

# DS32EL0421, DS32ELX0421 125 – 312.5 MHz Serializer with DDR LVDS Parallel LVDS Interface

## General Description

The DS32EL0421/DS32ELX0421 is a 125 MHz to 312.5 MHz (DDR) serializer for high-speed serial transmission over FR-4 printed circuit board backplanes, balanced cables, and optical fiber. This easy-to-use chipset integrates advanced signal and clock conditioning functions, with an FPGA friendly interface.

The DS32EL0421/DS32ELX0421 serializes up to 5 parallel input LVDS channels to create a maximum data payload of 3.125 Gbps. If the integrated DC-balance encoding is enabled, the maximum data payload achievable is 2.5 Gbps.

The DS32EL0421/DS32ELX0421 serializers feature remote sense capability to automatically detect and negotiate link status with its companion DS32EL0124/DS32ELX0124 deserializers without requiring an additional feedback path.

The parallel LVDS interface reduces FPGA I/O pins, board trace count and alleviates EMI issues, when compared to traditional single-ended wide bus interfaces.

The DS32EL0421/DS32ELX0421 is programmable through a SMBus interface as well as through control pins.

## Target Applications

- Imaging: Industrial, Medical Security, Printers
- Displays: LED walls, Commercial
- Video Transport
- Communication Systems
- Test and Measurement
- Industrial Bus

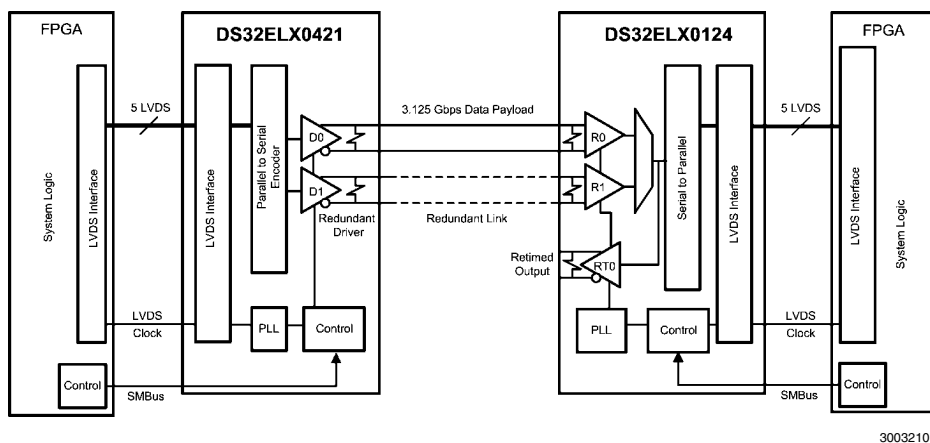
## Features

- 5-bit LVDS parallel data interface
- Programmable transmit de-emphasis
- Configurable output levels ( $V_{OD}$ )
- Selectable DC-balanced encoder
- Selectable data scrambler
- Remote Sense for automatic detection and negotiation of link status
- On chip LC VCOs
- Redundant serial output (ELX device only)
- Data valid signaling to assist with synchronization of multiple receivers
- Supports AC- and DC-coupled signaling
- Integrated CML and LVDS terminations
- Configurable PLL loop bandwidth
- Programmable output termination ( $50\Omega$  or  $75\Omega$ ).
- Built-in test pattern generator
- Loss of lock and error reporting
- Configurable via SMBus
- 48-pin LLP package with exposed DAP

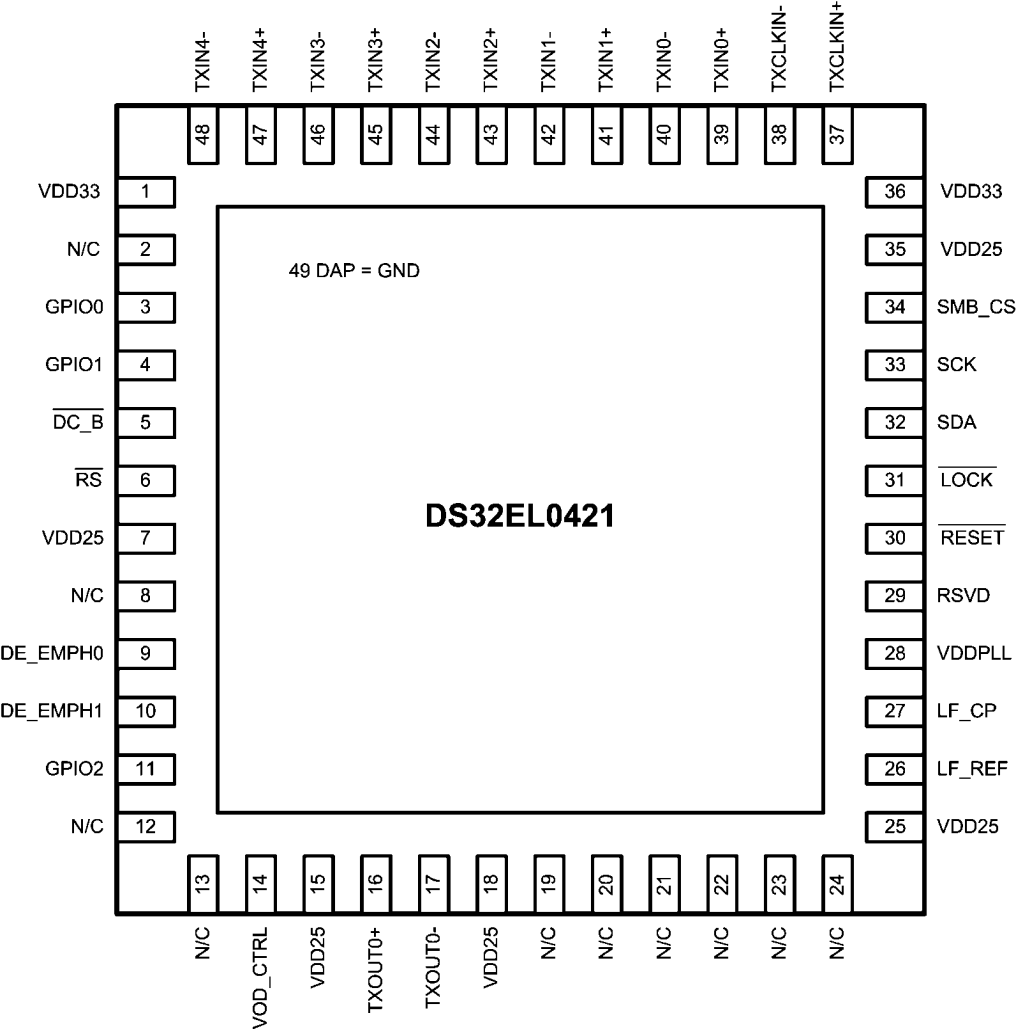
## Key Specifications

- 1.25 to 3.125 Gbps serial data rate
- 125 to 312.5 MHz DDR parallel clock
- $-40^{\circ}$  to  $+85^{\circ}\text{C}$  temperature range
- $>8$  kV ESD (HBM) protection
- Low Intrinsic Jitter — 35ps at 3.125 Gbps

