LXT310

T1 CSU / ISDN PRI Transceiver

General Description

The LXT310 is the first fully integrated transceiver for T1 CSU and ISDN Primary Rate Interface (ISDN PRI) applications at 1.544 MHz. This transceiver operates over 6,000 feet of 22 AWG twisted-pair cable without any external components. To compensate for shorter lines, 7.5 dB, 15 dB, and 22.5 dB frequency-dependent transmit Line Build-Outs (LBOs) are provided.

The device offers selectable B8ZS encoding/decoding, and unipolar or bipolar data I/O. The LXT310 also provides jitter attenuation in either the transmit or receive direction starting at 6 Hz, and incorporates a serial interface (SIO) for microprocessor control.

The LXT310 offers a variety of diagnostic features including loopbacks and loss of signal monitoring. It uses an advanced double-poly, double-metal CMOS process and require only a single 5-volt power supply.

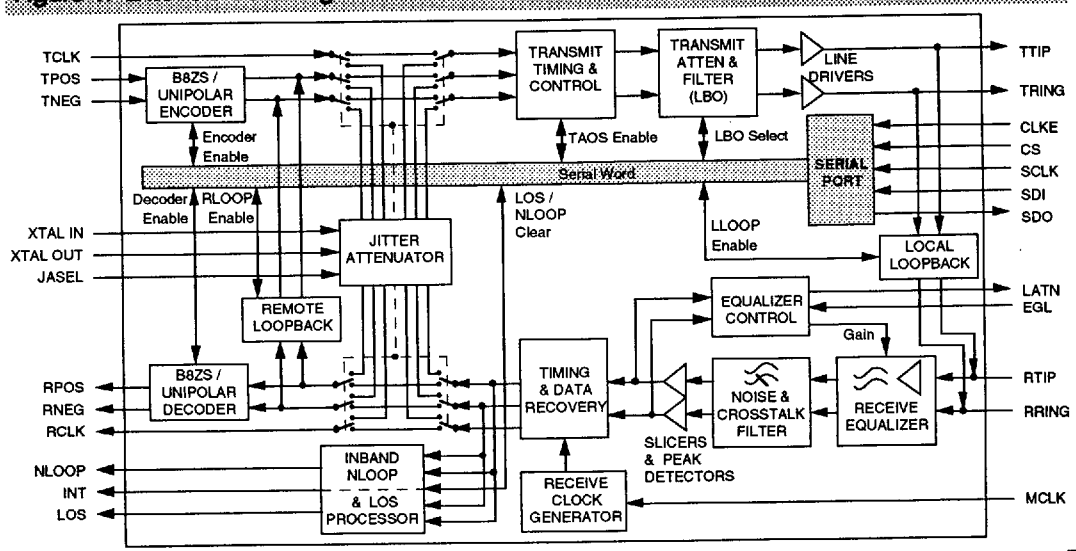
Applications

- ISDN Primary Rate Interface (PRI) (ANSI T1.408)
- CSU interface to T1 Service (Pub 62411)
- DS1 Metallic Interface (ANSI T1.403)
- T1 LAN bridge
- CPU to CPU Channel Extenders
- Digital Loop Carrier - Subscriber Carrier Systems
- T1 Mux
- Channel Banks

Features

- Fully integrated transceiver comprising: on-chip equalizer; timing recovery/control; data processor; receiver; and transmitter with Line Build-Out and digital control
- Meets or exceeds ANSI and CCITT specifications including T1.403, T1.408, and AT&T Pub 62411
- Selectable Receiver Sensitivity. Fully restores the received signal after transmission through a cable with attenuation of either 0 to 26 dB, or 0 to 36 dB @772 kHz
- Selectable Unipolar or Bipolar data I/O
- Selectable B8ZS encoding/decoding
- Line attenuation indication output
- 138 UI jitter tolerance at 1 Hz
- Output short circuit current limit protection
- On-line idle mode for redundant systems
- 7.5 dB, 15 dB, and 22.5 dB transmit LBOs
- Local, remote and inband network loopback functions
- Receive monitor with Loss of Signal (LOS) output
- Jitter attenuation starting at 6 Hz, switchable to transmit or receive path
- Microprocessor controllable

Figure 1: LXT310 Block Diagram



Absolute Maximum Ratings

Parameter	Sym	Min	Max	Units
DC supply (referenced to GND)	RV+, TV+	–	6.0	V
Input voltage, any pin	V_{IN}	RGND - 0.3	RV+ + 0.3	V
Input current, any pin [1]	I_{IN}	-10	10	mA
Ambient operating temperature	T_A	-40	85	°C
Storage temperature	T_{STG}	-65	150	°C

WARNING: Operations at or beyond these limits may result in permanent damage to the device. Normal operation not guaranteed at these extremes.
[1] Transient currents of up to 100 mA will not cause SCR latch-up. TTIP, TRING, TV+ and TGND can withstand a continuous current of 100mA.

Operating Conditions/Characteristics

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
DC supply [2]	RV+, TV+	4.75	5.0	5.25	V	
Ambient operating temperature	T_A	–	25	–	°C	
Power dissipation [3]	P_D	–	375	450	mW	100% ones density & maximum line length @ 5.25 V

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.
[2] TV+ must not exceed RV+ by more than 0.3 V.
[3] Power dissipation while driving 25 Ω load over operating temperature range. Includes device and load. Digital input levels are within 10% of the supply rails and digital outputs are driving a 50 pF capacitive load.

Digital Characteristics (T_A = -40° to 85°C, V+ = 5.0 V ±5%, GND = 0 V)

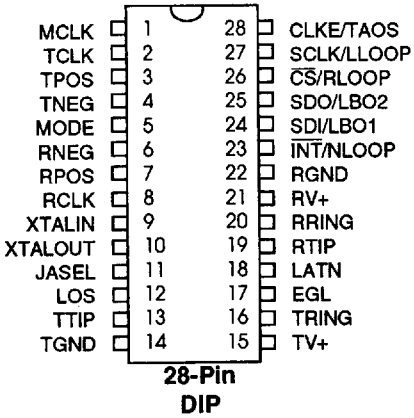
Parameter	Sym	Min	Typ	Max	Units	Test Conditions
High level input voltage [1,2] (pins 1-5, 10, 23-28)	V_{IH}	2.0	–	–	V	
Low level input voltage [1,2] (pins 1-5, 10, 23-28)	V_{IL}	–	–	0.8	V	
High level output voltage [1,2] (pins 6-8, 12, 23, 25)	V_{OH}	2.4	–	–	V	I_{OUT}=- 400 µA
Low level output voltage [1,2] (pins 6-8, 12, 23, 25)	V_{OL}	–	–	0.4	V	I_{OUT}=1.6mA
Input leakage current	I_{LL}	0	–	± 10	µA	
Three-state leakage current[1] (pin 25)	I_{3L}	0	–	± 10	µA	

[1] Functionality of pins 23 and 25 depends on mode. See Host / Hardware Mode descriptions.
[2] Output drivers will output CMOS logic levels into CMOS loads.

