

# Low-Jitter, 10-Port LVDS Repeater

**MAX9150**

## General Description

The MAX9150 low-jitter, 10-port, low-voltage differential signaling (LVDS) repeater is designed for applications that require high-speed data or clock distribution while minimizing power, space, and noise. The device accepts a single LVDS input and repeats the signal at 10 LVDS outputs. Each differential output drives a total of  $50\Omega$ , allowing point-to-point distribution of signals on transmission lines with  $100\Omega$  terminations on each end.

Ultra-low 120ps (max) peak-to-peak jitter (deterministic and random) ensures reliable communication in high-speed links that are highly sensitive to timing error, especially those incorporating clock-and-data recovery, or serializers and deserializers. The high-speed switching performance guarantees 400Mbps data rate and less than 100ps skew between channels while operating from a single +3.3V supply.

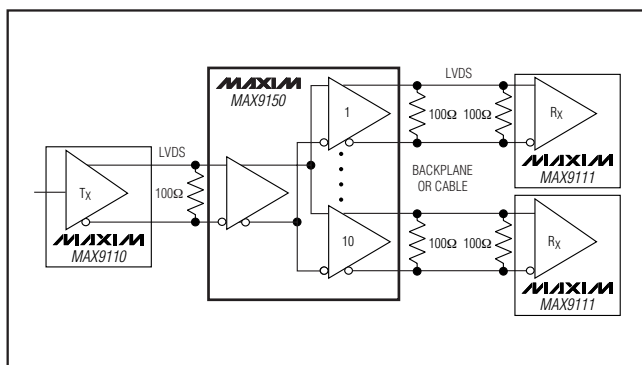
Supply current at 400Mbps is 160mA (max) and is reduced to 60 $\mu$ A (max) in low-power shutdown mode. Inputs and outputs conform to the EIA/TIA-644 LVDS standard. A fail-safe feature sets the outputs high when the input is undriven and open, terminated, or shorted. The MAX9150 is available in a 28-pin TSSOP package.

Refer to the MAX9110/MAX9112 and MAX9111/MAX9113 data sheets for LVDS line drivers and receivers.

## Applications

- Cellular Phone Base Stations
- Add/Drop Muxes
- Digital Crossconnects
- Network Switches/Routers
- Backplane Interconnect
- Clock Distribution

## Typical Application Circuit



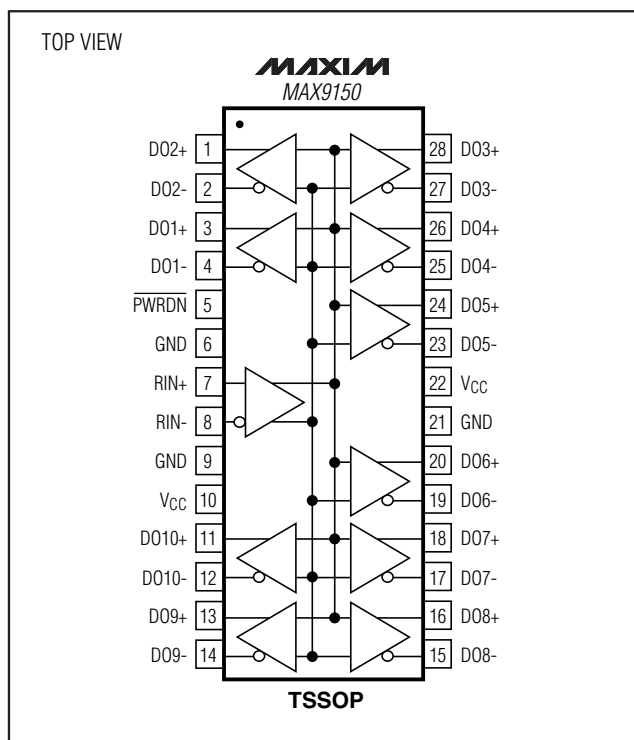
## Features

- ◆ Ultra-Low 120ps<sub>p-p</sub> (max) Total Jitter (Deterministic and Random)
- ◆ 100ps (max) Skew Between Channels
- ◆ Guaranteed 400Mbps Data Rate
- ◆ 60 $\mu$ A Shutdown Supply Current
- ◆ Conforms to EIA/TIA-644 LVDS Standard
- ◆ Single +3.3V Supply
- ◆ Fail-Safe Circuit Sets Output High for Undriven Inputs
- ◆ High-Impedance LVDS Input when  $V_{CC} = 0V$

## Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX9150EUI	-40°C to +85°C	28 TSSOP

## Pin Configuration



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## ABSOLUTE MAXIMUM RATINGS

V <sub>CC</sub> to GND	-0.3V to +4.0V
R <sub>IN+</sub> , R <sub>IN-</sub> to GND	-0.3V to +4.0V
PWRDN to GND	-0.3V to (V <sub>CC</sub> + 0.3V)
DO <sub>+</sub> , DO <sub>-</sub> to GND	-0.3V to +4.0V
Short-Circuit Duration (DO <sub>+</sub> , DO <sub>-</sub> )	Continuous
Continuous Power Dissipation (T <sub>A</sub> = +70°C)	
28-Pin TSSOP (derate 12.8mW/°C above +70°C)	.....1026mW

Storage Temperature	-65°C to +150°C
Maximum Junction Temperature	+150°C
Operating Temperature Range	-40°C to +85°C
Lead Temperature (soldering, 10s)	+300°C

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.

## DC ELECTRICAL CHARACTERISTICS

(V<sub>CC</sub> = +3.0V to +3.6V, R<sub>L</sub> = 50Ω ±1%, |V<sub>ID</sub>| = 0.1V to 1.0V, V<sub>CM</sub> = |V<sub>ID</sub> / 2| to 2.4V - |V<sub>ID</sub> / 2|, PWRDN = high, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at V<sub>CC</sub> = +3.3V, T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>PWRDN</b>						
Input High Voltage	V <sub>IH</sub>		2.0			V
Input Low Voltage	V <sub>IL</sub>				0.8	V
Input Current	I <sub>IN</sub>	V <sub>IN</sub> = V <sub>CC</sub> and 0V	-15		15	μA
<b>LVDS INPUT</b>						
Differential Input High Threshold	V <sub>TH</sub>			7	100	mV
Differential Input Low Threshold	V <sub>TL</sub>		-100	-7		mV
Single-Ended Input Current	I <sub>IN</sub>	PWRDN = high or low; V <sub>RIN+</sub> = 2.4V, R <sub>IN-</sub> = open or R <sub>IN+</sub> = open, V <sub>RIN-</sub> = 2.4V	-6		+1	μA
		PWRDN = high or low; V <sub>RIN+</sub> = 0V, R <sub>IN-</sub> = open or R <sub>IN+</sub> = open, V <sub>RIN-</sub> = 0V	-18		+1	
Power-Off Single-Ended Input Current	I <sub>IN(OFF)</sub>	V <sub>CC</sub> = 0V; V <sub>RIN+</sub> = 2.4V, R <sub>IN-</sub> = open or R <sub>IN+</sub> = open, V <sub>RIN-</sub> = 2.4V	-1		+12	μA
Differential Input Resistance	R <sub>IDIFF</sub>	V <sub>CC</sub> = +3.6V or 0V, PWRDN = high or low	5			kΩ
<b>LVDS DRIVER</b>						
Differential Output Voltage	V <sub>OD</sub>	Figure 1	250	320	450	mV
Change in VOD Between Complementary Output States	ΔV <sub>OD</sub>	Figure 1			25	mV
Offset (Common-Mode) Voltage	V <sub>OS</sub>	Figure 1	0.90	1.25	1.375	V
Change in VOS Between Complementary Output States	ΔV <sub>OS</sub>	Figure 1			25	mV
Output High Voltage	V <sub>OH</sub>	Figure 1			1.6	V
Output Low Voltage	V <sub>OL</sub>	Figure 1	0.7			V
Differential Output Resistance (Note 2)	R <sub>ODIFF</sub>	V <sub>CC</sub> = +3.6V or 0V, PWRDN = high or low	150	240	330	Ω
Differential High Output Voltage in Fail-Safe	V <sub>OD+</sub>	R <sub>IN+</sub> , R <sub>IN-</sub> undriven with short, open, or 100Ω termination	250		450	mV
Output Short-Circuit Current	I <sub>SC</sub>	V <sub>ID</sub> = +100mV, V <sub>DO+</sub> = GND	-15			mA
		V <sub>ID</sub> = -100mV, V <sub>DO-</sub> = GND				