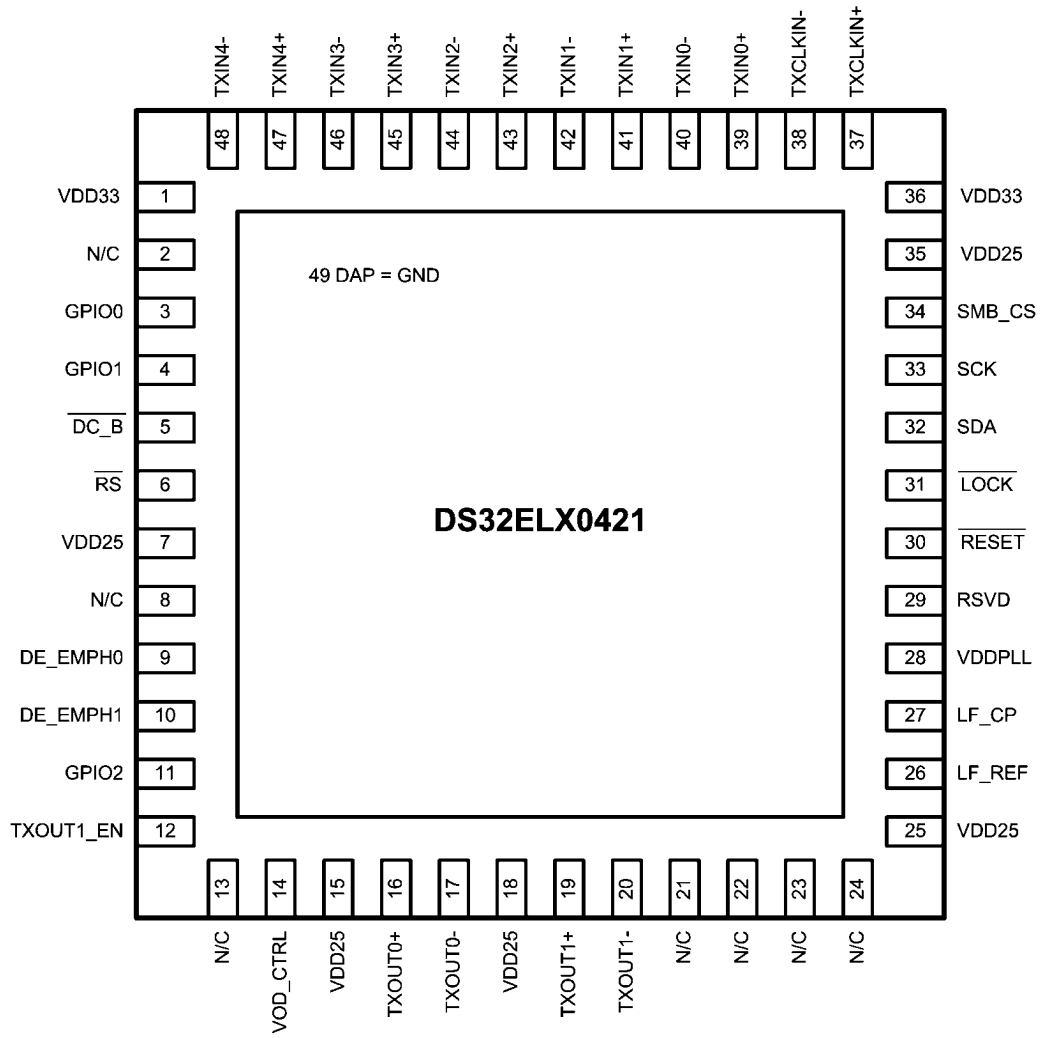
## Typical Application



Pin Diagram



30032102



30032103

## Pin Descriptions

Pin Name	Pin Number	I/O, Type	Description
<b>Power, Ground and Analog Reference</b>			
VDD33	1, 36	I, VDD	3.3V supply
VDD25	7, 15, 18, 25, 35	I, VDD	2.5V supply
VDDPLL	28	I, VDD	3.3V supply
VOD_CTRL	14	Analog	V <sub>OD</sub> control. The serializer output amplitude can be adjusted by connecting this pin to a pull-down resistor. The value of the resistor determines the VOD. Use the following equation to determine the value of the resistor. $R = (1400 \text{ mV} / V_{OD}) \times 9.1 \text{ k}\Omega$
LF_CP	27	Analog	Loop filter connection for PLL
LF_REF	26	Analog	Loop filter ground reference
Exposed Pad	49	GND	Exposed Pad must be connected to GND by 9 vias
<b>CML I/O</b>			
TxOUT0+ TxOUT0-	16 17	O, CML	Inverting and non-inverting high speed CML differential outputs of the serializer. These outputs are internally terminated.
TxOUT1+ TxOUT1-	19 20	O, CML	<b>DS32ELX0421 ONLY.</b> Redundancy output. Inverting and non-inverting high speed CML differential outputs of the serializer. These outputs are internally terminated
<b>LVDS Parallel Data Bus</b>			
TxCLKIN+ TxCLKIN-	37 38	I, LVDS	Serializer input clock. TxCLKIN+/- are the inverting and non-inverting LVDS transmit clock input pins.
TxIN[4:0]+/-	39, 40, 41, 42, 43, 44, 45, 46, 47, 48	I, LVDS	Serializer input data. TxIN[4:0]+/- are the inverting and non-inverting LVDS serializer input data pins.
<b>LVC MOS Control Pins</b>			
DC_B RS	5 6	I, LVC MOS	DC-balance and Remote Sense pins. See Device Configuration section for device behavior.
DE_EMPH0 DE_EMPH1	9 10	I, LVC MOS	DE_EMPH0, DE_EMPH1 select the output de-emphasis level. These pins are internally pull-down. 00: Off 01: Low 10: Medium 11: Maximum
TXOUT1_E N	12	I, LVC MOS	<b>DS32ELX0421 ONLY.</b> When held high, redundant output TxOUT1+/- is enabled. This pin must be tied high when using TxOUT1+/-.
RESET	30	I, LVC MOS	When held low, reset the device. 0 = Device Reset 1 = Normal operation
LOCK	31	O, LVC MOS	Lock indication output. The input data on TxIN[0:4]+/- pins is ignored when LOCK pin is high.
<b>SMBus Interface</b>			
SCK	33	I/O, SMBus	SMBus compatible clock.
SDA	32	I/O, SMBus	SMBus compatible data line.
SMB_CS	34	I, SMBus	SMBus chip select. When held high, SMBus management control is enabled.
<b>Other</b>			
GPIO0	3	I/O, LVC MOS	Software configurable I/O pin.

Pin Name	Pin Number	I/O, Type	Description
GPIO1	4	I/O, LVCMOS	Software configurable I/O pin.
GPIO2	11	I/O, LVCMOS	Software configurable I/O pin.
NC	2, 8, 12, 13, 19, 20, 21, 22, 23, 24, 29	Misc.	No Connect, for DS32EL0421
	2, 8, 13, 21, 22, 23, 24, 29	Misc.	No Connect, for DS32ELX0421

**Absolute Maximum Ratings** (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage (3.3V $V_{DD33}$ )	-0.3V to +4V
Supply Voltage (2.5V $V_{DD25}$ )	-0.3V to +3V
LVC MOS Input Voltage	-0.3V to ( $V_{DD} + 0.3V$ )
LVC MOS Output Voltage	-0.3V to ( $V_{DD} + 0.3V$ )
LVDS Input Voltage (IN+, IN-)	-0.3V to +3.6V
CML Output Voltage	-0.3V to +3.6V
Junction Temperature	+125°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature Range	
Soldering (4 sec.)	+260°C
Thermal Resistance, $\theta_{JA}$	25°C/W
ESD Susceptibility	
HBM (Note 2)	>8 kV

**Recommended Operating Conditions**

	Min	Typ	Max	Units
Supply Voltage ( $V_{DD33} - GND$ )	3.135	3.3	3.465	V
Supply Voltage ( $V_{DD25} - GND$ )	2.375	2.5	2.625	V
Supply Noise Amplitude from 10 Hz to 50 MHz			100	mV <sub>P-P</sub>
Ambient Temperature ( $T_A$ )	-40	+25	+85	°C

**Power Supply Specifications**

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 5)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$I_{DD25}$	2.5V supply current 1 Output Enabled	1.25 Gbps		87	94	mA
		2.5 Gbps		95	105	
		3.125 Gbps		101	112	
	2.5V supply current 2 Outputs Enabled	1.25 Gbps		126	135	
		2.5 Gbps		136	145	
		3.125 Gbps		142	152	
$I_{DD33}$	3.3V supply current 1 Output Enabled	1.25 Gbps		74	85	mA
		2.5 Gbps		74	85	
		3.125 Gbps		74	85	
	3.3V supply current 2 Outputs Enabled	1.25 Gbps		80	92	
		2.5 Gbps		80	92	
		3.125 Gbps		80	92	
$P_D$	Power Consumption 1 Output Enabled	1.25 Gbps		460	540	mW
		2.5 Gbps		485	560	
		3.125 Gbps		500	575	
	Power Consumption 2 Output Enabled	1.25 Gbps		580	670	
		2.5 Gbps		605	695	
		3.125 Gbps		620	710	

## LVC MOS Electrical Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. Applies to GPIO0, GPIO1, GPIO2, RESET, LOCK, RS, and DC\_BAL. (Notes 3, 4, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{IH}$	High Level Input Voltage		2.0		$V_{DD}$	V
$V_{IL}$	Low Level Input Voltage		0		0.8	V
$V_{OH}$	High Level Output Voltage	$I_{OH} = -2\text{mA}$	2.7	3.3		V
$V_{OL}$	Low Level Output Voltage	$I_{OL} = 2\text{mA}$			0.3	V
$V_{CL}$	Input Clamp Voltage	$I_{CL} = -18\text{mA}$		-0.79	-1.5	V
$I_{IN}$	Input Current	$V_{IN} = 0.4\text{V}, 2.5\text{V}, \text{ or } V_{DD}$	-35		35	$\mu\text{A}$
$I_{OS}$	Output Short Circuit Current	$V_{OUT} = 0\text{V}$ (Note 6)		42		mA

## SMBus Electrical Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 4, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{SIL}$	Data, Clock Input Low Voltage				0.8	V
$V_{SIH}$	Data, Clock Input High Voltage		2		$V_{SDD}$	V
$V_{SDD}$	Nominal Bus Voltage		2.375		3.6	V
$i_{SLEAKB}$	Input Leakage Per Bus Segment			$\pm 200$		$\mu\text{A}$
$C_{SI}$	Capacitance for SDA and SCLK	(Notes 9, 10)		10		pF