Analog Characteristics (T_A = -40° to 85°C, V+ = 5.0 V ±5%, GND = 0 V)

Parameter		Min	Typ[1]	Max	Units	Test Conditions
Recommended output load at TTIP and TRING		50	–	200	Ω	
AMI Output Pulse Amplitudes		2.4	3.0	3.6	V	measured at the output with LBO1 = 0, and LBO2 = 0
Jitter added by the transmitter [2]	10Hz - 8kHz [3]	–	–	0.01	UI	
	8kHz - 40 kHz [3]	–	–	0.02	UI	
	10Hz - 40 kHz [3]	–	–	0.02	UI	
	Broad Band	–	–	0.04	UI	
Receive signal attenuation range @ 772 kHz	Mode 1 (EGL = 1)	0	26	–	dB	
	Mode 2 (EGL = 0)	0	36	–	dB	
Allowable consecutive zeros before LOS		160	175	190	–	
Input jitter tolerance	10kHz - 100kHz	0.4	–	–	UI	0 dB line
	1 Hz	138	–	–	UI	
Jitter attenuation curve corner frequency [4]		–	6	–	Hz	

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.
[2] Input signal to TCLK is jitter-free.
[3] Guaranteed by characterization; not subject to production testing.
[4] Circuit attenuates jitter at 20 dB/decade above the corner frequency.



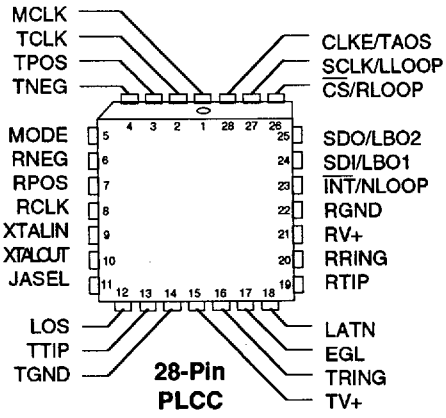


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Table 1: Pin Descriptions

Pin #	Sym	I/O	Name	Description
1	MCLK	I	Master Clock	A 1.544 MHz clock input used to generate internal clocks. Upon Loss of Signal (LOS), RCLK is derived from MCLK. If MCLK is not applied, this pin should be grounded.
2	TCLK	I	Transmit Clock	Transmit clock input. TPOS and TNEG are sampled on the falling edge of TCLK.
3	TPOS/ TDATA	I	Transmit Data Input	Input data to be transmitted on the twisted-pair line. Normally, pin 3 is TPOS and pin 4 is TNEG, the positive and negative sides of a bipolar input pair. However, if pin 4 is held high for at least 16 TCLK cycles (equivalent to 15 successive bipolar violations), the LXT310 switches to a unipolar mode. The LXT310 returns to bipolar I/O when pin 4 goes low.
4	TNEG/ UBS	I	Data Input/ Polarity Select	
5	MODE	I	Mode Select	Setting MODE to logic 1 selects the Host mode. In Host mode, the serial interface is enabled for control and status reporting. Setting MODE to logic 0 selects the Hardware (H/W) mode. In Hardware mode the serial interface is disabled; hard-wired pins control configuration and report status. Tying MODE to RCLK enables Hardware mode and the B8ZS encoder/decoder.
6	RNEG	O	Receive Data Negative	In Bipolar data I/O mode pins 6 and 7 are bipolar data outputs. A signal on RNEG corresponds to receipt of a negative pulse on RTIP/RRING, and a signal on RPOS corresponds to a positive pulse on RTIP/RRING. RNEG/ RPOS outputs are Non-Return-to-Zero (NRZ). In Host mode, CLKE determines the clock edge at which these outputs are stable and valid. In Hardware mode both outputs are stable and valid on the RCLK rising edge.
7	RPOS	O	Receive Data Positive	
6	BPV	O	Bipolar Violation	In Unipolar data I/O mode, pin 6 goes high to indicate receipt of a Bipolar Violation of the AMI code.
7	RDATA	O	Receive Data	In Unipolar mode, data received from the twisted-pair line is output at pin 7.
8	RCLK	O	Receive Clock	This is the clock recovered from the signal received at RTIP and RRING.

Table 1: Pin Descriptions continued

Pin #	Sym	I/O	Name	Description
9	XTALIN	I	Crystal Input	An external crystal (18.7 pF load capacitance, pullable) operating at 6.176 MHz (four times the bit rate) is required to enable the jitter attenuation function of the LXT310. These pins may also be used to disable the jitter attenuator by connecting the XTALIN pin to the positive supply through a resistor, and leaving the XTALOUT pin unconnected.
10	XTALOUT	O	Crystal Output	
11	JASEL	I	Jitter Attenuation Select	Selects jitter attenuation location. When JASEL = 1, the jitter attenuator is active in the receive path. When JASEL = 0, the jitter attenuator is active in the transmit path.
12	LOS	O	Loss Of Signal	LOS goes to a logic 1 when 175 consecutive spaces have been detected. LOS returns to a logic 0 when the received signal reaches a mark density of 12.5% (determined by receipt of four marks within 32 bit periods.) Received marks are output on RPOS and RNEG even when LOS is at a logic 1.
13	TTIP	O	Transmit Tip	Differential Driver Outputs. These outputs are designed to drive a 50 - 200 Ω load. Line matching resistors and transformer can be selected to give the desired pulse height.
16	TRING	O	Transmit Ring	
14	TGND	-	Tx Ground	Ground return for the transmit drivers power supply TV+.
15	TV+	I	Transmit Power Supply	+5 VDC power supply input for the transmit drivers. TV+ must not vary from RV+ by more than ± 0.3V.
17	EGL	I	Equalizer Gain Limit	Input sets equalizer gain. When EGL = 0, up to 36 dB of equalizer gain may be added. When EGL = 1, equalizer gain is limited to no more than 26 dB.
18	LATN	O	Line Attenuation Indication (See Figure 6)	Encoded output. Pulse width, relative to RCLK, indicates receive equalizer gain setting (line insertion loss at 772 kHz) in 7.5 dB steps. When LATN = 1 RCLK pulse, the equalizer is set at 7.5 dB gain, 2 pulses = 15 dB, 3 pulses = 22.5 dB and 4 pulses = 0 dB. Output is valid on the rising edge of RCLK.
19	RTIP	I	Receive Tip	The AMI signal received from the line is applied at these pins. A 1:1 transformer is required. Data and clock from the signal applied at these pins are recovered and output on the RPOS/RNEG, and RCLK pins.
20	RRING	I	Receive Ring	
21	RV+	I	Receive Power Supply	+5 VDC power supply for all circuits except the transmit drivers. (Transmit drivers are supplied by TV+.)
22	RGND	-	Rx Ground	Ground return for power supply RV+.
23	NLOOP	O	Network Loopback *(H/W Mode)*	When high, indicates Inband Network Loopback has been activated by reception of 00001 pattern for five seconds. NLOOP is reset by reception of 001 for five seconds, or by activation of RLOOP or LLOOP.
	INT	O	Interrupt *(Host Mode)*	This LXT310 Host mode output goes low to flag the host processor when LOS or NLOOP changes state. $\overline{INT}$ is an open drain output and should be tied to power supply RV+ through a resistor. $\overline{INT}$ is reset by clearing the LOS or NLOOP register bit.

