TDK SEMICONDUCTOR CORP.

78P2351R
155M NRZ to CMI Converter

PRELIMINARY DATASHEET

FEBRUARY 2004

DESCRIPTION

The 78P2351R is TDK's second generation Line Interface Unit (LIU) for 155 Mbit/s electrical SDH interfaces (STM1e). The device is a single chip solution that includes an integrated Clock & Data Recovery in the transmit path for easy, cost efficient NRZ to CMI conversion.

The device interfaces to 75Ω coaxial cable through wideband transformers and can handle over 15dB of cable loss.

By integrating CDR capabilities in the transmit path, the small 78P2351R (7x7mm MLF package) is also ideal for new STM1e Small Form-factor Pluggable (SFP) modules.

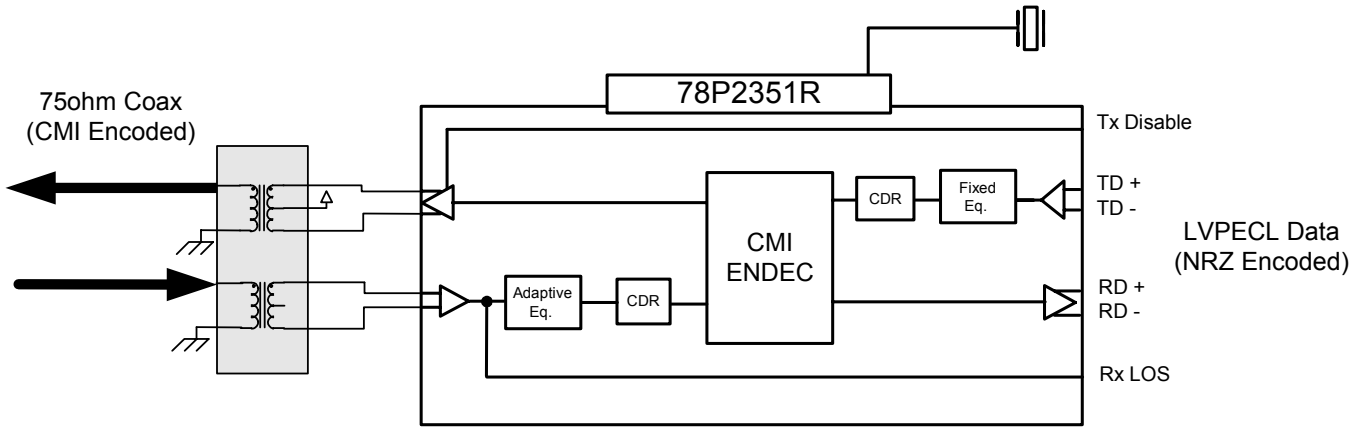
APPLICATIONS

- STM1e SFP modules
- SDH/ATM Line Cards
- Add Drop Multiplexers (ADMs)
- PDH/SDH test equipment

FEATURES

- G.703 compliant, adjustable cable driver for 155.52 Mbps CMI-coded coax transmission
- Integrated adaptive CMI equalizer and CDR in receive path handles over 15dB of cable loss
- Serial, LVPECL-compatible system interface with integrated CDR in transmit path for flexible NRZ to CMI conversion
- Configurable via HW control pins or 4-wire serial port interface
- Compliant with ANSI T1.105.03-1994; ITU-T G.813, G.825, G.958; and Telcordia GR-253-CORE for jitter performance
- Provides G.783 compliant Loss of Signal (LOS) detection
- Receive Monitor Mode handles up to 20dB of flat loss (at max 6dB cable loss)
- Optional fixed backplane equalizer compensates for up to 1.5m of trace
- Operates from a single 3.3V supply
- Available in a small 7x7mm 56-pin QFN package
- Industrial Temperature: -40˚C to +85˚C

BLOCK DIAGRAM



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FUNCTIONAL DESCRIPTION

The 78P2351R contains all the necessary transmit and receive circuitry for connection between 155.52Mbit/s NRZ data sources (STS-3/STM-1) and CMI encoded electrical interfaces. The 78P2351R system interface mimics a 3.3V optics module and only requires a reference clock and wideband transformer to complete the electrical interface. The chip can be controlled via control pins or serial port register settings.

In hardware mode (pin control) the SPSL pin must be low. Additionally, the following unused pins must be set accordingly:

- SDO pin must be tied low
- SDI pin must be tied low
- SEN pin must be tied high

In software mode (SPSL pin high), control pins set register defaults upon power-up or reset. The 78P2351R can then be configured via the 4-wire serial control interface. See Pin Descriptions section for more information.

REFERENCE CLOCK

The 78P2351R requires a reference clock supplied to the CKREFP/N pins. For reference frequencies of 19.44MHz or 77.76MHz, the device accepts a single ended CMOS level input at CKREFP (CKREFN tied to ground). For reference frequency of 155.52MHz, the device accepts a differential LVPECL clock input at CKREFP/N. The frequency of this reference input is selected by either the CKSL control pin or register bit as follows:

CKSL pin	CKSL[1:0] bits	Reference Frequency
Low	0 0	19.44MHz
Float	1 0	77.76MHz
High	1 1	155.52MHz

RECEIVER OPERATION

The receiver accepts G.703 compliant CMI encoded data at 155.52Mbit/s from the RXP/N inputs. When transformer-coupled to the line, the receiver can handle over 15dB of cable loss. The receive jitter tolerance is compliant with all relevant standards even with 12.7dB worth of cable attenuation and inter-symbol interference (ISI). See Receiver Jitter Tolerance section for more info.

The CMI signal first enters an AGC and a high performance adaptive equalizer designed to overcome inter-symbol interference caused by long cable lengths. The variable gain differential amplifier automatically controls the gain to maintain a constant voltage level output regardless of the input voltage level.

The outputs of the data comparators are connected to the clock recovery circuits. The clock recovery system employs a digital PLL, which utilizes a line-rate reference frequency derived from the clock applied to the CKREFP/N pins. After the clock and data have been recovered, the data is converted to binary by the CMI decoder. NRZ data is transmitted through LVPECL drivers at the SODP/N pins.

Receiver Monitor Mode

The SCK_MON pin or MON register bit puts the receiver in monitor mode and adds approximately 20dB of flat gain to the receive signal before equalization. Rx Monitor Mode can handle 20dB of flat loss typical of monitoring points with up to 6dB of cable loss. Note that Loss of Signal detection is disabled during Rx Monitor Mode.

Loss of Signal Detect

The 78P2351R includes an ITU-T G.783 compliant Loss of Signal (LOS) detector. When the received signal is less than approximately 18dB below nominal for 80 UI, the LOS pin is asserted. The LOS signal is cleared when the received signal is greater than approximately 17dB below nominal for 80 UI. During LOS conditions, the receive data outputs are squelched and held at logic '0'.

Note: Loss of Signal detection is disabled during Local Loopback and Receive Monitor Modes.

TRANSMITTER OPERATION

The transmitter section generates an adjustable G.703 compliant analog signal for transmission through a center-tapped transformer onto 75Ω coaxial cable. Serial NRZ data is input to the 78P2351R on the SIDP/N pins at LVPECL levels and passed to a low jitter clock and data recovery circuit. An optional clock decoupling FIFO is provided to decouple the on chip and off chip clocks. The NRZ data is encoded to CMI to ensure an adequate number of transitions.

Each of the transmit timing modes can be configured in HW mode or SW mode as shown in the table below.

Tx Mode	HW Control	SW Control
	CKMODE	SMOD[1:0]
Reserved	Low	0 0
Synchronous (FIFO enabled)	Floating	1 0
Plesiochronous	High	0 1
Loop-timing	n/a	1 1

Plesiochronous Mode

Plesiochronous mode represents a common condition where the transmit data is not source synchronous to the reference clock input (i.e. local crystal oscillator, external loopback). In this mode, the 78P2351R will recover the clock from the serial plesiochronous NRZ transmit data and bypass the internal FIFO.

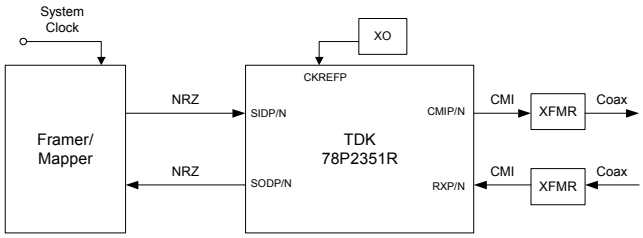


Figure 1: Plesiochronous Mode

Synchronous Mode

When the NRZ transmit data is source synchronous with the reference clock applied at CKREFP/N as shown in Figure 2, the 78P2351R can be optionally used in synchronous mode or re-timing mode. In this mode, the 78P2351R will recover the clock from the serial NRZ data input and pass the data through an integrated FIFO.

