



# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

MAX4969

## General Description

The MAX4969 active 2:1 and 1:2 multiplexer equalizes and redrives PCIe® signals up to 5.0GT/s (Gigatransfers per second) and operates from a single +3.3V supply.

The MAX4969 features PCIe-required electrical idle and receiver detection on each channel, and improves signal integrity at the receiver through independent programmable input equalization and output deemphasis.

The MAX4969 is available in a small, 42-pin (3.5mm x 9.0mm) TQFN package optimal for simplified layout and space-saving requirements. The MAX4969 is specified over the 0°C to +70°C commercial operating temperature range.

## Applications

Blade Servers  
Workstations  
Communications Switches  
Test Equipment  
Storage Area Network

## Features

- ◆ Single +3.3V Supply Operation
- ◆ PCIe Gen 1 (2.5GT/s) and Gen 2 (5.0GT/s) Return Loss  $\geq$  8dB ( $1.25\text{GHz} \leq f \leq 2.5\text{GHz}$ )
- ◆ Independent Input Equalization
- ◆ Independent Output Deemphasis
- ◆ Independent Output Level Selection  
Reduced Power and EMI
- ◆ On-Chip 50Ω Input/Output Terminations
- ◆ Inline Signal Traces for Simplified Layout
- ◆ Space-Saving, 3.5mm x 9.0mm TQFN Package

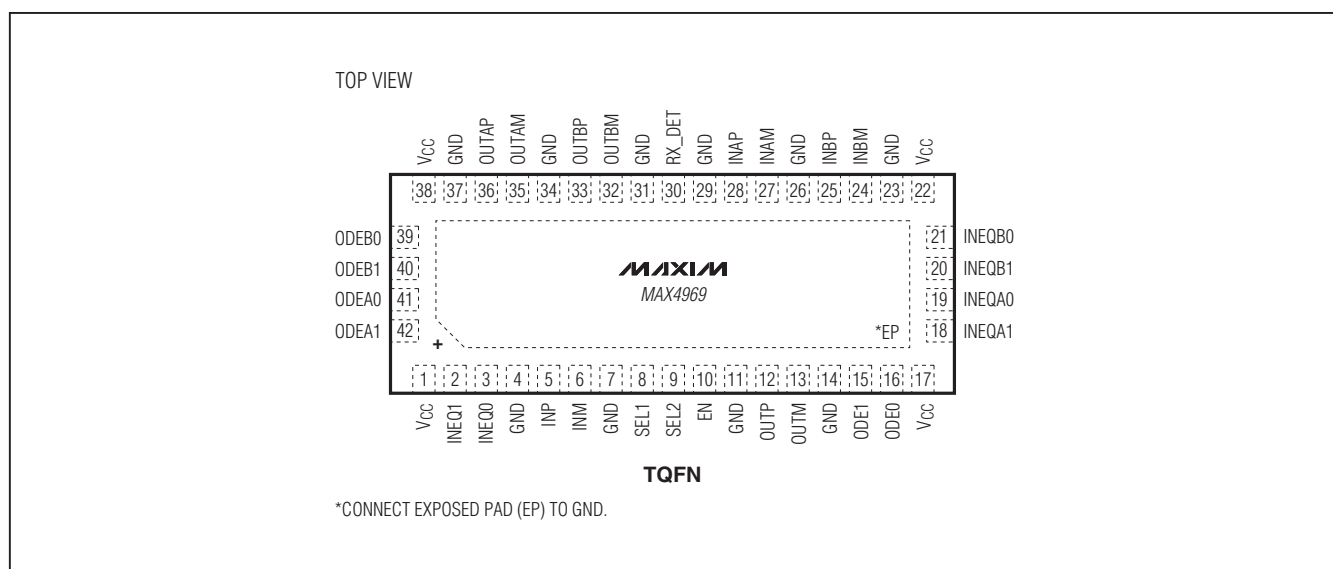
## Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX4969CTO+	0°C to +70°C	42 TQFN-EP*

+ Denotes a lead(Pb)-free/RoHS-compliant package.

\*EP = Exposed pad.

## Pin Configuration



PCIe is a registered trademark of PCI-SIG Corp.



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For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at [www.maxim-ic.com](http://www.maxim-ic.com).

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## ABSOLUTE MAXIMUM RATINGS

(Voltages referenced to GND.)