Table 1: Pin Descriptions continued

Pin #	Sym	I/O	Name	Description
24	SDI	I	Serial Data In *(Host Mode)*	The serial data input stream is applied to this pin when the LXT310 operates in the Host mode. SDI is sampled on the rising edge of SCLK.
	LBO1	I	Line Build-Out Select 1 *(H/W Mode)*	In Hardware mode this input is used in conjunction with LBO2 to select the transmit line build-outs: 00 = 0 dB, 01 = 7.5 dB, 10 = 15 dB, and 11 = 22.5 dB.
25	SDO	O	Serial Data Out *(Host Mode)*	The serial data from the on-chip register is output on this pin in the LXT310 Host mode. If CLKE is high, SDO is valid on the rising edge of SCLK. If CLKE is low SDO is valid on the falling edge of SCLK. This pin goes to a high-impedance state when the serial port is being written to and when $\overline{CS}$ is high.
	LBO2	I	Line Build-Out Select 2 *(H/W Mode)*	The signal applied at this pin in the LXT310 Hardware mode is used in conjunction with LBO1 to select the transmit line build-outs. 00 = 0 dB, 01 = 7.5 dB, 10 = 15 dB, and 11 = 22.5 dB.
26	$\overline{CS}$	I	Chip Select *(Host Mode)*	This input is used to access the serial interface in the Host mode. For each read or write operation, $\overline{CS}$ must transition from high to low, and remain low.
	RLOOP	I	Remote Loopback *(H/W Mode)*	This input controls loopback in the Hardware mode. Setting RLOOP to a logic 1 enables Remote Loopback. During Remote Loopback, in-line encoders and decoders are bypassed. Setting both RLOOP and LLOOP while holding TAOS low causes a Reset. Setting both RLOOP and LLOOP with TAOS high (or tying RCLK to RLOOP) enables Network Loopback detection.
27	SCLK	I	Serial Clock *(Host Mode)*	This clock is used in the Host mode to write data to or read data from the serial interface registers.
	LLOOP	I	Local Loopback *(H/W Mode)*	This input controls loopback functions in the Hardware mode. Setting LLOOP to a logic 1 enables the Local Loopback Mode. Setting both LLOOP and RLOOP while holding TAOS low causes a Reset.
28	CLKE	I	Clock Edge *(Host Mode)*	Setting CLKE to logic 1 causes RPOS and RNEG to be valid on the falling edge of RCLK, and SDO to be valid on the rising edge of SCLK. When CLKE is a logic 0, RPOS and RNEG are valid on the rising edge of RCLK, and SDO is valid on the falling edge of SCLK.
	TAOS	I	Transmit All Ones *(H/W Mode)*	When set to a logic 1 in the Hardware mode, TAOS causes the LXT310 to transmit a stream of marks at the TCLK frequency. Activating TAOS causes TPOS and TNEG inputs to be ignored. TAOS is inhibited during Remote Loopback. Setting TAOS, LLOOP and RLOOP simultaneously enables Network Loopback detection.

Functional Description

The LXT310 is a fully integrated PCM transceiver for 1.544 MHz (T1) applications. It allows full-duplex transmission of digital data over existing twisted-pair installations.

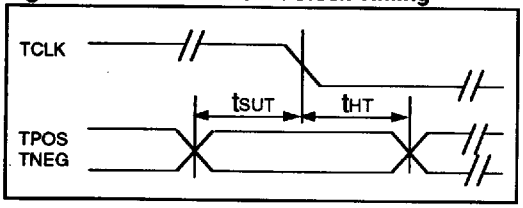
The LXT310 interfaces with two twisted-pair lines (one pair for transmit, one pair for receive) through standard pulse transformers and appropriate resistors.

Figure 1 is a block diagram of the LXT310. The transceiver may be controlled by a microprocessor through the serial port (Host Mode), or by individual pin settings (Hardware Mode). The jitter attenuator may be positioned in either the transmit or receive path.

Transmitter

Input data (bipolar or unipolar) for transmission onto the line is clocked serially into the device. Bipolar data is input at pin 3 (TPOS) and pin 4 (TNEG). Unipolar data is input at pin 3 (TDATA) only. (Unipolar mode is enabled by holding pin 4 high for 16 RCLK cycles). Input data may be passed through the Jitter Attenuator and/or B8ZS encoder, if selected. In Host mode, B8ZS is selected by setting bit D3 of the input data byte. In Hardware mode, B8ZS is selected by connecting the MODE pin to RCLK. Input synchronization is supplied by the transmit clock (TCLK). Timing requirements for TCLK and the Master Clock (MCLK) are defined in Table 2 and Figure 2.

Figure 2: LXT310 Transmit Clock Timing



Idle Mode

The LXT310 incorporates a transmit idle mode. This allows multiple transceivers to be connected to a single line for redundant applications. TTIP and TRING remain in a high impedance state when TCLK is not present (TCLK grounded). The high impedance state can be temporarily disabled by enabling either TAOS, Remote Loopback or Network Loopback.

The transmitted pulse shape is determined by Line Build Out (LBO) inputs LBO1 and LBO2 as follows:

Line Build-Out (dB)	0	7.5	15	22.5
LBO1	0	1	0	1
LBO2	0	0	1	1

LBO settings are input through the serial port in the Host mode. In the Hardware mode, LBO inputs are applied through individual pins. Shaped pulses meeting the various T1 CSU and ISDN PRI requirements are applied to the AMI line driver for transmission onto the line at TTIP and TRING. Refer to Table 3 and Figure 3 for T1 pulse mask specifications.

Table 2: LXT310 Master Clock and Transmit Timing Characteristics (See Figure 2)

Parameter	Sym	Min	Typ[1]	Max	Units	Notes
Master clock frequency	MCLK	-	1.544	-	MHz	
Master clock tolerance	MCLKt	-	±100	-	ppm	
Master clock duty cycle	MCLKd	40	-	60	%	
Crystal frequency	fc	-	6.176	-	MHz	LXT310 only
Transmit clock frequency	TCLK	-	1.544	-	MHz	
Transmit clock tolerance	TCLKt	-	-	±100	ppm	
Transmit clock duty cycle	TCLKd	10	-	90	%	
TPOS/TNEG to TCLK setup time	t_{SUT}	50	-	-	ns	
TCLK to TPOS/TNEG Hold time	t_{HT}	50	-	-	ns	

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

Short Circuit Limit

The LXT310 transmitter is equipped with a short-circuit limiter. This feature limits to approximately 120 mA RMS the current the transmitter will source into a low-impedance load. The limiter trips when the RMS current exceeds the limit for 100 µs (~ 150 marks). It automatically resets when the load current drops below the limit.

The LXT310 meets or exceeds FCC and AT&T specifications for CSU and NI applications, as well as ANSI T1E1, and CCITT requirements for ISDN PRI.