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## DC ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +3.0V$  to  $+3.6V$ ,  $R_L = 50\Omega \pm 1\%$ ,  $|V_{ID}| = 0.1V$  to  $1.0V$ ,  $V_{CM} = |V_{ID} / 2|$  to  $2.4V - |V_{ID} / 2|$ ,  $\overline{PWRDN} = \text{high}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $V_{CC} = +3.3V$ ,  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Single-Ended Output High-Impedance Current	I <sub>OZ</sub>	$V_{CC} = 0V$ , $\overline{PWRDN} = \text{GND}$ ; $V_{DO+} = 3.6V$ or $0V$ , $DO_- = \text{open}$ ; or $V_{DO-} = 3.6V$ or $0V$ , $DO_+ = \text{open}$	-1		+1	$\mu\text{A}$	
		$\overline{PWRDN} = \text{GND}$ ; $V_{DO+} = 3.6V$ or $0V$ , $DO_- = \text{open}$ ; or $V_{DO-} = 3.6V$ or $0V$ , $DO_+ = \text{open}$	-1		+1	$\mu\text{A}$	
<b>SUPPLY CURRENT</b>							
Supply Current (Note 2)	I <sub>CC</sub>	DC	Figure 2		100	140	mA
		200MHz (400Mbps)			130	160	
Power-Down Supply Current	I <sub>CCZ</sub>	$\overline{PWRDN} = \text{GND}$			60	$\mu\text{A}$	

## AC ELECTRICAL CHARACTERISTICS

( $V_{CC} = +3.0V$  to  $+3.6V$ ,  $R_L = 50\Omega \pm 1\%$ ,  $C_L = 5\text{pF}$ ,  $|V_{ID}| = 0.2V$  to  $1.0V$ ,  $V_{CM} = |V_{ID} / 2|$  to  $2.4V - |V_{ID} / 2|$ ,  $\overline{PWRDN} = \text{high}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $V_{CC} = +3.3V$ ,  $T_A = +25^\circ\text{C}$ .) (Notes 2-5)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Differential Propagation Delay High-to-Low	t <sub>PHLD</sub>	Figures 2, 3	1.6	2.2	3.5	ns
Differential Propagation Delay Low-to-High	t <sub>PLHD</sub>	Figures 2, 3	1.6	2.2	3.5	ns
Total Peak-to-Peak Jitter (Random and Deterministic) (Note 6)	t <sub>JPP</sub>	Figures 2, 3		20	120	ps <sub>p-p</sub>
Differential Output-to-Output Skew (Note 7)	t <sub>SKOO</sub>	Figures 2, 3		40	100	ps
Differential Part-to-Part Skew (Note 8)	t <sub>SKPP</sub>	Figures 2, 3			1.9	ns
Rise/Fall Time	T <sub>TLH</sub> , t <sub>THL</sub>	Figures 2, 3	150	220	450	ps
Maximum Input Frequency (Note 9)	f <sub>MAX</sub>	Figures 2, 3	400			Mbps

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## AC ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +3.0V$  to  $+3.6V$ ,  $R_L = 50\Omega \pm 1\%$ ,  $C_L = 5pF$ ,  $|V_{ID}| = 0.2V$  to  $1.0V$ ,  $V_{CM} = |V_{ID} / 2|$  to  $2.4V - |V_{ID} / 2|$ ,  $\overline{PWRDN} = \text{high}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $V_{CC} = +3.3V$ ,  $T_A = +25^\circ\text{C}$ .) (Notes 2–5)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power-Down Time	$t_{PD}$	Figures 4, 5			100	ns
Power-Up Time	$t_{PU}$				100	$\mu\text{s}$

**Note 1:** Current-into-device pins is defined as positive. Current-out-of-device pins is defined as negative. All voltages are referenced to ground, except  $V_{TH}$ ,  $V_{TL}$ ,  $V_{OD}$ , and  $\Delta V_{OD}$ .

**Note 2:** Guaranteed by design, not production tested.

**Note 3:** AC parameters are guaranteed by design and characterization.

**Note 4:**  $C_L$  includes scope probe and test jig capacitance.

**Note 5:** Signal generator conditions, unless otherwise noted: frequency = 200MHz, 50% duty cycle,  $R_O = 50\Omega$ ,  $t_R = 1\text{ns}$ , and  $t_F = 1\text{ns}$  (0% to 100%).

**Note 6:** Signal generator conditions for  $t_{JPP}$ :  $V_{OD} = 200\text{mV}$ ,  $V_{OS} = 1.2\text{V}$ , frequency = 200MHz, 50% duty cycle,  $R_O = 50\Omega$ ,  $t_R = 1\text{ns}$ , and  $t_F = 1\text{ns}$  (0% to 100%).  $t_{JPP}$  includes pulse (duty cycle) skew.

