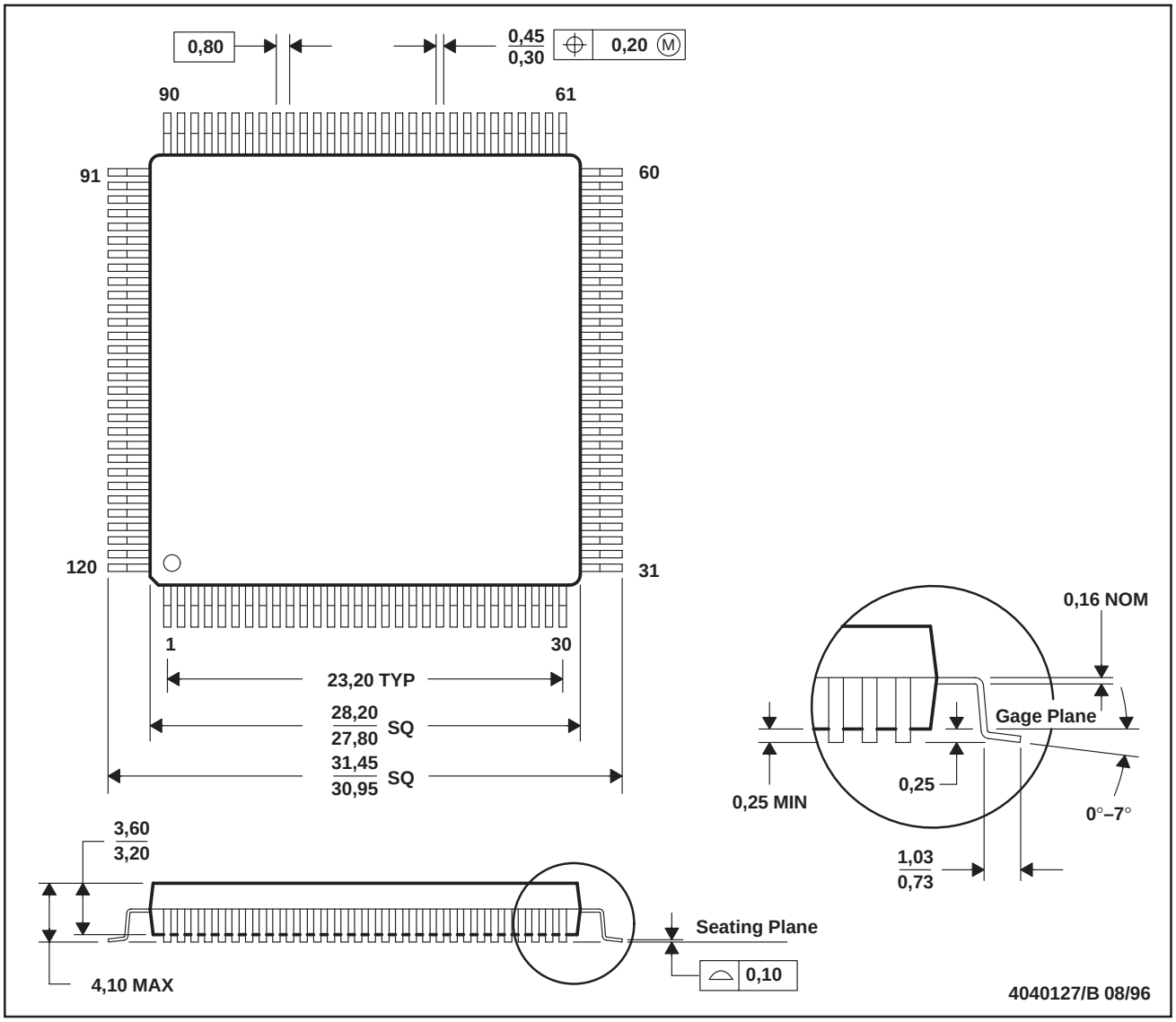


Figure 31. QuadPHY-to-TNETX3150 Interface Diagrams (Continued)

