



# **GN4121**

## **x1 Lane PCI Express to Local Bridge**

---

**Data Sheet**

# Revision History

Version	ECR	Date	Changes and Modifications
0	152184	June 2009	Became Data Sheet. Added LCLK_MODE[3] to Table 3-12.
A	150817	May 2009	New document.

## Contents

1. Introduction.....	3
1.1 Features .....	3
1.2 Live on Power-up .....	4
1.3 FPGA On-the-Fly Configuration Loader .....	5
1.4 Local Bus Interface .....	5
1.5 Virtual Channel Support .....	6
1.6 PCI Express Application Layer .....	6
1.7 Interrupt Controller .....	6
1.8 2-Wire Serial Controller .....	6
1.9 Data Sheet Usage .....	6
1.10 Getting Help from Gennum .....	7
1.11 Getting Answers to PCI Express Related Questions .....	7
2. Pin Descriptions .....	8
2.1 Pin Assignments .....	8
2.2 Pin Descriptions .....	9
3. Electrical Characteristics .....	15
3.1 Absolute Maximum Ratings .....	15
3.2 Operating Conditions .....	15
3.3 DC Electrical Characteristics .....	16
3.4 PCI Express Electrical Characteristics .....	17
3.4.1 PCI Express Transmitter Characteristics .....	17
3.4.2 PCI Express Receiver Characteristics .....	20
3.4.3 Local Bus Timing .....	21
3.4.4 Local Clocks' Pins Settings.....	23
4. Overview.....	24
4.1 GN4121 Signals .....	25
5. Package & Ordering Information .....	26
5.1 Package Dimensions .....	26
5.2 Packaging Data .....	27
5.3 Ordering Information .....	27



## GN4121 x1 Lane PCI Express to Local Bridge Data Sheet

### 1. Introduction

For the past decade, PCI has been a dominant interconnect for both PC and embedded systems. With the shift to high-speed serial interfaces, PCI Express® is quickly replacing parallel PCI. As a leader in providing solutions for high-speed serial communications, Gennum has developed the GN412x family of PCI bridge controller components to complement FPGA devices. The GN4121 is specifically designed to take advantage of the architectural features of low-cost FPGA devices that do not have PCI Express capable SerDes on-chip. The result is a low-cost bridging solution for high-performance native PCI Express bridging.

The GN4121 is a desirable companion to large FPGA devices, where the requirement for firmware upgrading and on-the-fly reconfiguration are required.

The GN4121 is a single lane PCI Express to local bus bridge that is designed to work as a companion for FPGA devices to provide a complete bridging solution for general applications. In addition to a PCI Express compliant PHY interface, the GN4121 contains the link and transaction layers, and an applications interface that is ideally suited to FPGA interfacing using a small number of pins.

Since the PCI Express transaction/link IP is hard-wired into the GN4121, there is no need to license PCIe IP. The level of integration and very low power operation of the GN4121 make it an ideal alternative to using a PIPE PHY, where IP licensing and the cost of FPGA resources and power consumption is unattractive by comparison. Using the GN4121, allows FPGA resources to be spent on what differentiates the product, rather than on implementing the PCI Express protocol.

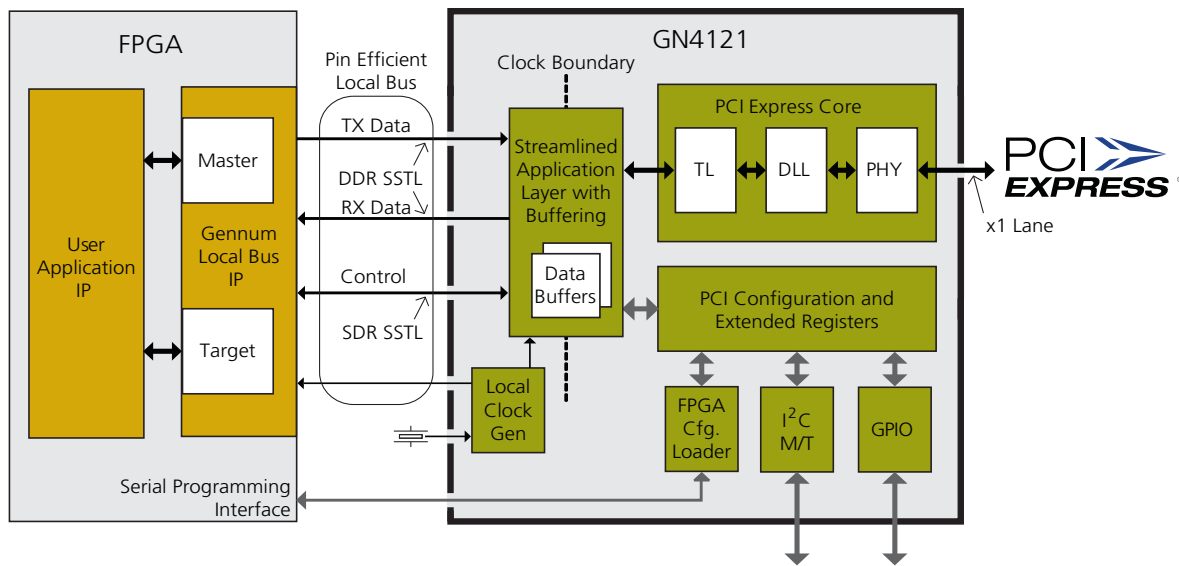
#### 1.1 Features

- 1 Lane PCI Express interface
  - ◆ Complies with PCI Express Base Specification 1.1
  - ◆ On-chip PHY, transaction, and link layer eliminates the cost of IP licensing
  - ◆ One hardware virtual channel supported
  - ◆ Payload size of up to 512 bytes with up to three outstanding transactions in each direction
  - ◆ Supports 3x64-bit base address registers
  - ◆ Provides flexible power management capability
- Provides pin efficient local bus interface for easy attachment to popular low-cost FPGA devices
  - ◆ Uses DDR SSTL I/O for high-speed data transfer (up to 500MB/s)

- ◆ FPGA source code provided for 64-bit master/target read/write buses for easy user logic attachment
- ◆ Local bus may be operated asynchronously to the PCIe clock rate for power optimization
- “Live” on power up
  - ◆ On-chip type 0 PCI configuration space enables auto detection without FPGA activity
  - ◆ On-chip extended configuration space supports power management, serial number, MSI, and PCIe capability registers
- FPGA bitstream loader
  - ◆ Allows easy configuration of the attached FPGA through PCIe
  - ◆ Provides on-the-fly FPGA reconfiguration capability
- 2-wire master/target
  - ◆ Boot master mode allows PCI configuration space defaults to be loaded from a small EEPROM upon system reset
  - ◆ General master mode allows attached 2-wire devices to be read/written
  - ◆ Target mode allows internal registers to be accessed from an external circuit or processor

A simplified block diagram of the GN4121 chip is shown in [Figure 1-1](#).

Figure 1-1: GN4121 with FPGA Simplified Block Diagram



## 1.2 Live on Power-up

Since the GN4121 contains a complete type 0 PCI configuration space, it is live on power-up so that a plug-and-play BIOS can auto-detect it and enumerate it without an attached FPGA having to be configured.

## 1.3 FPGA On-the-Fly Configuration Loader

An FPGA bitstream may be downloaded from the host system over PCIe to the attached FPGA using the on-chip FPGA configuration loader. This eliminates the expense of a dedicated FPGA ROM and makes on-the-fly reconfiguration and firmware upgrades simple. The ability to dynamically configure an attached FPGA over PCIe makes the GN4121 an ideal companion to all ranges of FPGA devices, including large SerDes capable devices, that require reconfiguration or firmware upgrades over PCIe.

## 1.4 Local Bus Interface

The local bus interface uses a combination of single and dual data rate SSTL I/O to accomplish very high data rates in the fewest possible pins. A single data rate clock is used for SSTL control signals and separate dual data rate source synchronous clocking is used for the DDR SSTL data. The SDR control signals operate at up to 125MHz and the DDR I/O operate at up to 250MT/s across 16 bits using a 125MHz DDR clock. This provides 500MB/s in each direction.

The local bus may operate asynchronously from the PCI Express rate. In order to save power, the local bus clock can operate at the lowest possible rate required by an application.

The local bus protocol facilitates four types of transactions:

- PCIe-to-Local Target Writes: A PCIe agent (such as the host processor/root complex) writes data to the local bus.
- PCIe-to-Local Target Reads: A PCIe agent reads data from the local bus. Reads are split into a request phase (address phase) and a completion phase (data phase).
- Local-to-PCIe Master Writes: The attached FPGA writes data to a PCIe device (such as host memory via a root complex).
- Local-to-PCIe Master Reads: The attached FPGA reads data from a PCIe device.