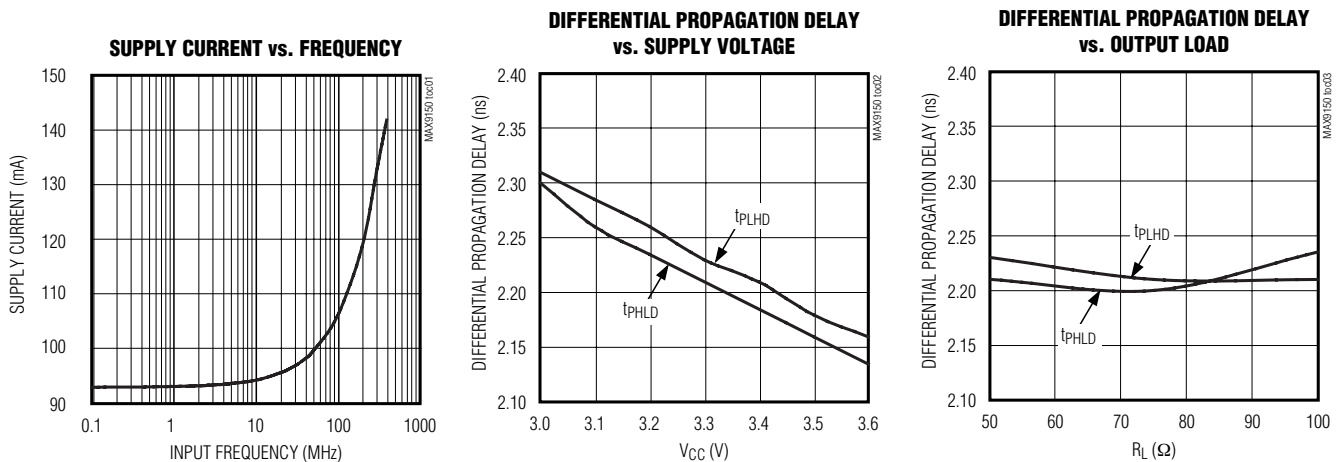
**Note 7:**  $t_{SKOO}$  is the magnitude difference in differential propagation delay between outputs for a same-edge transition.

**Note 8:**  $t_{SKPP}$  is the |MAX - MIN| differential propagation delay.

**Note 9:** Device meets  $V_{OD}$  and AC specifications while operating at  $f_{MAX}$ .

## Typical Operating Characteristics

(Figure 2,  $V_{CC} = +3.3V$ ,  $R_L = 50\Omega$ ,  $C_L = 5pF$ ,  $|V_{ID}| = 200\text{mV}$ ,  $V_{CM} = 1.2V$ ,  $f_{IN} = 50\text{MHz}$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