VCC	-0.3V to +4.0V
All Other Pins (Note 1)	-0.3V to (VCC + 0.3V)
Continuous Current, IN_P, IN_M, OUT_P, OUT_M	±30mA
Peak Current, IN_P, IN_M, OUT_P, OUT_M (for 10kHz, 1% duty cycle)	±100mA
Continuous Power Dissipation (TA = +70°C)	
42-Pin TQFN (derate 34.5mW/°C above +70°C)	2758mW

Junction-to-Case Thermal Resistance

θ<sub>JC</sub> (Note 2) ..... +2°C/W

Junction-to-Ambient Thermal Resistance

θ<sub>JA</sub> (Note 2) ..... +29°C/W

Operating Temperature Range ..... 0°C to +70°C

Junction Temperature Range ..... -40°C to +150°C

Storage Temperature Range ..... -65°C to +150°C

Lead Temperature (soldering, 10s) ..... +300°C

**Note 1:** All I/O pins are clamped by internal diodes.

**Note 2:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maxim-ic.com/thermal-tutorial](http://www.maxim-ic.com/thermal-tutorial).

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(VCC = +3.0V to +3.6V, C<sub>CL</sub> = 75nF coupling capacitor on each output, R<sub>L</sub> = 50Ω on each output, TA = 0°C to +70°C, unless otherwise noted. Typical values are at VCC = +3.3V and TA = +25°C.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC PERFORMANCE</b>						
Power-Supply Range	VCC		3.0		3.6	V
Supply Current	ICC	EN = VCC		120	150	mA
			INEQ_ = ODE_ = GND			
			INEQ_ = ODE_ = VCC	160	200	
		EN = GND		50		
Input Impedance, Differential	ZRX-DIFF-DC	DC	80	100	120	Ω
Output Impedance, Differential	ZTX-DIFF-DC	DC	80	100	120	Ω
Common-Mode Resistance to GND, Input Terminations Not Powered	ZRX-HIGH-IMP-DC-POS	VIN_P = VIN_M = 0 to 200mV	50			kΩ
	ZRX-HIGH-IMP-DC-NEG	VIN_P = VIN_M = -150mV to 0V	1			kΩ
Common-Mode Resistance to GND, Input Terminations Powered	ZRX-DC	DC	40	50	60	Ω
Output Short-Circuit Current	ITX-SHORT	Single-ended (Note 4)			90	mA
Common-Mode Delta, Between Active and Idle States	VTX-CM-DC-ACTIVE-IDLE-DELTA		-100		+100	mV
DC Output Offset, During Active State	VTX-CM-DC-LINE-DELTA	Difference between DC average of VOUT_P and VOUT_M	-25		+25	mV
DC Output Offset, During Electrical Idle	VTX-IDLE-DIFF-DC	ABS(VOUT_P - VOUT_M)	-10		+10	mV
<b>AC PERFORMANCE</b>						
Input Return Loss, Differential	RLRX-DIFF	0.05GHz < f ≤ 1.25GHz (Note 4)	10			dB
		1.25GHz < f ≤ 2.5GHz (Note 4)	8			dB

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## ELECTRICAL CHARACTERISTICS (continued)