## SMBus Timing Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$t_{SMB}$	Bus Operating Frequency		10		100	kHz
$t_{BUF}$	Bus Free Time between Stop and Start Condition		4.7			$\mu\text{s}$
$t_{HD:STA}$	Hold time after (repeated) start condition. After this period, the first clock is generated.		4.0			$\mu\text{s}$
$t_{SU:STA}$	Repeated Start Condition Setup Time		4.7			$\mu\text{s}$
$t_{SU:STO}$	Stop Condition Setup Time		4.0			$\mu\text{s}$
$t_{HD:DAT}$	Data Hold Time		300			ns
$t_{SU:DAT}$	Data Setup Time		250			ns
$t_{LOW}$	Clock Low Time		4.7			$\mu\text{s}$
$t_{HIGH}$	Clock High Time		4.0		50	$\mu\text{s}$
$t_F$	Clock/Data Fall Time	20% to 80%			300	ns
$t_R$	Clock/Data Rise Time				1000	ns
$t_{SU:CS}$	SMB_CS Setup Time			30		ns
$t_{POR}$	Time in which the device must be operation after power on	(Note 8)			500	ms

## LVDS Electrical Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 4, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{TH}$	Differential Input High Threshold	$0.05V < V_{LVCm} < V_{DD25} - 0.05V$			+100	mV
$V_{TL}$	Differential Input Low Threshold		-100			mV
$V_{LVCm}$	LVDS Input Common Mode Voltage		0.05		$V_{DD25} - 0.05$	V
$V_{LVOS}$	LVDS Input Loss of Signal	LVDS input loss of signal level. (Note 7)		20		mV <sub>P-P</sub>
$R_{LVIN}$	Input Impedance	Internal LVDS input termination between differential pairs.	85	100	115	$\Omega$

## LVDS Timing Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
f	Input DDR Clock (TxCLKIN) Frequency Range		125		312.5	MHz
$t_{CIP}$	TxCLKIN Period	See Figure 3	3.2	2T	8	ns
$t_{CIT}$	TxCLKIN Transition Time	See Figure 2 (Note 8)	0.5	1.0	3.0	ns
$t_{XIT}$	TxIN Transition Time		0.15		3	ns
$t_{CIH}$	TxCLKIN High Time	See Figure 3	0.7T	T	1.3T	ns
$t_{CIL}$	TxCLKIN Low Time		0.7T	T	1.3T	ns
$t_{STC}$	TxIN Setup to TxCLKIN		-550			ps
$t_{HTC}$	TxIN Hold to TxCLKIN		900			ps
$t_{LVDS}$	LVDS Input Clock Delay Step Size	Programmable through the SMBus, register 30'h Default setting = 011'b [7:5] See		100		ps

## CML Electrical Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 4, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$R_{OT}$	Output Terminations	On chip termination from TxOUT0/1 + and TxOUT0/1 - to $V_{DD25}$ 50 $\Omega$ mode	40	50	60	$\Omega$
		75 $\Omega$ mode	60	75	90	$\Omega$
$\Delta R_{OT}$	Mismatch in Output Termination Resistors				5	%
$V_{OD}$	Output Differential Voltage Swing	Based on VOD_CTRL = 9.1 k $\Omega$	1175	1350	1450	mV <sub>P-P</sub>

## CML Timing Specifications

Over recommended operating supply and temperature ranges unless otherwise specified. (Notes 3, 5)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
LR	Line Rate	Tested with alternating 1-0 pattern.	1.25		3.125	Gbps
$t_{OS}$	Output Overshoot	(Note 8)			10	%
$t_R$	Differential Low to High Transition Time	(Note 8)		60	90	ps
$t_F$	Differential High to Low Transition Time			60	90	ps
$t_{RFMM}$	Mismatch in Rise/Fall Time	(Note 8)			15	ps
$t_{DE}$	De-emphasis width	Measured from zero-crossing at rising edge to 80% of VOD from zero- crossing at falling edge. TDE is measured at the High setting during test.		1		UI



Symbol	Parameter	Conditions	Min	Typ	Max	Units
$t_{BIT}$	Serializer Bit Width			$0.2 \times t_{CIP}$		ns
$t_{SD}$	Serializer Propagation Delay – Latency			$t_{CIP} + 5.5$		ns
$t_{JIND}$	Serializer Output Deterministic Jitter	Serializer output intrinsic deterministic jitter. Measure with PRBS-7 test pattern De-emphasis disabled. (Note 8) 1.25 Gbps		10		ps
		2.5 Gbps		24		ps
		3.125 Gbps		21		ps
$t_{JINR}$	Serializer Output Random Jitter	Serializer output intrinsic random jitter. Bit error rate $\geq 10^{-15}$ . Alternating–10 pattern. De-emphasis disabled. (Note 8) 1.25 Gbps		1.3		$ps_{RMS}$
		2.5 Gbps		1.15		$ps_{RMS}$
		3.125 Gbps		1.14		$ps_{RMS}$
$t_{JINT}$	Peak-to-peak Serializer Output Jitter	Serializer output peak-to-peak jitter includes deterministic jitter, random jitter, and jitter transfer from serializer input. Measure with PRBS-7 test pattern. Bit error rate $\geq 10^{-15}$ . De-emphasis disabled. (Note 8) 1.25 Gbps		28		ps
		2.5 Gbps		38		ps
		3.125 Gbps		35		ps
$\lambda_{TXBW}$	Jitter Transfer Function -3 dB Bandwidth (Note 8)	1.25 Gbps		100		kHz
		3.125 Gbps		300		kHz
$\delta_{TX}$	Jitter Transfer Function Peaking (Note 8)			0.5		dB

**Note 1:** “Absolute Maximum Ratings” indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the Absolute Maximum Ratings or other conditions beyond those indicated in the Recommended Operating Conditions is not implied. The Recommended Operating Conditions indicate conditions at which the device is functional and the device should not be operated beyond such conditions.

**Note 2:** Human Body Model, applicable std. JESD22-A114C

**Note 3:** The Electrical Characteristics tables list guaranteed specifications under the listed Recommended Operating Conditions except as otherwise modified or specified by the Electrical Characteristics Conditions and/or Notes. Typical specifications are estimations only and are not guaranteed.

**Note 4:** Current into device pins is defined as positive. Current out of device pins is defined as negative. All voltages are referenced to ground except  $V_{OD}$  and  $\Delta V_{OD}$ .

**Note 5:** Typical values represent most likely parametric norms for  $V_{CC} = +3.3V$  and  $T_A = +25^\circ C$ , and at the Recommended Operation Conditions at the time of product characterization and are not guaranteed.

**Note 6:** Output short circuit current ( $I_{OS}$ ) is specified as magnitude only, minus sign indicates direction only.

**Note 7:** If input LVDS signal is below  $20mV_{P-P}$ , loss of signal (LOS) is detected. The device will flag a valid input signal if the signal level is above  $100mV_{P-P}$ .

**Note 8:** Parameter is guaranteed by characterization and is not tested at production.

**Note 9:** Recommended value, parameter is not tested.

**Note 10:** Recommended maximum capacitance load per bus segment is 400 pF.



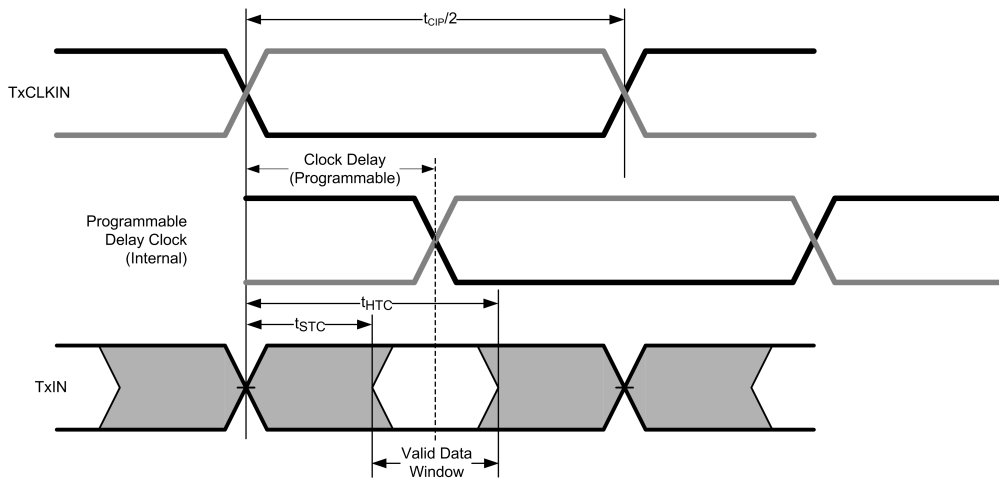
The diagram shows a digital signal labeled TXCLK. It transitions from a low level to a high level, staying high for a period, and then transitions back to a low level. The rising edge is marked with a 20% level point and a vertical line at the 80% level. The falling edge is marked with a vertical line at the 80% level and a 20% level point. The time interval from the 20% point of the rising edge to the 80% level is labeled  $t_{CIT}$ . Similarly, the time interval from the 80% level of the falling edge to the 20% point is labeled  $t_{CIT}$ .