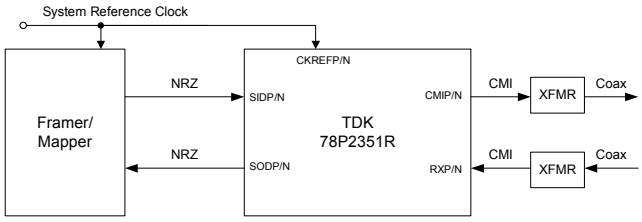


Figure 2: Synchronous

Since the reference clock and transmit clock/data go through different delay paths, it is inevitable that the phase relationship between the two clocks can vary in a bounded manner due to the fact that the absolute delays in the two paths can vary over time. The FIFO allows long-term clock phase drift, not exceeding +/- 25.6ns, to be handled without transmit error. If the clock wander exceeds the specified limits, the FIFO will over or under flow, and the FERR register signal will be asserted. The FIFO is re-centered by asserting the FRST bit. Note that the FIFO is also automatically re-centered when the TXLOL register bit (Transmit Loss of Lock) transitions from high to low.

Note: External remote loopbacks (i.e. loopback within framer) are not possible in synchronous operation (FIFO enabled) unless the reference clock is synchronous with the recovered receive clock (loop-timing).

Clock Synthesizer

The transmit clock synthesizer is a low-jitter PLL that generates a 311.04 MHz clock for the CMI encoder. A synthesized 155.52 MHz reference clock is also used in both the receive and transmit sides for clock and data recovery.

Pulse Amplitude Adjustment

Controls for adjusting the transmit pulse amplitude are provided in both hardware and software modes. Amplitude boosts of 5% and 10% can be enabled by the TXOUT0 pin or BST[1:0] register bits as follows:

TXOUT0 pin	BST[1:0] bits	Amplitude
Low	0 0	Normal
Float	0 1	5% boost
High	1 1	10% boost

Transmit Backplane Equalizer

An optional fixed equalizer is integrated in the transmit path for architectures that use LIUs on active interface cards. The fixed equalizer can compensate for up to 1.5m of trace and can be enabled by the TXOUT1 pin or TXEQ bit as follows:

TXOUT1 pin	TXEQ bit	Tx Equalizer
Low	1	Enabled
Float	0	Disabled

POWER-DOWN FUNCTION

Power-down control is provided to allow the 78P2351R to be shut off. Transmit and receive power-down can be set independently through SW control. Global power-down is achieved by powering down both the transmitter and receiver.

Note: the serial interface and configuration registers are not affected by power-down.

The transmitter can also be powered down using the TXPD control pin. The CMI outputs are tri-stated during transmit power-down for redundancy applications. The TXPD pin is active in both hardware and software modes.

LOOPBACK MODES

In SW mode, LLBK and RLBK bits are provided to activate the local and remote loopback modes respectively. In HW mode, the LPBK pin can be used to activate local and remote loopback modes as shown below.

LPBK pin	Loopback Mode
Low	Normal operation
Float	Remote Loopback: Recovered receive data looped back to transmitter input
High	Local Loopback: Recovered transmit data looped back to receiver input

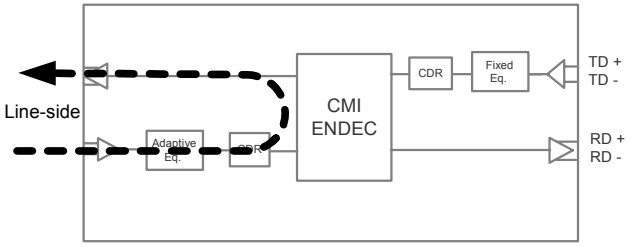


Figure 3: Remote Loopback

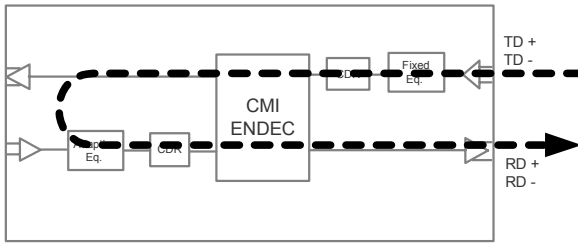


Figure 4: Local Loopback

INTERNAL POWER-ON RESET

Power-On Reset (POR) function is provided on chip. Roughly 50us after Vcc reaches 2.4V at power up, a reset pulse is internally generated. This resets all registers to their default values as well as all state machines within the transceiver to known initial values. The reset signal is also brought out to the PORB pin. The PORB pin is a special function pin that allows for the following:

- Override the internal POR signal by driving in an external active low reset signal;
- Use the POR signal to drive other IC's power-on reset;
- Add external capacitor to slow down the release of power-on reset (approximately 8µs per nF added).

SERIAL CONTROL INTERFACE

The serial port controlled register allows a generic controller to interface with the 78P2351R. It is used for mode settings, diagnostics and test, and retrieval of status and performance information. The SPSL pin must be high in order to use the serial port. The serial interface consists of four pins:

- Serial Port Enable (SEN),
- Serial Clock (SCK_MON),
- Serial Data In (SDI),
- Serial Data Out (SDO).

The SEN pin initiates the read and write operations. It can also be used to select a particular device allowing SCK_MON, SDI and SDO to be bussed together.

SCK_MON is the clock input that times the data on SDI and SDO. Data on SDI is latched in on the rising-edge of SCK_MON, and data on SDO is clocked out using the falling edge of SCK_MON.

SDI is used to insert mode, address, and register data into the chip. Address and Data information are input least significant bit (LSB) first. The mode and address bit assignment and register table are shown in the following section.

SDO is a tristate capable output. It is used to output register data during a read operation. SDO output is normally high impedance, and is enabled only during the duration when register data is being clocked out. Read data is clocked out least significant bit (LSB) first.

If SDI coming out of the micro-controller chip is also tristate capable, SDI and SDO can be connected together to simplify connections.

The maximum clock frequency for register access is 20MHz.

REGISTER DESCRIPTION

REGISTER ADDRESSING

Address Bits	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	Port Address				Sub-Address			Read/ Write
Assignment	PA[3]	PA[2]	PA[1]	PA[0]	SA[2]	SA[1]	SA[0]	R/W*

REGISTER TABLE

a) PA[3:0] = 0 : Global Registers

Sub Addr	Reg. Name	Description	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	MSCR (R/W)	Master Control	-- <0>	-- <0>	-- <0>	CKSL[1] <X>	CKSL[0] <X>	-- <X>	-- <X>	SRST <0>
1	-- (R/W)	Reserved	-- <0>	-- <0>	-- <1>	-- <0>	-- <0>	-- <0>	-- <1>	-- <1>
2	-- (R/W)	Reserved	-- <X>	-- <X>	-- <X>	-- <X>	-- <X>	-- <X>	-- <X>	-- <0>

b) PA[3:0] = 1 : Port-Specific Registers

Sub Addr	Reg. Name	Description	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	MDCR (R/W)	Mode Control	PDTX <0>	PDRX <0>	-- <0>	SMOD[1] <X>	SMOD[0] <X>	MON <0>	-- <0>	-- <1>
1	SGCR (R/W)	Signal Control	-- <0>	-- <0>	LOSOR <0>	RLBK <0>	LLBK <0>	-- <0>	-- <0>	FRST <0>
2	ACR1 (R/W)	Advanced Tx Control 1	-- <0>	-- <0>	-- <0>	-- <0>	-- <0>	-- <0>	TPK <0>	TXEQ <0>
3	ACR0 (R/W)	Advanced Tx Control 0	-- <1>	-- <0>	-- <1>	-- <0>	-- <1>	BST[1] <0>	BST[0] <0>	-- <0>
4	-- (R/W)	Reserved	-- <1>	-- <X>	-- <X>	-- <0>	-- <0>	-- <0>	-- <0>	-- <0>
5	STAT (R/C)	Status Monitor	-- <X>	-- <X>	-- <X>	RXLOS <X>	RXLOL <X>	-- <X>	TXLOL <X>	FERR <X>
6-7	--	Reserved	--	--	--	--	--	--	--	--

REGISTER DESCRIPTION (continued)

LEGEND

TYPE	DESCRIPTION	TYPE	DESCRIPTION
R/O	Read only	R/W	Read or Write
R/C	Read and Clear		

GLOBAL REGISTERS

ADDRESS 0-0: MASTER CONTROL REGISTER

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:5	--	R/W	0X0	Reserved.
4:3	CKSL [1:0]	R/W	X	**Reference Clock Frequency Select**: Selects the reference clock frequency input at CKREFP/N pins. 11: 155.52 MHz (differential) 10: 77.76 MHz (single-ended) – *Tie CKREFN to ground*. 00: 19.44 MHz (single-ended) – *Tie CKREFN to ground*. **Note**: Default values depend on the CKSL pin setting upon reset or power up.
2:1	--	R/W	X0	Reserved.
0	SRST	R/W	0	**Register Soft-Reset**: When this bit is set, all registers are reset to their default values. This register bit is self-clearing.