MECHANICAL DATA

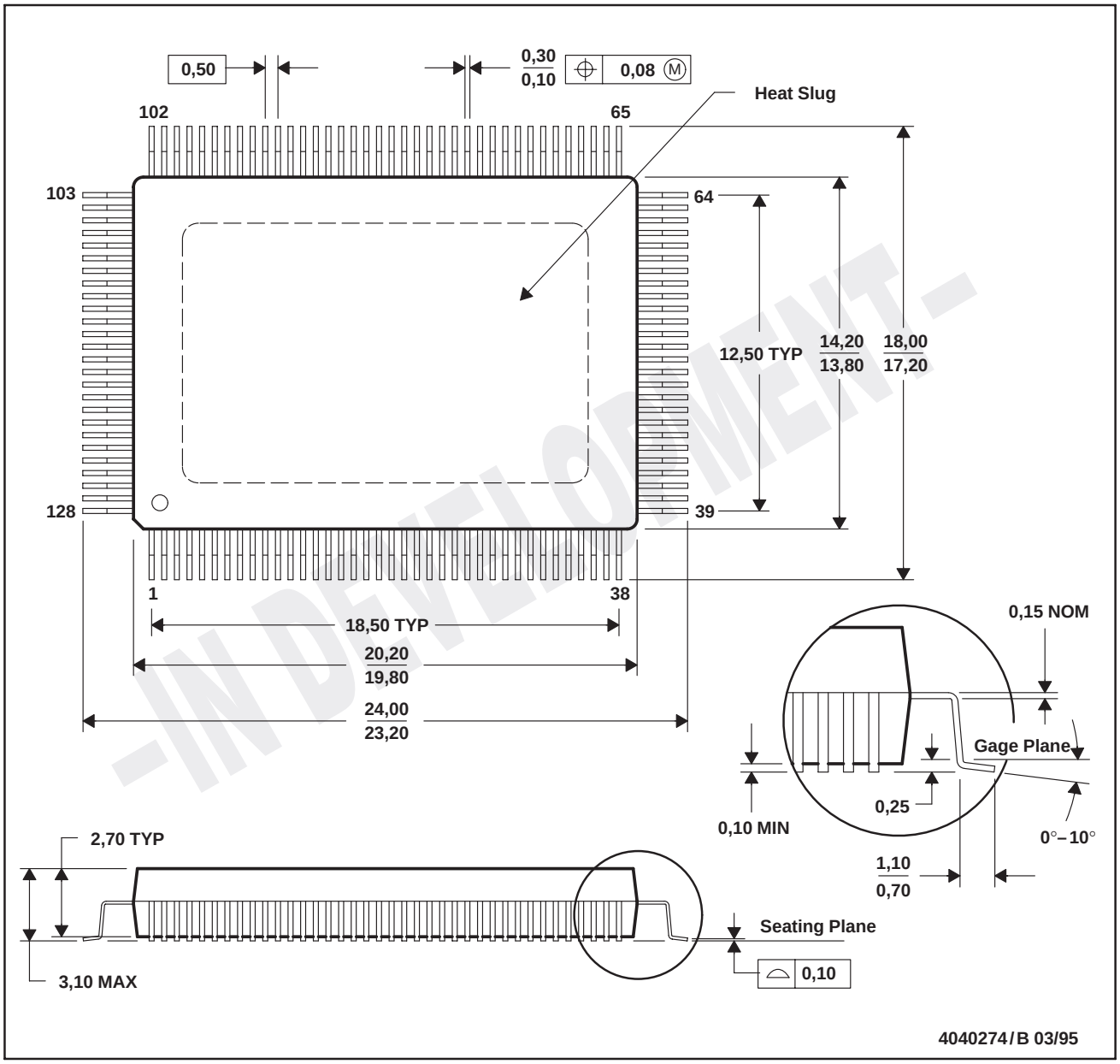
PBE (S-PQFP-G120) **PLASTIC QUAD FLATPACK**



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

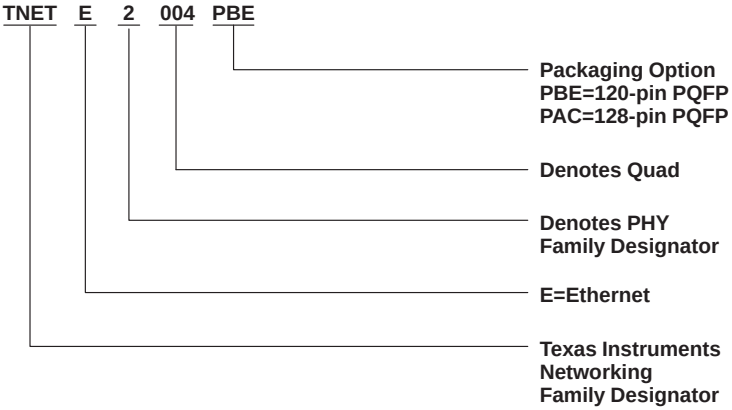
MECHANICAL DATA

PAC (R-PQFP-G128) **PLASTIC QUAD FLATPACK (DIE-DOWN)**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Thermally enhanced molded plastic package (HSL) exposed on package bottom
D. Contact field sales office to determine if a tighter coplanarity requirement is available for this package.

ORDERING INFORMATION



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