The PCIe-to-Local transactions would typically involve a target controller implemented in the FPGA. Local-to-PCIe Master transactions allow a DMA controller in the FPGA to access PCI Express devices.

## 1.5 Virtual Channel Support

The GN4121 has one virtual channel that support the eight PCIe defined traffic classes.

## 1.6 PCI Express Application Layer

The on-chip applications layer transfers data between the PCI Express port and an attached FPGA using the local bus interface. It provides a mechanism to access internal registers through configuration space access and through one of the Base Address Registers (BAR4). The applications layer supports the transmission of message signalled interrupts.

## 1.7 Interrupt Controller

A flexible interrupt controller automatically generates PCIe message signalled interrupts from either external pins (GPIO pins) or internally generated interrupt sources. The interrupt controller can route any interrupt source to up to four GPIO pins.

## 1.8 2-Wire Serial Controller

An on-chip I<sup>2</sup>C compatible controller provides both a master and target mode. After device reset, default configuration register values, such as Subsystem Vendor ID and BAR sizes, can be automatically loaded from a small serial EEPROM. After initialization, an external 2-wire master can access on-chip registers to read/write them.

## 1.9 Data Sheet Usage

The GN4121 Data Sheet includes detailed specifications on GN4121 device. However, there are other complementary documents to assist designers available on the Gennum Web site: [www.gennum.com/mygennum](http://www.gennum.com/mygennum). A complete set of documentation includes the following:

- GN4121 Data Sheet (this document)
- GN412x PCI Express Family Reference Manual (Document ID: 52624), which provides the details on functionality and the register map associated with the GN412x family of chips
- GN4121 Master List of Documents & Electronic Files (Document ID: 52571), which provides a summary of the content of the documentation & electronic files, to help navigate the content on MyGennum
- Reference Design Kit (RDK) board and the associated documentation

Following chapters detail the specifications of the GN4121:

- [2. Pin Descriptions](#)
- [3. Electrical Characteristics](#)
- [5. Package & Ordering Information](#)

Before finalizing a system design based on the GN4121, please contact Gennum to verify that you have the most recent specifications.

Gennum is constantly trying to improve the quality of its product documentation. If you have any questions or comments, please contact Gennum Technical Support.

## **1.10 Getting Help from Gennum**

For technical support, contact Gennum by telephone or e-mail. E-mail ensures the quickest response. The most up-to-date technical support information is also posted on the Gennum website. E-mail: [vbapps@gennum.com](mailto:vbapps@gennum.com).

## **1.11 Getting Answers to PCI Express Related Questions**

This data sheet assumes a basic understanding of the PCI Express Specification. If you are looking for a copy of the specification please contact the PCI Special Interest group at 503-619-0569 or visit their Web site at: <http://www.pcisig.com>.

If you are not familiar with the PCI Express specification, a good place to start is by reading one of several books on the subject. One of the most popular is PCI Express System Architecture written by Tom Shanley, Don Anderson, and Ravi Budruk (published by MindShare Inc.).

# 2. Pin Descriptions

## 2.1 Pin Assignments

Figure 2-1: GN4121 Pin Assignment

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
A	VSS_PCIE	PERn	VSS_PCIE	DBG0	DBG7	GPIO15	GPIO9	SPRI_CLK	TDI	GPIO7	GPIO6	SPRI_DONE	GPIO4	TDO	PLL_TEST_OUT	VSS	A
B	VDD_PCIE	PERp	NC	DBG2	DBG6	GPIO13	GPIO14	RSTIN	GPIO8	SPRI_DATAOUT	SCLK	TRST	SPRI_XL_SWAP	SPRI_STATUS	VSS	L2P_DATA15	B
C	PETp	VSS_PCIE	VDD_PCIE	VSS	DBG5	DBG1	GPIO12	GPIO10	RSTOUT33	GPIO2	SPRI_CONFIG	SDATA	LB_REF_CLK_MO	VSS	L2P_DATA7	L2P_DATA14	C
D	PETn	VSS_PCIE	VDD_PCIE	VSS	VDDC	SCAN_EN	DBG3	VDDC	GPIO3	NC	GPIO1	LB_REF_CLK_MI	VDDC	NC	L2P_DATA6	VDDC	D
E	VDDP	NC	VSS_PCIE	VCCO33	EEPROM_EN	TEST_EN	DBG4	VCCO33	VCCO33	VDDC	GPIO5	GPIO0	VDDC	NC	L2P_DATA5	L2P_DATA13	E
F	VTT_AB	NC	VSS_PCIE	NC	VDDW	VDDC	GPIO11	VCCO33	VCCO33	TMS	TCK	VDDC	VDDC	L2P_RDY	L2P_DATA4	L2P_DATA12	F
G	NC	VSS_PCIE	VDDAUX	VSS	PECLKINp	VSS	VSS	VSS	VSS	VSS	VSS	VDDC	NC	L2P_EDB	L2P_CLKn	L2P_CLKp	G
H	NC	VSS_PCIE	PCIE_VDDA	VDDC	PECLKINn	VSS	VSS	VSS	VSS	VSS	VCCO18	VCCO18	VSS	L2P_DFRAME	VDDC	L2P_VALID	H
J	NC	VSS_PCIE	PCIE_VDDA	VSS	VSS	NC	VSS	VSS	VSS	VSS	VCCO18	VCCO18	VDDC	NC	L2P_DATA3	L2P_DATA11	J
K	NC	VSS_PCIE	VSS	VDDP	VDDW	LCLK_MODE3	VSS	VSS	VSS	VSS	VSS	VSS	NC	L_WR_RDY	VDDC	L2P_DATA10	K
L	VSS	NC	VSS_PCIE	LCLK_MODE2	VDDC	VDDC	NC	VCCO18	VCCO18	VDDC	VSS	VSS	VDDC	NC	L2P_DATA2	L2P_DATA9	L
M	VTT_CD	NC	VSS_PCIE	LCLK_MODE1	LCLK_MODE0	VDDC	VSS	VCCO18	VCCO18	VDDC	VSS	VSS	NC	P_RD_D_RDY	L2P_DATA1	VDDC	M
N	NC	VSS_PCIE	VDD_PCIE	NC	VSS	RX_ERROR	NC	VDDC	P_WR_REQ	VDDC	NC	P_WR_RDY	PLL_AV55	TX_ERROR	L2P_DATA0	L2P_DATA8	N
P	NC	VSS_PCIE	VDD_PCIE	VSS	P2L_DATA15	VDDC	P2L_VALID	P2L_CLKp	P2L_RDY	NC	NC	VC_RDY	VDDC	LCLK	VDDC	RSTOUT18	P
R	VDD_PCIE	NC	VSS	P2L_DATA14	P2L_DATA13	P2L_DATA12	P2L_DFRAME	P2L_CLKn	P2L_DATA11	VREF	P2L_DATA10	P2L_DATA9	P2L_DATA8	NC	VSS	LCLKn	R
T	VSS_PCIE	NC	VSS_PCIE	VDDC	P2L_DATA7	P2L_DATA6	P2L_DATA5	P2L_DATA4	P2L_DATA3	P2L_DATA2	P2L_DATA1	VDDC	P2L_DATA0	PLL_AVDD	NC	VSS	T

3.3V

1.8V

1.2V

900mV

0V



## 2.2 Pin Descriptions

Table 2-1: GN4121 Pin Descriptions

Group	Pin No.	No. of Pins	Pin Name	I/O	Description
Global	B8	1	$\overline{\text{RSTIN}}$	I	Global Asynchronous Reset (Active LOW). LVCMOS, 3.3V, input, hysteresis.
	C9	1	$\overline{\text{RSTOUT33}}$	O	Reset Output; 3.3V (Active LOW). 3.3 V LVCMOS, totem-pole.
	D12	1	LB_REF_CLK_MI	I	Local Bus Reference Clock Crystal or Oscillator Input.
	C13	1	LB_REF_CLK_MO	O	Local Bus Reference Clock Crystal feedback output. Functional mode only.
	H3, J3	2	PCIE_VDDA	P	Clock Reference Analog Supply. (1.2V)
	G5, H5	2	PECLKIN <sub>p</sub> , PECLKIN <sub>n</sub>	I	PCIe Reference Clock Signal. For a PCI Express add-in card, these signals should be driven by the card edge connector and AC coupled using 150nF capacitors.
	E5	1	EEPROM_EN	I	Used to report that EEPROM is present. (1 = present) LVCMOS, 3.3V, input. EEPROM_EN should be tied HIGH, to allow the internal GN4121 registers to load on power up from the EEPROM. Refer to Initialization from a 2-Wire EEPROM in the GN412x PCI Express Family Reference Manual on what is required for EEPROM boot up options.