ADDRESS 0-1: RESERVED

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:0	--	R/W	00100X11	Reserved.

ADDRESS 0-2: RESERVED

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:0	--	R/W	XXXXXXX0	Reserved.

REGISTER DESCRIPTION (continued)

PORT-SPECIFIC REGISTERS

For PA[3:0] = 1 only. Accessing a register with port address greater than 1 constitutes an invalid command, and the read/write operation will be ignored.

ADDRESS 1-0: MODE CONTROL REGISTER

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7	PDTX	R/W	0	**Transmitter Power-Down**: 0 : Normal Operation 1 : Power-Down. CMI Transmit outputs are also tri-stated.
6	PDRX	R/W	0	**Receiver Power-Down**: 0 : Normal Operation 1 : Power-Down
5	--	R/W	0	Reserved.
4	SMOD[1]	R/W	X	**Serial Mode Interface Selection**: SMOD[1] SMOD[0] 0 0 Reserved 1 0 Synchronous data is passed through the CDR and then through the FIFO. 0 1 Plesiochronous data is passed through the CDR to recover a clock, but the FIFO is bypassed because the data is not synchronous with the reference clock. 1 1 Loop Timing Mode Enable: The recovered receive clock is used as the reference for the transmit section. The transmit data is passed through the CDR, but the FIFO is bypassed. **Note**: Default values depend on the CKMODE pin setting upon reset or power up.
3	SMOD[0]	R/W	X	
2	MON	R/W	0	**Receive Monitor Mode Enable**: 0: Normal Operation 1: Adds 20dB of flat gain to the receive signal before equalization.
1:0	--	R/W	01	Reserved.

REGISTER DESCRIPTION (continued)

ADDRESS 1-1: SIGNAL CONTROL REGISTER

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7	TCMIINV	R/W	0	**Transmit CMI Inversion**: This bit will flip the polarity of the transmit CMI data outputs at CMIP/N. 0: Normal 1: Invert
6	RCMIINV	R/W	0	**Receive CMI Inversion**: This bit will flip the polarity of the receive CMI data inputs at RXP/N. 0: Normal 1: Invert
5	LOSOR	R/W	0	**Receive Loss of Signal Override/Disable**: When set, the LOS signal will always remain low. 0: Normal 1: Forces LOS output to be low and resets counter
4	RLBK	R/W	0	**Loopback Selection**: RLBK LLBK 0 0 Normal operation 1 0 Remote Loopback Enable: Recovered receive data is looped back to the transmitter for retransmission. 0 1 Local Loopback Enable: The transmit data is looped back and used as the input to the receiver.
3	LLBK	R/W	0	
2:1	--	R/W	00	Reserved.
0	FRST	R/W	0	**FIFO Reset**: 0: Normal operation 1: Reset FIFO pointers to default locations.

ADDRESS 1-2: ADVANCED TRANSMIT CONTROL REGISTER 1

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:2	--	R/W	000000	Reserved.
1	TPK	R/W	0	**Transmit Driver Peaking Enable**: When high, adds a 2% peak to the beginning of a transition in the CMI line driver to compensate for low inductive backplanes. 0: Normal Operation 1: Add peaking
0	TXEQ	R/W	0	**Transmit Fixed Equalizer Enable**: When enabled, compensates for between 0.75m and 1.5m of FR4 trace to the serial LVPECL data inputs SIDP/N 0: Normal Operation 1: Enable equalizer

REGISTER DESCRIPTION (continued)

ADDRESS 1-3: ADVANCED TRANSMIT CONTROL REGISTER 0

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:3	--	R/W	10101	Reserved.
2:1	BST[1:0]	R/W	00	**Transmit Driver Amplitude Boost**: Adds 5% or 10% of boost to the CMI output. 00 : Normal amplitude 01 : 5% boost 10 : Reserved 11 : 10% boost
0	--	R/W	0	Reserved.

ADDRESS 1-4: RESERVED

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:0	--	R/W	1XX00000	Reserved.

ADDRESS 1-5: STATUS MONITOR REGISTER

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:5	--	R/C	XXX	Reserved.
4	RXLOS	R/C	X	**Loss of Signal Indication**: 0: Normal operation 1: Loss of signal condition detected
3	RXLOL	R/C	X	**Receive Loss of Lock Indication**: 0: Normal operation 1: Recovered receive clock frequency differs from the reference by more than +/- 100ppm.
2	--	R/C	X	Reserved.
1	TXLOL	R/C	X	**Transmit Loss of Lock Indication**: 0: Normal operation 1: Transmit CDR unlocked
0	FERR	R/C	X	**Transmit FIFO Error Indication**: This bit is set whenever the internal FERR signal is asserted, indicating that the FIFO is operating at its depth limit. It is reset to 0 when the FRST bit is asserted. 0: Normal operation 1: Transmit FIFO phase error

ADDRESS 1-6, 1-7: RESERVED

BIT	NAME	TYPE	DFLT VALUE	DESCRIPTION
7:0	RSVD	R/O	0	Reserved for test.

PIN DESCRIPTION

LEGEND

TYPE	DESCRIPTION	TYPE	DESCRIPTION
A	Analog Pin	PO	LVPECL-Compatible Differential Output
CIT	3-State CMOS Digital Input	OD	Open-drain Output
CI	CMOS Digital Input	PI	LVPECL-Compatible Differential Input
CID	CMOS Digital Input w/ Pull-down	S	Supply
CIS	CMOS Schmitt Trigger Input	G	Ground
COZ	CMOS Tristate Digital Output		

TRANSMITTER PINS

NAME	PIN	TYPE	DESCRIPTION
SIDP SIDN	4 5	PI	**Transmit Serial Data Input**: Differential NRZ data input. See *Transmitter Operation* section for more info on different timing modes.
CMIP CMIN	53 54	A	**Transmit Serial CMI Data Output**: A CMI encoded data signal conforming to the relevant ITU-T G.703 pulse templates when properly terminated and transformer coupled to 75ohm cable. **Notes**: 1) Pins are tri-stated during transmit power-down. 2) Pins are active, but undefined during reset.

RECEIVER PINS

NAME	PIN	TYPE	DESCRIPTION
SODP SODN	13 14	PO	**Receive Serial NRZ Data Output**: Recovered receive serial NRZ data. **Notes**: 1) Outputs are squelched during LOS and held low. 2) Pins are active, but undefined during reset.
RXP RXN	50 51	A	**Receive Serial CMI Input**: Receive inputs that should be differentially terminated and transformer coupled to the line.

REFERENCE AND STATUS PINS

NAME	PIN	TYPE	DESCRIPTION
CKREFP CKREFN	45 44	PI/ CI	**Reference Clock Input**: A required reference clock input used for clock/data recovery and frequency synthesizer. Can be a differential 155.52MHz differential LVPECL clock input at CKREFP/N or a single-ended 19.44MHz or 77.78MHz CMOS clock input at CKREFP (tie CKREFN to ground when unused).
LOS	33	OD	**Loss of Signal** (active-high): Standards compliant loss of signal indicator.
PORB	36	A	**Power-On Reset** (active low): See Power-On Reset description on use of this pin.