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The diagram shows two signals: TXCLK and TXn. TXCLK is a differential signal with a high level of +100 mV and a low level of -100 mV. TXn is a single-ended signal that transitions from Setup to Hold at 0V. Key timing parameters are indicated:  $t_{CIP}/2$  is the period of TXCLK;  $t_{CIL}, t_{CIH}$  are the setup times before TXn transitions;  $t_{STC}$  is the setup time after TXn transitions; and  $t_{HTC}$  is the hold time after TXn transitions.

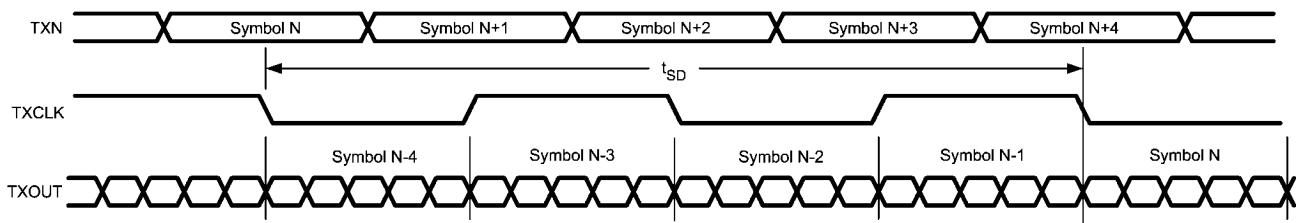
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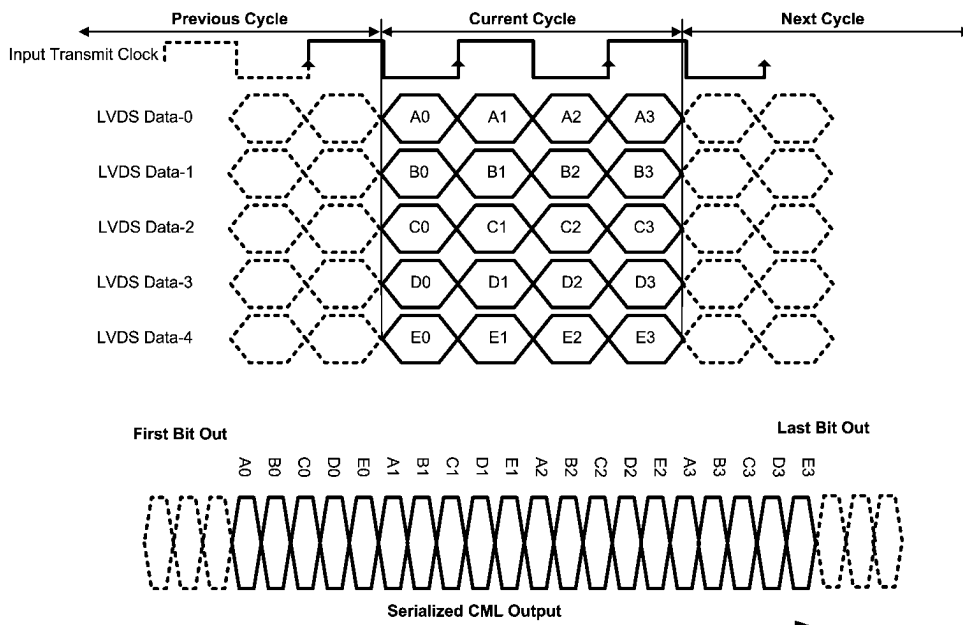
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FIGURE 4. LVDS Input Clock Delay



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FIGURE 5. Propagation Delay Timing Diagram



30032104

FIGURE 6. 5-Bit Parallel LVDS Inputs Mapped to CML Output

## Functional Description

### POWER SUPPLIES

The DS32EL0421 and DS32ELX0421 have several power supply pins, at 2.5V as well as 3.3V. It is important that these pins all be connected and properly bypassed. Bypassing should consist of parallel 4.7 $\mu$ F and 0.1 $\mu$ F capacitors as a minimum, with a 0.1 $\mu$ F capacitor on each power pin. A 22  $\mu$ F capacitor is required on the VDDPLL pin which is connected to the 3.3V rail.

These devices have a large contact in the center on the bottom of the package. This contact must be connected to the system GND as it is the major ground connection for the device.

### POWER UP

It is recommended, although not necessary, to bring up the 3.3V power supply before the 2.5V supply. If the 2.5V supply is powered up first, an initial current draw of approximately 600mA from the 2.5V rail may occur before settling to its final value. Regardless of the sequence, both power rails should monotonically ramp up to their final values.

### POWER MANAGEMENT

These devices have two methods to reduce power consumption. To enter the first power save mode, the on board host FPGA or controlling device can cease to output the DDR transmit clock. To further reduce power consumption, write 40'h to register 26'h and 10'h to register 01'h. This will put the device in its lowest power consumption mode.

### RESET

There are three ways to reset these devices. A reset occurs automatically during power-up. The device can also be reset by pulling the RESET pin low, with normal operation resuming when the pin is driven high again. The device can also be reset by writing to the reset register. This reset will put all of the register values back to their default values, except it will not affect the address register value if the SMBus default address has been changed.

### LVDS INPUTS

The DS32EL0421 and DS32ELX0421 have standard 2.5V LVDS inputs which are compliant with ANSI/TIA/EIA-644. These inputs have internal 100 $\Omega$  termination resistors. It is recommended that the PCB trace between the FPGA and the serializer be less than 40-inches. Longer PCB traces may degrade the quality of the input signal. The connection between the host and the DS32EL0421 or DS32ELX0421 should be over a controlled impedance transmission line with impedance that matches the termination resistor – usually 100 $\Omega$ . Setup and hold times are specified in the LVDS Switch-

ing Characteristics table, however the clock delay can be adjusted by writing to register 30'h.

### LOOP FILTER

The DS32EL0421 and DS32ELX0421 have an internal PLL which is used to generate the serialization clock from the parallel clock input. The loop filter for this PLL is external; and for optimum results, a 100nF capacitor and a 1.5 k $\Omega$  resistor in series should be connected between pins 26 and 27. See typical interface circuit (*Figure 11*).

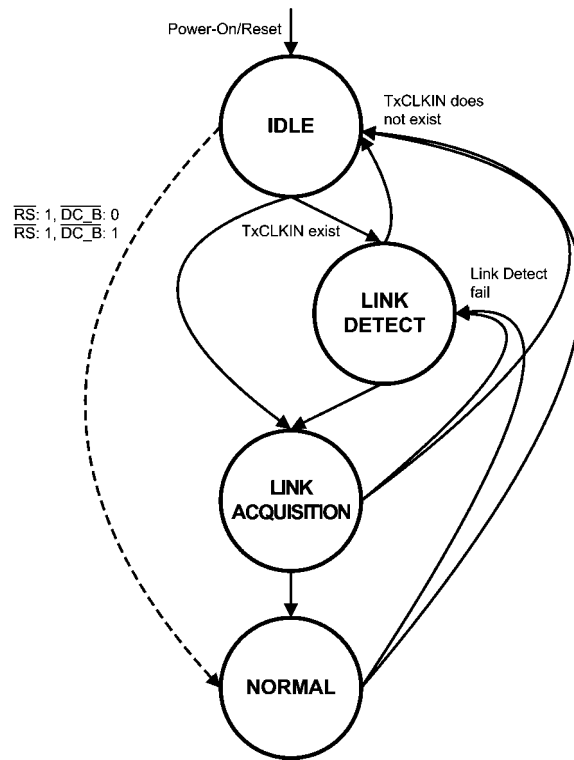
### REMOTE SENSE

The remote sense feature can be used when a DS32EL0421 or DS32ELX0421 serializer is directly connected to a DS32EL0124 or DS32ELX0124 deserializer. Active components in the signal path between the serializer and the deserializer may interfere with the back channel signaling of the devices.

When remote sense is enabled, the serializer will cycle through four states to successfully establish a link and align the data. The state diagram for the serializer is shown in *Figure 7*. The serializer will remain in the low power IDLE state until it receives an input clock. Once the PLL of the serializer has locked to the input clock, the device will enter the LINK DETECT state. While in this state, the serializer will monitor the line to see if the deserializer is present. If a deserializer is detected, the serializer will enter the LINK ACQUISITION state. The serializer will transmit the entire training pattern and then enter the NORMAL state. If the deserializer is unable to successfully lock or maintain lock, it will break the link sending the serializer back to the IDLE or LINK DETECT states.