(V<sub>CC</sub> = +3.0V to +3.6V, C<sub>CL</sub> = 75nF coupling capacitor on each output, R<sub>L</sub> = 50Ω on each output, T<sub>A</sub> = 0°C to +70°C, unless otherwise noted. Typical values are at V<sub>CC</sub> = +3.3V and T<sub>A</sub> = +25°C.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Return Loss, Common Mode	RLRX-CM	0.05GHz < f ≤ 2.5GHz (Note 4)	6			dB
Output Return Loss, Differential	RLTX-DIFF	0.05GHz < f ≤ 1.25GHz (Note 4)	10			dB
		1.25GHz < f ≤ 2.5GHz (Note 4)	8			dB
Output Return Loss, Common Mode	RLTX-CM	0.05GHz < f ≤ 2.5GHz (Note 4)	6			dB
Differential Input Signal Range, Redriver Operation	VRX-DIFF-PP	0.05GHz < f ≤ 2.5GHz	150		1200	mV <sub>P-P</sub>
Differential Output Voltage, Full Swing, No Deemphasis	VTX-DIFF-PP	2 × ABS(V <sub>OUT_P</sub> - V <sub>OUT_M</sub> ), ODE <sub>1</sub> = GND, ODE <sub>0</sub> = V <sub>CC</sub> (see Table 1), f = 500MHz	800	1000	1200	mV <sub>P-P</sub>
Differential Output Voltage, Low Swing, No Deemphasis	VTX-DIFF-PP-LOW	2 × ABS(V <sub>OUT_P</sub> - V <sub>OUT_M</sub> ), ODE <sub>1</sub> = ODE <sub>0</sub> = GND (see Table 1), f = 500MHz	600	750	900	mV <sub>P-P</sub>
Output Deemphasis Ratio, 0dB	VTX-DE-RATIO-0dB	f = 2.5GHz, ODE <sub>1</sub> = GND, ODE <sub>0</sub> = V <sub>CC</sub> or GND, Figure 1 (see Table 1)		0		dB
Output Deemphasis Ratio, 3.5dB	VTX-DE-RATIO-3.5dB	f = 2.5GHz, ODE <sub>1</sub> = V <sub>CC</sub> , ODE <sub>0</sub> = GND, Figure 1 (see Table 1)		3.5		dB
Output Deemphasis Ratio, 6dB	VTX-DE-RATIO-6dB	f = 2.5GHz, ODE <sub>1</sub> = V <sub>CC</sub> , ODE <sub>0</sub> = V <sub>CC</sub> , Figure 1 (see Table 1)		6		dB
Input Equalization, 0dB	VRX-EQ-0dB	f = 2.5GHz, INEQ <sub>1</sub> = GND, INEQ <sub>0</sub> = GND or V <sub>CC</sub> (see Table 2)		0		dB
Input Equalization, 3.5dB	VRX-EQ-3.5dB	f = 2.5GHz, INEQ <sub>1</sub> = V <sub>CC</sub> , INEQ <sub>0</sub> = GND (see Table 2)		3.5		dB
Input Equalization, 6dB	VRX-EQ-6dB	f = 2.5GHz, INEQ <sub>1</sub> = V <sub>CC</sub> , INEQ <sub>0</sub> = V <sub>CC</sub> (see Table 2)		6		dB
Output Common-Mode Voltage	VTX-CM-AC-PP	MAX(V <sub>OUT_P</sub> + V <sub>OUT_M</sub> )/2 - MIN(V <sub>OUT_P</sub> + V <sub>OUT_M</sub> )/2 (Note 4)			100	mV <sub>P-P</sub>
Propagation Delay	TPD	(Note 4)	160	280	400	ps
Rise/Fall Time	T <sub>TX-RISE-FALL</sub>	(Notes 4, 5)	30			ps
Rise/Fall Time Mismatch	T <sub>TX-RF-MISMATCH</sub>	(Notes 4, 5)			20	ps
Output Skew Same Pair	T <sub>SK</sub>	(Note 4)		10	15	ps
Deterministic Jitter	T <sub>TX-DJ-DD</sub>	K28.5 ≤ pattern, AC-coupled, R <sub>L</sub> = 50Ω, effects of deemphasis deembedded (Note 4), 5GT/s		20		ps <sub>P-P</sub>
Random Jitter	T <sub>TX-RJ-DD</sub>	D10.2 pattern, f > 1.5MHz		0.5	1.4	ps <sub>RMS</sub>
Electrical Idle Entry Delay	T <sub>TX-IDLE-SET-TO-IDLE</sub>	From input to output		15		ns
Electrical Idle Exit Delay	T <sub>TX-IDLE-TO-DIFF-DATA</sub>	From input to output		8		ns

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## ELECTRICAL CHARACTERISTICS (continued)

(V<sub>CC</sub> = +3.0V to +3.6V, C<sub>CL</sub> = 75nF coupling capacitor on each output, R<sub>L</sub> = 50Ω on each output, T<sub>A</sub> = 0°C to +70°C, unless otherwise noted. Typical values are at V<sub>CC</sub> = +3.3V and T<sub>A</sub> = +25°C.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Electrical Idle Detect Threshold	V <sub>TX-IDLE-THRESH</sub>		65	100	120	mV <sub>P-P</sub>
Output Voltage During Electrical Idle (AC)	V <sub>TX-IDLE-DIFF-AC-P</sub>	ABS(V <sub>OUT_P</sub> - V <sub>OUT_M</sub> )			35	mV <sub>P-P</sub>
Receiver Detect Pulse Amplitude	V <sub>TX-RCV-DETECT</sub>	Voltage change in positive direction (Note 4)			600	mV
Receiver Detect Pulse Width				100		ns
Receiver Detect Retry Period				200		ns
<b>CONTROL LOGIC</b>						
Input Logic-Level Low	V <sub>IL</sub>				0.6	V
Input Logic-Level High	V <sub>IH</sub>		1.4			V
Input Logic Hysteresis	V <sub>HYST</sub>			130		mV
Input Pulldown Resistor	R <sub>DOWN</sub>		37.5	60	150	kΩ

**Note 3:** All devices are 100% production tested at T<sub>A</sub> = +70°C. Specifications for all temperature limits are guaranteed by design.