PIN DESCRIPTION (continued)

CONTROL PINS

NAME	PIN	TYPE	DESCRIPTION
LPBK	10	CIT	**Loopback Selection**: Low: Normal operation Float: Remote Loopback Enable: Recovered receive data and clock are looped back to the transmitter for retransmission. High: Local Loopback Enable: The serial transmit data is looped back and used as the input to the receiver.
CKMODE	9	CIT	**Clock Mode Selection**: Low: Reserved Float: Reference clock is synchronous to transmit data. Clock is recovered with a CDR and data is passed through a FIFO High: Reference clock is plesiochronous to transmit data. Clock is recovered with a CDR and the FIFO is bypassed
TXOUT1	56	CIT	**Advanced Tx Control 1**: Low: Enables fixed LVPECL equalizer at the transmit inputs SIDP/N (for FR4 trace lengths up to 1.5m). Float: Normal operation High: Adds 2% positive peaking on leading edge (for bandwidth limiting components between LIU and coax connector)
TXOUT0	1	CIT	**Advanced Tx Control 0**: Low: Nominal amplitude Float: 5% amplitude boost High: 10% amplitude boost
TXPD	8	CID	**Transmitter Power Down**: When high, powers down the transmitter.
SPSL	32	CID	**Serial Port Selection**: When high, chip is SW controlled through the serial port.
CKSL	34	CIT	**Reference Clock Frequency Selection**: Selects the reference frequency that is supplied at the CKREFP/N pins. Its level is read in at power-up or on the rising edge of a reset signal at the PORB pin. Low: 19.44MHz Float: 77.76MHz High: 155.52MHz

PIN DESCRIPTION (continued)

SERIAL-PORT PINS

NAME	PIN	TYPE	DESCRIPTION
SEN	41	CIT	[SPSL=1] **Serial-Port Enable**: High during read and write operations. Low disables the serial port. While SEN is low, SDO remains in high impedance state, and SDI and SCK activities are ignored. [SPSL=0] **Reserved. Must be tied high**
SCK_MON	42	CIS	[SPSL=1] **Serial Clock**: Controls the timing of SDI and SDO. [SPSL=0] **Receive Monitor Mode Enable**: When high, adds 20dB of flat gain to the incoming signal before equalization.
SDI	40	CI	[SPSL=1] **Serial Data Input**: Inputs mode and address information. Also inputs register data during a Write operation. Both address and data are input least significant bit first. [SPSL=0] **Reserved. Must be tied low**
SDO	39	COZ	[SPSL=1] **Serial Data Output**: Outputs register information during a Read operation. Data is output least significant bit first [SPSL=0] **Must be tied low**

POWER AND GROUND PINS

It is recommended that all supply pins be connected to a single power supply plane and all ground pins be connected to a single ground plane.

NAME	PIN	TYPE	DESCRIPTION
VCC	2, 6, 11, 31, 38, 43, 48, 52	S	**Power Supply** (Vdd)
GND	3, 7, 12, 30, 35, 37, 46, 47, 49, 55	G	**Ground**

ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operation beyond these limits may permanently damage the device.

PARAMETER	RATING
Supply Voltage (Vdd)	-0.5 to 4.0 VDC
Storage Temperature	-65 to 150 °C
Junction Temperature	-40 to 125 °C
Pin Voltage (CMIP,CMIN)	Vdd + 1.5 VDC
Pin Voltage (all other pins)	-0.3 to (Vdd+0.6) VDC
Pin Current	±100 mA

RECOMMENDED OPERATING CONDITIONS

Unless otherwise noted all specifications are valid over these temperatures and supply voltage ranges.

PARAMETER	RATING
DC Voltage Supply (Vdd)	3.15 to 3.45 VDC
Ambient Operating Temperature	-40 to 85°C

DC CHARACTERISTICS:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Supply Current (including transmitter current through transformer)	Idd	Max cable length		160	178	mA
Receive-only Supply Current	Iddr	Transmitter disabled (PDTX=1)		92		mA
Power down Current	Iddq	PDTX=1, PDRX=1		7	10	mA

ELECTRICAL SPECIFICATIONS (continued)

ANALOG PINS CHARACTERISTICS:
The following table is provided for informative purpose only. Not tested in production.

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
RXP and RXN Common-Mode Bias Voltage	Vblin	Ground Reference	1.9		2.6	V
RXP and RXN Differential Input Impedance	Rilin			20		kΩ
Analog Input/Output Capacitance	Cin			8		pF
PORB Input Impedance	--			5		kΩ

DIGITAL I/O CHARACTERISTICS:
Pins of type CI, CID:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Input Voltage Low	Vil				0.8	V
Input Voltage High	Vih		2.0			V
Input Current	Iil, Iih		-1	0	1	µA
Pull-down Resistance	Rpd	Type CID only	43	58	118	kΩ
Input Capacitance	Cin			8		pF

Pins of type CIT:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Input Voltage Low	Vtil				0.4	V
Input Voltage High	Vtih		Vcc-0.8			V
Minimum impedance to be considered as “float” state	Rtiz		30			kΩ

Pins of type CIS:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Low-to-High Threshold	Vt+		1.3		1.7	V
High-to-Low Threshold	Vt-		0.8		1.2	V
Input Current	Iil, Iih		-1		1	µA
Input Capacitance	Cin			8		pF

Pins of type COZ:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Output Voltage Low	Vol	Iol = 8mA			0.4	V
Output Voltage High	Voh	Ioh = -8mA	2.4			V
Output Transition Time	Tt	C_L = 20pF, 10-90%			2	ns
Effective Source Impedance	Rscr			30		Ω
Tri-state Output Leakage Current	Iz		-1		1	µA

ELECTRICAL SPECIFICATIONS (continued)

DIGITAL I/O CHARACTERISTICS: (continued)

Pins of type PO:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Signal Swing	Vpk		0.5	0.8	1.1	V
Common Mode Level	Vcm	Vdd referenced	-1.4	-1.2	-1.1	V
Effective Source Impedance	Reff			20		Ω
Rise Time	Tr	10-90%		0.8	1.2	ns
Fall Time	Tf	10-90%		0.8	1.2	ns

Pins of type PI:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Signal Swing	Vpki		0.3			V
Common Mode Level	Vcm	Vdd referenced	-1.6		-0.8	V

Pins of type OD

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
Output Voltage Low	Vol	Iol = 8mA			0.4	V
Pull-down Leakage Current	Ipd	Logic high output			1	nA
Pull-up Resistor	Rpu		4.7		10	kΩ

REFERENCE CLOCK CHARACTERISTICS:

PARAMETER	SYMBOL	CONDITIONS	MIN	NOM	MAX	UNIT
CKREF Duty Cycle	--		40		60	%
CKREF Frequency Stability	--	Synchronous mode	-20		+20	ppm
		Plesiochronous or Loop-timing mode. (see Note 1)	-75		+75	

Note 1: In Plesiochronous mode, the transmit data source (i.e. framer) must still be of +/-20ppm quality in order to meet SONET/SDH bit rate requirements.

ELECTRICAL SPECIFICATIONS (continued)

SERIAL-PORT TIMING CHARACTERISTICS:

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
SDI to SCK setup time	tsu		4			ns
SDI to SCK hold time	th		4			ns
SCK to SDO propagation delay	tprop				10	ns
SCK Frequency	SCK				20	MHz

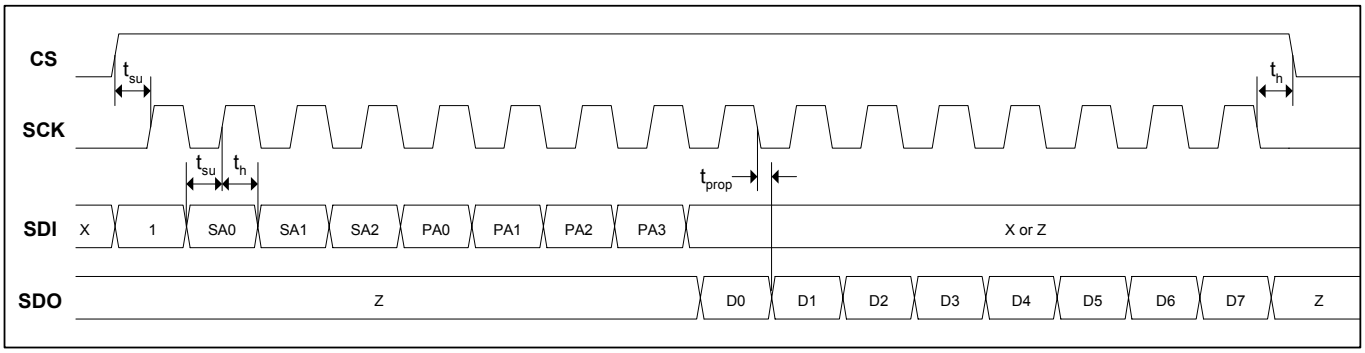


Figure 5: Read Operation

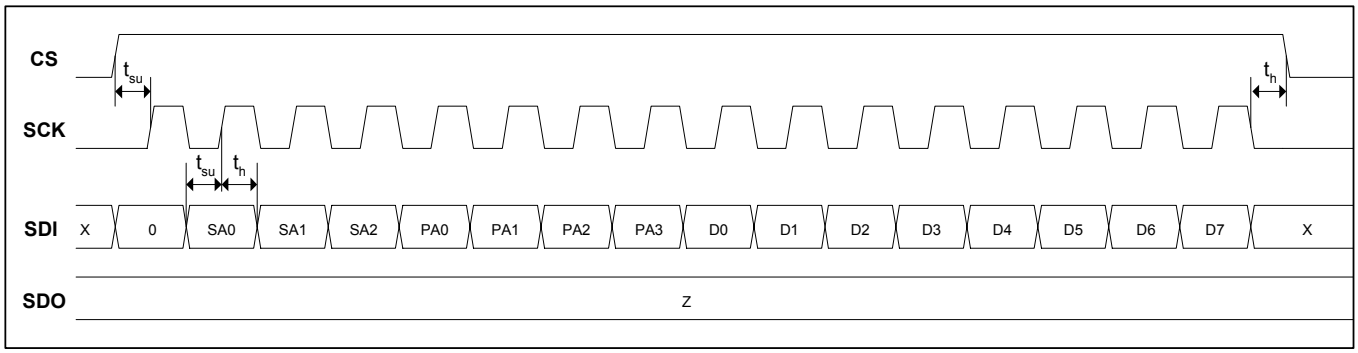


Figure 6: Write Operation

ELECTRICAL SPECIFICATIONS (continued)

