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Cortina Systems® LXT6155 155 Mbps SDH/SONET/ATM Transceiver

Datasheet

The Cortina Systems® LXT6155 155 Mbps SDH/SONET/ATM Transceiver (LXT6155 Transceiver) is a high speed fully integrated transceiver designed for 155 Mbps SDH/SONET/ATM transmission system applications. The LXT6155 Transceiver provides a LVPECL interface for fiber optics modules, and a CMI interface for coax cable drive. These circuits are implemented using Cortina Systems, Inc.'s proven low power 3.3V CMOS analog and digital circuits. The transmitter incorporates a parallel-to-serial converter, a frequency multiplier PLL, CMI line encoders, and line interfaces for both coax cable and optical fiber. The receiver incorporates an adaptive equalizer, a clock recovery PLL, Loss of Signal (LOS) detector, CMI and NRZ decoders, a serial-to-parallel converter, and an SDH/SONET frame byte detector/aligner. At the system interface, the LXT6155 Transceiver offers both parallel 8-bit and serial differential interfaces. The LXT6155 Transceiver also operates in either Hardware stand-alone mode or Software mode. Software mode is controlled by a serial microprocessor (µP) to program formats and operating/test modes.

Product Features

- Complies with:
  - Bellcore* SONET GR-253
  - ITU-T G.703/813/958 STM1
- Two line interface formats:
  - Fiber LVPECL NRZ
  - Coax CMI
- Transmit synthesizer PLL
- Receive clock recovery PLL
- Adaptive CMI equalizer
- Analog circuitry for transformer drive
- Programmable LOS function
- CMI encoder and decoder
- Serial/Parallel and Parallel/Serial conversion
- Byte alignment for SDH/SONET frames
- Two modes of operation:
  - Microprocessor controlled; software mode
  - Stand-alone; hardware mode
- No external crystal required. A 19.44 MHz crystal is optional
- Low power consumption (less than 760 mW typical)
- Operates from a single 3.3 V supply
- 64 pin LQFP package

Applications

- OC3/STM1 SDH/SONET Cross Connects
- OC3/STM1 SDH/SONET Add/Drop Mux
- OC3/STM1 Transmission Systems
- OC3/STM1 Short Haul Serial Links
- OC3/STM1 ATM/WAN Transmission Systems
- OC3/STM1 ATM/WAN Access Systems

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Contents

Figures

Tables

Revision History

Revision 7.0 Revision Date: 14 February 2007
First release of this document from Cortina Systems, Inc.

Revision 006 Revision Date: 01 February 2006
• Table 2, *Standards Compliance*, on page 15 — changed line rate from 155 Mbps to 155.52 Mbps. • Figure 5, *Receive Frame Synchronization and Frame Pulse Position*, on page 17 — Added Receive Output Frame Pulse (ROFP) heading to the drawing • Section 3.2.2.1, *Loss of Signal (LOS)*, on page 18 — New last paragraph in this section • Section 3.5.1.1.2, *XTAL*, on page 22 — Added mention of RX LOS state machine. • Table 4, *Loopback Selection*, on page 22 — Updated pin headings to specify ADDR0 and ADDR1. • Figure 17, *75 Ohm Coax Cable Interface*, on page 36 — Figure was incorrect. • Section 5.2, *Coax Interface*, on page 35 — Added a caution to ensure to decouple the system side center tap of the transformer. • Table 27, *Recommended Operating Conditions*, on page 38 — “Changed Ambient Operating Temperature” to “Case Operating Temperature”. • Table 28, *DC Electrical Characteristics (Vcc = 3.0 V to 3.6 V; TA = -40 °C to 85 °C)*, on page 38 — Added “Differential input voltage (LVPECL)” parameter. Also, added a note to specify that the High and Low Level Input Voltage specs are valid for XTALIN when using an external clock.

Revision 005 Revision Date: 01 January 2004
• Table 30, *Transmit Analog Characteristics*, on page 40 — Updated specifications for jitter transfer and jitter tolerance based on Bench DV data, and corrected figure reference for jitter transfer. • Figure 21, *Receive Parallel Output Data Timing*, on page 42 — Revised diagram. • Table 32, *Receive Analog Characteristics*, on page 42 — Updated specifications for jitter transfer and jitter tolerance based on Bench DV data. • Table 35, *Jitter Generation*, on page 47 — Updated specifications based on Bench DV data. • Table 36, *Jitter Transfer*, on page 47 — Updated specifications based on Bench DV data.

Revision 004 Revision Date: 01 January 2003
Updated Figure 18

Revision 003 Revision Date: 01 August 2002
Updated Figure 16, note 1: R3, R4, R7, R8 = 82.5

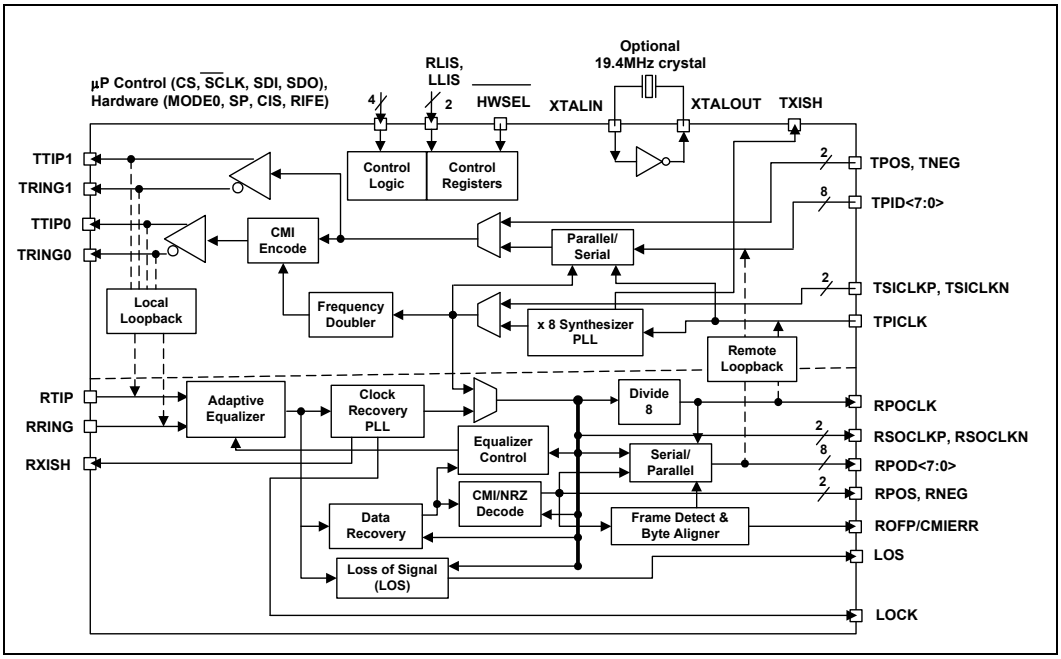
Revision 002 **Revision Date: 01 July 2002**
Formatting change

Revision 001 **Revision Date: 01 January 2001**
Initial version

1.0 LXT6155 Transceiver Block Diagram

Figure 1 shows the block diagram for the LXT6155 Transceiver.