Line Code

The LXT310 transmits data as a 50% AMI line code as shown in Figure 4. Power consumption is reduced by activating the AMI line driver only to transmit a mark. The output driver is disabled during transmission of a space. Biasing of the transmit DC level is on-chip.

Receiver

The twisted-pair input is received via a 1:1 transformer. Recovered data is output at RPOS/RNEG (RDATA in unipolar mode), and the recovered clock is output at RCLK. Refer to Table 4 and Figure 5 for receiver timing.

Figure 3: 1.544 MHz T1 Pulse Mask

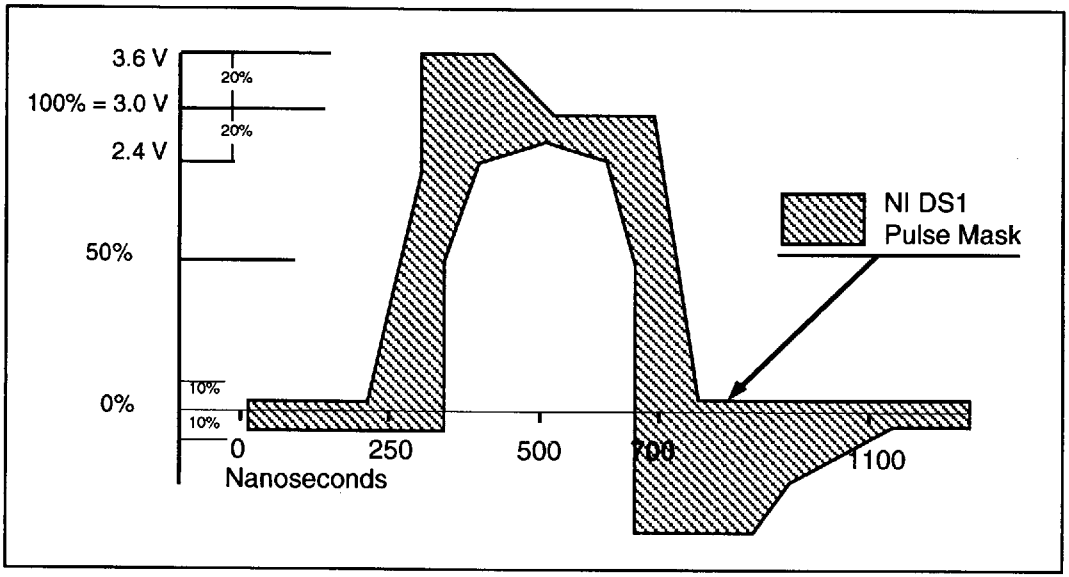
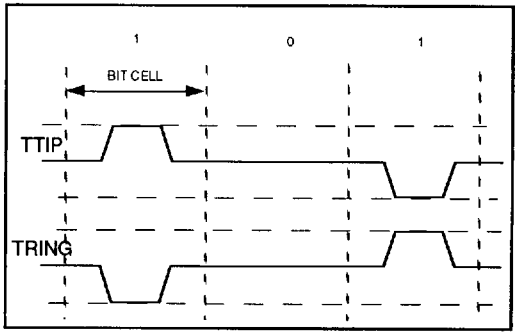


Table 3: Pulse Mask Corner Point Specifications

Maximum Curve		Minimum Curve	
Time (ns)	% V	Time (ns)	% V
0	5	0	-5
250	5	350	-5
325	80	350	50
325	120	400	90
425	120	500	95
500	105	600	90
675	105	650	50
725	5	650	-45
1100	5	800	-45
1250	5	896	-26
		1100	-5
		1250	-5

Figure 4: 50% AMI Coding Diagram



The signal received at RPOS and RNEG is processed through the receive equalizer. The Equalizer Gain Limit (EGL) input determines the maximum gain that may be applied at the equalizer. When set to 0, up to 36 dB of gain may be applied.

When EGL = 1, gain is limited to no more than 26 dB providing for increased noise margin in shorter loop operation. Insertion loss of the line in 7.5 dB steps, as indicated by the receive equalizer setting, is encoded in the LATN output as shown in Figure 6.

Table 4: LXT310 Receive Timing Characteristics (See Figure 5)

Parameter	Sym	Min	Typ[1]	Max	Units
Receive clock duty cycle [2]	RCLKd	40	50	60	%
Receive clock pulse width [2]	t_{PW}	600	648	700	ns
Receive clock pulse width high	t_{PWH}	-	324	-	ns
Receive clock pulse width low	t_{PWL}	303	324	345	ns
RPOS / RNEG to RCLK rising setup time	t_{SUR}	-	274	-	ns
RCLK rising to RPOS /RNEG hold time	t_{HR}	-	274	-	ns

[1] Typical figures are at 25°C and are for design aid only; not guaranteed and not subject to production testing.
[2] RCLK duty cycle widths will vary depending on extent of received pulse jitter displacement. Max and Min RCLK duty cycles are for worst case jitter conditions (0.4 UI clock displacement for 1.544 MHz.)

Figure 5: LXT310 Receive Clock Timing

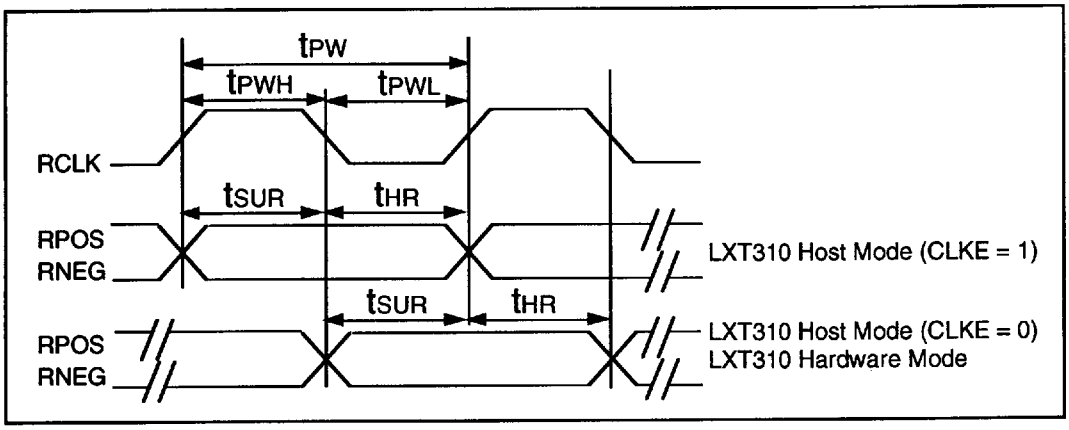
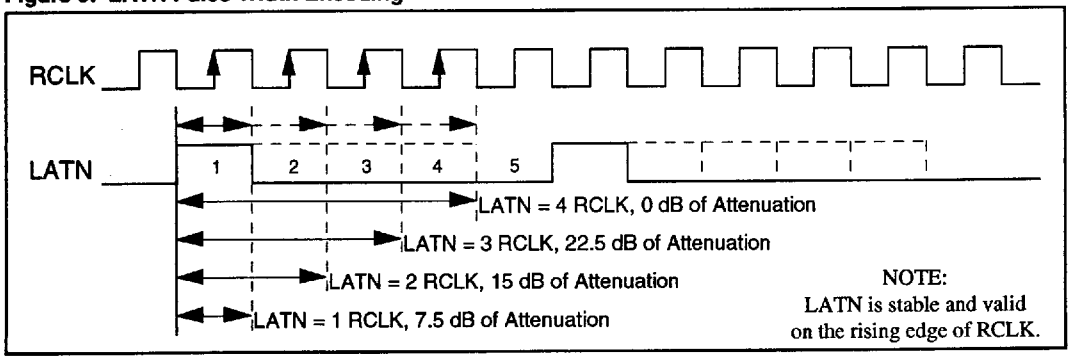


Figure 6: LATN Pulse Width Encoding



The equalized signal is filtered and applied to the peak detector and data slicers. The peak detector samples the inputs and determines the maximum value of the received signal. A percentage of the peak value is provided to the data slicers as a threshold level to ensure optimum signal-to-noise ratio. The threshold is set to 50% of the peak value. The receiver is capable of accurately recovering signals with up to 36 dB of cable attenuation (from 2.4 V).