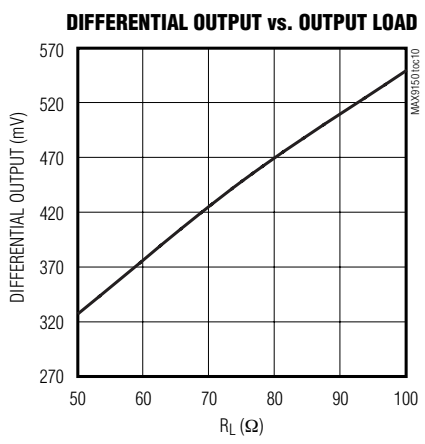
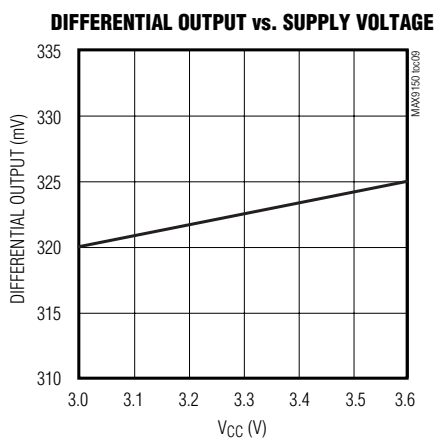
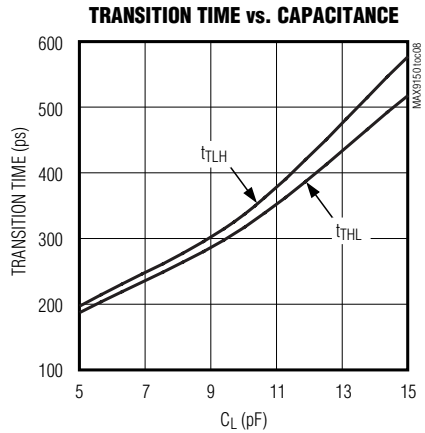
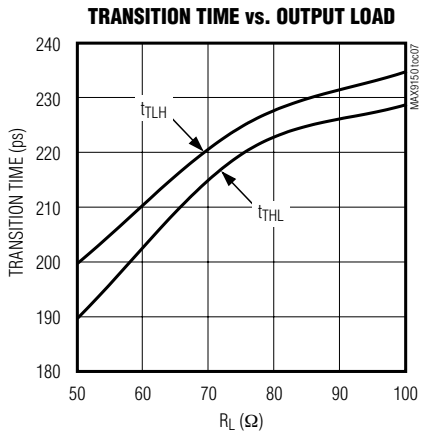
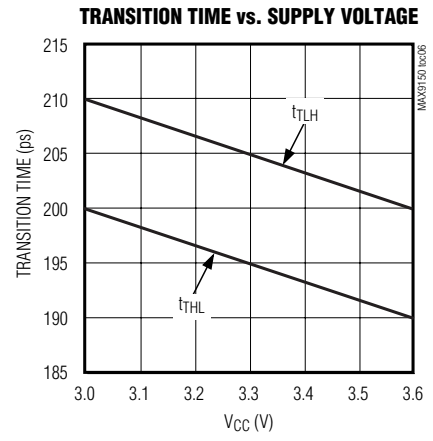
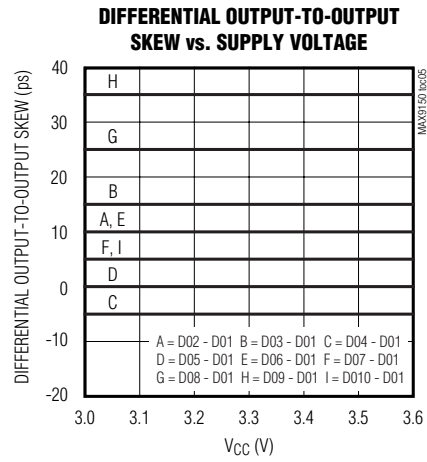
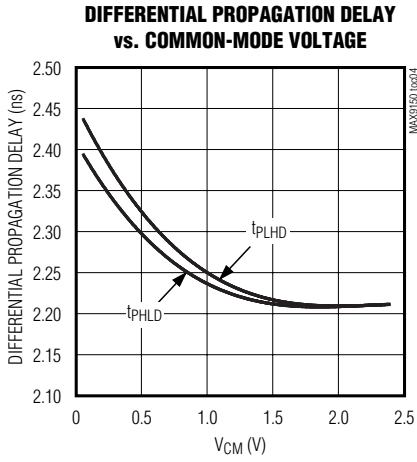


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## Typical Operating Characteristics (continued)

(Figure 2,  $V_{CC} = +3.3V$ ,  $R_L = 50\Omega$ ,  $C_L = 5pF$ ,  $|V_{ID}| = 200\text{ mV}$ ,  $V_{CM} = 1.2V$ ,  $f_{IN} = 50\text{MHz}$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.)



# Low-Jitter, 10-Port LVDS Repeater

## Pin Description

PIN	NAME	FUNCTION
1, 3, 11, 13, 16, 18, 20, 24, 26, 28	DO2+, DO1+, DO10+, DO9+, DO8+, DO7+, DO6+, DO5+, DO4+, DO3+	Differential LVDS Outputs. Connect a 100Ω resistor across each of the output pairs (DO <sub>-</sub> + and DO <sub>-</sub> -) adjacent to the IC, and connect a 100Ω resistor at the input of the receiving circuit.
2, 4, 12, 14, 15, 17, 19, 23, 25, 27	DO2-, DO1-, DO10-, DO9-, DO8-, DO7-, DO6-, DO5-, DO4-, DO3-	
5	$\overline{\text{PWRDN}}$	Power Down. Drive $\overline{\text{PWRDN}}$ low to disable all outputs and reduce supply current to 60μA. Drive $\overline{\text{PWRDN}}$ high for normal operation.
6, 9, 21	GND	Ground
10, 22	V <sub>CC</sub>	Power. Bypass each V <sub>CC</sub> pin to GND with 0.1μF and 1nF ceramic capacitors.
7	RIN+	LVDS Receiver Inputs. RIN+ and RIN- are high-impedance inputs. Connect a resistor from RIN+ to RIN- to terminate the input signal.
8	RIN-	

## Detailed Description

The LVDS interface standard is a signaling method intended for point-to-point communication over a controlled impedance medium, as defined by the ANSI/TIA/EIA-644 and IEEE 1596.3 standards. The LVDS standard uses a lower voltage swing than other common communication standards, achieving higher data rates with reduced power consumption while reducing EMI emissions and system susceptibility to noise.