Figure 1 LXT6155 Transceiver Block Diagram



2.0 Pin Assignments and Signal Descriptions

Figure 2 LXT6155 Transceiver Pin Assignments

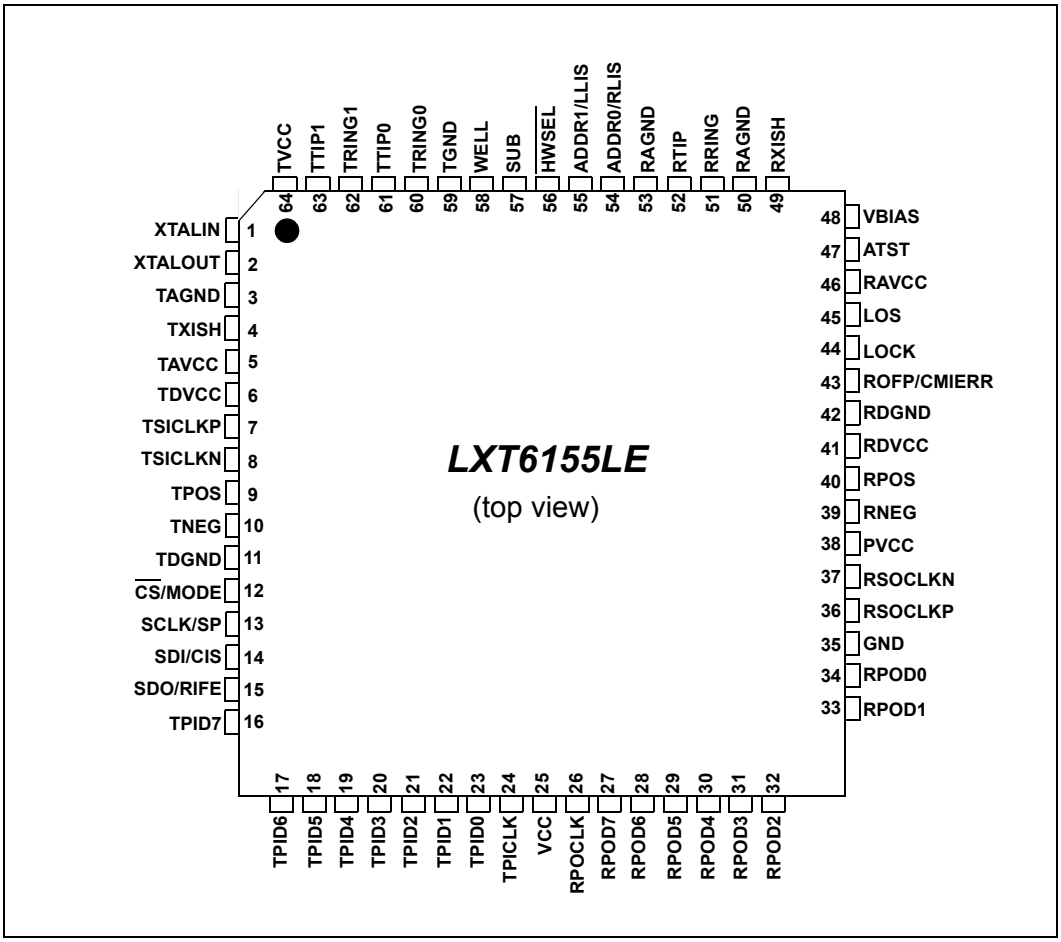


Table 1 Pin Descriptions (Sheet 1 of 4)

Pin #	Pin Name	I/O[1]	Type[2]	Description
1	XTALIN	AI/O		**Crystal Input/Output**. These pins are connected to an external 19.44 MHz crystal. Alternately, a stable external clock signal may be connected to XTALIN with XTALOUT left open. XTALIN should be connected to TAGND and XTALOUT should be left open if the transmit input clock is used as a clock reference
2	XTALOUT			
3	TAGND	S		Transmit Analog Ground.
4	TXISH	AI/O		**Transmit PLL Loop Filter Pin.** Connecting a capacitor to TAGND from this pin controls the Tx PLL transfer function. This pin requires a 68 nF cap to TAGND.
5	TAVCC	S		Transmit Analog Power Supply.
6	TDVCC	S		Transmit Digital Power Supply.
7	TSICLKP	DI	LVPECL	**Transmit Serial Input Clock, positive and negative**. Differential Transmit clocks at 155.52 MHz. These pins are disabled when parallel mode is selected.
8	TSICLKN			
9	TPOS	DI	LVPECL	**Transmit Serial Input Data, positive and negative.** Differential input data from an overhead terminator at 155.52 Mbps, clocked in by TSICLK. These pins are disabled when parallel mode is selected.
10	TNEG			
11	TDGND	S		Transmit Digital Ground.
12	CS/MODE	DI	TTL	**Chip Select Input, software mode** ($\overline{\text{HWSEL}}$ = High). Register transactions through the µP interface are initiated by the falling edge of this signal.
				Line Interface Mode, hardware mode ($\overline{\text{HWSEL}}$ = Low). Sets line interface mode to LVPECL (MODE = Low) or CMI (MODE = High).
13	SCLK/SP	DI	TTL	**Serial Clock Input, software mode** ($\overline{\text{HWSEL}}$ = High). Serial Microprocessor uses this pin to clock in/out data. SCLK can be from 0 to 4.096 MHz.
				Serial/Parallel Select, hardware mode ($\overline{\text{HWSEL}}$ = Low). When SP = Low, serial systems interface is used. When SP = High, 8-bit parallel system interface is used.
14	SDI/CIS	DI	TTL	**Serial Input Data, software mode** ($\overline{\text{HWSEL}}$ = High). The serial data is applied to this pin when the LXT6155 Transceiver operates in software mode. SDI is sampled on the rising edge of SCLK.
				Clock Input Select, hardware mode ($\overline{\text{HWSEL}}$ = Low). CIS sets the reference clock for centering the Rx PLL. If CIS = Low, then the LXT6155 Transceiver uses the transmit input clock as the reference. If CIS = High, then the LXT6155 Transceiver uses the crystal clock input (XTALIN) as the reference.

1. DI = Digital Input; DO = Digital Output; DI/O = Digital Input/Output; AI = Analog Input; AO = Analog Output; AI/O = Analog Input/Output; S=Supply.
2. TTL = Transistor-to-Transistor Logic (5 V tolerant); LVPECL = Low-Voltage positive ECL.

Table 1 Pin Descriptions (Sheet 2 of 4)