After processing through the data slicers, the received signal is routed to the data and timing recovery section, then to the B8ZS decoder (if selected) and to the LOS processor. The LOS Processor loads a digital counter at the RCLK frequency. The count is incremented each time a zero (space) is received, and reset to zero each time a one (mark) is received. Upon receipt of 175 consecutive zeros the LOS pin goes high, and a smooth transition replaces the RCLK output with the MCLK. (*During LOS if MCLK is not supplied and JASEL = 1, the RCLK output is replaced with the centered crystal clock.*)

Received marks will be output regardless of the LOS status, but the LOS pin will not reset until the ones density reaches 12.5 %. This level is based on receipt of at least 4 ones in any 32 bit periods.

Jitter Attenuation

Jitter attenuation is provided by a Jitter Attenuation Loop (JAL) and an Elastic Store (ES). An external crystal oscillating at 4 times the bit rate provides clock stabilization. Refer to Table 5 for crystal specifications. The ES is a 32 x 2-bit register. When JASEL = 1, the JAL is positioned in the receive path. When JASEL = 0, the JAL is positioned in the transmit path.

Data (TPOS/TNEG / TDATA or RPOS/RNEG / RDATA) is clocked into the ES with the associated clock signal (TCLK or RCLK), and clocked out of the ES with the dejittered clock from the JAL. When the bit count in the ES is within two bits of overflowing or underflowing, the ES adjusts the output clock by 1/8 of a bit period. The ES produces an average delay of 16 bits in the associated path.

2

Operating Modes

The LXT310 can be controlled by a microprocessor through a serial interface (Host mode), or through individual pins, (Hardware mode). The mode of operation is set by the MODE pin logic level.

Host Mode Operation

The LXT310 operates in the Host mode when MODE is set to 1. The 16-bit serial word consists of an 8-bit Command/Address byte and an 8-bit Data byte. Table 6 lists the output data bit combinations. Figure 7 shows the serial interface data structure and timing. The Host mode provides a latched Interrupt output (INT) which is triggered by a change in the LOS or NLOOP bits. The Interrupt is cleared when the interrupt condition no longer exists, and the host processor writes a one to the respective bit in the serial input data byte.

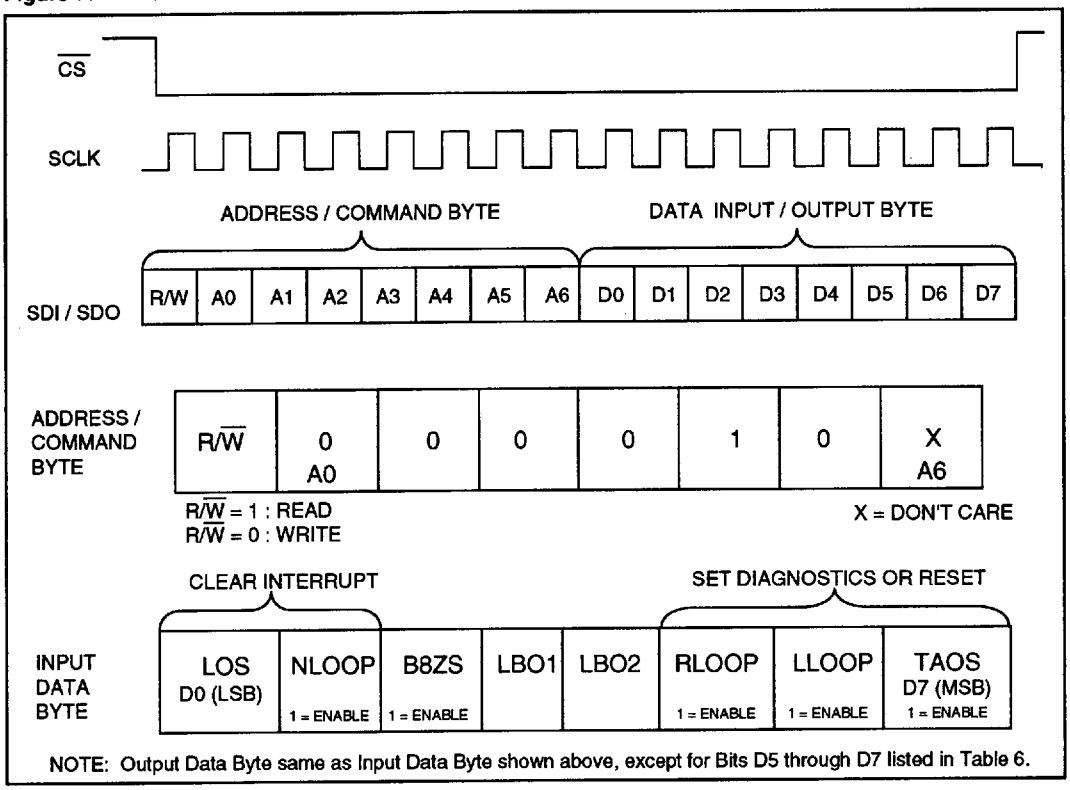
Table 5: LXT310 Crystal Specifications (External)

Parameter	Specification
Frequency	6.176 MHz
Frequency Stability	±20 ppm @ 25° C ± 25 ppm from -40° C to + 85° C (Ref 25° C reading)
Pullability	CL = 11.7 pF to 18.7 pF, +ΔF = 175 to 195 ppm CL = 18.7 pF to 34 pF, -ΔF = 175 to 195 ppm
Effective series resistance	40 Ω Maximum
Crystal cut	AT
Resonance	Parallel
Maximum drive level	2.0 mW
Mode of operation	Fundamental
Crystal holder	HC49 (R3W), C_O = 7 pF maximum C_M = 17 fF typical

Table 6: LXT310 Serial Data Output Bit Coding (See Figure 7)

Bit D5	Bit D6	Bit D7	Status
0	0	0	Reset has occurred, or no program input.
0	0	1	TAOS active
0	1	0	LLOOP active
0	1	1	TAOS and LLOOP active
1	0	0	RLOOP active
1	0	1	NLOOP has changed state since last Clear NLOOP occurred.
1	1	0	LOS has changed state since last Clear LOS occurred.
1	1	1	LOS and NLOOP have both changed state since last Clear NLOOP and Clear LOS.