TRANSMITTER SPECIFICATIONS FOR CMI INTERFACE

Bit Rate: 155.52Mbits/s ± 20ppm
Code: Coded Mark Inversion (CMI)
Relevant Specification: ITU-T G.703

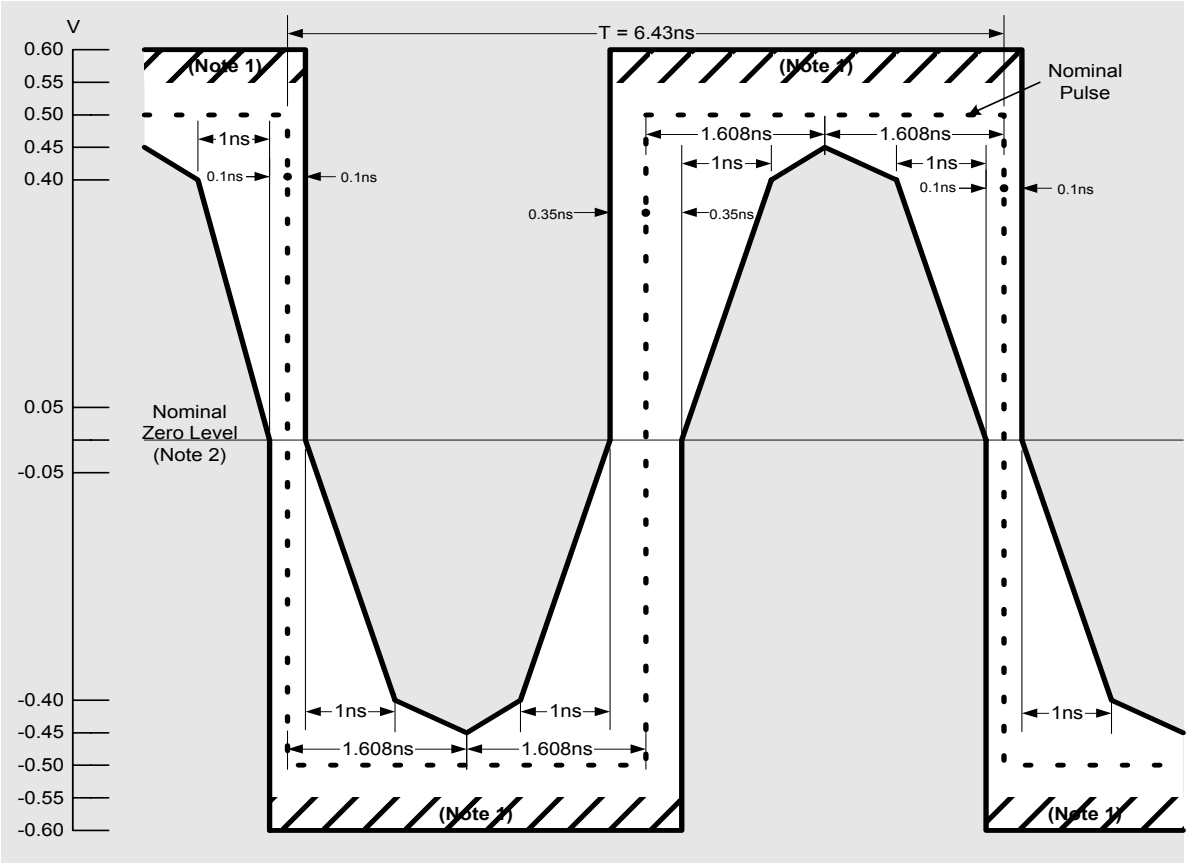
With the coaxial output port driving a 75Ω load, the output pulses conform to the templates in Figures 7 and 8. These specifications are tested during production test.

PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
Peak-to-peak Output Voltage	Template, steady state	0.9		1.1	V
Rise/ Fall Time	10-90%			2	ns
Transition Timing Tolerance	Negative Transitions	-0.1		0.1	ns
	Positive Transitions at Interval Boundaries	-0.5		0.5	
	Positive Transitions at mid-interval	-0.35		0.35	

The following specifications are not tested during production test. They are included for information only.
Note that the return loss depends on the board layout and the particular transformer used.

PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
Output Impedance	Driver is open drain		1 8		MΩ pF
Return Loss	7MHz to 240MHz	15			dB

ELECTRICAL SPECIFICATIONS (continued)



Note 1 – The maximum “steady state” amplitude should not exceed the 0.55V limit. Overshoots and other transients are permitted to fall into the shaded area bounded by the amplitude levels 0.55V and 0.6V, provided that they do not exceed the steady state level by more than 0.05V.

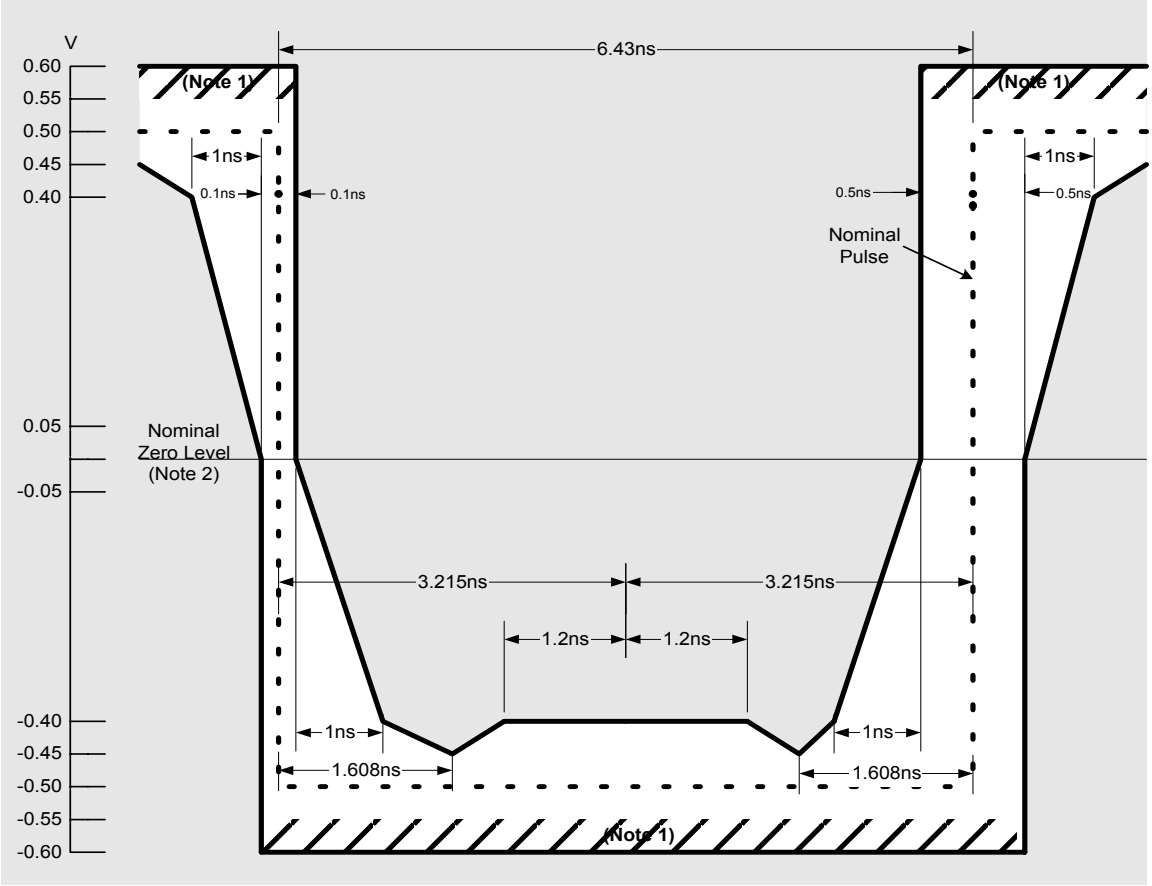
Note 2 – For all measurements using these masks, the signal should be AC coupled, using a capacitor of not less than 0.01 μF, to the input of the oscilloscope used for measurements. The nominal zero level for both masks should be aligned with the oscilloscope trace with no input signal. With the signal then applied, the vertical position of the trace can be adjusted with the objective of meeting the limits of the masks. Any such adjustment should be the same for both masks and should not exceed ±0.05V. This may be checked by removing the input signal again and verifying that the trace lies with ±0.05V of the nominal zero level of the masks.