Pin #	Pin Name	I/O[1]	Type[2]	Description
15	SDO/RIFE	DI/O	TTL	**Serial Output Data, software mode** ($\overline{\text{HWSEL}}$ = High). The serial data from the on-chip register is output on this pin in software mode. Data output is valid on the rising edge of SCLK. This pin goes to a high impedance state when the serial port is being written to or when $\overline{\text{CS}}$ is High.
				Receive Input Frame Enabler, hardware mode ($\overline{\text{HWSEL}}$ = Low). The frame detection option is available only in parallel mode. If RIFE = Low, then the LXT6155 Transceiver disables the frame detection, and byte alignment. If RIFE = High, then the LXT6155 Transceiver enables the frame detection, and outputs RPOD bytes aligned to the SONET/SDH framer. This feature, if used, must be enabled prior to applying data to Rtip/Rring.
16 17 18 19	TPID7/TXTRIM3 TPID6/TXTRIM2 TPID5/TXTRIM1 TPID4/TXTRIM0	DI	TTL	**Transmit Parallel Input Data**. Transmit data from an Overhead Terminator at parallel speed 19.44 MHz, clocked in by TPICLK. TPID7 is the most significant bit, and is the first bit to be sent. These pins should be grounded or not connected when the LXT6155 Transceiver is used in serial mode.
				Transmit Trim Controls, in serial, hardware, coax mode only. These pins trim the amplitude of the line driver output from (nom -21%) to (nom +24%) in 3% steps. This feature is only enabled when pin #20 (TXTRIMENA) is High.
20	TPID3/TXTRIMENA	DI	TTL	**Transmit Parallel Input Data**. Transmit data from an Overhead Terminator at parallel speed 19.44 MHz, clocked in by TPICLK. TPID7 is the most significant bit, and is the first bit to be sent. These pins should be grounded or not connected when the LXT6155 Transceiver is used in serial mode.
				Transmit Trim Enable, in serial, hardware, coax mode only. This pin enables the trimming of the line driver output by pins 16-19 when high.
21 22 23	TPID2 TPID1 TPID0	DI	TTL	**Transmit Parallel Input Data**. Transmit data from an Overhead Terminator at parallel speed 19.44 MHz, clocked in by TPICLK. TPID7 is the most significant bit, and is the first bit to be sent. These pins should be grounded or not connected when the LXT6155 Transceiver is used in serial mode.
24	TPICLK	DI	TTL	**Transmit Parallel Input Clock**. Parallel transmit clock at 19.44 MHz. This pin is disabled when serial mode is selected and should be grounded or not connected.
25	VCC	S		**Power Supply**.
26	RPOCLK	DO	TTL	**Receive Parallel Output Clock**. Parallel receive clock as recovered from received data. The clock is nominally 19.44 MHz, synchronized with RPOD<7:0>.
27 28 29 30 31 32 33 34	RPOD7 RPOD6 RPOD5 RPOD4 RPOD3 RPOD2 RPOD1 RPOD0	DO	TTL	**Receive Parallel Output Data**. RPOD<7:0> output aligned 8-bit bytes at RPOCLK clock rate. These pins are to be left open when serial mode is selected. RPOD7 is the most significant bit, and is the first to arrive.
35	GND	S		**Ground**.

1. DI = Digital Input; DO = Digital Output; DI/O = Digital Input/Output; AI = Analog Input; AO = Analog Output; AI/O = Analog Input/Output; S=Supply.
2. TTL = Transistor-to-Transistor Logic (5 V tolerant); LVPECL = Low-Voltage positive ECL.

Table 1 Pin Descriptions (Sheet 3 of 4)

Pin #	Pin Name	I/O[1]	Type[2]	Description
36	RSOCLKP	DO	LVPECL	**Receive Serial Output Clock**. Serial receive clock as recovered from received data. The clock is nominally 155.52 MHz, synchronized with output serial data RPOS and RNEG.
37	RSOCLKN			
38	PVCC	S		**PECL Buffers Power Supply**.
39	RNEG	DO	LVPECL	**Receive Serial Output Data, positive and negative**. These two pins provide recovered data synchronized to receive serial output clocks RSOCLKP and RSOCLKN. These pins are tristated and should be left open when parallel mode is selected.
40	RPOS			
41	RDVCC	S		**Receive Digital Power Supply**.
42	RDGND	S		**Receive Digital Ground**.
43	ROFP/ CMIERR	DO	TTL	**Receive Output Frame Pulse**. In hardware mode ($\overline{\text{HWSEL}}$ = Low), this pin is asserted (High) on the last A2 byte in the (A1.....A1, A2.....A2) sequence in the RPOD<7:0> traffic. A1=1111,0110 and A2=0010,1000 in binary. In software mode ($\overline{\text{HWSEL}}$ = High), this position is programmable. During coax operation, when frame detection is disabled (RIFE = 0 in HW/Reg #12, bit3 = 0), or in serial mode, this pin indicates CMI line code errors. These pulses are 50 ns wide (active high). One or more errors in 16 consecutive bits will causes a single pulse.
44	LOCK	DO	TTL	**Receive Output PLL Lock**. A High indicates receive PLL has locked to incoming data. A Low indicates receive PLL is not locked.
45	LOS	DO	TTL	**Loss of Signal**. An alarm output signal (high) indicating incoming signal voltage is weak or incoming data does not contain enough transitions. In software mode ($\overline{\text{HWSEL}}$ = 1) this pin can be configured to combine LOS and LOCK alarms.
46	RAVCC	S		**Receive Analog Power Supply**.
47	ATST	-		**Analog Test**. For factory test purposes only; do not connect.
48	VBIAS	AI	Analog	**Bias Input Voltage.** This pin requires a 15 K (1%) pull-down resistor to RAGND.
49	RXISH	A0	Analog	Rx PLL External Cap. Connecting a capacitor to RAGND from this pin controls the Rx PLL transfer function. This pin requires a 330 nF cap to RAGND.
50	RAGND	S		**Receive Analog Ground**.
51	RRING	AI	Analog	**Receive Input Data, positive (RTIP) and negative (RRING)**. Accepts incoming signals (LVPECL or CMI) from the line interface.
52	RTIP			
53	RAGND	S		**Receive Analog Ground**.
54	ADDR0/RLIS	DI	TTL	**Address 0, software mode** ($\overline{\text{HWSEL}}$ = High). This pin together with ADDR1 sets the chip select address. Up to 4 LXT6155 Transceiver chips can be addressed by the µP interface.
				Remote Loopback Input Select, hardware mode ($\overline{\text{HWSEL}}$ = Low). Together with LLIS sets the LXT6155 Transceiver in a loopback test mode. See Table 4

1. DI = Digital Input; DO = Digital Output; DI/O = Digital Input/Output; AI = Analog Input; AO = Analog Output; AI/O = Analog Input/Output; S=Supply.
2. TTL = Transistor-to-Transistor Logic (5 V tolerant); LVPECL = Low-Voltage positive ECL.

Table 1 Pin Descriptions (Sheet 4 of 4)

Pin #	Pin Name	I/O[1]	Type[2]	Description
55	ADDR1/LLIS	DI	TTL	**Address 1, software mode** ($\overline{\text{HWSEL}}$ = High). This pin together with ADDR0 sets the chip select address. Up to 4 LXT6155 Transceiver chips can be addressed by the µP interface.
				Local Loopback Input Select, hardware mode ($\overline{\text{HWSEL}}$ = Low). Together with RLIS sets the LXT6155 Transceiver in remote loopback mode. See Table 4
56	HWSEL	DI	TTL	**Hardware/Software Mode Select**. When $\overline{\text{HWSEL}}$ = High, the LXT6155 Transceiver enters software (host) mode, and is ready to communicate with a serial microprocessor. When $\overline{\text{HWSEL}}$ = Low, the LXT6155 Transceiver operates in hardware standalone mode (without a serial µP).
57	SUB	S		**Reserved**. Must be connected to GND.
58	WELL	S		**Reserved**. Must be connected to VCC.
59	TAGND	S		**Transmit Analog Ground**.
60	TRING0	AO		**Transmit Output Data, positive (TTIP0) and negative (TRING0)**. Differential CMI driver outputs for coax interface.
61	TTIP0			
62	TRING1	DO		**Transmit Output Data, positive (TTIP1) and negative (TRING1)**. Differential LVPECL NRZ driver outputs for a fiber optic transceiver.
63	TTIP1			
64	TAVCC	S		**Transmit Analog Power Supply**.