### DC-BALANCE ENCODER

The DS32EL0421 and DS32ELX0421 have a built-in DC-balance encoder to support AC-coupled applications. When enabled, the input signal on TXIN4+/- is treated as a data valid bit. If TXIN4+/- is low, then the four bit nibbles from TXIN0-TXIN3 are taken to form a 16 bit word. This 16 bit word is processed as two 8 bit words and converted to two 10 bit words by using the standard 8b/10b data coding scheme. The two 10 bit words are then combined to create a 20 bit code. This 20 bit word is serialized and driven on the output. The nibble taken in on the rising edge of the clock is the most significant nibble and the nibble taken in on the falling edge is the least significant nibble. If TXIN4+/TXIN4- is high, then the inputs TXIN0 -TXIN3 are ignored and a programmable DC-balanced SYNC character is inserted in the output stream. The default character is a K28.5 code. In order to send other K codes, they must first be programmed into the serializer via the SMBus.



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FIGURE 7. Serializer State Diagram

## SCRAMBLER

If the scrambler is enabled, the raw or DC-balanced serialized data is scrambled to improve transition density. The scrambler accepts 20 bits of data and encodes it using the polynomial  $X^9 + X^4 + 1$ . The data can then be sent to the NRZ-to-NRZI converter before being output. Data is converted to the NRZI format using the polynomial  $X + 1$ .

Enabling the scrambler helps to lower EMI emissions by spreading the spectrum of the data. Scrambling also creates transitions for the deserializer's CDR to properly lock onto.

The scrambler and NRZI encoder are enabled or disabled by default depending on how the  $\overline{DC\_B}$  and  $\overline{RS}$  pins are configured. To override the default scrambler setting two register writes must be performed. First, write to register 22'h and set bit 3 to unlock the scrambler register. Next write to register 21'h and change bit 4 to the desired value. The NRZI encoder can be enabled or disabled independently of the scrambler by controlling bit 7 of register 21'h and bit 4 of register 22'h.

## CML OUTPUT DATA INTERFACING

The serial outputs provide low-skew differential signals. Internal resistors connected from TxOUTn+ and TxOUTn- to VDD25 terminate the outputs. The output level can be programmed by adjusting the pull-down resistor to the VOD\_CTRL pin. The output terminations can also be programmed to be either 50  $\Omega$  or 75  $\Omega$ .

The output buffer consists of a current mode logic (CML) driver with user configurable de-emphasis control, which can be used to optimize performance over a wide range of transmission line lengths and attenuation distortions resulting from low cost CAT(-5, -6, -7) cable or FR-4 backplane. Output de-emphasis is user programmable through either device pins

DE\_EMPH0 and DE\_EMPH1 or SMBus interface. Users can control the strength of the de-emphasis to optimize for a specific system environment. Please see the De-Emphasis Control Table for details.

## De-Emphasis Control Table

DE_EMPH[1:0]	Output De-Emphasis Level
00'b	Off
01'b	Low
10'b	Medium
11'b	High

The DS32ELX0421 provides a secondary serial output, supporting redundancy applications. The redundant output driver can be enabled by setting TXOUT1\_EN pin to HIGH or by activating it through the SMBus registers.

## DEVICE CONFIGURATION

There are four ways to configure the DS32EL0421 and DS32ELX0421 serializers, these combinations are shown in Table 1. Refer to Figure 7 to see how the combinations of the  $\overline{RS}$  and  $\overline{DC\_B}$  pins change the link startup behavior of the serializers. When connecting to a deserializer other than the DS32EL0124 or DS32ELX0124, Remote Sense should be disabled. The scrambler and NRZI encoder shown in Table 1 can be enabled or disabled through register programming.

When Remote Sense is enabled, with  $\overline{RS}$  pin tied low, the serializer must be connected directly to a DS32EL0124 or DS32ELX0124 deserializer without any active components between them. The Remote Sense module features an upstream communication method for the serializer and deseri-

alizer to communicate. This feature is used to pass link status information between the 2 devices.

If DC-Balance is enabled, a maximum of 4 parallel LVDS lanes can be used to receive data. The fifth lane (TXIN4±) is used for Data Valid signaling. Each time a serializer establishes a link to a deserializer with DC-Balance enabled, the Data Valid input to the serializer must be held high for 110 LVDS clock periods. If the Data Valid input to the serializer is logic HIGH, then SYNC characters are transmitted. If the deserializer receives a SYNC character, then the LVDS data outputs will all be logic low and the Data Valid output will be logic high. If the deserializer detects a DC-Balance code error, the output data pins will be set to logic high with the Data Valid output also set to logic high.

In the case where DC-Balance is enabled and Remote Sense is disabled, with RS set to high and DC\_B set to low, it is recommended that the host device periodically toggle the Da-

ta Valid input to the serializer, to transmit SYNC symbols on the line, to ensure that the deserializer is and remains locked. In this configuration the deserializer or receiving device does not have a way to directly notify the serializer if it has lost lock. Periodically sending SYNC symbols will allow the receiving system to reacquire lock if a problem has occurred. With these pin settings the DS32EL0421/DS32ELX0421 and DS32EL0124/DS32ELX0124 devices can interface with other active component in the high speed signal path, such as fiber modules.

When both Remote Sense and DC-Balance are disabled, RS and DC\_B pins set to high, the LVDS lane alignment is not maintained. In this configuration, data formatting is handled by an FPGA or external source. This pin setting combination also allows for the DS32EL0421/DS32ELX0421 devices to interface with active components other than the DS32EL0124/DS32ELX0124 in the high speed signal path.

**TABLE 1. Device Configuration Table**

Remote Sense Pin (RS)	DC-Balance Pin (DC_B)	Configuration
0	0	Remote Sense enabled DC-Balance enabled Data Alignment Scrambler and NRZI encoder disabled by default
0	1	Remote Sense enabled DC-Balance disabled Data Alignment Scrambler and NRZI encoder enabled by default
1	0	Remote Sense disabled DC-Balance enabled Data Alignment Scrambler and NRZI encoder enabled by default
1	1	Remote Sense disabled DC-Balance disabled No Data Alignment Scrambler and NRZI encoder disabled by default

## SMBus INTERFACE

The System Management Bus interface is compatible to SMBus 2.0 physical layer specification. The use of the Chip Select signal is **required**. Holding the SMB\_CS pin HIGH enables the SMBus port, allowing access to the configuration registers. Holding the SMB\_CS pin LOW disables the device's SMBus, allowing communication from the host to other slave devices on the bus. In the STANDBY state, the System Management Bus remains active. When communication to other devices on the SMBus is active, the SMB\_CS signal for the serializer must be driven LOW.

The address byte for all DS32EL0421 and DS32ELX0421 devices is AE'h. Based on the SMBus 2.0 specification, these devices have a 7-bit slave address of 1010111'b. The LSB is set to 0'b (for a WRITE), thus the 8-bit value is 1010 1110 'b or AE'h.

The SCK and SDA pins are 3.3V LVCMOS signaling and include high-Z internal pull up resistors. External low impedance pull up resistors maybe required depending upon SMBus loading and speed. Note, these pins are not 5V tolerant.

### Transfer of Data via the SMBus

During normal operation the data on SDA must be stable during the time when SCK is HIGH.

There are three unique states for the SMBus:

- START** A HIGH to LOW transition on SDA while SCK is HIGH indicates a message START condition
- STOP** A LOW to HIGH transition on SDA while SCK is HIGH indicates a message STOP condition.
- IDLE** If SCK and SDA are both high for a time exceeding  $t_{BUF}$  from the last detected STOP condition or if they are HIGH for a total exceeding the maximum specification for  $t_{HIGH}$  then the bus will transfer to the IDLE state.

### SMBus Transactions

The devices support WRITE and READ transactions. See Register Description Table for register address, type (Read/Write, Read Only), default value and function information.

### Writing to a Register

To write a register, the following protocol is used (see SMBus 2.0 specification).

1. The Host (Master) selects the device by driving its SMBus Chip Select (SMB\_CS) signal HIGH.
2. The Host drives a START condition, the 7-bit SMBus address, and a "0" indicating a WRITE.
3. The Device (Slave) drives the ACK bit ("0").
4. The Host drives the 8-bit Register Address.
5. The Device drives an ACK bit ("0").
6. The Host drive the 8-bit data byte.
7. The Device drives an ACK bit ("0").
8. The Host drives a STOP condition.

9. The Host de-selects the device by driving its SMBus CS signal Low.

The WRITE transaction is completed, the bus goes IDLE and communication with other SMBus devices may now occur.

### Reading a Register

To read a register, the following protocol is used (see SMBus 2.0 specification).