Group	Pin No.	No. of Pins	Pin Name	I/O	Description
Global: Test Interface	A9	1	TDI	I	JTAG Test Data Input. LVCMOS, 3.3V, input, pull-up.
	F10	1	TMS	I	JTAG Test Mode Select Input. LVCMOS, 3.3V, input, pull-up.
	F11	1	TCK	I	JTAG Test Clock. LVCMOS, 3.3V, input.
	B12	1	TRST	I	JTAG Test Reset. LVCMOS, 3.3V, input, hysteresis, pull-up.
	A14	1	TDO	O	JTAG Test Data Output. LVTTTL, 3.3V, output, 6mA, tristate.
	D6	1	SCAN_EN	I	Scan Enable (Tied LOW for normal operations). LVCMOS, 3.3V, input, pull-down.
	E6	1	TEST_EN	I	Test Mode Enable (Tied LOW for normal operations). LVCMOS, 3.3V, input, pull-down.
	A15	1	PLL_TEST_OUT	I/O	PLL Test Output (No connect for normal operations). LVCMOS, 3.3V, bidirectional, 4mA, tristate.
Global: 2-Wire Interface	B11	1	SCLK	I/O	Two-wire Clock port. LVCMOS, 3.3V, bidirectional, 4mA, tristate.
	C12	1	SDATA	I/O	Two-wire Data port. LVCMOS, 3.3V, bidirectional, 4mA, tristate.
Global: General Purpose Interface	A6, B7, B6, C7, F7, C8, A7, B9, A10, A11, E11, A13, D9, C10, D11, E12	16	GPIO[15:0]	I/O	General Purpose Input/Output. LVCMOS, 3.3V, bidirectional, 4mA, tristate.
Global: Debug Interface	A5, B5, C5, E7, D7, B4, C6, A4	8	DBG[7:0]	I	Debug Bus Port (Tied LOW for normal operations). LVCMOS, 3.3V, input, pull-down.

Group	Pin No.	No. of Pins	Pin Name	I/O	Description
Global: Serial Programming Interface	A8	1	SPRI_CLK	I/O	Serial Programming Interface (FPGA Configuration Loader). LVCMOS, 3.3V, bidirectional, 12mA, tristate.
	B10	1	SPRI_DATAOUT	I/O	Serial Programming Interface (FPGA Configuration Loader). LVCMOS, 3.3V, bidirectional, 12mA, tristate.
	C11	1	SPRI_CONFIG	I/O	Serial Programming Interface (FPGA Configuration Loader). LVCMOS, 3.3V, bidirectional, 12mA, tristate.
	A12	1	SPRI_DONE	I/O	Serial Programming Interface (FPGA Configuration Loader). LVCMOS, 3.3V, bidirectional, 12mA, tristate.
	B13	1	SPRI_XI_SWAP	I/O	Serial Programming Interface (FPGA Configuration Loader). LVCMOS, 3.3V, bidirectional, 12mA, tristate.
	B14	1	SPRI_STATUS	I/O	Serial Programming Interface (FPGA Configuration Loader). LVCMOS, 3.3V, bidirectional, 12mA, tristate.
PCI Express Link: PCIe x1 PHY interface	A1, A3, C2, D2, E3, F3, G2, H2, J2, K2, L3, M3, N2, P2, T1, T3	16	VSS_PCIE	G	PHY VSS.
	B1, C3, D3, N3, P3, R1	6	VDD_PCIE	P	PHY VDD. 1.2V (Core)
	G3	1	VDDAUX	P	PHY VDDAUX. 1.2V
	F1	1	VTT_AB	P	PCIe PHY transmit termination lanes A/B. Driven to voltage VTT. 1.5V See <a href="#">Table 3-6</a> .
	M1	1	VTT_CD	P	PCIe PHY transmit termination lanes C/D. Driven to voltage VTT. 1.5V See <a href="#">Table 3-6</a> .
PCI Express Link: PCIe Transmit [Output from the device]	D1	1	PETn	O	PCIe Transmit -Bus Lane A. CML
	C1	1	PETp	O	PCIe Transmit +Bus Lane A. CML
PCI Express Link: PCIe Receive [Input to the device]	A2	1	PERn	I	PCIe Receive -Bus Lane A. CML
	B2	1	PERp	I	PCIe Receive +Bus Lane A. CML

Group	Pin No.	No. of Pins	Pin Name	I/O	Description
Local Bus	P14, R16	2	LCLK, LCLKn	O	Local Bus Clock. SSTL, 1.8V, differential
	K6, L4, M4, M5	4	LCLK_MODE[3:0]	I	Selects the clock mode. LVCMOS, 3.3V, input, pull-down.
	P16	1	$\overline{\text{RSTOUT18}}$	O	Reset Output; 1.8V (Active LOW). CMOS, 1.8V, output
Local Bus: PCIe to Local [Inbound Data]	P9	1	P2L_RDY	I	Rx Buffer Full Flag. SSTL, 1.8V, input.
	P5, R4, R5, R6, R9, R11, R12, R13, T5, T6, T7, T8, T9, T10, T11, T13	16	P2L_DATA[15:0]	O	Parallel Receive Data. SSTL, 1.8V, output
	R7	1	P2L_DFRAME	O	Receive Frame. SSTL, 1.8V, output
	P7	1	P2L_VALID	O	Receive Data Valid. SSTL, 1.8V, output
	P8, R8	2	P2L_CLKp, P2L_CLKn	O	Receiver Source Synchronous Clock. SSTL, 1.8V, output, differential
	Local Bus: Inbound Buffer Request/Status	N9	1	P_WR_REQ	O
N12		1	P_WR_RDY	I	PCIe Write Ready. SSTL, 1.8V, input.
N6		1	RX_ERROR	I	Receive Error. SSTL, 1.8V, input.
P12		1	VC_RDY	O	Virtual Channel Ready Status. This provides a VC_RDY output to indicate the DL_UP <sup>1</sup> status of the Virtual Channel. This can be used to provide a synchronous reset to the external application in the event the Virtual Channel goes down e.g. hot reset initiated by PCIe host. SSTL, 1.8V, output

Group	Pin No.	No. of Pins	Pin Name	I/O	Description
Local Bus: Local PCIe [Outbound Data]	B16, C16, E16, F16, J16, K16, L16, N16, C15, D15, E15, F15, J15, L15, M15, N15	16	L2P_DATA[15:0]	I	Parallel Transmit Data. SSTL, 1.8V, input.
	H14	1	L2P_DFRAME	I	Transmit Data Frame. SSTL, 1.8V, input.
	H16	1	L2P_VALID	I	Transmit Data Valid. SSTL, 1.8V, input.
	G14	1	L2P_EDB	I	End-of-Packet Bad Flag. When a packet is considered bad and is terminated with EDB. SSTL, 1.8V, input.
	G16, G15	2	L2P_CLKp, L2P_CLKn	I	Transmitter Source Synchronous Clock. SSTL, 1.8V, input, differential.
Local Bus: Outbound Buffer Status	F14	1	L2P_RDY	O	Tx Buffer Full Flag. SSTL, 1.8V, output
	K14	1	L_WR_RDY	O	Local-to-PCIe Write. SSTL, 1.8V, output
	M14	1	P_RD_D_RDY	O	PCIe-to-Local Read Response Data Ready. SSTL, 1.8V, output
	N14	1	TX_ERROR	O	Transmit Error. SSTL, 1.8V, output
Power	F5, K5	2	VDDW	P	3.3V
	R10	1	VREF	P	900mV reference voltage for SSTL I/O
	T14	1	PLL_AVDD	P	1.2V PLL supply voltage
	D5, D8, D13, D16, E10, E13, F6, F12, F13, G12, H4, H15, J13, K15, L5, L6, L10, L13, M6, M10, M16, N8, N10, P6, P13, P15, T4, T12	28	VDDC	P	1.2V core power
	E1, K4	2	VDDP	P	3.3V
	H11, H12, J11, J12, L8, L9, M8, M9	8	VCCO18	P	Power for 1.8V I/O
	E4, E8, E9, F8, F9	5	VCCO33	P	Power for 3.3V I/O

Group	Pin No.	No. of Pins	Pin Name	I/O	Description
Ground	N13	1	PLL_AVSS	G	PLL Ground. This pin is internally connected to VSS and, for noise isolation, should not be connected to VSS externally. Refer to the Gullwing-x1 RDK schematics and PCB layout for proper implementation.
	A16, B15, C4, C14, D4, G4, G6, G7, G8, G9, G10, G11, H6, H7, H8, H9, H10, H13, J4, J5, J7, J8, J9, J10, K3, K7, K8, K9, K10, K11, K12, L1, L11, L12, M7, M11, M12, N5, P4, R3, R15, T16	43	VSS	G	Ground.
No Connect	B3, D10, D14, E2, E14, F2, F4, G1, G13, H1, J1, J6, J14, K1, K13, L2, L7, L14, M2, M13, N1, N4, N7, N11, P1, P10, P11, R2, R14, T2, T15	31	NC	—	No Connect.