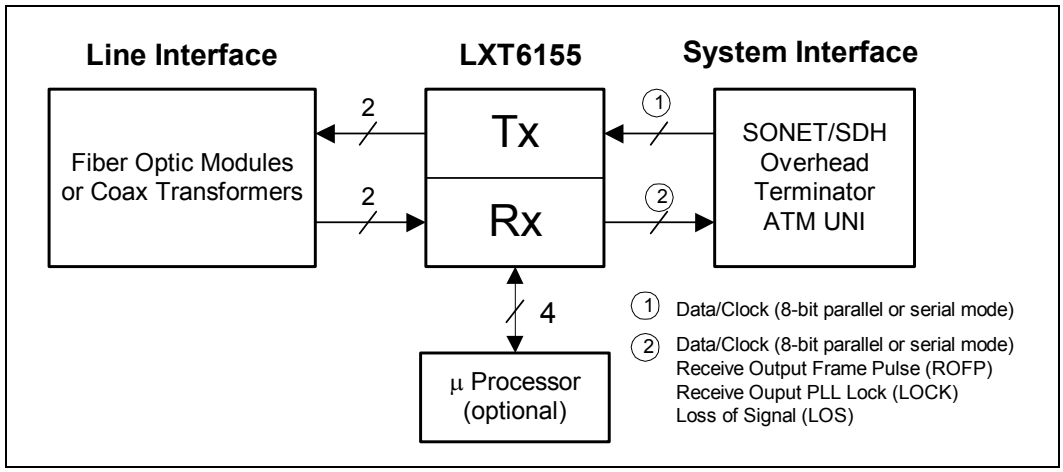
1. DI = Digital Input; DO = Digital Output; DI/O = Digital Input/Output; AI = Analog Input; AO = Analog Output; AI/O = Analog Input/Output; S=Supply.
2. TTL = Transistor-to-Transistor Logic (5 V tolerant); LVPECL = Low-Voltage positive ECL.

3.0 Functional Description

The LXT6155 Transceiver is a front-end transceiver designed for 155 Mbps OC3/STM1/ATM transmission applications. Table 2 lists the standards with which the LXT6155 Transceiver is compliant.

The LXT6155 Transceiver interfaces to either a fiber transceiver or a coax cable on the line side, and on the system side, to an SDH/SONET Overhead Terminator or an ATM UNI. As shown in Figure 3, the LXT6155 Transceiver can function in Hardware stand-alone mode, or in Software mode controlled through an industry standard Motorola compatible 4-wire serial microprocessor interface.

Figure 3 LXT6155 Transceiver System Interface



The LXT6155 Transceiver can be set to operate in either CMI mode for the 75 Ω coax interface or NRZ mode for the optical transceiver interface. The operating mode can be set in either hardware mode by using the MODE pin, or software mode by using Primary Control Register, bit 0.

3.1 Transmitter

In serial mode, the LXT6155 Transceiver accepts both data (TPOS, TNEG) and clock signals (TSICLKP, TSICLKN). Serial clock signals are required for the LXT6155 Transceiver to run internal logic, reshape the line transmit pulses and generate the low-jitter clocks for Tx data generation.

In parallel mode, the LXT6155 Transceiver accepts data TPID<7:0> and clock TPICLK. TPICLK is internally multiplied by 8 to yield the 155.52 MHz clock for Tx data generation.

Both serial and parallel clocks (TSICLKP/TSICLKN and TPICLK) must conform to the SONET/SDH standard frequency accuracy requirements.

Depending on whether the selected media interface is coax or fiber, the data is CMI or NRZ encoded respectively, and passed to the appropriate line drivers. The LXT6155 Transceiver line drivers are high-speed buffers that meet the CMI templates and industry standard LVPECL signal requirements. The CMI output pins are TTIP0 and TRING0, and the NRZ LVPECL pins, TTIP1 and TRING1.

3.1.1 Transmitted Signal

Transmitted signals conform to the standard templates listed in Table 2.

Table 2 Standards Compliance

Item	SDH/SONET (Fiber)		SDH/SONET (Coax)	
	STM1	OC3	STM1	STS-3
Line Rate (Mbps)	155.52	155.52	155.52	155.52
Line Interface	50 Ω LVPECL	50 Ω LVPECL	75 Ω coax	75 Ω coax
Line Code	NRZ	NRZ	CMI	CMI
Signal Templates	G.957 STM1 Eye	OC3 OC3 Eye	G.703 CMI Template. CMI Eye	STSX-3 CMI Template. CMI Eye
Jitter	G.958 G.825	GR-253	G.813 G.825	GR-253

3.1.1.1 Fiber Based G.957/GR-253 Transmission Systems

The LXT6155 Transceiver provides 3.3 V LVPECL compatible signals for interfacing to a fiber optic transceiver. Please refer to Application Information for interface schematics.

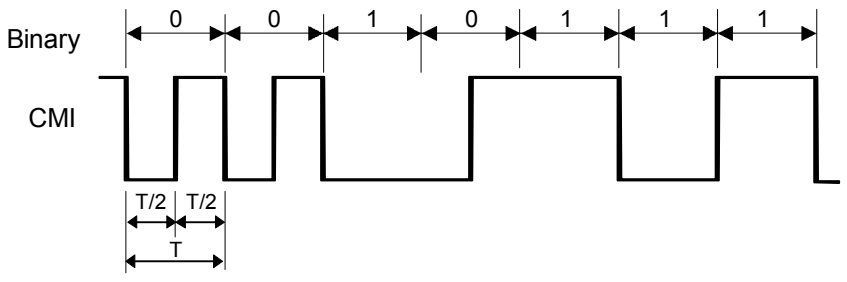
3.1.2 Coax Based G.703/GR-253 Transmission Systems

The LXT6155 Transceiver encodes and decodes CMI signals that are transmitted onto a 75 Ω coax cable compliant with STM1/STS-3 CMI templates. Please refer to the CMI templates shown in Figure 24 on page 45 and Figure 25 on page 46.

3.1.2.1 CMI Encoding

Coded Mark Inversion (CMI) is an encoding scheme adopted by SONET STS-3 and SDH STM1 standards. CMI encoding guarantees at least one transition per bit, thereby enhancing the clock recovery process. CMI encodes a “0” with a midpoint positive transition, and a “1” as Low or High, in opposite polarity to the previous encoded “1”. Refer to Figure 4, Figure 24 on page 45 and Figure 25 on page 46 for encoding and pulse template information.

Figure 4 Example of CMI Encoded Binary Signal



3.1.3 Tx Clock Monitoring

The LXT6155 Transceiver provides transmit clock monitoring for both serial and parallel operating modes. When using the crystal clock as a reference, the LXT6155 Transceiver monitors the TSICLKP/TSICLKN or the TPICLK input(s) for transitions. If no transition is seen within 200 ns, the tx_clk_alarm flag will be set (reg #15) and the transmitter outputs ttip1/tring1 or ttip0/tring0 will stop sending data to the line. This condition will remain until the LXT6155 Transceiver detects clock transitions at the transmitter input(s) TSICLKP/ TSICLKN or TPICLK. Transmit clock monitoring can be disabled in software mode only.

In remote loopback, transmit clock monitoring is disabled in SW and HW mode. In SW mode, when using transmit clocks as the receive PLL reference, the user must disable transmit clock monitoring by setting reg #1 bit <0> low.