1. The Host (Master) selects the device by driving its SMBus Chip Select (SMB\_CS) signal HIGH.
2. The Host drives a START condition, the 7-bit SMBus address, and a "0" indicating a WRITE.
3. The Device (Slave) drives the ACK bit ("0").
4. The Host drives the 8-bit Register Address.
5. The Device drives an ACK bit ("0").
6. The Host drives a START condition.
7. The Host drives the 7-bit SMBus Address, and a "1" indicating a READ.
8. The Device drives an ACK bit "0".
9. The Device drives the 8-bit data value (register contents).
10. The Host drives a NACK bit "1" indicating end of the READ transfer.
11. The Host drives a STOP condition.
12. The Host de-selects the device by driving its SMBus CS signal Low.

The READ transaction is completed, the bus goes IDLE and communication with other SMBus devices may now occur.

### SMBus Configurations

Many different configurations of the SMBus are possible and depend upon the specific requirements of the applications. Several possible applications are described.

#### Configuration 1

The deserializer SMB\_CS may be tied High (always enabled) since it is the only device on the SMBus. See *Figure 8*.

#### Configuration 2

Since the multiple SER devices have the same address, the use of the individual SMB\_CS signals is required. To communicate with a specific device, its SMB\_CS is driven High to select the device. After the transaction is complete, its SMB\_CS is driven Low to disable its SMB interface. Other devices on the bus may now be selected with their respective chip select signals and communicated with. See *Figure 9*.

#### Configuration 3

The addressing field is limited to 7-bits by the SMBus protocol. Thus it is possible that multiple devices may share the same 7-bit address. An optional feature in the SMBus 2.0 specification supports an Address Resolution Protocol (ARP). This optional feature is not supported by the DS32EL0421/DS32ELX0421 devices. Solutions for this include: the use of the independent SMB\_CS signals, independent SMBus segments, or other means.



### FIGURE 10. SMBus Daisy Chained CS Configuration



### FIGURE 10. SMBus Daisy Chained CS Configuration





## Applications Information

### GPIO PINS

The GPIO pins can be useful tools when debugging or evaluating the system. For specific GPIO configurations and functions refer to registers 2, 3, 4, 5 and 6 in the device register map.

GPIO pins are commonly used when there are multiple serializers on the same SMBus. In order to program individual settings into each serializer, they will each need to have a unique SMBus address. To reprogram multiple serializers on a single SMBus, configure the first serializer such that the SMBus lines are connected to the FPGA or host controller. The CS pin of the second serializer should be tied to GPIO0 of the first serializer, with the CS pin of the next serializer tied to GPIO0 of its preceding serializer. By holding all of the GPIO0 pins low, the first serializer's address may now be reprogrammed by writing to register 0. The first serializer's GPIO pin can now be asserted and the second serializer's address may now be reprogrammed.

### HIGH SPEED COMMUNICATION MEDIA

Using the serializer's integrated de-emphasis blocks in combination with the DS32EL0124 or DS32ELX0124's integrated equalization blocks allows data to be transmitted across a variety of media at high speeds. Factors that can limit device performance include excessive input clock jitter, noisy power rails, EMI from nearby noisy components and poor layout techniques. Although many cables contain wires of similar gauge and shielding, performance can vary greatly depending on the quality of the connector.

### REDUNDANCY APPLICATIONS

The DS32ELX0421 has two high speed CML serial outputs. SMBus register control allows the device to use a single output exclusively, or both outputs simultaneously. This allows a single serializer to transmit data to two independent receiving systems, a primary and secondary endpoint. Some applications require a redundancy measure in case the primary signal path is compromised. The secondary output can be

activated "on-the-go", if a problem is detected on the primary link. See the *Redundancy / Fail Over Configuration* section located under *Register Recipes*.

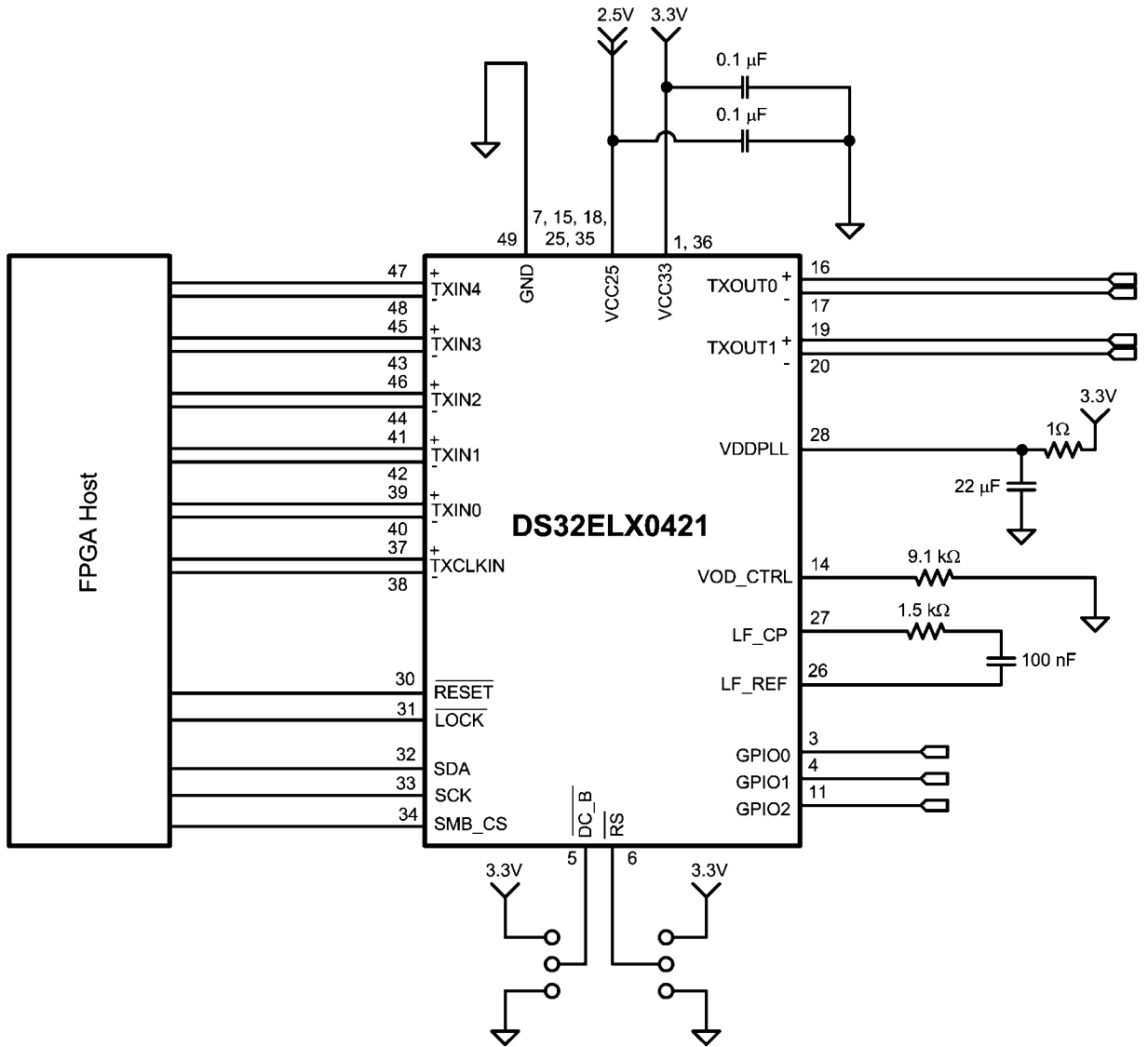
### LINK AGGREGATION

Multiple DS32EL0421/DS32ELX0421 serializers and D32EL0124/DS32ELX0124 deserializers can be aggregated together if an application requires a data throughput of more than 3.125 Gbps. By utilizing the data valid signal of each device, the system can be properly deskewed to allow for a single cable, such as CAT-6, DVI-D, or HDMI, to carry data payloads beyond 3.125 Gbps. The ELXLEVK01 evaluation kit includes sample IP for a link aggregation system to operate at an application throughput of up to 6.25 Gbps.

Link aggregation configurations can also be implemented in applications which require longer cable lengths. In these type of applications the data rate of each serializer and deserializer chipset can be reduced, such that the applications' net data throughput is still the same. Since each high speed channel is now operating at a fraction of the original data rate, the loss over the cable is reduced, allowing for greater lengths of cable to be used in the system.

### LAYOUT GUIDELINES

It is important to follow good layout practices for high speed devices. The length of LVDS input traces should not exceed 40 inches. In noisy environment the LVDS traces may need to be shorter to prevent data corruption due to EMI. Noisy components should not be placed next to the LVDS or CML traces. The LVDS and CML traces must have a controlled differential impedance of 100  $\Omega$ . Do not place termination resistor at the LVDS inputs or CML outputs, the DS32EL0421 and DS32ELX0421 have internal termination resistors. It is recommended to avoid using vias. Vias create an impedance mismatch in the transmission line and result in reflections, which can greatly lower the maximum distance of the high speed data link. If vias are required, they should be placed symmetrically on each side of the differential pair. For more tips and detailed suggestions regarding high speed board layout principles, please consult the LVDS Owner's Manual.