Figure 7: LXT310 Serial Interface Data Structure



NOTE: Output Data Byte same as Input Data Byte shown above, except for Bits D5 through D7 listed in Table 6.

Host mode also allows control of the serial data and receive data output timing. The Clock Edge (CLKE) signal determines when these outputs are valid, relative to the Serial Clock (SCLK) or RCLK as listed in Table 7.

Table 7: CLKE Settings

Output	Clock	CLKE = 0	CLKE = 1
RPOS/RNEG	RCLK	Rising Edge	Falling Edge
SDO	SCLK	Falling Edge	Rising Edge

The LXT310 serial port is addressed by setting bit A4 in the Address/Command byte, corresponding to address 16. The LXT310 contains only a single output data register so no complex chip addressing scheme is required. The register is accessed by causing the Chip Select (CS) input to transition from high to low. Bit 1 of the serial Address/Command byte provides Read/Write control when the chip is accessed. A logic 1 indicates a read operation, and a logic 0 indicates a write operation. Serial data I/O timing characteristics are shown in Table 8, and Figures 8 and 9.

Hardware Mode Operation

In Hardware mode the transceiver is accessed and controlled through individual pins. With the exception of the INT and CLKE functions, Hardware mode provides all the functions provided in the Host mode. In the Hardware mode RPOS/RNEG or RDATA outputs are valid on the rising edge of RCLK. The LXT310 operates in Hardware mode only when MODE is set to 0 or connected to RCLK.

Initialization and Reset Operation

Upon power up, the transceiver is held static until the power supply reaches approximately 3V. Upon crossing this threshold, the device begins a 32 ms reset cycle to calibrate the transmit and receive delay lines and lock the Phase Lock Loop to the receive line. A reference clock is required to calibrate the delay lines. The transmitter reference is provided by TCLK. The crystal oscillator provides the receiver reference. If the crystal oscillator is grounded, MCLK is used as the receiver reference clock.

The transceiver can also be reset from the Host or Hardware mode. In Host mode, reset is commanded by simultaneously writing ones to RLOOP and LLOOP, and a zero to TAOS. In Hardware mode, reset is commanded by holding RLOOP and LLOOP high simultaneously for 200 ns while holding TAOS low. In either mode, reset clears and sets all registers to 0.

Diagnostic Mode Operation

In Transmit All Ones (TAOS) mode, the TPOS and TNEG inputs to the transceiver are ignored and the transceiver transmits a continuous stream of 1's at the TCLK frequency. (If TCLK is not provided, TAOS is locked to the MCLK.) This can be used as the Blue Alarm Indicator (AIS). In Host mode, TAOS is commanded by writing a one to bit D7 of the input data byte. In Hardware mode, TAOS is commanded by setting pin 28 high. TAOS can be commanded simultaneously with Local Loopback, but is inhibited during Remote Loopback.

Local Loopback (LLOOP) is designed to exercise the maximum number of functional blocks. During LLOOP operation, the RTIP/RRING inputs from the line are disconnected. Instead, the transmit outputs are routed back into the receive inputs. This tests the encoders/decoders, jitter attenuator, transmitter, receiver and timing recovery sections. In Host mode, Local Loopback is commanded by writing a one to bit D6 of the input data byte. In Hardware mode, Local Loopback is commanded by setting pin 27 high. If TAOS and LLOOP are both set, the All Ones pattern is transmitted onto the line while the TPOS/TNEG input data is looped back to the RPOS/RNEG outputs.

In Remote Loopback (RLOOP) mode, the transmit data and clock inputs (TCLK and TPOS/TNEG or TDATA) are ignored, and the in-line encoders and decoders are bypassed. The RPOS/RNEG or RDATA outputs are looped back through the transmit circuits and output on TTIP and TRING at the RCLK frequency. Receiver circuits are unaffected by the RLOOP command and continue to output the RCLK and RPOS/RNEG or RDATA signals received from the twisted-pair line. In Host mode, Remote Loopback is commanded by writing a one to bit D5 of the input data byte. In Hardware mode, Remote Loopback is commanded by setting pin 26 high.

Network Loopback can be commanded from the network when the Network Loopback detect function is enabled. In Host mode, Network Loopback (NLOOP) detection is enabled by simultaneously writing ones to RLOOP, LLOOP and TAOS, then writing zeros in the next cycle. In Hardware mode, Network Loopback detection is enabled by holding RLOOP, LLOOP and TAOS high simultaneously for 200 ns then bringing them to logic 0, or by tying RCLK to RLOOP. NLOOP detection may be disabled by resetting the chip.

When NLOOP detection is enabled, the receiver monitors the input data stream for the NLOOP data patterns (00001 = enable, 001 = disable). When an NLOOP enable data pattern is repeated for a minimum of five seconds (with 10^{-3} BER), the device begins remote loopback operation. The LXT310 responds to both framed and unframed NLOOP patterns. Once remote network loopback detection is enabled at the chip and activated by the correct data pattern, it is identical to remote loopback initiated at the chip. NLOOP is reset by receiving the disable pattern for 5 seconds, or by activation of RLOOP. NLOOP is temporarily interrupted by LLOOP, but the NLOOP state is not reset.

Table 9: LXT310 Serial I/O Timing Characteristics (See Figures 9 and 10)

Parameter	Sym	Min	Typ[1]	Max	Units	Test Conditions
Rise/Fall time - any digital output	t_{RF}	-	-	100	ns	Load 1.6 mA, 50pF
SDI to SCLK setup time	t_{DC}	50	-	-	ns	
SCLK to SDI hold time	t_{CDH}	50	-	-	ns	
SCLK low time	t_{CL}	240	-	-	ns	
SCLK high time	t_{CH}	240	-	-	ns	
SCLK rise and fall time	t_R, t_F	-	-	50	ns	
CS to SCLK setup time	t_{CC}	50	-	-	ns	
SCLK to CS hold time	t_{CCH}	50	-	-	ns	
CS inactive time	t_{CWH}	250	-	-	ns	
SCLK to SDO valid	t_{CDV}	-	-	200	ns	
SCLK falling edge or CS rising edge to SDO high Z	t_{CDZ}	-	100	-	ns	