3.2 Receiver

3.2.1 Analog Front End and Timing Recovery

3.2.1.1 CMI Mode

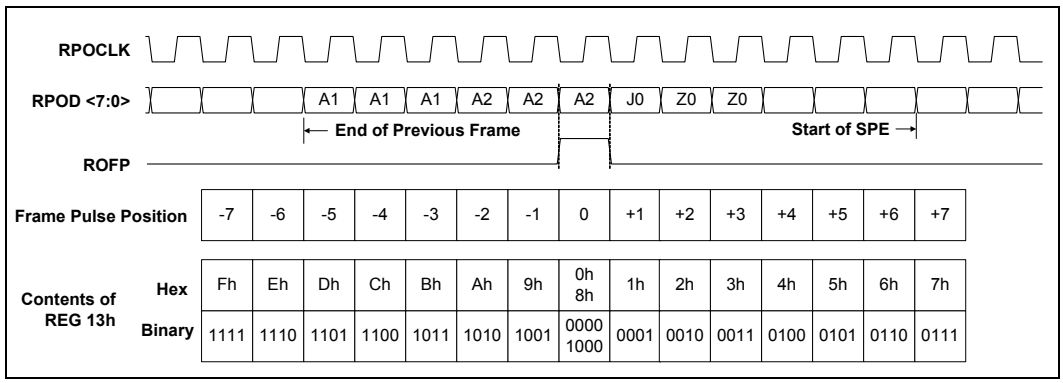
Received data on RTIP/RRING goes through an adaptive equalizer. An adaptive $\sqrt{f}$ equalizer and adaptive Automatic Gain Control (AGC) compensate the frequency-and-cable length dependent loss in data signal, and reshapes the signal to the optimal waveform. A Phase Locked Loop (PLL) then performs clock recovery operation, comparing the reshaped data phase against the receive output clock phase. The receive PLL requires an external reference (e.g. transmit input clock or XTAL clock) to start up the clock recovery process. This clock can be derived from XTALIN, TPICLK or TSICLK (÷8). The recovered clock is used to retime the CMI signals, and to decode CMI to NRZ. Coding errors are detected and flagged via the CMIERR pin in HW mode with the frame detect disabled or in serial mode. In software mode (HWSEL = High) CMI coding errors are indicated via the µP interface interrupt register: Reg #15, mode 05.

3.2.1.2 NRZ Mode

The on chip adaptive equalizer is bypassed. Data goes straight to the clock recovery phase locked loop. The PLL then performs clock recovery operation, comparing the data phase against the clock phase. This clock can be derived from XTALIN, TPICLK or TSICLK (÷8). The receive PLL requires an external reference (for example, a transmit input clock or XTAL clock) to start up the clock recovery process.

The recovered clock is used to retime the data signals. When the recovered clock is within 488 ppm of the reference clock, the LOCK signal asserts. This alarm is also accessible on the µP interface as a status bit (Reg #15, mode 0) and as an interrupt (Reg #15, mode 05). Once the recovered clock has been obtained and the NRZ data has been recovered, the LXT6155 Transceiver performs frame-detect-and-byte-alignment, and serial-to-parallel conversion. The LXT6155 Transceiver optionally provides output data RPOD<7:0> aligned to the SDH/SONET byte boundary. The user has the option to enable/disable the frame-alignment function in both hardware and software mode. The frame detect/byte alignment function generates the receive output frame pulse (ROFP). In HW mode (HWSEL = Low) ROFP asserts (high) on the third A2 byte. In SW mode (HWSEL = High) this position is programmable via register #13, bits <6:3>. When byte alignment is disabled and the LXT6155 Transceiver is in CMI mode, the ROFP pin indicates CMI coding errors including polarity errors for ones and inversion errors for zeroes.

Figure 5 Receive Frame Synchronization and Frame Pulse Position



Frame Pulse Position	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7
Contents of REG 13h Hex	Fh	Eh	Dh	Ch	Bh	Ah	9h	0h 8h	1h	2h	3h	4h	5h	6h	7h
Contents of REG 13h Binary	1111	1110	1101	1100	1011	1010	1001	0000 1000	0001	0010	0011	0100	0101	0110	0111

The clock recovery PLL's center frequency comes from either the local crystal or a stable transmit input clock (TSICLKP/TSICLKN or TPICLK). If operated in loop-timed mode or remote loopback mode, an external reference clock must be used to center the internal PLL clock. In remote loopback, the receive reference remains either XTALIN or TSICLK or TPICLK, depending on the control selection. If an independent and stable transmit clock is available, the designer has the option of applying this clock to pin XTALIN to center the PLL, without the external crystal.

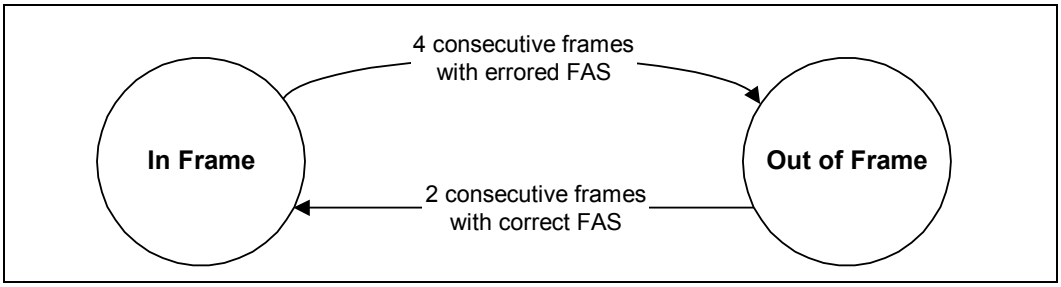
The user can also replace the crystal by connecting the TPICLK (19.44 MHz) signal to the XTALIN pin. However, a local crystal is recommended for "keep alive" purposes in case the clock becomes unavailable.

3.2.2 Receive Frame Detect and Byte Alignment

Receive Frame Detection only operates in parallel mode, if Frame Detection is enabled. The LXT6155 Transceiver provides aligned bytes RPOD<7:0> following the distinct SONET OC3/STM1 frame marker word, 3 x A1, followed by 3 x A2, where A1=F6h and A2=28h. The Receive Output Frame Pulse (ROFP) asserts during the third A2 byte, and de-asserts after one complete RPOCLK clock period. If this feature is used, it can be enabled in register #12 bit <3> in software mode[1], or by setting the RIFE (pin 15) high in hardware mode prior to applying data to Rtip/Rring. Two consecutive frames with correct frame words (A_1… A_1 A_2…A_2) are required to change from an out-of-frame state (OOF) to an in-frame state. The OOF alarm is accessible in SW mode (HWSEL = High) as a status or interrupt signal (Reg #15). To declare an OOF condition, four consecutive frames with incorrect frame words are required. Byte alignment occurs when entering the in-frame state. In case of an OOF event, the byte alignment and frame pulse position are frozen. The ROFP output continues unchanged until re-entering the in-frame state.

1. For further details see register #12 description for usage.

Figure 6 Framing State



3.2.2.1 Loss of Signal (LOS)

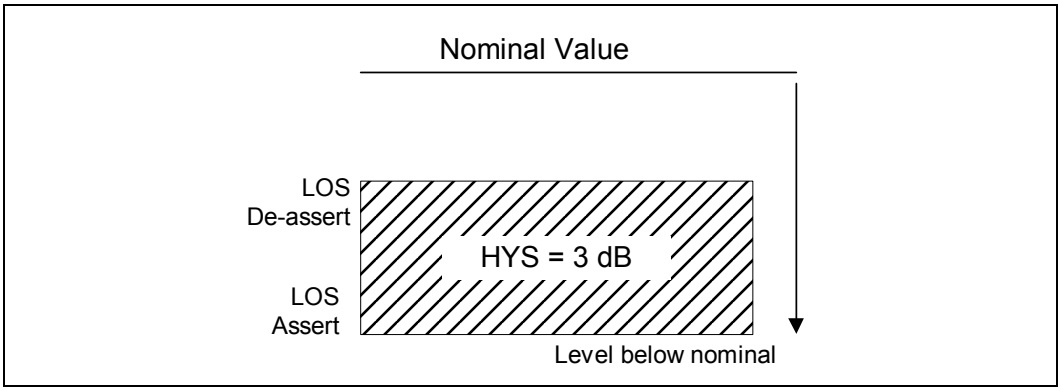
Loss of Signal provides an alarm signal indicating incoming signal voltage is weak or incoming data does not contain enough transitions. This signal is available in HW mode on pin #45 and in SW mode as status and interrupt (Reg #15, modes 00 and 05).