Note 3 – Each pulse in a coded pulse sequence should meet the limits of the relevant mask, irrespective of the state of the preceding or succeeding pulses, with both pulse masks fixed in the same relation to a common timing reference, i.e. with their nominal start and finish edges coincident. The masks allow for HF jitter caused by intersymbol interference in the output stage, but not for jitter present in the timing signal associated with the source of the interface signal. When using an oscilloscope technique to determine pulse compliance with the mask, it is important that successive traces of the pulses overlay in order to suppress the effects of low frequency jitter. This can be accomplished by several techniques [e.g. a) triggering the oscilloscope on the measured waveform or b) providing both the oscilloscope and the pulse output circuits with the same clock signal].

Note 4 – For the purpose of these masks, the rise time and decay time should be measured between –0.4V and 0.4V, and should not exceed 2ns.

Figure 7 – Mask of a Pulse corresponding to a binary Zero.

ELECTRICAL SPECIFICATIONS (continued)



Note 1 – The maximum "steady state" amplitude should not exceed the 0.55V limit. Overshoots and other transients are permitted to fall into the shaded area bounded by the amplitude levels 0.55V and 0.6V, provided that they do not exceed the steady state level by more than 0.05V.

Note 2 – For all measurements using these masks, the signal should be AC coupled, using a capacitor of not less than 0.01 μF, to the input of the oscilloscope used for measurements. The nominal zero level for both masks should be aligned with the oscilloscope trace with no input signal. With the signal then applied, the vertical position of the trace can be adjusted with the objective of meeting the limits of the masks. Any such adjustment should be the same for both masks and should not exceed ±0.05V. This may be checked by removing the input signal again and verifying that the trace lies with ±0.05V of the nominal zero level of the masks.

Note 3 – Each pulse in a coded pulse sequence should meet the limits of the relevant mask, irrespective of the state of the preceding or succeeding pulses, with both pulse masks fixed in the same relation to a common timing reference, i.e. with their nominal start and finish edges coincident. The masks allow for HF jitter caused by intersymbol interference in the output stage, but not for jitter present in the timing signal associated with the source of the interface signal. When using an oscilloscope technique to determine pulse compliance with the mask, it is important that successive traces of the pulses overlay in order to suppress the effects of low frequency jitter. This can be accomplished by several techniques [e.g. a) triggering the oscilloscope on the measured waveform or b) providing both the oscilloscope and the pulse output circuits with the same clock signal].

Note 4 – For the purpose of these masks, the rise time and decay time should be measured between –0.4V and 0.4V, and should not exceed 2ns.

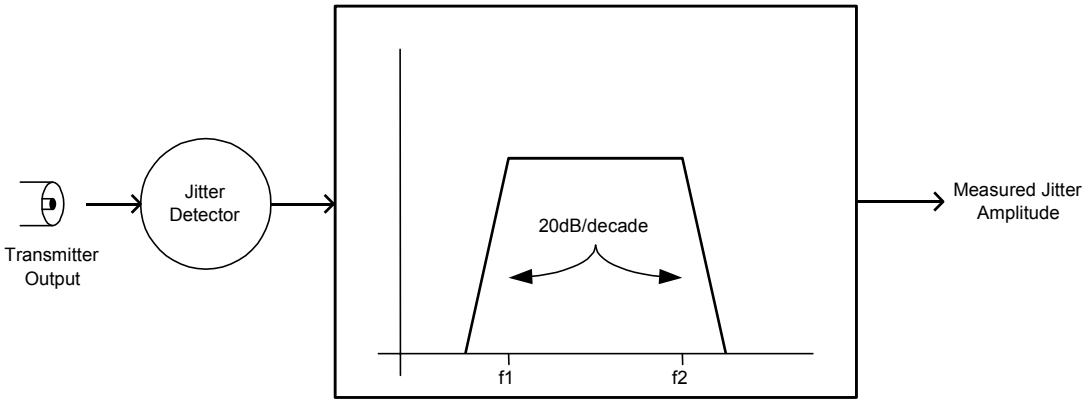
Note 5 –The inverse pulse will have the same characteristics, noting that the timing tolerance at the level of the negative and positive transitions are ± 0.1ns and ±0.5ns respectively.

Figure 8 – Mask of a Pulse corresponding to a binary One

ELECTRICAL SPECIFICATIONS (continued)

TRANSMITTER OUTPUT JITTER

The transmit jitter specification ensures compliance with ITU-T G.813, G.823, G.825 and G.958; ANSI T1.102-1993 and T1.105.03-1994; and GR-253-CORE for all supported rates. Transmit output jitter is not tested during production test.



PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
Transmitter Output Jitter	200 Hz to 3.5 MHz, measured with respect to CKREF for 60s			0.075	UIpp

ELECTRICAL SPECIFICATIONS (continued)

RECEIVER SPECIFICATIONS FOR CMI INTERFACE (Transformer-coupled)

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Peak Differential Input Amplitude, RXP and RXN	MON=0. 12.7dB of cable loss	70		550	mVpk
Peak Differential Input Amplitude, RXP and RXN	MON=1. 20dB flat loss with 6dB cable loss (max)	25		80	mVpk
Flat-loss Tolerance	MON=0. All valid cable lengths.	-2		6	dB
Latency			5	10	UI
PLL Lock Time			1	10	µs
Return Loss	7MHz to 240MHz	15			dB

The input signal is assumed compliant with ITU-T G.703 and can be attenuated by the dispersive loss of a cable. The minimum cable loss is 0dB and the maximum is –12dB at 70MHz.

The “Worst Case” line corresponds to the ITU-T G.703 recommendation. The “Typical” line corresponds to a typical installation referred to in ANSI T1.102-1993. The receiver is tested using the cable model. It is a lumped element approximation of the “Worst Case” line.

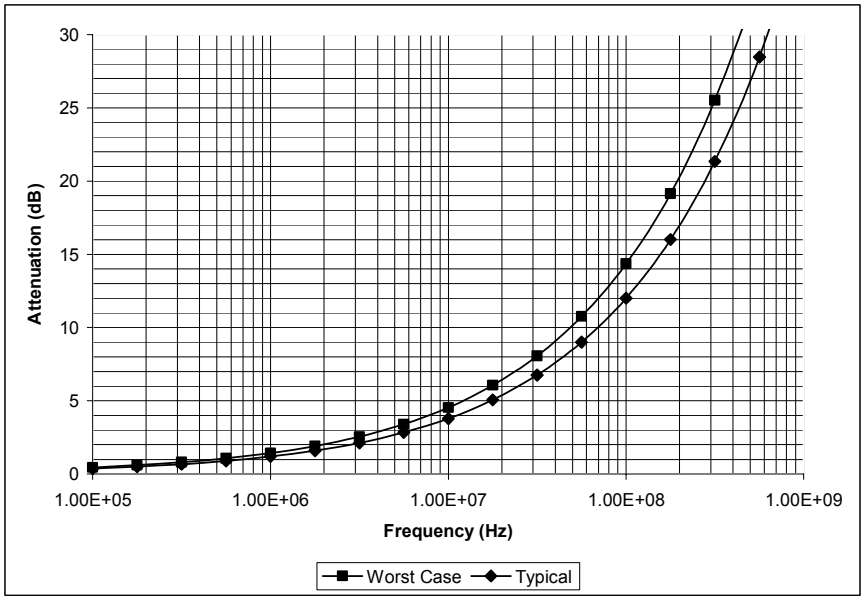


Figure 9: Typical and worst-case Cable attenuation

ELECTRICAL SPECIFICATIONS (continued)

RECEIVER JITTER TOLERANCE

The 78P2351R is compliant with all relevant jitter tolerance specifications shown in Figure 10. STM-1e (electrical) jitter tolerance specifications are in ITU-T G.825. Receive jitter tolerance is not tested during production test.