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

Figure 8: LXT310 Serial Data Input Timing Diagram

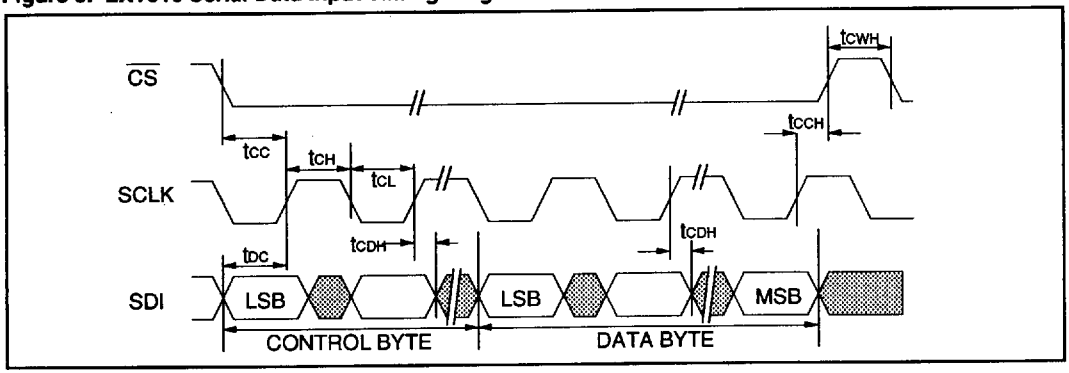
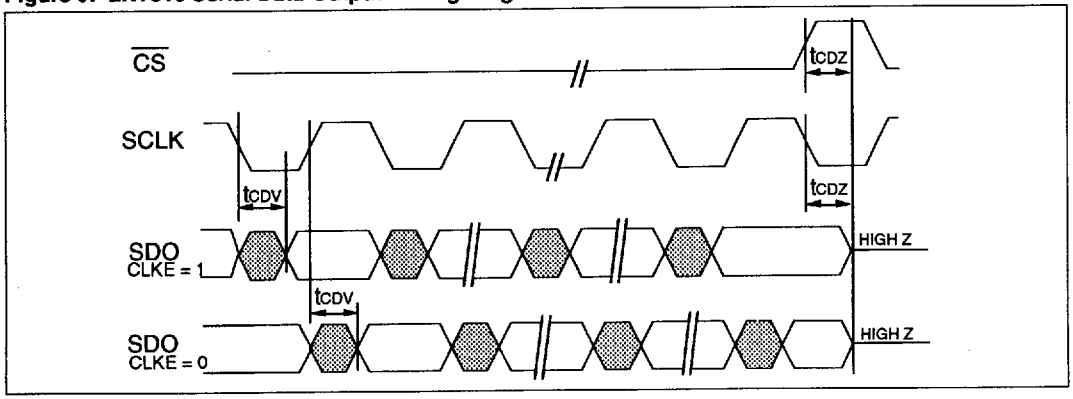


Figure 9: LXT310 Serial Data Output Timing Diagram



Application Considerations

LATN Decoding Circuits and External Components

To conserve pins, the line attenuation output is encoded as a simple serial bit stream. Table 9 provides the decoded output for each equalizer setting. Figure 10 is a typical decoding circuit for the LATN output. It uses a 2-bit synchronous counter (half of a 4-bit counter) with synchronous reset, and a pair of flip-flops. Table 10 lists approved crystals and transformers.

Power Requirements

The LXT310 is a low-power CMOS device. It operates from a single +5 V power supply which can be connected externally to both the transmitter and receiver. However, the two inputs must be within ± .3V of each other, and decoupled to their respective grounds separately, as shown in Figure 11. Isolation between the transmit and receive circuits is provided internally.

Table 9: LATN Output Coding

L1	L2	Line Attenuation
0	0	0.0 dB
0	1	-7.5 dB
1	0	-15.0 dB
1	1	-22.5 dB

Figure 10: Typical LATN Decoding Circuit

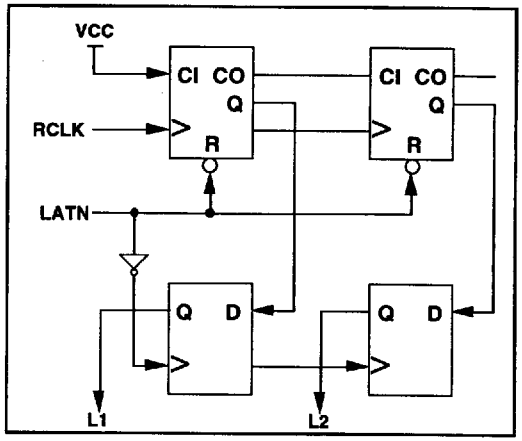


Table 10: Approved Crystals and Transformers

Component	Manufacturer	Part Numbers
Crystal (6.176 MHz)	M-Tron	MP-1 3808-010 / 4144-002
	Monitor Products	MSC1311-01B
	CTS Knights	6176-180
	Valpey Fisher	VF49A16FN1
	U .S. Crystal	U18-18-6176SP
Tx Transformer (1 : 2)	Bell Fuse	0553-5006-IC
	FEE Fil-Mag	66Z1308
	Midcom	671-5832
	Pulse Engineering	65351, 65771
	Schott Corp	67127370 and 67130850
	HALO	TD61-1205G and TD67-1205G (combo Tx/Rx)
Rx Transformer (1 : 1)	FEE Fil-Mag	FE 8006-155
	Midcom	671-5792
	Pulse Engineering	64936 and 65778
	Schott Corp	67130840 and 67109510
	HALO	TD61-1205G and TD67-1205G (combo Tx/Rx)