During power-up, the LOS state machine may be stuck in an incorrect state until the LXT6155 Transceiver receives a transmit clock (TPICLK or TSICLKP/TSICLKN). For correct initialization in serial mode, a clock or local crystal should also be applied on XTALIN. The LOS alarm should be ignored until the clock(s) is in place.

3.2.2.2 Coax Interface

Loss of Signal provides an alarm output that indicates weak line input signal. The LOS signal asserts when the incoming signals fall below a specified loss threshold, and de-asserts when the line signal rises nominally 2 dB above the assert threshold, as shown in Figure 7 on page 18. The threshold is adjustable in SW mode (HWSEL = High) via the µProcessor interface.

Figure 7 Criteria for LOS Output



3.2.2.3 Fiber Interface

If no transition is detected during any 3112 bit times (20 µsec), LOS asserts. LOS is cleared when two consecutive frame words with no LOS events between then are received. In SW mode (HWSEL = High) the assertion window is programmable from 128 bits to 4096 bits in four steps. The de-assertion criteria can also be configured to 12.5% transition density. The 12.5% density is determined by receipt of at least 4 transitions during a 32-bit sliding window.

3.3 Clocks

3.3.1 Parallel Mode

The LXT6155 Transceiver accepts TPICLK synchronized with transmit input parallel data TPID<7:0>. The data is serialized and transmitted at TTIP0/TRING0 or TTIP1/TRING1 depending on which line encoding mode is selected. The LXT6155 Transceiver in turn produces the receive output parallel clock RPOCLK, that is recovered from incoming line data RTIP/RRING, and is synchronized with receive output parallel data RPOD<7:0>.

3.3.1.1 Transmit Parallel Input Clock (TPICLK)

TPICLK is the transmit parallel input clock provided by the systems interface. This clock must be nominally 19.44 MHz, synchronized with parallel input data TPID<7:0>. This clock is then internally multiplied by 8 to produce a serial clock, used for parallel-to-serial conversion, line drivers, and pulse reshaping. In HW mode (HWSEL = Low), TPID data is sampled on the falling edge of TPICLK. In SW mode (HWSEL = High), the clock polarity can be inverted (Reg #0, bit #3).

3.3.1.2 Receive Parallel Output Clock (RPOCLK)

RPOCLK is the parallel output clock that is recovered from the line input data RTIP/RRING. This clock is at 19.44 MHz, synchronized with parallel output data RP0D<7:0>. In HW mode (HWSEL = Low), the RPOCLK clock rising edge is at the center of eye opening of RPOD<7:0> as shown in Figure 21. In SW mode (HWSEL = High), the clock polarity can be inverted (Reg #0, bit #2). Under LOS (LOS=High) or Rx PLL loss of lock (LOCK=Low) conditions RPOCLK is switched to the reference selected by the CIS control in HW mode, or Reg #0 bit #5 in SW mode. Also, the parallel output is forced to all zeros. This feature can be disabled in SW mode (HWSEL = High) via register #10, bit #7.

3.3.2 Serial Mode

At the transmit systems interface, the LXT6155 Transceiver accepts the transmit input clock TSICLKP/TSICLKN that is synchronized to incoming serial differential data TPOS/TNEG. At the line interface, the LXT6155 Transceiver accepts RTIP/RRING data and produces the clocks RSOCLKP/RSOCLKN synchronized to receive output data RPOS/RNEG. RSOCLKP/RSOCLKN clock edges are at the center of RPOS/RNEG.

3.3.2.1 Transmit Serial Input Clock (TSICLKP/TSICLKN)

TSICLKP/TSICLKN is the serial input clock from the overhead terminator. This 155.52 MHz clock is rising edge centered with input serial data on TPOS and TNEG. These clock pins should be left open when the LXT6155 Transceiver operates in parallel mode.

3.3.2.2 Receive Serial Output Clock (RSOCLKP/RSOCLKN)

RSOCLKP/RSOCLKN is the serial clock recovered from the line input data on RTIP/RRING. This 155.52 MHz clock is falling edge centered with receive serial output data on RPOS/RNEG. These clock pins should be left open when the LXT6155 Transceiver operates in parallel mode. Under LOS (LOS=High) or Rx PLL loss of lock (LOCK=Low) conditions RSOCLK P/N is switched to the Tx serial clock. Also the serial output data is forced to all zeros. This feature can be disabled in SW mode (HWSEL = High) via register #10, bit #7.

3.3.3 Crystal Reference Clock (XTALIN/XTALOUT)

An optional 19.44 MHz crystal can be connected across the XTALIN and XTALOUT pins. This crystal reference provides an onchip clock that is independent of the external system clock (TSICLKP/TSICLKN or TPICLK). The main functions of the crystal reference clock are threefold: (1) to center the receive PLL at 155 MHz, (2) to keep the PLL centered at 155 MHz when LOS asserts, and (3) In the event incoming data is lost, to provide a reference clock for other devices which require it. The designer has the option to use this crystal reference clock or the transmit input clock (TSICLKP/TSICLKN or TPICLK) to center the receive PLL.

Refer to Section Section 3.2.2.1, *Loss of Signal (LOS)*, on page 18 for clock requirements relating to the LOS alarm signal.

3.4 Jitter

The Bellcore GR-253 standard defines jitter as the “short-term variations of a digital signal’s significant instants from their ideal positions in time”. Significant instants are the optimum data sampling instants. Jitter parameters can be measured at the line interface, with system interface in loopback mode, yielding jitter accumulated in both transmitter and receiver. Isolated jitter measurements for transmitter and receiver can also be performed. Jitter specs are divided into three categories: jitter tolerance, jitter generation, and jitter transfer. Jitter values, in effect, measure the performance of the receive PLL and the transmit synthesizer PLL.

3.4.1 Jitter Tolerance

Jitter tolerance is the peak-to-peak amplitude of sinusoidal jitter applied at the line interface input that causes an equivalent 1 dB SNR loss measured as BER = 10^{-10}. Refer to Figure 26 on page 47 for the LXT6155 Transceiver performance.

3.4.2 Jitter Generation (Intrinsic Jitter)

Jitter generation is the amount of transmit jitter at the output of the equipment with a jitter-free transmit input data and clock. For SONET/SDH, jitter generation is less than 0.01 UI rms, measured with a band-pass filter from 12 kHz to 1.3 MHz. Refer to Figure 27 on page 48 for the LXT6155 Transceiver performance.

3.4.3 Jitter Transfer

Jitter transfer is defined as the ratio of output jitter to input jitter amplitude versus jitter frequency for a given bit rate. Input jitter amplitude is shown in the Jitter Tolerance curve. Output jitter is under the Jitter Transfer template. Refer to Figure 27 on page 48 and Figure 28 on page 48 for the LXT6155 Transceiver performance.