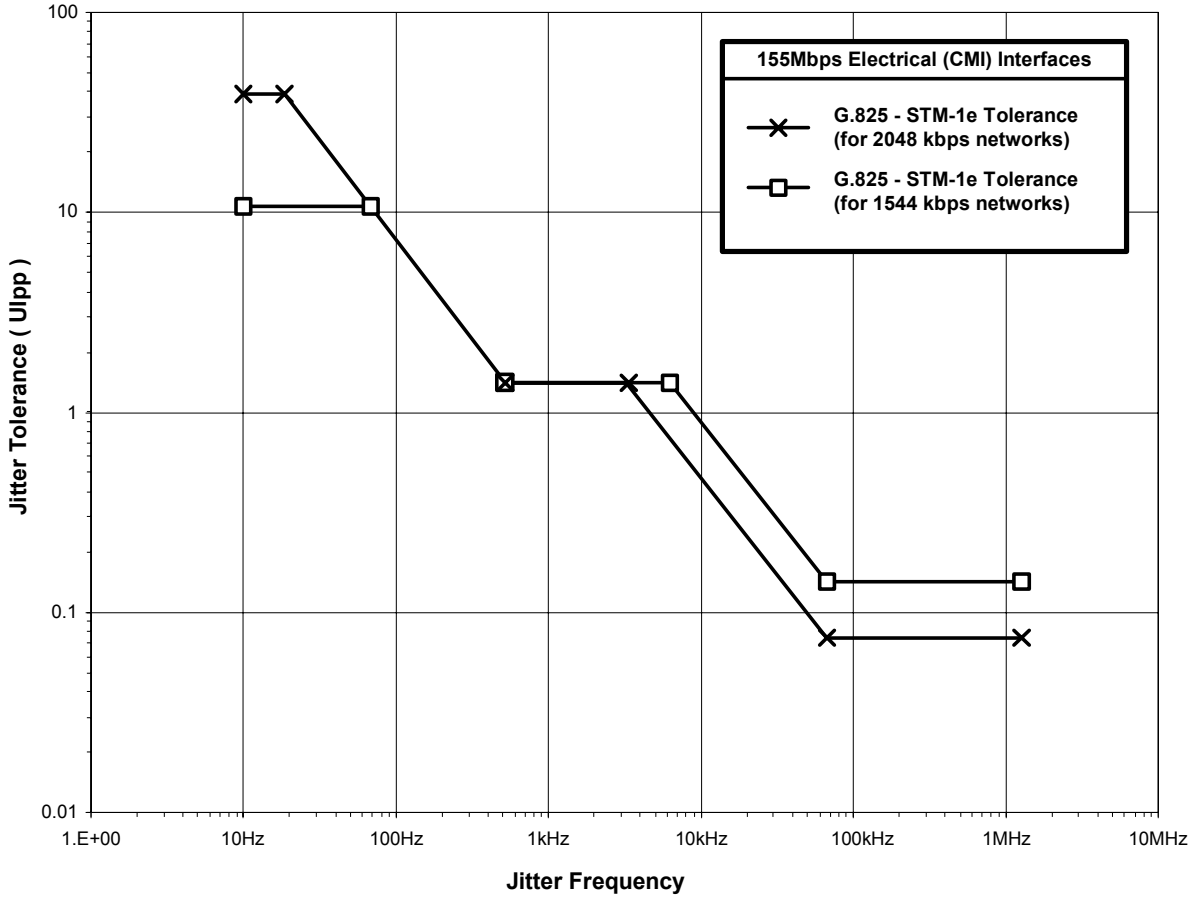


Figure 10: Jitter Tolerance - electrical (CMI) interfaces

PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
STM-1e Jitter Tolerance	10Hz to 19.3Hz	38.9			UIpp
	19.3Hz to 500Hz		750 f-1		µs
	500Hz to 6.5kHz	1.5			UIpp
	6.5kHz to 65kHz		9800 f-1		µs
	65kHz to 1.3MHz	0.15			UIpp

ELECTRICAL SPECIFICATIONS (continued)

RECEIVER JITTER TRANSFER FUNCTION

The receiver clock recovery loop filter characteristics such that the receiver has the following transfer function. The corner frequency of the PLL is approximately 120 kHz. Receiver jitter transfer function is not tested during production test.

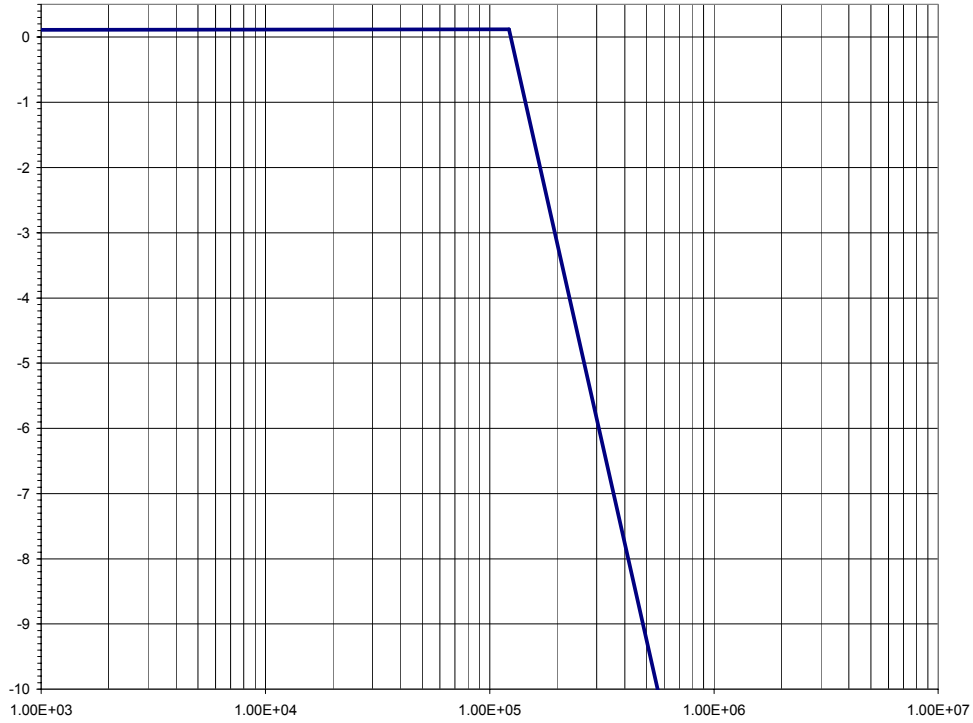


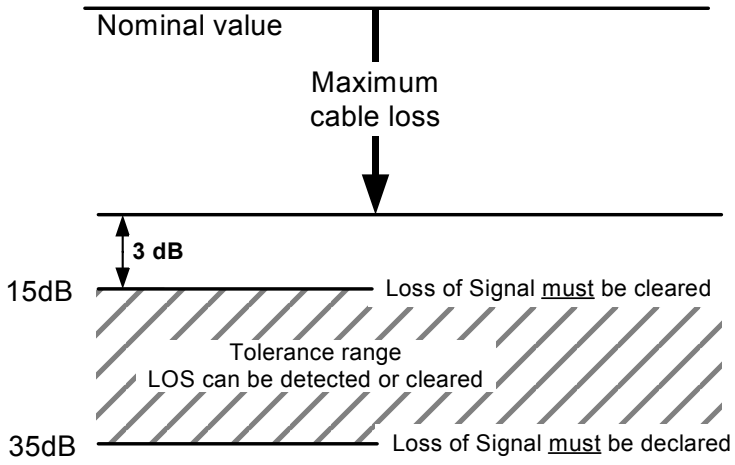
Figure 11: Jitter Transfer

PARAMETER	CONDITION	MIN	NOM	MAX	UNIT
Receiver Jitter transfer function	below 120 kHz			0.1	dB
Jitter transfer function roll-off			20		dB per decade

ELECTRICAL SPECIFICATIONS (continued)

LOSS OF SIGNAL CONDITION

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
LOS threshold		-35	-18	-15	dB
LOS timing		10	80	255	UI



APPLICATION INFORMATION

EXTERNAL COMPONENTS:

COMPONENT	PIN(S)	VALUE	UNITS	TOLERANCE
Receiver Termination Resistor	RXP RXN	75	Ω	1%
Transmitter Termination Resistor	CMIP CMIN	75	Ω	1%

TRANSFORMER SPECIFICATIONS:

COMPONENT	VALUE	UNITS	TOLERANCE
Turns Ratio for the Receiver		1:1	
Turns Ratio for the Transmitter (center-tapped)		1:1CT	