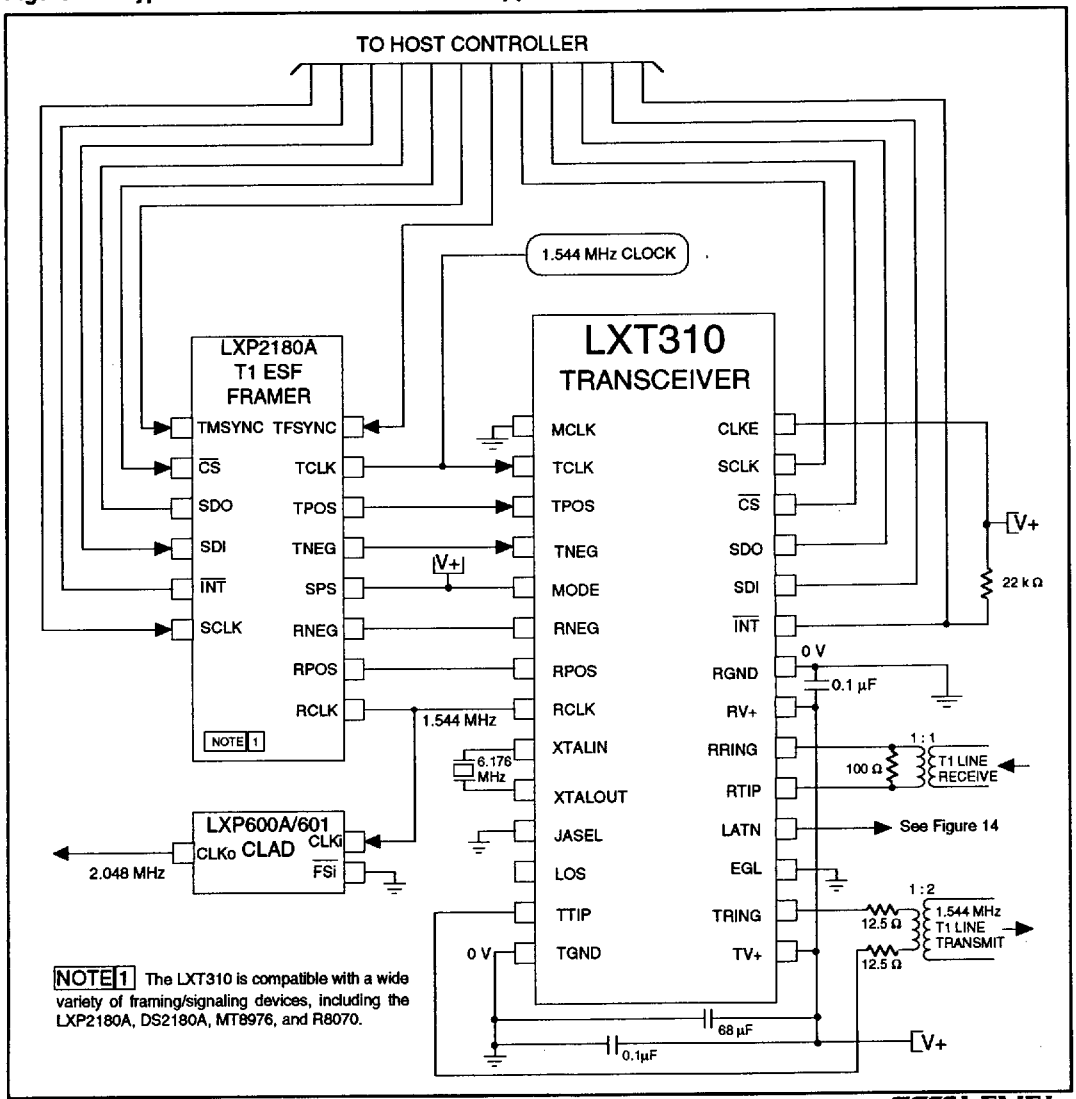
Host Mode Applications

Figure 11 shows a typical T1 CSU application with the LXT310 operating in the Host mode (MODE pin tied high). The LXP2180A T1/ESF Framer provides the digital interface with the host controller. Both devices are controlled through the serial interface. In the Host mode, the LOS alarm is reported via the serial port so the LOS pin is allowed to float.

An LXP600A Clock Adapter (CLAD) provides the 2.048 MHz system backplane clock, locked to the recovered 1.544 MHz clock signal. The 6.176 MHz crystal across XTALIN and XTALOUT enables the JAL which is switched to the transmit side by the ground on JASEL. (Refer to Table 10 for approved crystals and transformers.) The power supply inputs are tied to a common bus with appropriate decoupling capacitors (68µF and 0.1 µF) installed on each side.

The twisted-pair interfaces are relatively simple. A 100 Ω resistor across the input of a 1:1 transformer is used on the receive side, and a pair of 12.5 Ω resistors are installed in line with the 1:2 output transformer.

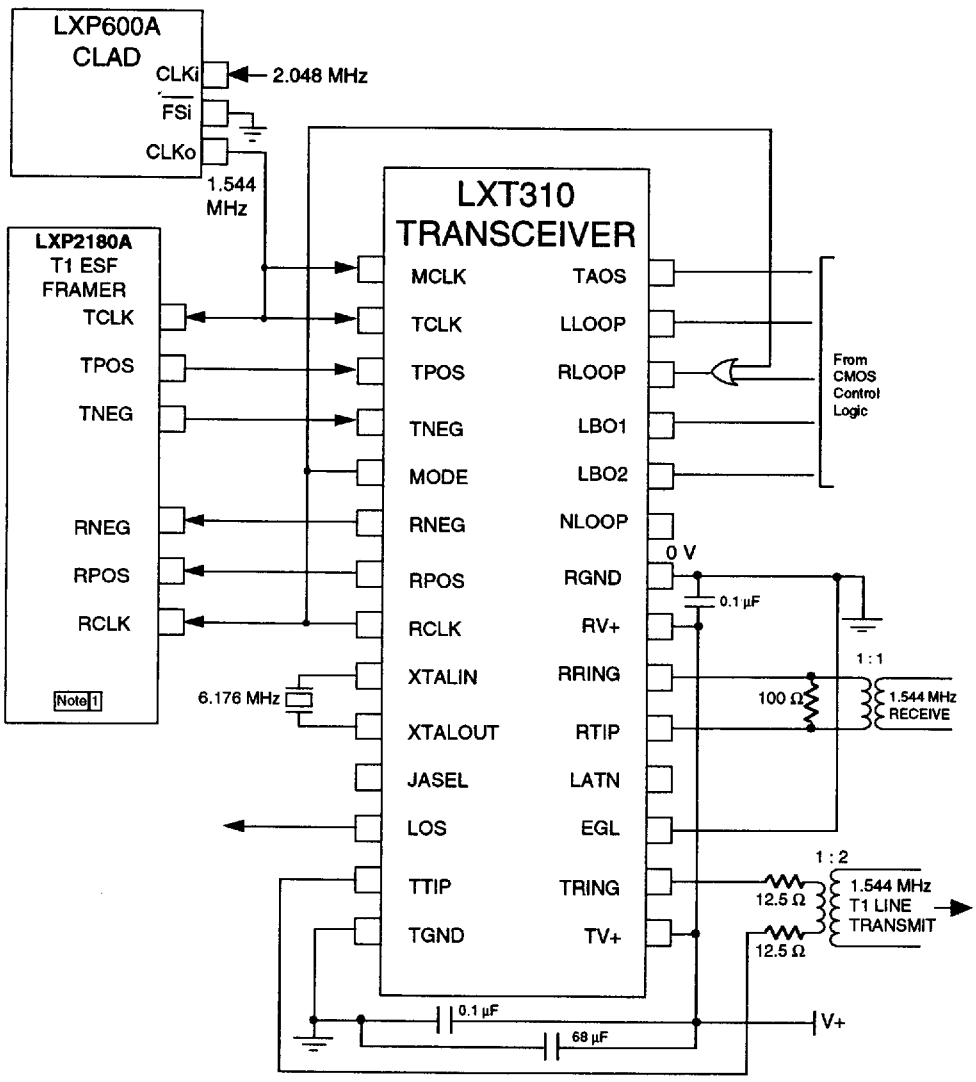
Figure 11: Typical LXT310 Host Mode T1/CSU Application



LXT310 Hardware Mode Applications

Figure 12 is a typical 1.544 MHz ISDN PRI application with the LXT310, LXP2180A framer and an LXP600A clock adapter. The LXT310 is operating in the Hardware mode with B8ZS encoding enabled (MODE pin 5 tied to RCLK). As in the T1 CSU application, Figure 11, this configuration is illustrated with a single power supply bus. CMOS control logic is used to set both LBO pins high, selecting the 22.5 dB LBO, and the EGL pin is tied low, allowing for full receiver gain. The TAOS, LLOOP and RLOOP diagnostic modes are individually controllable. The RCLK input to the OR gate at RLOOP allows for clocking of the RLOOP pin, which enables network loopback detection. The receive and transmit line interfaces are identical to the Host mode application shown in Figure 11.

Figure 12: Typical LXT310 Hardware Mode Application



NOTE 1 In addition to the LXP2180A, the LXT310 is compatible with a wide variey of framing/signaling devices, including the DS2180A, MT8976 and R8070.