1. Data Link Layer indicates that a connection with the upstream devices has been established.

## 3. Electrical Characteristics

### 3.1 Absolute Maximum Ratings

Table 3-1: Absolute Maximum Ratings

Parameter	Value
Core Supply Voltage	-0.5V to +1.8 VDC
SSTL IO Supply Voltage	-0.5V to +2.5 V <sub>DC</sub>
LVC MOS IO Supply Voltage	-0.5V to +4.6 V <sub>DC</sub>
Input ESD Voltage (HBM)	2kV
Storage Temperature Range	-50°C < T <sub>s</sub> < 125°C
Solder Reflow Temperature	260°C

### 3.2 Operating Conditions

Table 3-2: Operating Conditions

All electrical characteristics are valid over the range of these operating conditions, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
Core Supply Voltage on pins V <sub>DDC</sub> , V <sub>DD_PCIE</sub> , V <sub>DDAUX</sub> , PLL_AV <sub>DD</sub> , PCIE_V <sub>DDA</sub>	V <sub>CORE</sub>	–	1.14	1.2	1.26	V	±5%
SSTL IO Supply Voltage on pins V <sub>CCO18</sub>	V <sub>VCCO18</sub>	–	1.71	1.8	1.89	V	±5%
LVC MOS IO and 3.3V Core Supply Voltage: pins V <sub>CCO33</sub> , V <sub>DDW</sub> , V <sub>DDP</sub>	V <sub>VCCO33</sub>	–	3.0	3.3	3.6	V	±10%
Operating Temperature Range	T <sub>A</sub>	Ambient	0	25	85	°C	

### 3.3 DC Electrical Characteristics

**Table 3-3: DC Electrical Characteristics**

Power and current limits listed have been derived from design and characteristics data. They are not 100% tested in production.

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
Power Consumption	$P_D$	PCIe x1, LCLK=100MHz	–	475	695	mW	1
Total Core Supply Current on pins VDDC, VDD_PCIE, VDDAUX, PLL_AVDD, PCIE_VDDA	$I_{CORE}$	–	–	70 <sup>2</sup>	– (See Note 3)	mA	–
SSTL IO Supply Current	$I_{VCCO18}$	–	–	320 <sup>4</sup>	– (See Note 3)	mA	–
LVC MOS IO and 3.3V Core Supply Current: pins VCCO33, VDDW, VDDP	$I_{VCCO33}$	–	–	40 <sup>5</sup>	– (See Note 3)	mA	–

1. Data is based on an application circuit equivalent to that used on the GN4121 RDK board (Gullwing-x1), typical operating conditions, PCIe negotiated to 1 lane, default PCIe PHY settings, 100MHz local bus operation, and with concurrent data traffic at 75% bus utilization. Doesn't include power dissipated by components outside of the GN4121.
2. This information is intended to guide power supply design. Data is based on an application circuit equivalent to that used on the GN4121 RDK board (Gullwing-x1), typical operating conditions, 100MHz local bus operation, and with concurrent data traffic at 75% bus utilization.
3. Maximum supply current will vary greatly depending on the application circuit and device usage. A specific application's maximum current can be predicted by measuring current under high temperature, high supply and full load conditions. To this resultant number, the following factors needed to be added:  
 +25% for  $I_{CORE}$   
 +35% for  $I_{VCCO18}$   
 +25% for  $I_{VCCO33}$
4. See Note 2. Based on use of 22-ohm serial termination and 51-ohm parallel termination in the application circuit.
5. See Note 2. Also includes current draw from an LDO used to power VTT\_AB and VTT\_CD.



**Table 3-4: DC Electrical Characteristics for LVCMOS Buffers**

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
High-level input voltage	$V_{IH}$	-	2	-	-	V	-
Low-level input voltage	$V_{IL}$	-	-	-	0.8	V	-
Input leakage current	$I_L$	-	-	-	±5	µA	-
High-level output voltage	$V_{OH}$	$I_{OH} = -100 \mu A$	2.8	-	-	V	-
Low-level output voltage	$V_{OL}$	$I_{OL} = 100 \mu A$	-	-	0.2	V	-

**Table 3-5: DC Electrical Characteristics for SSTL Buffers**

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
VREF input reference voltage	$V_{REF}$	-	833	900	969	mV	1
SSTL termination voltage	$V_{TT}$	-	$V_{REF}-40$	$V_{REF}$	$V_{REF}+40$	mV	2
High-level input voltage (DC)	$V_{IH}$	-	$V_{REF}+125$	-	$V_{VCC018+300}$	mV	-
Low-level input voltage (DC)	$V_{IL}$	-	-300	-	$V_{REF}-125$	mV	-
High-level input voltage (AC)	$V_{IH}$	-	$V_{REF}+250$	-	-	mV	-
Low-level input voltage (AC)	$V_{IL}$	-	-	-	$V_{REF}-250$	mV	-

1. Typically the value of VREF is expected to be 50% \* VDDQ of the transmitting device. Peak to peak AC noise on VREF may not exceed +/- 2% of VREF.
2. The termination voltage VTT should track the reference voltage VREF.

## 3.4 PCI Express Electrical Characteristics

### 3.4.1 PCI Express Transmitter Characteristics

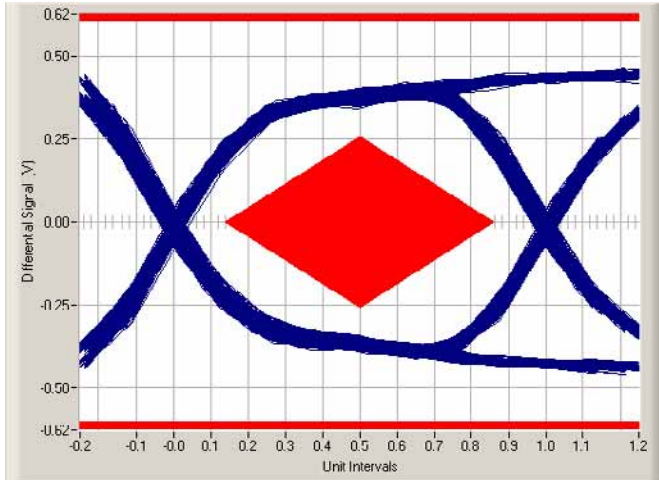
**Table 3-6: Transmitter Characteristics**

Symbol	Description	Min	Typical	Max	Unit
<b>Voltage Parameters</b>					
$V_{TX-DIFF}^1$	Output voltage compliance @ typical swing				
	$V_{TX-DIFFp}$ (peak-to-peak, single ended)	400	500	600	mV
	$V_{TX-DIFFpp}$ (peak-to-peak, differential)	800	1000	1200	mV
$V_{TT}$	Transmitter termination voltage	1.2	1.5	1.89	V
$V_{OL}$	Low-level output voltage	-	$V_{TT} - 1.5 * V_{TX-DIFFp}$	-	V