Suggested Manufacturers: Halo, MiniCircuits, Tamura, Belfuse

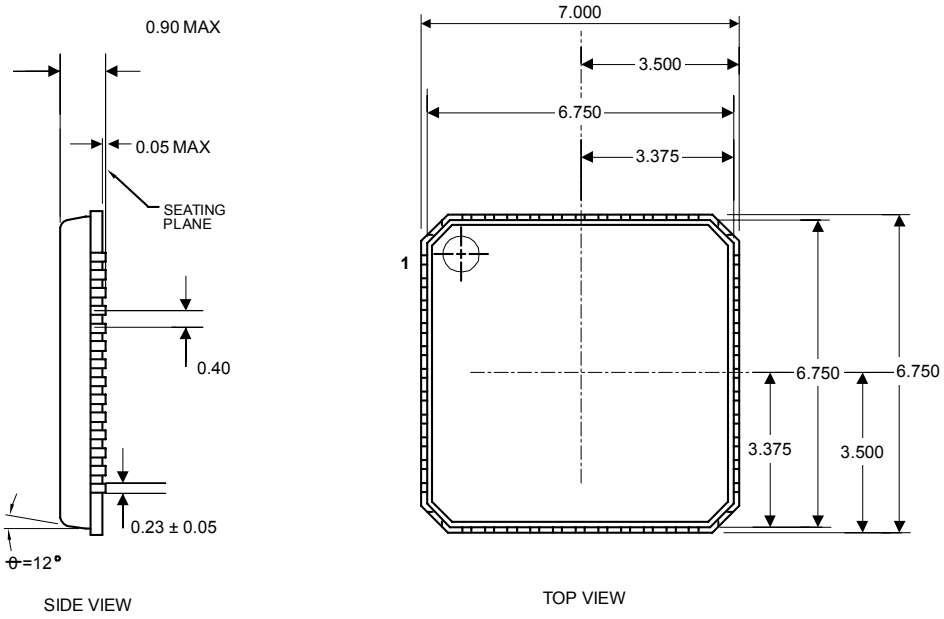
THERMAL INFORMATION:

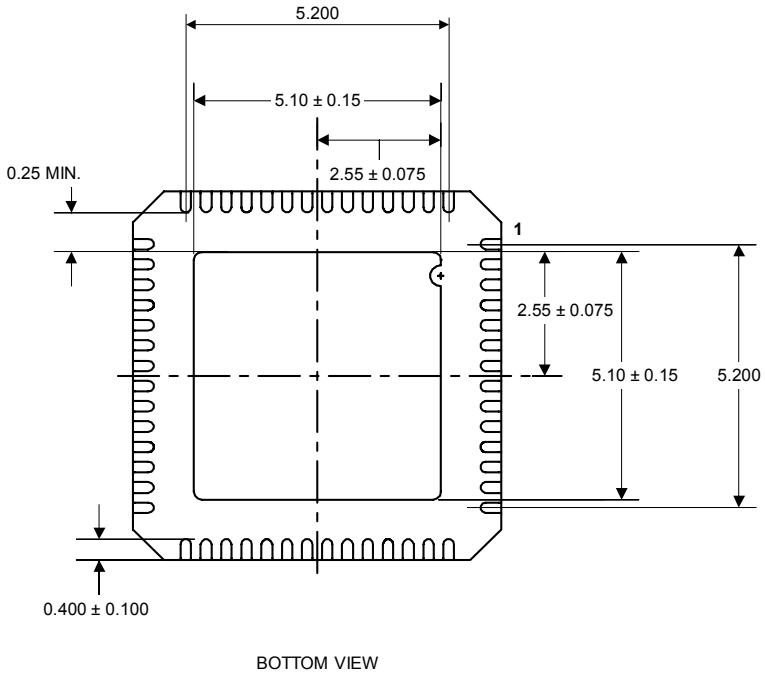
PACKAGE	CONDITIONS	Θ_{JA} (˚C/W)	Θ_{JC} (˚C/W)
Standard 56-pin JEDEC QFN	No forced air; 4-layer JEDEC test board	46.8	16.6
	No forced air; 4-layer JEDEC test board Die attach pad soldered to PCB	23.5	15.6

SCHEMATICS

For schematics, recommended transformer part numbers, etc. please check TDK Semiconductor's website or contact your local sales representative for the latest application note(s) and/or demo board manuals.

MECHANICAL SPECIFICATIONS

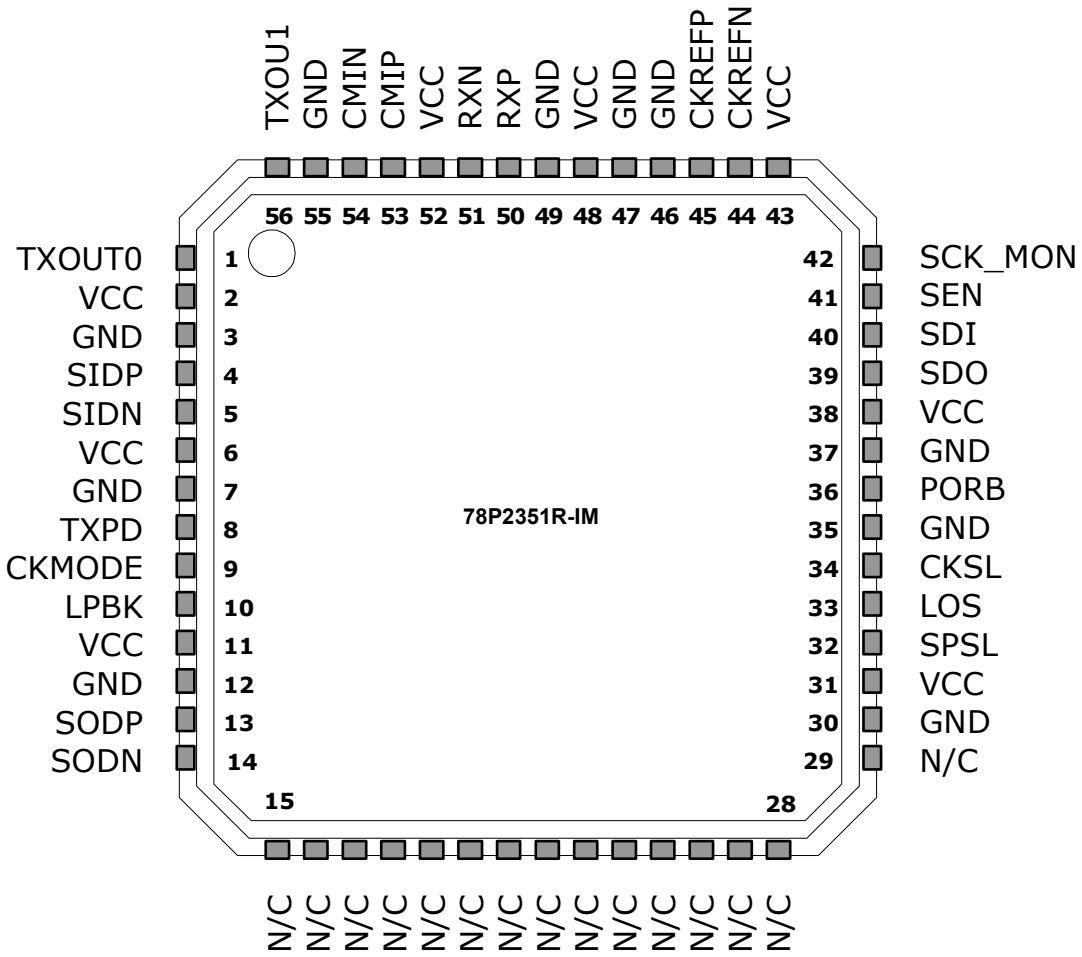




56-pin Quad Flat No-lead package (QFN)
(All dimensions in mm)

PACKAGE INFORMATION

(Top View)



ORDERING INFORMATION

PART DESCRIPTION	ORDER NUMBER	PACKAGE MARK
56-pin JEDEC QFN	78P2351R-IM /A04	78P2351R-IM xxxxxxxxxC4
Tape & Reel option	*append* 'R'	n/a
Lead-free option	*append* '/F'	78P2351R-IM xxxxxxxxxC4F

Revision History	
v1-0	**November, 2003**: Initial customer release
v1-1	**February 11, 2004:** ▪ Updated Mechanical Drawings ▪ Corrected pin numbers in Receiver Pin Table ▪ Pin naming convention change (TXOUT2 → TXOUT0) ▪ Updated thermal information ▪ Updated DC characteristics ▪ Updated I/O characteristics

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