**Note 4:** Guaranteed by design.

**Note 5:** Rise and fall times are measured using 20% and 80% levels.

## Timing Diagram

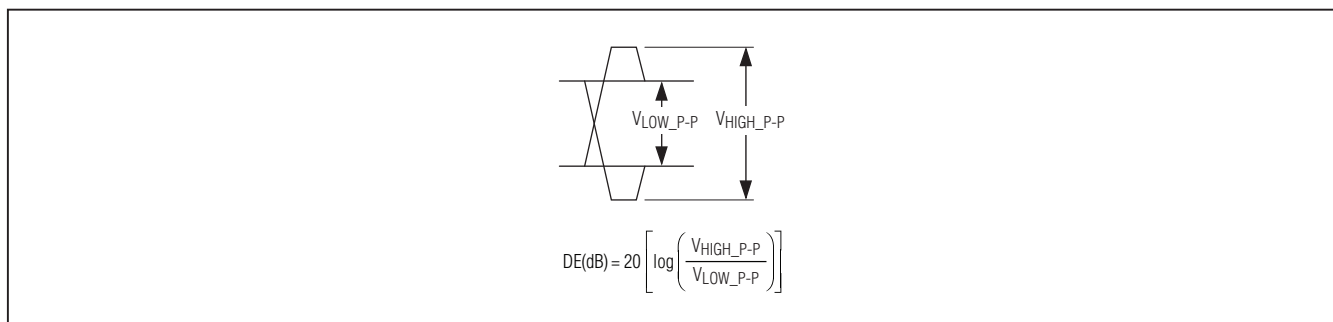


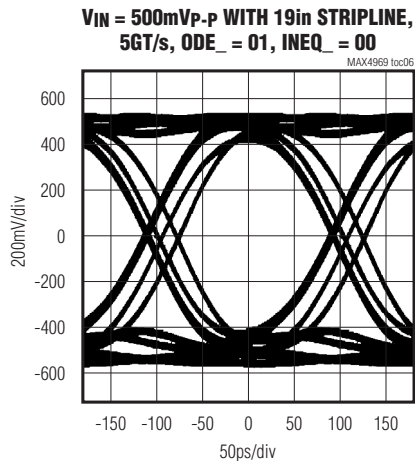
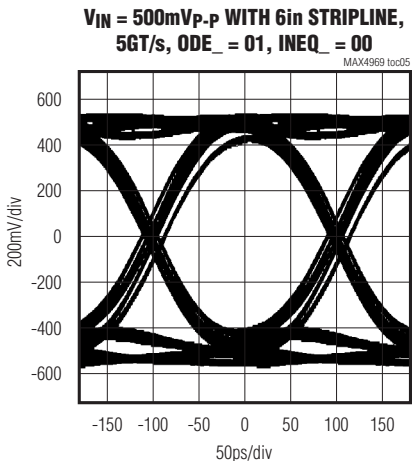
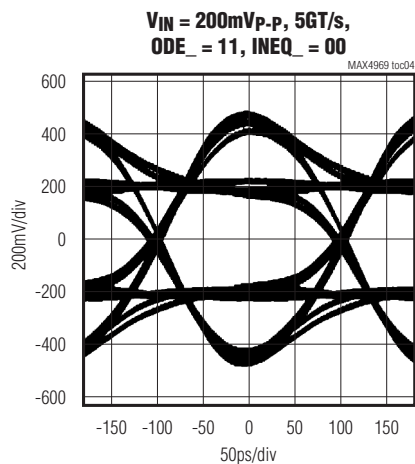
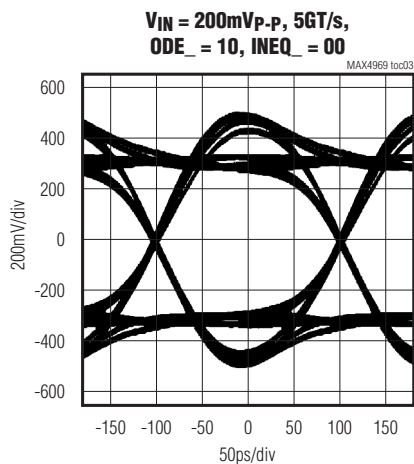
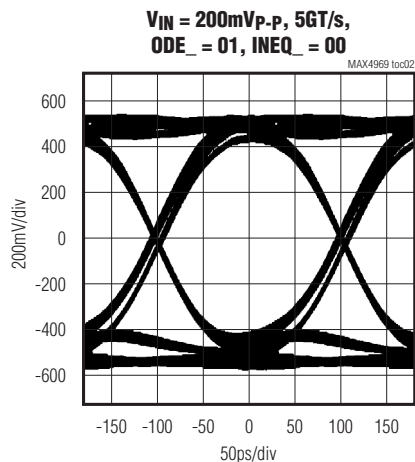
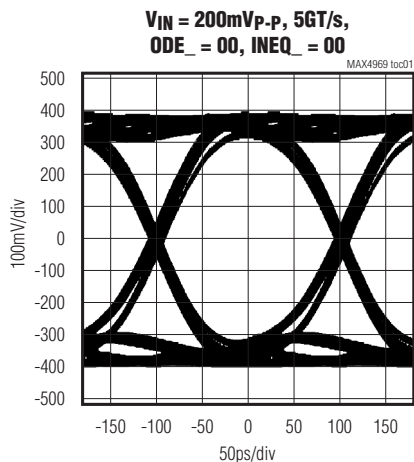
Figure 1. Illustration of Output Deemphasis

# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

## Typical Operating Characteristics

( $V_{CC} = +3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

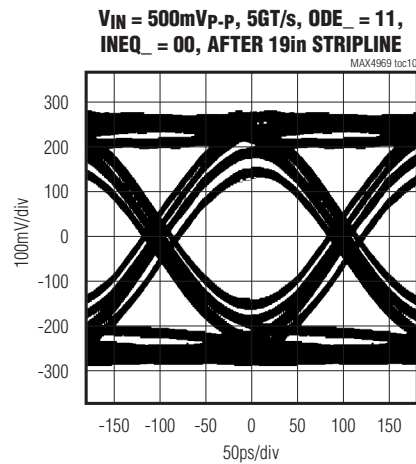
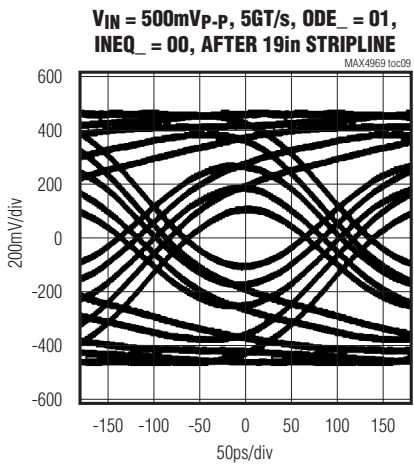
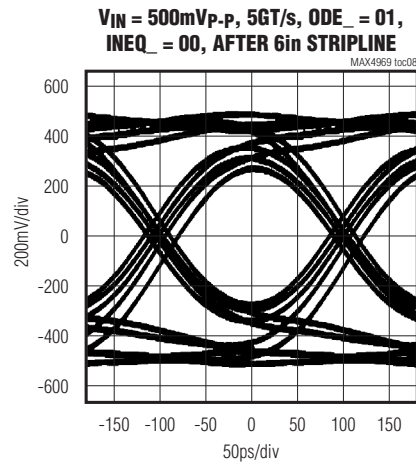
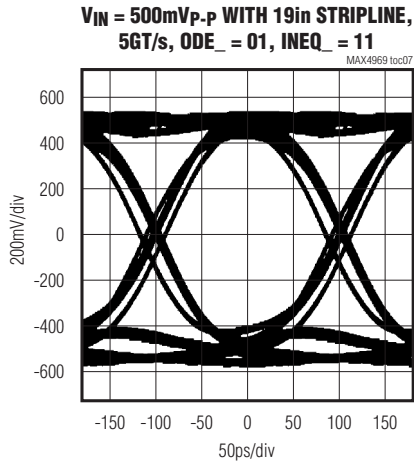
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# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

## Typical Operating Characteristics (continued)

(VCC = +3.3V, TA = +25°C, unless otherwise noted.)



# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

## Pin Description

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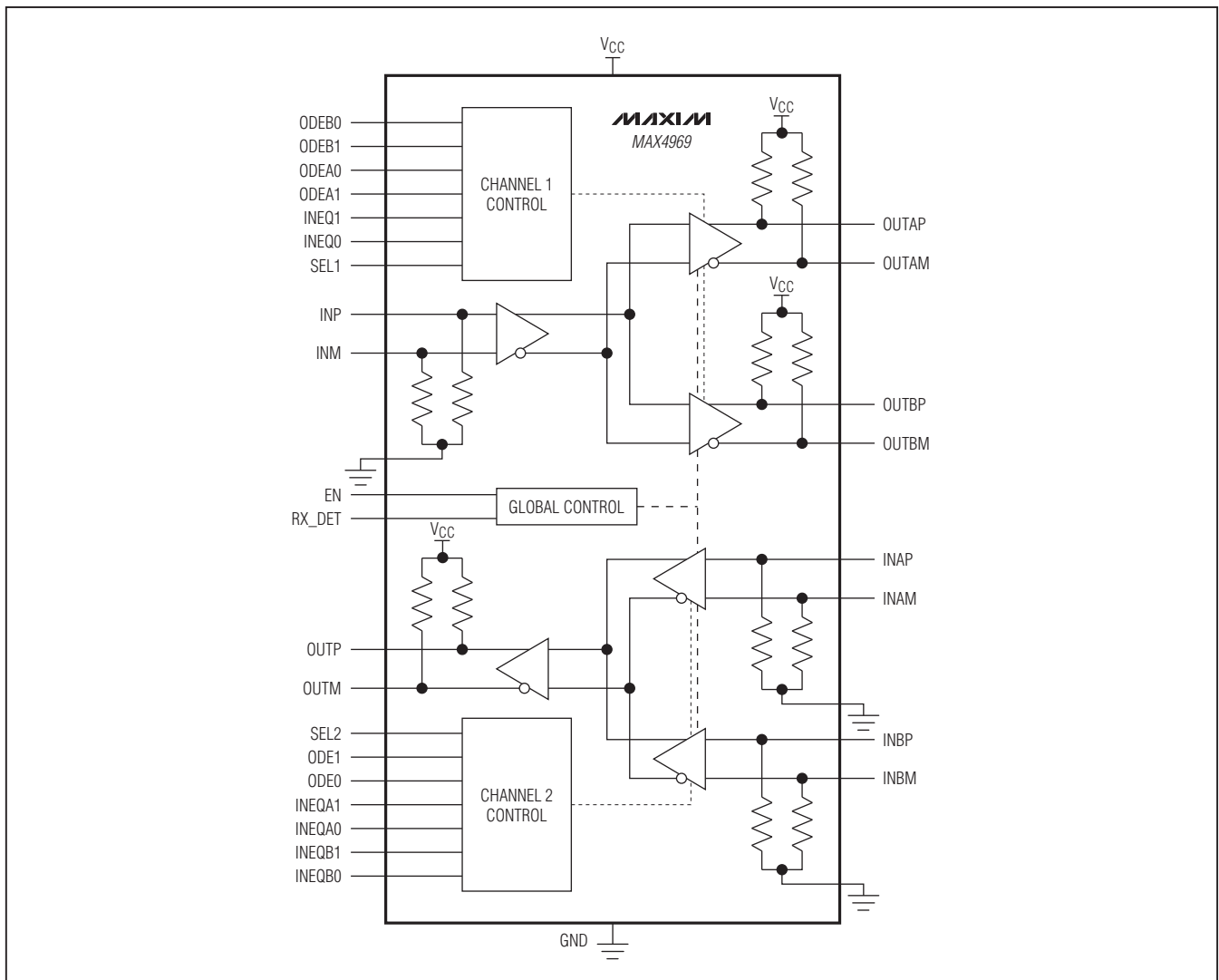
PIN	NAME	FUNCTION
1, 17, 22, 38	V <sub>CC</sub>	Power-Supply Input. Bypass V <sub>CC</sub> to GND with 1μF and 0.01μF capacitors in parallel as close to the device as possible, recommended on each V <sub>CC</sub> pin.
2	INEQ1	Channel 1 Input Equalization Control MSB. See Table 2. INEQ1 is internally pulled down by a 60kΩ (typ) resistor.
3	INEQ0	Channel 1 Input Equalization Control LSB. See Table 2. INEQ0 is internally pulled down by a 60kΩ (typ) resistor.
4, 7, 11, 14, 23, 26, 29, 31, 34, 37	GND	Ground
5	INP	Channel 1 Noninverting Input
6	INM	Channel 1 Inverting Input
8	SEL1	Channel 1 Active Output Selection Input. Drive SEL1 low to activate A outputs. Drive SEL high to activate B outputs. SEL1 is internally pulled down by a 60kΩ (typ) resistor.
9	SEL2	Channel 2 Active Input Selection Input. Drive SEL2 low to activate A inputs. Drive SEL high to activate B inputs. SEL2 is internally pulled down by a 60kΩ (typ) resistor.
10	EN	Enable Input. Drive EN low for reduced power standby mode. Drive EN high for normal operation. EN is internally pulled down by a 60kΩ (typ) resistor.
12	OUTP	Channel 2 Noninverting Output
13	OUTM	Channel 2 Inverting Output
15	ODE1	Channel 2 Output Deemphasis Control MSB. See Table 1. ODE1 is internally pulled down by a 60kΩ (typ) resistor.
16	ODE0	Channel 2 Output Deemphasis Control LSB. See Table 1. ODE0 is internally pulled down by a 60kΩ (typ) resistor.
18	INEQA1	Channel 2 Input A Equalization Control MSB. See Table 2. INEQA1 is internally pulled down by a 60kΩ (typ) resistor.
19	INEQA0	Channel 2 Input A Equalization Control LSB. See Table 2. INEQA0 is internally pulled down by a 60kΩ (typ) resistor.
20	INEQB1	Channel 2 Input B Equalization Control MSB. See Table 2. INEQB1 is internally pulled down by a 60kΩ (typ) resistor.
21	INEQB0	Channel 2 Input B Equalization Control LSB. See Table 2. INEQB0 is internally pulled down by a 60kΩ (typ) resistor.
24	INBM	Channel 2 Inverting Input B
25	INBP	Channel 2 Noninverting Input B
27	INAM	Channel 2 Inverting Input A
28	INAP	Channel 2 Noninverting Input A
30	RX_DET	Receiver Detection Control Bit. Toggle RX_DET to initiate receiver detection. RX_DET is internally pulled down by a 60kΩ (typ) resistor.
32	OUTBM	Channel 1 Inverting Output B
33	OUTBP	Channel 1 Noninverting Output B
35	OUTAM	Channel 1 Inverting Output A
36	OUTAP	Channel 1 Noninverting Output A
39	ODEB0	Channel 1 Output B Deemphasis Control LSB. See Table 1. ODEB0 is internally pulled down by a 60kΩ (typ) resistor.

# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

## Pin Description

PIN	NAME	FUNCTION
40	ODEB1	Channel 1 Output B Deemphasis Control MSB. See Table 1. ODEB1 is internally pulled down by a 60kΩ (typ) resistor.
41	ODEA0	Channel 1 Output A Deemphasis Control LSB. See Table 1. ODEA0 is internally pulled down by a 60kΩ (typ) resistor.
42	ODEA1	Channel 1 Output A Deemphasis Control MSB. See Table 1. ODEA1 is internally pulled down by a 60kΩ (typ) resistor.
—	EP	Exposed Pad. Internally connected to GND. Connect EP to a large ground plane to maximize thermal performance. EP is not intended as an electrical connection point.

## Functional Diagram





# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

## Detailed Description

The MAX4969 is an active 2:1/1:2 multiplexer designed to equalize and redrive PCIe signals up to 5.0GT/s. The MAX4969 features PCIe-required electrical idle and receiver detection on each channel, and improves signal integrity at the receiver through independent programmable input equalization and output deemphasis.

### Enable Input (EN)

The MAX4969 features an active-high enable input (EN). EN has an internal pulldown resistor of 60kΩ (typ). When EN is driven low or left unconnected, the MAX4969 enters reduced power standby mode and the redrivers are disabled. Drive EN high for normal operation.

### Active Input/Output Select (SEL1, SEL2)

SEL1 selects the active output for channel 1 and SEL2 selects the active input for channel 2. Drive SEL1 or SEL2 low or leave unconnected to activate A inputs or outputs. Drive SEL1 or SEL2 high to activate B inputs or outputs. SEL1 and SEL2 have internal pulldown resistors of 60kΩ (typ).

**Table 1. Output Deemphasis**

ODE_1	ODE_0	OUTPUT DEEMPHASIS (dB)
0	0	0, low swing
0	1	0, full swing
1	0	3.5, full swing
1	1	6, full swing

**Table 2. Input Equalization**

INEQ_1	INEQ_0	INPUT EQUALIZATION (dB)
0	X	0
1	0	3.5
1	1	6

X = Don't Care

**Table 3. Receiver Detection**

RX_DET/ SEL1/SEL2	EN	DESCRIPTION
X	0	Receiver detection inactive
0	1	Following a rising or falling edge; indefinite retry until receiver detected
Rising or falling edge	1	Initiate receiver detection
1	1	Following a rising or falling edge; indefinite retry until receiver detected

X = Don't Care

### Programmable Output Deemphasis (ODE\_0, ODE\_1)

The MAX4969 features independent programmable output deemphasis capable of providing 0dB, 3.5dB, or 6dB deemphasis on any channel. When both ODE\_0 and ODE\_1 are driven low or left unconnected, the output is in low-swing mode (750mV typ) (see Table 1). ODE0, ODE1, ODEA0, ODEA1, ODEB0, and ODEB1 have internal pulldown resistors of 60kΩ (typ).

### Programmable Input Equalization (INEQ\_0, INEQ\_1)

The MAX4969 features independent programmable input equalization capable of providing 0dB, 3.5dB, or 6dB of high-frequency equalization on any channel (see Table 2.) INEQ0, INEQ1, INEQA0, INEQA1, INEQB0, and INEQB1 have internal pulldown resistors of 60kΩ (typ).