30032105

FIGURE 11. Typical Interface Circuit

## Register Map

The register information for the serializer is shown in the table below. Some registers have been omitted or marked as re-

served; these are for internal testing and should not be written to. Some register bits require an override bit to be set before they can be written to.

Addr (Hex)	Name	Bits	Field	R/W	Default	Description
00	Device ID	7:1	SMBus Address	R/W	57'h	Some systems will use all 8 bits as the device ID. This will shift the value from 57'h to AE'h
		0	Reserved		0	
01	Reset	7:5	Reserved		0	
		4	Analog Disable	R/W	0	1: Disables analog blocks. Power save feature
		3:1	Reserved		0	
		0	Software Reset		0	1: Reset the device. Does not affect device ID.
02	GPIO0 Config	7:4	GPIO0 Mode	R/W	0	0000: GP out register 0001: Link loss indicator 0011: TxCLKIN loss of signal 0100: TxCLKIN detect <b>All others: Reserved</b>
		3:2	GPIO0 R Enable	R/W	01'b	00: Pullup/down disabled 01: Pulldown enabled 10: Pullup enabled <b>11: Reserved</b>
		1	Input Enable	R/W	0	0: Input buffer disabled 1: Input buffer enabled
		0	Output Enable	R/W	1'b	0: Output Tri-State™ 1: Output enabled
03	GPIO1 Config	7:4	GPIO1 Mode	R/W	0	0000: Power on reset 0001: GP out register 0010: PLL lock indicator 0011: TxIN0 loss of signal 0100: TxIN1 loss of signal 0101: TxIN2 loss of signal 0110: TxIN3 loss of signal 0111: TxIN4 loss of signal <b>All others: Reserved</b>
		3:2	GPIO1 R Enable	R/W	01'b	00: Pullup/down disabled 01: Pulldown enabled 10: Pullup enabled <b>11: Reserved</b>
		1	Input Enable	R/W	0	0: Input buffer disabled 1: Input buffer enabled
		0	Output Enable	R/W	1'b	0: Output Tri-State™ 1: Output enabled
04	GPIO2 Config	7:4	GPIO2 Mode	R/W	0	0000: GP out register 0001: Always on clock out 0010: Parallel-to-serial clock out 0100: Digital clock out <b>All others: Reserved</b>
		3:2	GPIO2 R Enable	R/W	01'b	00: Pullup/down disabled 01: Pulldown enabled 10: Pullup enabled <b>11: Reserved</b>
		1	Input Enable	R/W	0	0: Input buffer disabled 1: Input buffer enabled
		0	Output Enable	R/W	1'b	0: Output Tri-State™ 1: Output enabled

Addr (Hex)	Name	Bits	Field	R/W	Default	Description
05	GP In	7:3	Reserved		0	
		2	GP In 2	R	0	Input value on GPIO2
		1	GP In 1	R	0	Input value on GPIO1
		0	GP In 0	R	0	Input value on GPIO0
06	GP Out	7:3	Reserved		0	
		2	GP Out 2	R/W	0	Output value on GPIO2
		1	GP Out 1	R/W	0	Output value on GPIO1
		0	GP Out 0	R/W	0	Output value on GPIO0
07–1F Reserved						
20	De-Emphasis	7:3	Reserved		0	
		2	Pin Override	R/W	0	0: Pin values determine setting 1: Register overrides pin values
		1:0	De-emphasis level	R/W	0	00: No de-emphasis 01: Low 10: Medium 11: High
21	Device Config	7	NRZ enable	R/W	0	1: Enable NRZ, if override bit is set
		6	DV disable	R/W	0	1: Disable Data Valid
		5	Reserved	R/W	0	
		4	Scrambler Enable	R/W	0	1: Scrambler enable, requires override bit to change setting
		3	DC Bal encoder bypass	R/W	0	1: Bypass encoder, requires override bit to change setting
		2	Training Sequence Enable	R/W	0	1: Enable training sequence, requires override bit to change setting
		1:0	Device Configuration	R/W	0	MSB: Remote Sense enable, active low LSB: DC balance encoder enable, active low Requires override bit to change settings through registers. Normally controlled by pins. See <i>Table 1</i> for more information.
22	Device Config Override	7:5	Reserved		0	
		4	NRZ bypass override	R/W	0	1: Unlock reg 21'h bit 7
		3	Scrambler bypass override	R/W	0	1: Unlock reg 21'h bit 4
		2	DC Bal encoder bypass override	R/W	0	1: Unlock reg 21'h bit 3
		1	Training sequence enable override	R/W	0	1: Unlock reg 21'h bit 2
		0	Config pin override	R/W	0	1: Unlock reg 21'h bits 1 and 0
23 Reserved						
24	LVDS Clock Delay Enable	7	TxCLKIN Delay Bypass	R/W	0	0: TxCLKIN delay enable 1: Bypass TxCLKIN delay
		6:0	Reserved		0	
25 Reserved						

Addr (Hex)	Name	Bits	Field	R/W	Default	Description
26	Power Down	7	Channel Reset	R/W	0	1: Reset high speed channel. Self-clearing bit.
		6	Clock Powerdown	R/W	0	1: Power down parallel, parallel-to-serial, and always on clock
		5	LVDS Clock enable	R/W	1'b	0: Disable TxCLKIN 1: Enable TxCLKIN
		4	TxIN4 Enable	R/W	1'b	0: Disable TxIN4 1: Enable TxIN4
		3	TxIN3 Enable	R/W	1'b	0: Disable TxIN3 1: Enable TxIN3
		2	TxIN2 Enable	R/W	1'b	0: Disable TxIN2 1: Enable TxIN2
		1	TxIN1 Enable	R/W	1'b	0: Disable TxIN1 1: Enable TxIN1
		0	TxIN0 Enable	R/W	1'b	0: Disable TxIN0 1: Enable TxIN0
27	Event Disable	7:5	Reserved	R/W	0	
		4	PLL Lock Disable	R/W	0	0: Count clock errors 1: Clock error count disabled
		3	FIFO Error Disable	R/W	0	0: Count FIFO errors 1: FIFO error count disabled
		2	Parallel Clock Detect Disable	R/W	0	0: Count clock detect errors 1: Clock detect count disabled
		1	Clock Loss of Signal Disable	R/W	0	0: Count clock loss of signal errors 1: Clock loss of signal count disabled
		0	Data Loss of Signal Disable	R/W	0	0: Count data loss of signal errors 1: Clock data of signal count disabled
28	LVDS Operation	7:2	Reserved		0	
		1	LVDS Loss of Signal Preset	R/W	0	1: Preset signal for LVDS loss of signal register
		0	LVDS Loss of Signal Reset	R/W	0	1: Clear signal for LVDS loss of signal register
29	Loss of Signal Status	7:6	Reserved		0	
		5	Clock Loss of Signal	R	0	0: No clock present on TxCLKIN 1: Clock present
		4:0	Data Loss of Signal	R	0	0: No data present on TxIN4:0 1: Data present
2A	Event Status	7:4	Reserved		0	
		3	TxCLKIN Detect	R/W	0	0: TxCLKIN not detected 1: TxCLKIN detected
		2	PLL Lock	R/W	0	0: PLL not locked 1: PLL locked
		1:0	Link Detect 1:0	R/W	0	0: Link not detected 1: Link detected

Addr (Hex)	Name	Bits	Field	R/W	Default	Description
2B	Event Config	7	Reserved		0	
		6	PLL Lock Event	R/W	0	0: Count PLL lock events 1: Do not count PLL lock events
		5	Link Event	R/W	0	0: Count link events 1: Do not count link events
		4	Loss of Signal Event	R/W	0	0: Count loss of signal events 1: Do not count loss of signal events
		3	Event Count Select	R/W	0	0: Select PLL event count for reading 1: Select link event count for reading
		2	Clear PLL Error Count	R/W	0	1: Reset PLL error count. Self clearing bit.
		1	Clear Link Error Count	R/W	0	1: Reset link error count. Self clearing bit.
		0	Enable Count	R/W	0	0: Disable event counters 1: Enable event counters
2C	Event Count	7:0	Event Counter	R	0	
2D Reserved						
2E	Analog Driver	7	Reserved		0	
		6	Reverse Data Order	R/W	0	0: Normal 1: Reverse output data order
		5:2	Reserved	R/W	0	
		1	Link Detect 1	R/W	0	Link detect value for channel 1
		0	Link Detect 0	R/W	0	Link detect value for channel 0
2F	Tx Config	7:6	Reserved		0	
		5	Output Termination	R/W	1'b	0: 75 Ω terminations 1: 50 Ω terminations
		4	Link Start	R/W	1'b	0: Start when TxOUT0 or TxOUT1 link 1: Start when TxOUT0 and TxOUT1 linke
		3	Link Stop	R/W	1'b	0: Stop when TxOUT0 and TxOUT1 both links invalid 1: Stop when TxOUT0 or TxOUT1 break link, either link is invalid
		2	TxOUT Override	R/W	0	0: TxOUT0 enabled by default, TxOUT1_en pin controls channel1 1: Override enable of TxOUT0 and TxOUT1
		1	TxOUT1 Enable	R/W	0	0: TxOUT1 disabled 1: TxOUT1 enabled For proper operation of TxOUT1, the TxOUT1_EN pin must be held high.
		0	TxOOUT0 Enable	R/W	0	0: TxOUT0 disabled 1: TxOUT0 enabled
		30	Clock Delay	7:5	TxCLKIN Delay	R/W
4:0	Reserved				00010'b	
31–68 Reserved						