Symbol	Description	Min	Typical	Max	Unit
V <sub>OH</sub>	High-level output voltage	–	V <sub>TT</sub> - 0.5 * V <sub>TX-DIFFp</sub>	–	V
V <sub>TX-DC-CM</sub>	Transmit common-mode voltage	0	V <sub>TT</sub> - V <sub>TX-DIFFp</sub>	3.6	V
V <sub>TX-CM-DCACTIVE-IDLEDELTA</sub>	Absolute Delta of DC Common Mode Voltage During L0 and Electrical Idle.	–	–	100	mV
V <sub>TX-DE-RATIO</sub>	De-emphasized differential output voltage	0	-3.35	-7.96	dB <sup>2</sup>
V <sub>TX-IDLE-DIFFp</sub>	Electric Idle differential peak voltage	–	–	20	mV
V <sub>TX-RCV-DETECT</sub>	Voltage change during Receive Detection	–	–	600	mV
RL <sub>TX-DIFF</sub>	Transmitter Differential Return loss	10	–	–	dB
RL <sub>TX-CM</sub>	Transmitter Common Mode Return loss	6	–	–	dB
Z <sub>OSE</sub>	Single-ended output impedance	40	50	60	Ω
Z <sub>TX-DIFF-DC</sub>	DC Differential TX Impedance	80	100	120	Ω
T <sub>TX-RISE</sub> , T <sub>TX-FALL</sub>	Rise / Fall time of TxP, TxN outputs	.125	–	–	UI <sup>3</sup>
<b>Jitter Parameters</b>					
UI	Unit Interval	399.88	400	400.12	ps <sup>4</sup>
T <sub>TX-MAX-JITTER</sub>	Transmitter total jitter (peak-to-peak)	–	–	0.30 <sup>5</sup>	UI
T <sub>TX-EYE</sub>	Minimum TX Eye Width (1 - T <sub>TX-MAX-JITTER</sub> )	0.70	–	–	UI
T <sub>TX-EYE-MEDIAN-to-MAX-JITTER</sub>	Maximum time between the jitter median and maximum deviation from the median	–	–	0.15	UI
<b>Timing Parameters</b>					
T <sub>TX-IDLE-SET-TO-IDLE</sub>	Maximum time to transition to a valid electrical idle after sending an Electrical Idle ordered set	–	4	6	ns
T <sub>EIExit</sub>	Time to exit Electrical Idle (L0s) state into L0	–	12	16	ns

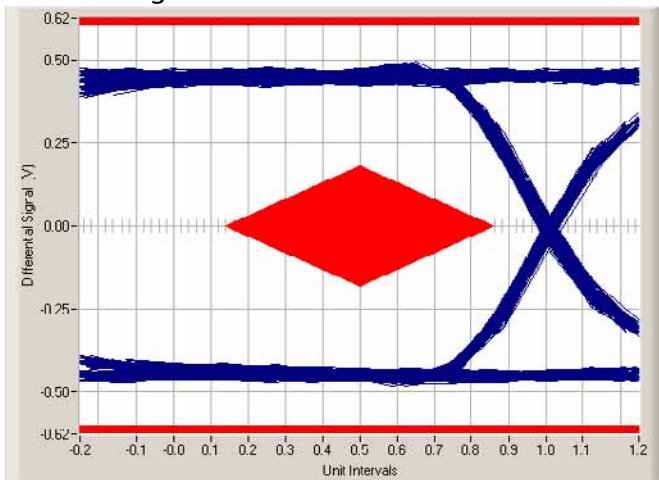
1. Measured with V<sub>tt</sub> = 1.2V, PHY\_CONTROL register bits HIDRV='0', LODRV='0' and DTX="0000"(1x).
2. The de-emphasis ratio is determined through the DEQ bits of the PHY\_CONTROL register inside the GN4121. Typical value is based on recommended setting of the PHY\_CONTROL register.
3. As measured between 20% and 80% points.
4. UI does not account for SSC dictated variations.
5. Measured using PCI Express Compliance Pattern.

Figure 3-1: Typical Transition Signal Eye, De-emphasis Disabled, Default Drive Setting



The eye diagram is generated from SIGtest Version 2.1 available from the PCI Special Interest Group.

Figure 3-2: Typical Non-Transition Signal Eye, De-emphasis Disabled, Default Drive Setting



### 3.4.2 PCI Express Receiver Characteristics

Table 3-7: PCI Express Receiver Characteristics

Symbol	Description	Min	Typical	Max	Unit
<b>Voltage Parameters</b>					
$V_{RX-DIFFp-p}$	Differential input voltage (peak-to-peak)	170	–	1200	mV
$V_{RX-IDLE-DET-DIFFp-p}$	Differential input threshold voltage (peak-to-peak) to assert TxIdleDetect output	65	–	235	mV
$V_{RX-CM-AC}$	Receiver common-mode voltage for AC-coupling	–	0	150	mV
$T_{RX-RISE}, T_{RX-FALL}$	Rise time / Fall time of RxP, RxN inputs	–	–	160	ps
$Z_{RX-DIFF-DC}$	Differential input impedance (DC)	80	100	120	$\Omega$
$Z_{RX-COM-DC}$	Single-ended input impedance	40	50	60	$\Omega$
$Z_{RX-COM-INITIAL-DC}$	Initial input common mode impedance (DC)	5	50	60	$\Omega$
$Z_{RX-COM-HIGH-IMP-DC}$	Powered down input common mode impedance (DC)	200k	–	–	$\Omega$
$R_{L-RX-DIFF}$	Receiver Differential Return Loss <sup>1</sup>	10	–	–	dB
$R_{L-RX-CM}$	Receiver Common Mode Return Loss	6	–	–	dB
<b>Jitter Parameters</b>					
$T_{RX-MAX-JITTER}$	Receiver maximum total jitter tolerance	0.65	–	–	UI
$T_{RX-EYE}$	Minimum Receiver Eye Width	0.35	–	–	UI
$T_{RX-EYE-MEDIAN-to-MAX-JITTER}$	Maximum time between jitter median and max deviation from median	–	–	0.325	UI
<b>Timing Parameters</b>					
$T_{BDDly}$	Beacon-Activity on channel to detection of Beacon <sup>2</sup>	33	–	100	ns
$T_{RX-IDLE\_ENTER}$	Delay from detection of Electrical Idle condition on the channel to assertion of TxIdleDetect output	–	10	20	ns
$T_{RX-IDLE\_EXIT}$	Delay from detection of L0s to L0 transition to de-assertion of TxIdleDetect output	–	5	10	ns

1. Over a frequency range of 50MHz to 1.25GHz.

2. This is a function of beacon frequency.

**Table 3-8: Reference Clock (PECLKINn) Requirements**

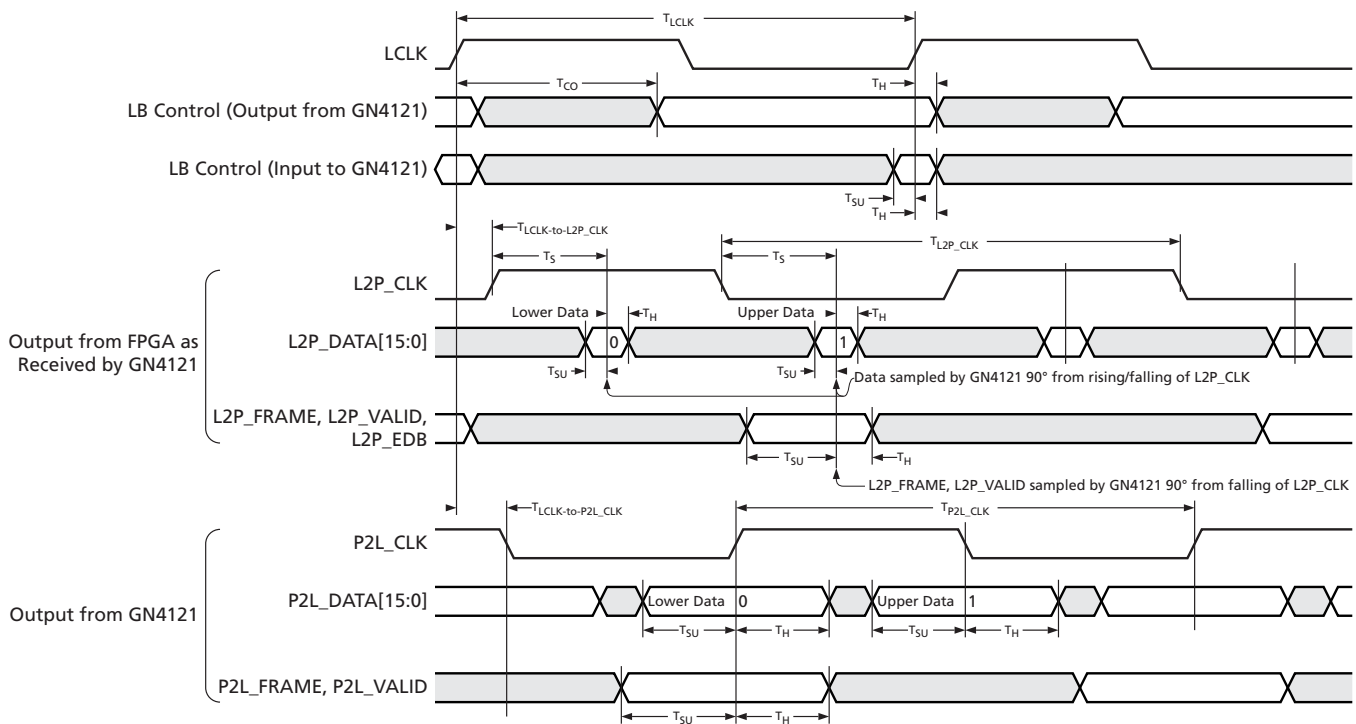
Symbol	Description	Min	Typical	Max	Unit
$V_{IL-RC}$	Low-level CML/CMOS input voltage	0	-	$V_{DD} - 0.5$	V
$V_{IH-RC}$	High-level CML/CMOS input voltage	-	$V_{DD}$		V
$F_{RefClk}$	Clock frequency range	99.5	100	100.03	MHz <sup>1</sup>
$D.C._{RefClk}$	Duty cycle	40	50	60	%
$T_{Skew-Ref}$	Skew between PECLKINp/PECLKINn inputs	-	-	0.05	RCUI
TCCJITTER	Cycle to Cycle jitter	-	-	150	ps
$T_{RRef}, T_{FRef}$	Rise/Fall time of PECLKINp/PECLKINn inputs	-	0.2	0.25	RCUI
PPM	PPM difference between reference clocks on different ends of a link	-300	-	+300	PPM