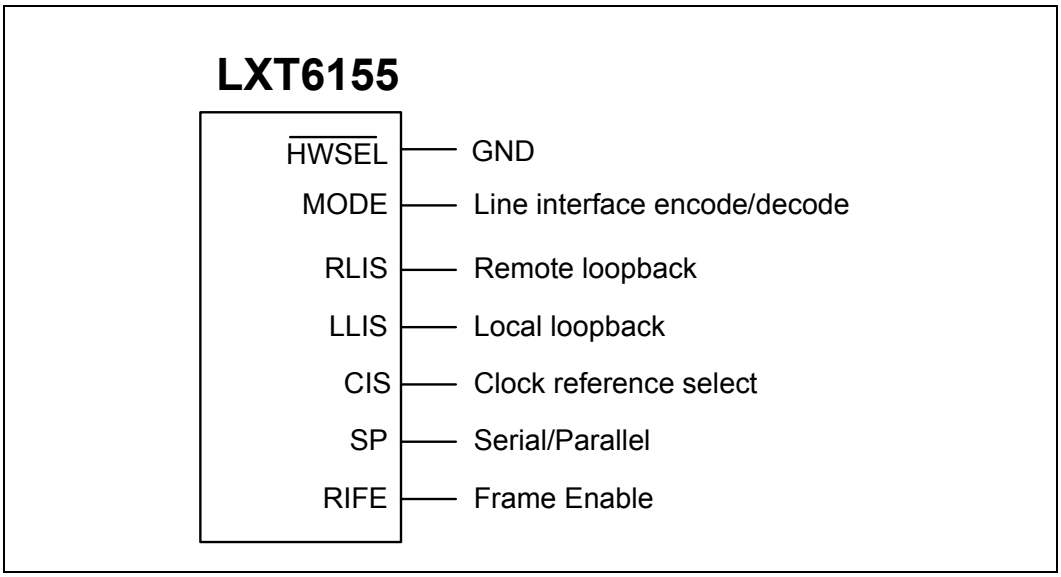
3.5 Operational Modes

The LXT6155 Transceiver functions in both Hardware standalone and Software modes. The operating mode is set by the state of the HWSEL pin.

3.5.1 Hardware Mode

By setting $\overline{\text{HWSEL}}$ = Low, the LXT6155 Transceiver operates in standalone hardware mode, without a serial microprocessor interface. A subset of the functions available in the Software Mode can be set in Hardware Mode. LXT6155 Transceiver provides a comprehensive flexibility in configuring system clock preference settings, as well as providing pins for activating loopback test modes. Table 3, Table 4 and Table 5 show the settings that enable the functions available in hardware mode.

Figure 8 Hardware Mode



3.5.1.1 PLL Clock Reference (CIS pin)

The reference clock plays two roles: it centers the receive PLL, and it provides the receive output clocks RSOCLKP/RSOCKLN and RPOCLK in case of Loss of Signal. When the LXT6155 Transceiver powers up, it looks for this reference clock to start-up internal blocks, including the receive PLL circuitry.

Table 3 Reference Clock Settings

CIS	Clock Reference	Note
Low	TICLK	Default mode. The LXT6155 Transceiver uses the transmit input clock as the reference clock for on chip operations. No crystal is needed.
High	XTAL	The LXT6155 Transceiver uses the clock signal at XTALIN as the reference clock for Rx operation. This can either be an applied 19.44 MHz clock or a 19.44 MHz crystal can be connected across XTALIN & XTALOUT. See Table 25 for the crystal specifications.

3.5.1.1.1 TICLK

This is the transmit input clock(s): either TSICLKP/TSICLKN in serial mode or TPICLK in parallel mode.

3.5.1.1.2 XTAL

XTAL is an optional clock, created using an external crystal, connected across the XTALIN and XTALOUT pins. The crystal provides an independent and stable clock source. This clock is also used as the reference for the Tx clock monitoring circuitry and the Rx LOS state machine.

3.5.1.2 Loopback Test (RLIS and LLIS pins)

The LXT6155 Transceiver allows two types of loopback test: Remote loopback and Local loopback. In Remote loopback, the received data and clock are looped back to the transmit line interface. The LXT6155 Transceiver still outputs recovered data and clock at the system interface. In Local loopback, the transmit data is looped back to the receive input at the line interface. The LXT6155 Transceiver also transmit data onto the line interface while looping back. For descriptive diagrams, please refer to Figure 14 on page 26 and Figure 15 on page 26.

Table 4 Loopback Selection

ADDR0/RLIS	ADDR1/LLIS	Description
Low	Low	Normal operation. No loopback testing.
Low	High	Local loopback test activate.
High	Low	Remote loopback test activate.
High	High	Invalid mode. Do not use.

3.5.1.3 Line Interface Selection (MODE Pin)

The MODE pin sets one of the two line interfaces, as described in Table 5.

Table 5 MODE Line Interface Settings

MODE	Description
Low	Sets LVPECL NRZ mode to interface to a fiber optic module. CMI related blocks (e.g. input/output buffers, equalizer) are disabled.
High	Sets CMI mode to interface to a transformer and a 75 Ω coax cable. NRZ related input/output buffers are disabled.

3.5.1.4 Parallel/Serial Mode Selection (SP pin)

In Hardware Mode, $\overline{\text{HWSEL}}$ = Low, the LXT6155 Transceiver can be set to operate in serial or parallel data mode, depending on how the Serial/Parallel SP pin is set.

Setting the SP pin = High sets the LXT6155 Transceiver to an 8-bit parallel mode. Parallel pins TPID<7:0>, TPICLK, RPOD<7:0>, ROFP, RPOCLK, LOCK and LOS are be used. Serial pins TPOS, TNEG, TSICLKP, TSICLKN, RPOS, RNEG, RSOCLKP, RSOCLKN are unused and should be left open.

Setting the SP pin = Low sets the LXT6155 Transceiver to serial mode. Pins TPOS, TNEG, TSICLKP, TSICLKN, RPOS, RNEG, RSOCLKP, RSOCLKN, LOCK and LOS are used. Pins TPID<7:0>, TPICLK, RPOD<7:0> and RPOCLK are unused and should be left open.

3.5.1.5 Tx Amplitude Trim

In Hardware, serial, coax mode, the line driver output amplitude can be controlled via pins 16 to 20. Setting TXTRIMENA (pin #20) high enables the trim capability. The trim range is -21% to +24% in 3% steps controlled by TXTRIM0-TXTRIM3. The minimum amplitude is at 0000 and the maximum amplitude is at 1111. This is the same control range as in SW mode.

3.5.2 Software Mode

When $\overline{\text{HWSEL}}$ = High, the LXT6155 Transceiver operates in Software Mode. Control is through an external serial µP interface. Figure 9 shows the pins used in Software Mode. The LXT6155 Transceiver uses four pins for the industry standard Serial Control Interface (SCP) bus: SCLK, $\overline{\text{CS}}$, SDI and SDO. SCLK is the serial input control clock pin. $\overline{\text{CS}}$ is the chip select input. SDI is the serial data input pin, and SDO is the serial data output pin. Figure 10 and Figure 11 show the serial interface data structure. A data transaction is initiated by a falling edge on the Chip Select pin $\overline{\text{CS}}$. A High-to-Low transition on $\overline{\text{CS}}$ is required for each access to the control registers. The first bit is a read/write bit (R/$\overline{\text{W}}$), followed by seven address bits (A<6:0>), and eight data bits (D<7:0>). Every data transaction requires 16 SCLK cycles to complete. If R/$\overline{\text{W}}$ = High (Read), the LXT6155 Transceiver outputs a data byte D<7:0> on the SDO pin. If R/$\overline{\text{W}}$ = Low (Write), the LXT6155 Transceiver accepts a data byte D<7:0> on the SDI pin, while tristating SDO pin.

It is recommended in SW mode operation, the registers are first initialized by writing a “0” to register #11 bit #6 ($\overline{\text{reset}}$).

3.5.2.1 Serial Input Clock (SCLK)

This pin accepts a clock up to 4.096 MHz for data transactions between the LXT6155 Transceiver and the SCP bus. The LXT6155 Transceiver clocks SDO data out on the falling edge, and clocks SDI data in on the rising edge of SCLK (see Figure 10 and Figure 11).