Addr (Hex)	Name	Bits	Field	R/W	Default	Description
69	Output Amplitude Adjust	7:3	Reserved		0	
		2:0	Amplitude Adjust	R/W	011'b	000: Level 7 001: Level 8 (Highest output) 010: Level 5 011: Level 6 (Normal output) 100: Level 4 101: Level 3 110: Level 2 111: Level 1 (Lowest output)

## Register Recipes

Many features of the serializer contained within the SMBus registers require multiple writes to configure and enable. This methodology was implemented to prevent accidental register writes from causing undesired device behavior. Several recipes for common features are listed below. When experimenting with other SMBus register features, be sure to read through the register map for override and enable bits.

### SCRAMBLER OVERRIDE CONTROL

The scrambler's default settings are described in the device configuration section. However, the scrambler's setting can be overridden if desired.

Reg 22'h, write 08'h

Reg 21'h, write to bit 3 to enable/disable

### 75Ω MODE

The serializer can be programmed to interface with 75Ω media by using the recipe shown below. The inverting serial output should be terminated when interfacing with single ended media.

Reg 2F'h, write 0 to bit 5

### OUTPUT CHANNEL MUX CONTROL

**DS32ELX0421 only.** TxOUT0 is the output channel enabled by default. By using the external pin TxOUT1\_EN, TxOUT1 will be activated along with TxOUT0. If an application requires that only one channel be active at a time, the following recipe allows for each channel to be enabled or disabled independent of the other.

Reg 2F'h, write 1'b to bit 2

Reg 2F'h, write to bits 1 or 0 to control the output channels

### OUTPUT THE SERIAL CLOCK ON GPIO2

It is very helpful to be able to monitor high speed communication systems and observe their signal integrity. Generally,

this is done with a high speed real time oscilloscope or a sampling oscilloscope. Sampling oscilloscopes require a reference clock to trigger on. The following recipe can be used to bring out the serial clock on GPIO2 to provide a trigger for sampling oscilloscopes.

Reg 04'h, write 21'h

### Power Save Mode

When a system does not need to transmit high speed data from the DS32EL0421 or DS32ELX0421, the power consumption of the device can be managed as described in the Power Management section on the Functional Description page. The following recipe powers down many of the analog and digital blocks in the serializer, but leaves the SMBus module operational. Please note that in order to resume normal operation the recipe below will have to be unwritten.

Reg 01'h, write 10'h

Reg 26'h, write 40'h

### Redundancy / Fail Over Configuration

**DS32ELX0421 only.** Implementing a redundancy system with the DS32ELX0421 can be done in several ways. One method would be to program the redundancy or fail over logic into the host device or FPGA. The recipe below will describe a different method, for which a DS32ELX0421 will communicate to two different DS32EL0124 deserializers. The recipe below will configure the DS32ELX0421 serializer to automatically switch to the alternate output when the current high speed link fails.

Configure all device with Remote Sense enabled either by pin or register control.

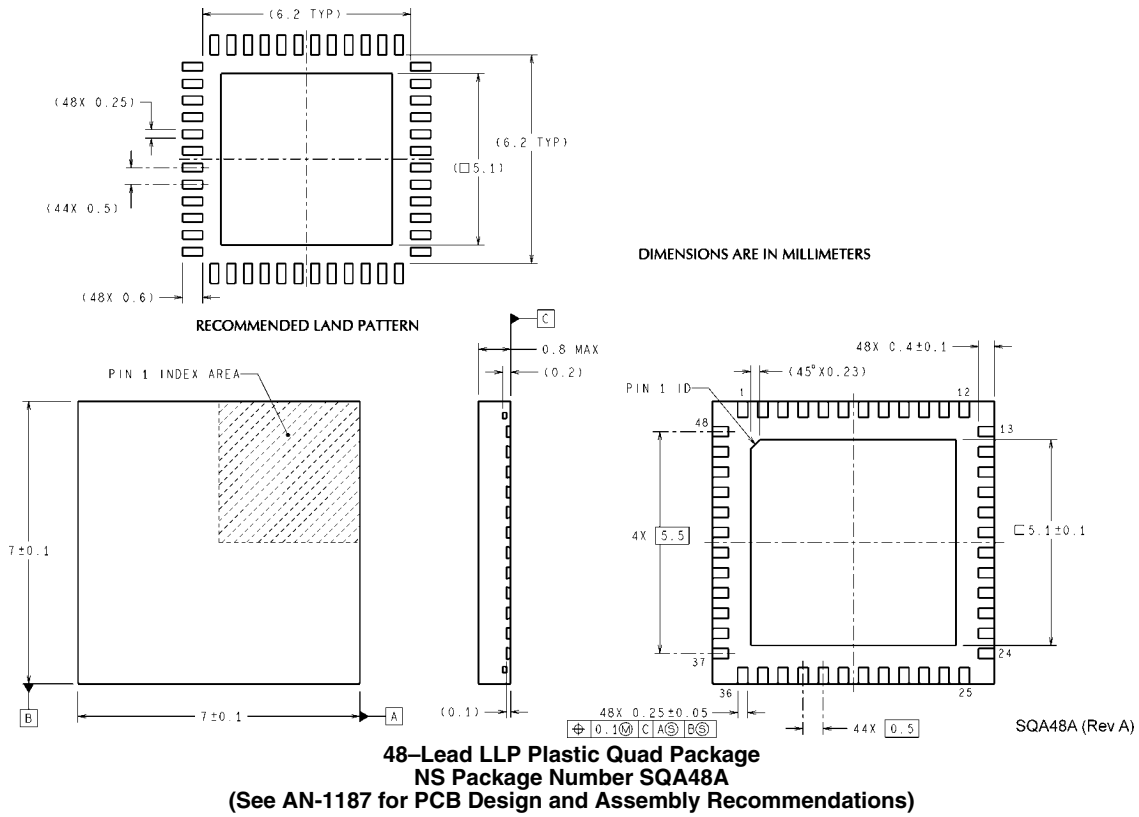
Pull TxOUT1\_EN pin high

reg 2F'h, write 2D'h

Reg 2F'h, write 28'h



# Physical Dimensions inches (millimeters) unless otherwise noted



**48-Lead LLP Plastic Quad Package**  
**NS Package Number SQA48A**  
**(See AN-1187 for PCB Design and Assembly Recommendations)**

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Data Converters	<a href="http://www.national.com/adac">www.national.com/adac</a>	Distributors	<a href="http://www.national.com/contacts">www.national.com/contacts</a>
Displays	<a href="http://www.national.com/displays">www.national.com/displays</a>	Green Compliance	<a href="http://www.national.com/quality/green">www.national.com/quality/green</a>
Ethernet	<a href="http://www.national.com/ethernet">www.national.com/ethernet</a>	Packaging	<a href="http://www.national.com/packaging">www.national.com/packaging</a>
Interface	<a href="http://www.national.com/interface">www.national.com/interface</a>	Quality and Reliability	<a href="http://www.national.com/quality">www.national.com/quality</a>
LVDS	<a href="http://www.national.com/lvds">www.national.com/lvds</a>	Reference Designs	<a href="http://www.national.com/refdesigns">www.national.com/refdesigns</a>
Power Management	<a href="http://www.national.com/power">www.national.com/power</a>	Feedback	<a href="http://www.national.com/feedback">www.national.com/feedback</a>
Switching Regulators	<a href="http://www.national.com/switchers">www.national.com/switchers</a>		
LDOs	<a href="http://www.national.com/ldo">www.national.com/ldo</a>		
LED Lighting	<a href="http://www.national.com/led">www.national.com/led</a>		
PowerWise	<a href="http://www.national.com/powerwise">www.national.com/powerwise</a>		
Serial Digital Interface (SDI)	<a href="http://www.national.com/sdi">www.national.com/sdi</a>		
Temperature Sensors	<a href="http://www.national.com/tempsensors">www.national.com/tempsensors</a>		
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Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

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**National Semiconductor Asia  
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Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

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