### Receiver Detection (RX\_DET)

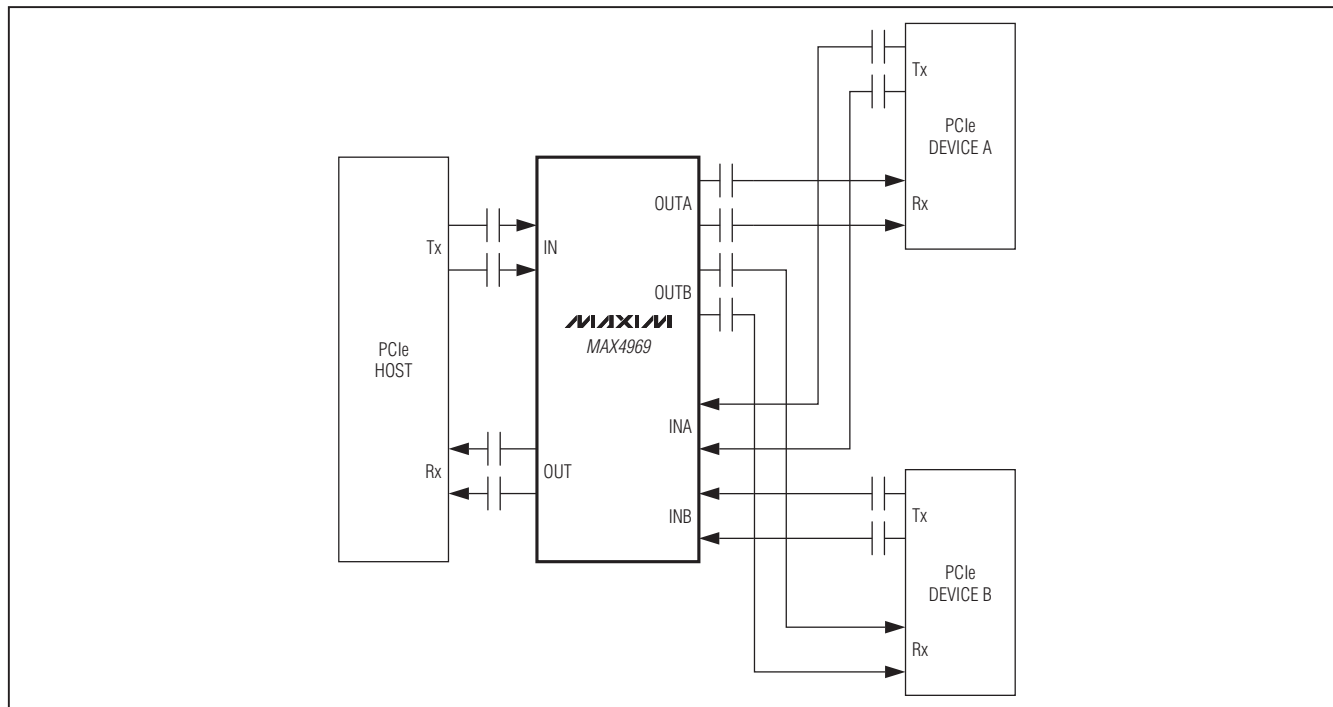
The MAX4969 features receiver detection on each channel. Receiver detection initializes on the rising edge of EN, or upon initial power-up if EN is high. Receiver detection can also be initiated on a rising or falling edge of the RX\_DET, SEL1, or SEL2 inputs when EN is high. During this time, the part remains in reduced power standby mode and the outputs are squelched, despite the logic-high state of EN. Once started, receiver detection repeats indefinitely on each channel. Once a receiver is detected on one of the channels, up to 2<sup>16</sup> more attempts are made on the other channel. Upon receiver detection, channel output and electrical idle detection are enabled (see Table 3). RX\_DET has an internal pulldown resistor of 60kΩ (typ).

### Electrical Idle Detection

The MAX4969 features electrical idle detection to prevent unwanted noise from being redriven at the output. If the MAX4969 detects that the differential input has fallen below VTX-IDLE-THRESH, the MAX4969 squelches the output. For differential input signals that are above VTX-IDLE-THRESH, the MAX4969 turns on the output and redrives the signal.

# PCIe, Single Lane, 2:1/1:2 Multiplexer and Redriver with Equalization

## Typical Application Circuit



## Applications Information

### Layout

Circuit board layout and design can significantly affect the performance of the MAX4969. Use good high-frequency design techniques, including minimizing ground inductance and using controlled-impedance transmission lines on data signals. It is recommended to run receive and transmit on different layers to minimize crosstalk and to place 1 $\mu$ F and 0.01 $\mu$ F power-supply bypass capacitors in parallel as close to V<sub>CC</sub> as possible on each V<sub>CC</sub> pin. Always connect V<sub>CC</sub> to a power plane.

### Exposed Pad Package

The exposed-pad, 42-pin TQFN package incorporates features that provide a very low thermal resistance path for heat removal from the IC. The exposed pad on the MAX4969 must be soldered to the circuit board ground plane for proper thermal performance. For more information on exposed-pad packages, refer to Application Note 862: *HFAN-08.1: Thermal Considerations of QFN and Other Exposed-Paddle Packages*.

### Power-Supply Sequencing

**Caution: Do not exceed the absolute maximum ratings because stresses beyond the listed ratings may cause permanent damage to the device.**

Proper power-supply sequencing is recommended for all devices. Always apply GND then V<sub>CC</sub> before applying signals, especially if the signal is not current limited.

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
42 TQFN-EP	T423590+1	<a href="#">21-0181</a>

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[ADG658TRUZ-EP](#) [74HC4053D.653](#) [74HCT4052PW.118](#) [74LVC2G53DP.125](#) [74HC4052DB.112](#) [74HC4052PW.112](#) [74HC4053DB.112](#)  
[74HC4067DB.112](#) [74HC4351DB.112](#) [74HCT4052D.112](#) [74HCT4052DB.112](#) [74HCT4351D.112](#) [74LV4051PW.112](#) [FSA1256L8X\\_F113](#)  
[PI5V330QE](#) [PI5V331QE](#) [5962-8771601EA](#) [5962-87716022A](#) [ADG5249FBRUZ](#) [ADG1438BRUZ](#) [ADG5207BCPZ-RL7](#) [ADW54003-0](#)