1. Includes 0 to -0.5% spread spectrum clock range.

### 3.4.3 Local Bus Timing

Figure 3-3 illustrates the timing relationships of the three local bus clock domains.

Figure 3-3: Local Bus Timing



**Table 3-9: Local Bus Signal Timing for Single Data Rate SSTL Over Specified Operating Conditions (TARGET SPECIFICATION)**

Symbol	Description	Min	Max	Units
T <sub>LCLK</sub>	LCLK Cycle Time	8	10	ns
T <sub>CO</sub>	Clock to output delay for local bus control signals	0.7	5.0	ns <sup>1</sup>
T <sub>SU</sub>	Required input set-up time to LCLK for local bus control inputs	–	1.0 <sup>2</sup>	ns
T <sub>H</sub>	Required input hold time from LCLK for local bus control inputs	–	0.7	ns

1. Local bus control signals received by an attached FPGA should be treated as asynchronous. See Local Bus Signals in the GN412x PCI Express Family Reference Manual for details.
2. Local bus control inputs are synchronized by the GN4121. Failure to meet setup time will simply delay the cycle in which the change is recognized.

**Table 3-10: Local Bus Timing for Source Synchronous SSTL Input Signals Over Specified Operating Conditions (TARGET SPECIFICATION)**

Input signals include L2P\_CLK, L2P\_DATA(15:0), L2P\_DFRAME, and L2P\_VALID.

Symbol	Description	Min	Max	Units
T <sub>L2P_CLK</sub>	L2P_CLK Cycle Time or Unit Interval (UI)	T <sub>LCLK</sub>		ns
IJT <sub>L2P_CLK</sub>	L2P_CLK input jitter tolerance (cycle-to-cycle)	–	100	ps
T <sub>L2P_CLK_LOCK</sub>	L2P_CLK input lock time	–	1380	cycles
T <sub>LCLK-to-L2P_CLK</sub>	Delay from LCLK to L2P_CLK	0	T <sub>LCLK</sub>	ns
T <sub>S</sub>	Sample point for data relative to L2P_CLK (rising and falling)	L2P_CLK +90°		
T <sub>SU</sub> (L2P_DATA)	Required input set-up time to L2P_CLK+T <sub>S</sub> (rising and falling)	–	400	ps
T <sub>H</sub> (L2P_DATA)	Required input hold time from L2P_CLK+T <sub>S</sub> (rising and falling)	–	400	ps

**Table 3-11: Local Bus Timing for Source Synchronous SSTL Output Signals Over Specified Operating Conditions (TARGET SPECIFICATION)**

Output signals include P2L\_CLK, P2L\_DATA(15:0), P2L\_DFRAME, and P2L\_VALID.

Symbol	Description	Min	Max	Units
T <sub>P2L_CLK</sub>	P2L_CLK Cycle Time or Unit Interval (UI)	T <sub>LCLK</sub>		ns
T <sub>LCLK-to-P2L_CLK</sub>	Delay from LCLK to P2L_CLK	T <sub>LCLK</sub> /2 - 1.2	T <sub>LCLK</sub> /2 + 1.2	ns
T <sub>SU</sub> (P2L_DATA)	Output set-up time to P2L_CLK (rising and falling)	1200	–	ps
T <sub>H</sub> (P2L_DATA)	Output hold time from P2L_CLK (rising and falling)	400	–	ps
T <sub>SKEW</sub>	Skew between P2L_DATA lanes	–	300	ps

### 3.4.4 Local Clocks' Pins Settings

There are 3 local clocks used by the GN4121 and attached FPGA. They are:

- LCLK/LCLKn: The primary clock generated by the GN4121 and driven to the FPGA in the form of a differential SSTL output.
- P2L\_CLKp/n: The source synchronous clock used by the GN4121 to communicate data to the FPGA. It is derived from the same source as LCLK/LCLKn.
- L2P\_CLKp/n: The source synchronous clock generated by the attached FPFA to communicate data to the GN4121. It is derived by the FPGA from LCLK/LCLKn.

The local clock LCLK/LCLKn may be derived from either the PCI Express clock or a low frequency crystal oscillator. The options are described in [Table 3-12](#).

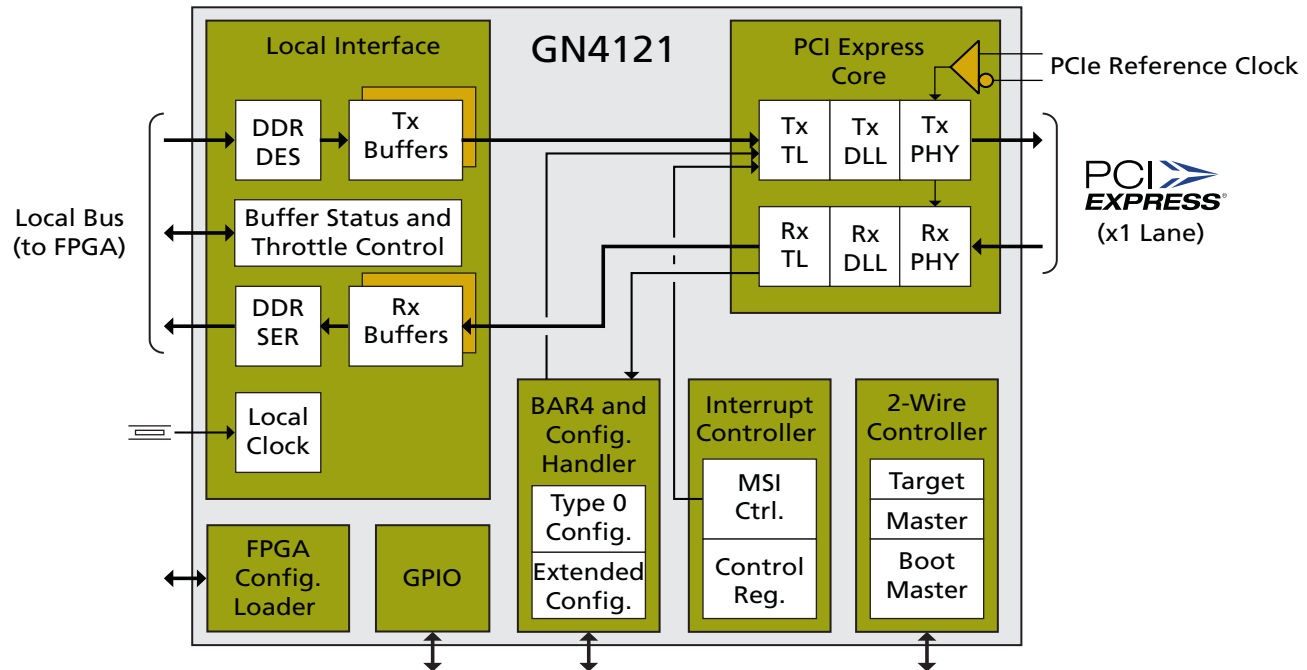
**Table 3-12: GN4121 Clocks' Pins Settings**

Signal	Description
LCLK_MODE[3]	Control IDDQ of the pads. Set to LOW for normal operation.
LCLK_MODE[2]	Controls PLL Bypass. '0' = LCLK is generated by the PLL, which is configurable. This is recommended for low and predictable LCLK clock jitter. '1' = LCLK is driven by 125MHz clock generated from the PCI Express link.
LCLK_MODE[1]	Resets the PLL test clock divider. '0' = Resets the PLL test clock divider, so that PLL_TEST_OUT = '0'. '1' = PLL_TEST_OUT pin outputs a clock with a frequency of the PLL clock divided by 1024. This is used for test purposes.
LCLK_MODE[0]	Selects the source for the LCLK PLL. '0' = LB_REF_CLK oscillator (20-40MHz). This is recommended for low and predictable LCLK clock jitter. '1' = 125MHz clock generated from the PCI Express link.