3.5.2.2 Chip Select Input ($\overline{\text{CS}}$)

On the falling edge of $\overline{\text{CS}}$, the LXT6155 Transceiver starts data transactions. On the rising edge of $\overline{\text{CS}}$, the LXT6155 Transceiver stops data transaction. The $\overline{\text{CS}}$ pin must be held Low for at least 16 SCLK cycles to complete a full Read or Write data transaction. If $\overline{\text{CS}}$ is held Low less than 16 SCLK cycles, then the data transaction is ignored. At the end of each Write/Read transaction, $\overline{\text{CS}}$ must return High, between the 16th and 17th clock edges.

3.5.2.3 Serial Input Word (SDI)

Figure 11 shows the serial interface input data word structure. When the first input bit R/$\overline{\text{W}}$ = Low, a Write operation is performed. The SCLK clocks data in on the SDI pin during the second 8 bits D<7:0> of the Write operation. Data is clocked in on the rising edge of SCLK. During the entire 16 bit operation, SDO remains tristated. Refer to Table 6 on page 27 through Table 23 on page 33 for control register descriptions.

3.5.2.4 Serial Output Word (SDO)

The serial output word structure is shown in Figure 10. When the first input bit R/$\overline{\text{W}}$ = High, a Read operation is specified. SDO becomes active after A0 has been clocked in. The first bit out of SDO changes the state of SDO from High-Z to a Low/High. SDO is clocked out on the falling edge of SCLK.

Figure 9 Software Mode

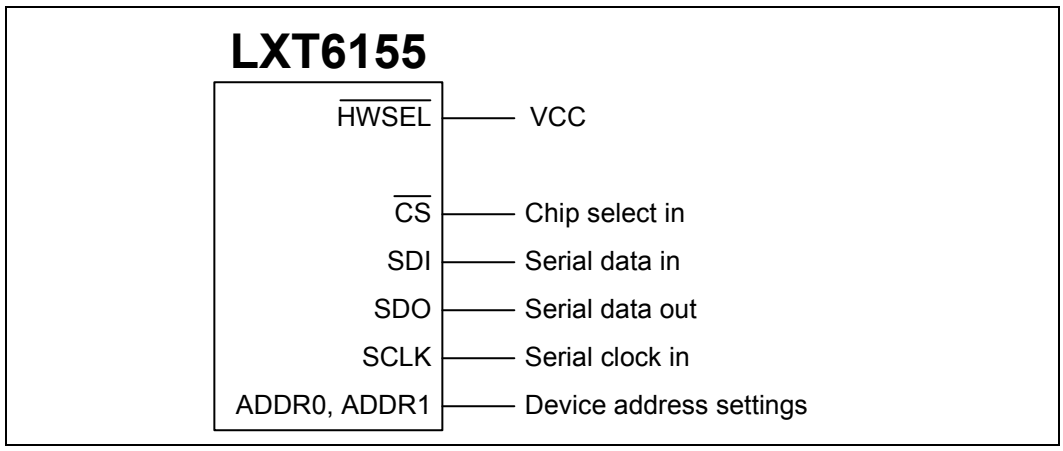


Figure 10 Serial Data Output Word Structure (Read Cycle: R/$\overline{W}$=High)

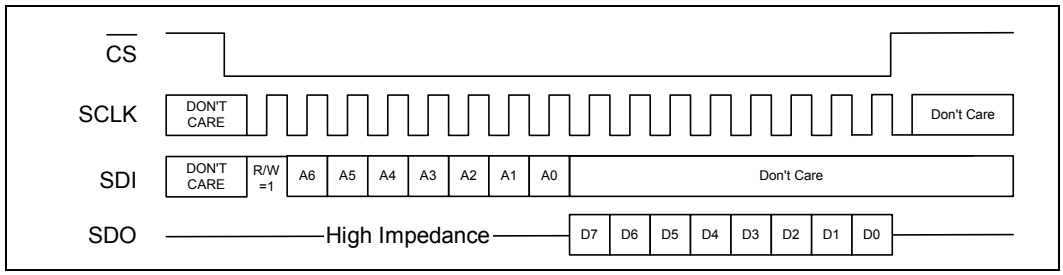
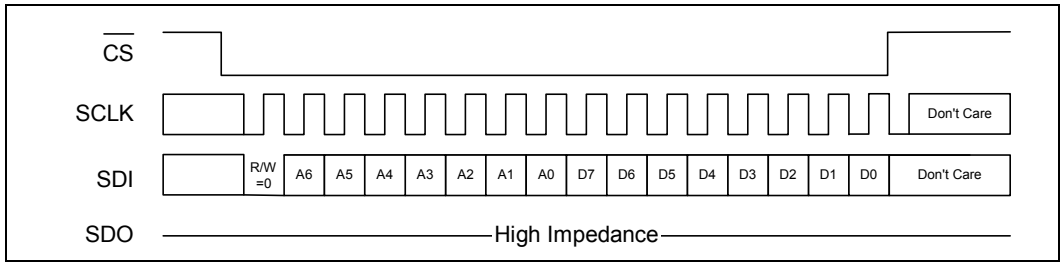


Figure 11 Serial Data Input Word Structure (Write Cycle: R/$\overline{W}$ = Low)



3.6 Serial System Interface

The serial interface permits the LXT6155 Transceiver to communicate with an Overhead Termination device at 155.52 Mbps. Data and clock lines are differential 3.3 V LVPECL signals. Refer to Figure 12.

3.7 Parallel System Interface

The parallel interface allows the LXT6155 Transceiver to communicate with the system chip at 19.44 MHz, 8 bits per clock cycle. Data and clock lines are TTL compatible signals. Refer to Figure 13.

Figure 12 Serial Interface

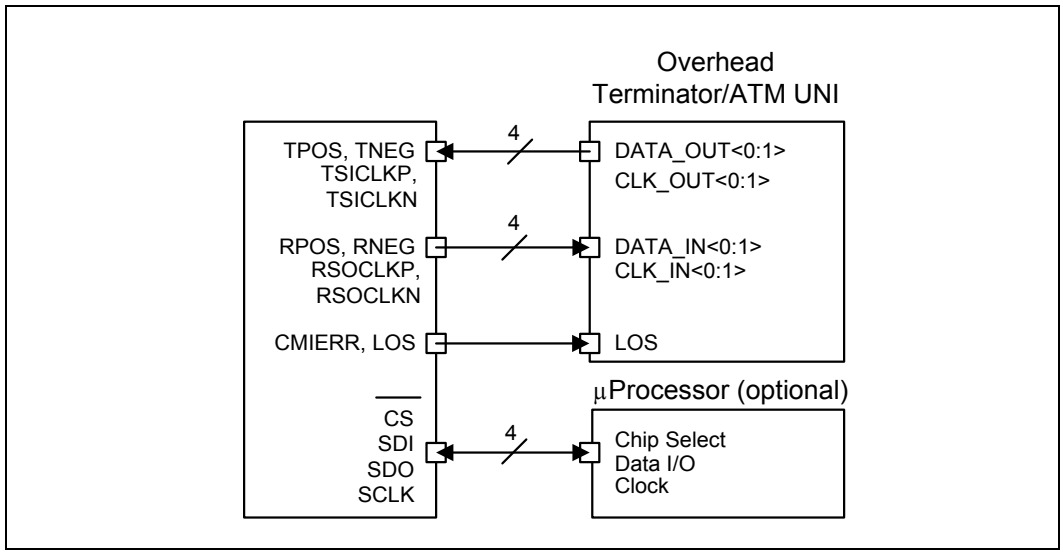


Figure 13 Parallel Interface