## 4. Overview

A block diagram of the GN4121 is depicted in Figure 4-1.

Figure 4-1: GN4121 Block Diagram



Each of the internal blocks is described in detail in the following chapters. They are:

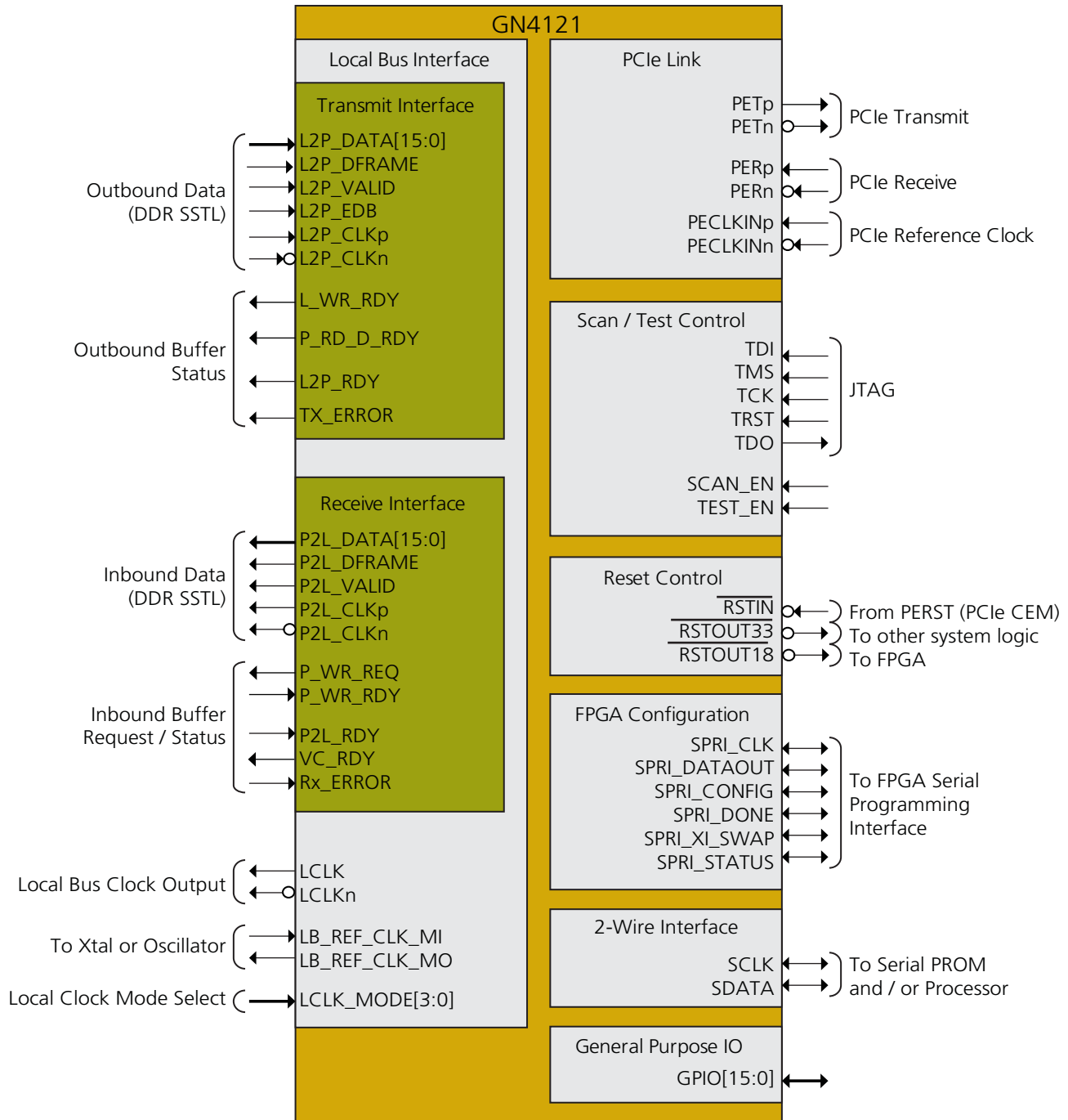
- The PCI Express link is described in PCI Express Link section of the GN412x PCI Express Family Reference Manual. This includes a description of the PCI Express related configuration registers.
- The Local bus is described in Local Bus Interface section of the GN412x PCI Express Family Reference Manual.
- The interrupt controller is described in Interrupt Control Unit section of the GN412x PCI Express Family Reference Manual.
- The boot master mode of the 2-wire controller is described in Initialization from a 2-Wire EEPROM section of the GN412x PCI Express Family Reference Manual.
- General purpose master/target mode of the 2-wire controller is described in 2-Wire Interface section of the GN412x PCI Express Family Reference Manual.
- General purpose IO are described in General Purpose IO Block section of the GN412x PCI Express Family Reference Manual.
- Details of all the internal registers and their respective register bit fields are described in Internal Registers section of the GN412x PCI Express Family Reference Manual.



# 4.1 GN4121 Signals

Figure 4-2 depicts the signals of the GN4121 laid out in their logical groupings.

Figure 4-2: GN4121 Signal Groups Diagram

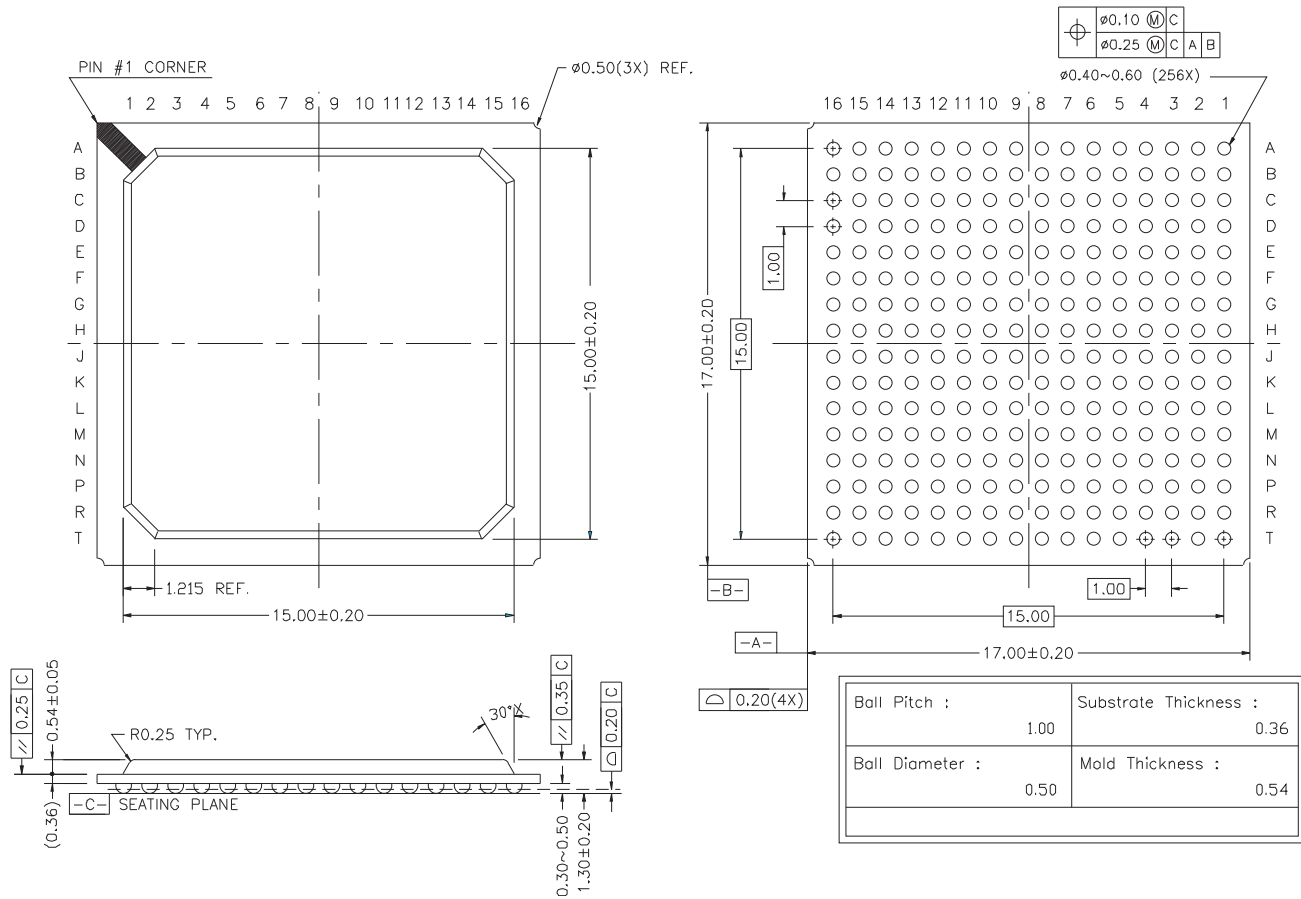


# 5. Package & Ordering Information

## 5.1 Package Dimensions

The GN4121 is packaged in a 256 ball BGA as illustrated in Figure 5-1.

Figure 5-1: GN4121 Package Dimensions



## 5.2 Packaging Data

Table 5-1: Packaging Data

Parameter	Value
Package Type	17mm x 17mm 256-ball BGA
Package Drawing Reference	
Moisture Sensitivity Level	3
Junction to Air Thermal Resistance, $\theta_{j-a}$ (at zero airflow)	27°C/W
Junction to Air Thermal Resistance, $\theta_{j-a}$ (at 1m/s airflow)	24°C/W
Junction to Air Thermal Resistance, $\theta_{j-a}$ (at 2m/s airflow)	22°C/W
Junction to Case Thermal Resistance, $\theta_{j-c}$	5.5°C/W
Psi	11.0°C/W
Pb-free and RoHS compliant	Yes

## 5.3 Ordering Information

Table 5-2: Packaging Data

Part Number	Package	Temperature Range
GN4121-CBE3	256-BGA	0°C to 85°C

# Index

## Numerics

2-wire serial controller 6

## A

absolute maximum ratings, electrical characteristics 15

application layer

PCI Express 6

## C

configuration loader

FPGA on-the-fly 5

## D

data sheet usage 6

DC electrical characteristics 16

## E

electrical characteristics

absolute maximum ratings 15

DC 16

DC, LVCMOS buffers 17

DC, SSTL buffers 17

local bus timing 21

operating conditions 15

PCIe receiver 20

PCIe transmitter 17

## F

features 3

FPGA on-the-fly configuration loader 5

## G

Gennum contact information 7

getting answers to PCI Express related questions 7

getting help from Gennum 7

GN4121 signals 25

## I

I2C serial controller 6

interrupt controller 6

introduction 3

## L

live on power-up 4

local bus interface 5

local bus timing

electrical characteristics 21

local clocks' pins settings 23

LVCMOS buffers, DC electrical characteristics 17

## O

operating conditions, electrical characteristics 15

ordering information 27

overview 24

## P

package dimensions 26

packaging and ordering information 26

packaging data 27

PCI Express application layer 6

PCI Express contact information 7

PCI Special Interest Group 7

PCIe receiver, electrical characteristics 20

PCIe transmitter, electrical characteristics 17

pin descriptions 9

pins

global 9

global, 2-wire interface 10

global, debug interface 10

global, general purpose interface 10

global, serial programming interface 11

global, test interface 10

ground 14

local bus 12

local bus, inbound buffer request/status 12

local bus, local PCIe (outbound data) 13

local bus, outbound buffer status 13

local bus, PCIe to local (inbound data) 12

no connect 14

PCIe link, PCIe receive (input from the device) 11

PCIe link, PCIe transmit (output from the device) 11

PCIe link, PCIe x1 PHY interface 11  
power 13  
power-up  
live 4

## **S**

signals  
GN4121 25  
SSTL buffers, DC electrical characteristics 17

## **V**

virtual channel support 6

---

**DOCUMENT IDENTIFICATION  
DATA SHEET**

The product is in production. Gennum reserves the right to make changes to the product at any time without notice to improve reliability, function or design, in order to provide the best product possible.

**CAUTION**

ELECTROSTATIC SENSITIVE DEVICES

DO NOT OPEN PACKAGES OR HANDLE EXCEPT AT A  
STATIC-FREE WORKSTATION

---

**GENNUM CORPORATE HEADQUARTERS**

4281 Harvester Road, Burlington, Ontario L7L 5M4 Canada

Phone: +1 (905) 632-2996

E-mail: [corporate@gennum.com](mailto:corporate@gennum.com)

Fax: +1 (905) 632-2055

[www.gennum.com](http://www.gennum.com)

---

**OTTAWA**232 Herzberg Road, Suite 101  
Kanata, Ontario K2K 2A1  
Canada

Phone: +1 (613) 270-0458

Fax: +1 (613) 270-0429

**CALGARY**3553 - 31st St. N.W., Suite 210  
Calgary, Alberta T2L 2K7  
Canada

Phone: +1 (403) 284-2672

**UNITED KINGDOM**North Building, Walden Court  
Parsonage Lane,  
Bishop's Stortford Hertfordshire, CM23 5DB  
United Kingdom

Phone: +44 1279 714170

Fax: +44 1279 714171

**INDIA**#208(A), Nirmala Plaza,  
Airport Road, Forest Park Square  
Bhubaneswar 751009  
India

Phone: +91 (674) 653-4815

Fax: +91 (674) 259-5733

**SNOWBUSH IP - A DIVISION OF GENNUM**439 University Ave. Suite 1700  
Toronto, Ontario M5G 1Y8  
Canada

Phone: +1 (416) 925-5643

Fax: +1 (416) 925-0581

E-mail: [sales@snowbush.com](mailto:sales@snowbush.com)Web Site: <http://www.snowbush.com>**MEXICO**288-A Paseo de Maravillas  
Jesus Ma., Aguascalientes  
Mexico 20900

Phone: +1 (416) 848-0328

**JAPAN KK**Shinjuku Green Tower Building 27F  
6-14-1, Nishi Shinjuku  
Shinjuku-ku, Tokyo, 160-0023  
Japan

Phone: +81 (03) 3349-5501

Fax: +81 (03) 3349-5505

E-mail: [gennum-japan@gennum.com](mailto:gennum-japan@gennum.com)Web Site: <http://www.gennum.co.jp>**TAIWAN**6F-4, No.51, Sec.2, Keelung Rd.  
Sinyi District, Taipei City 11502  
Taiwan R.O.C.

Phone: (886) 2-8732-8879

Fax: (886) 2-8732-8870

E-mail: [gennum-taiwan@gennum.com](mailto:gennum-taiwan@gennum.com)**GERMANY**Hainbuchenstraße 2  
80935 Muenchen (Munich), Germany

Phone: +49-89-35831696

Fax: +49-89-35804653

E-mail: [gennum-germany@gennum.com](mailto:gennum-germany@gennum.com)**NORTH AMERICA WESTERN REGION**Bayshore Plaza  
2107 N 1st Street, Suite #300  
San Jose, CA 95131  
United States

Phone: +1 (408) 392-9454

Fax: +1 (408) 392-9427

E-mail: [naw\\_sales@gennum.com](mailto:naw_sales@gennum.com)**NORTH AMERICA EASTERN REGION**4281 Harvester Road  
Burlington, Ontario L7L 5M4  
Canada

Phone: +1 (905) 632-2996

Fax: +1 (905) 632-2055

E-mail: [nae\\_sales@gennum.com](mailto:nae_sales@gennum.com)**KOREA**8F Jinnex Lakeview Bldg.  
65-2, Bangidong, Songpagu  
Seoul, Korea 138-828

Phone: +82-2-414-2991

Fax: +82-2-414-2998

E-mail: [gennum-korea@gennum.com](mailto:gennum-korea@gennum.com)

---

Gennum Corporation assumes no liability for any errors or omissions in this document, or for the use of the circuits or devices described herein. The sale of the circuit or device described herein does not imply any patent license, and Gennum makes no representation that the circuit or device is free from patent infringement.

PCIe and PCI Express mark are registered trademarks and/or service marks of PCI-SIG.

All other trademarks mentioned are the properties of their respective owners.

GENNUM and the Gennum logo are registered trademarks of Gennum Corporation.

© Copyright 2009 Gennum Corporation. All rights reserved.

[www.gennum.com](http://www.gennum.com)