The MAX9150 is a 400Mbps, 10-port LVDS repeater intended for high-speed, point-to-point, low-power applications. This device accepts an LVDS input and repeats it on 10 LVDS outputs. The device is capable of detecting differential signals as low as 100mV and as high as 1V within a 0 to 2.4V input voltage range. The LVDS standard specifies an input voltage range of 0 to 2.4V referenced to ground.

The MAX9150 outputs use a current-steering configuration to generate a 5mA to 9mA output current. This current-steering approach induces less ground bounce and no shoot-through current, enhancing noise margin and system speed performance. The driver outputs are short-circuit current limited, and are high impedance (to ground) when  $\overline{\text{PWRDN}}$  = low or the device is not powered. The outputs have a typical differential resistance of 240Ω.

The MAX9150 current-steering architecture requires a resistive load to terminate the signal and complete the

transmission loop. Because the device switches the direction of current flow and not voltage levels, the output voltage swing is determined by the total value of the termination resistors multiplied by the output current. With a typical 6.4mA output current, the MAX9150 produces a 320mV output voltage when driving a transmission line terminated at each end with a 100Ω termination resistor (6.4mA x 50Ω = 320mV). Logic states are determined by the direction of current flow through the termination resistors.

### Fail-Safe

Fail-safe is a receiver feature that puts the output in a known logic state (high) under certain fault conditions. The MAX9150 outputs are differential high when the inputs are undriven and open, terminated, or shorted (Table 1).

**Table 1. Input/Output Function Table**

INPUT, V <sub>ID</sub>		OUTPUTS, V <sub>OD</sub>
+100mV		High
-100mV		Low
Open		High
Short	Undriven	High
Terminated		High

**Note:** V<sub>ID</sub> = RIN+ - RIN-, V<sub>OD</sub> = DO<sub>-</sub>+ - DO<sub>-</sub>-  
 High = 450mV > V<sub>OD</sub> > 250mV  
 Low = -250mV > V<sub>OD</sub> > -450mV

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## Applications Information

### Supply Bypassing

Bypass each of the V<sub>CC</sub> pins with high-frequency surface-mount ceramic 0.1μF and 1nF capacitors in parallel as close to the device as possible, with the smaller valued capacitor closest to the V<sub>CC</sub> pins.

### Differential Traces

Output trace characteristics affect the performance of the MAX9150. Use controlled impedance traces to match trace impedance to both the transmission medium impedance and termination resistor. Ensure that noise couples as common mode by running the differential traces close together. Reduce skew by matching the electrical length of the traces. Excessive skew can result in a degradation of magnetic field cancellation.

Maintain the distance between the differential traces to avoid discontinuities in differential impedance. Avoid 90° turns and minimize the number of vias to further prevent impedance discontinuities.

### Cables and Connectors

Transmission media should have a controlled differential impedance of 100Ω. Use cables and connectors that have matched differential impedance to minimize impedance discontinuities.

Avoid the use of unbalanced cables, such as ribbon or simple coaxial cable. Balanced cables, such as twisted pair, offer superior signal quality and tend to generate

less EMI due to canceling effects. Balanced cables tend to pick up noise as common mode, which is rejected by the LVDS receiver.

### Termination

Termination resistors should match the differential characteristic impedance of the transmission line. Since the MAX9150 has current-steering devices, an output voltage will not be generated without a termination resistor. Output voltage levels are dependent upon the value of the total termination resistance. The MAX9150 produces LVDS output levels for point-to-point links that are double terminated (100Ω at each end). With the typical 6.4mA output current, the MAX9150 produces an output voltage of 320mV when driving a transmission line terminated at each end with a 100Ω termination resistor (6.4mA x 50Ω = 320mV). Termination resistance values may range between 90Ω and 150Ω, depending on the characteristic impedance of the transmission medium.

Minimize the distance between the output termination resistor and the corresponding MAX9150 transmitter output. Use ±1% surface-mount resistors.

Minimize the distance between the input termination resistor and the MAX9150 receiver input. Use a ±1% surface-mount resistor.

## Chip Information

PROCESS : CMOS

## Test Circuits and Timing Diagrams

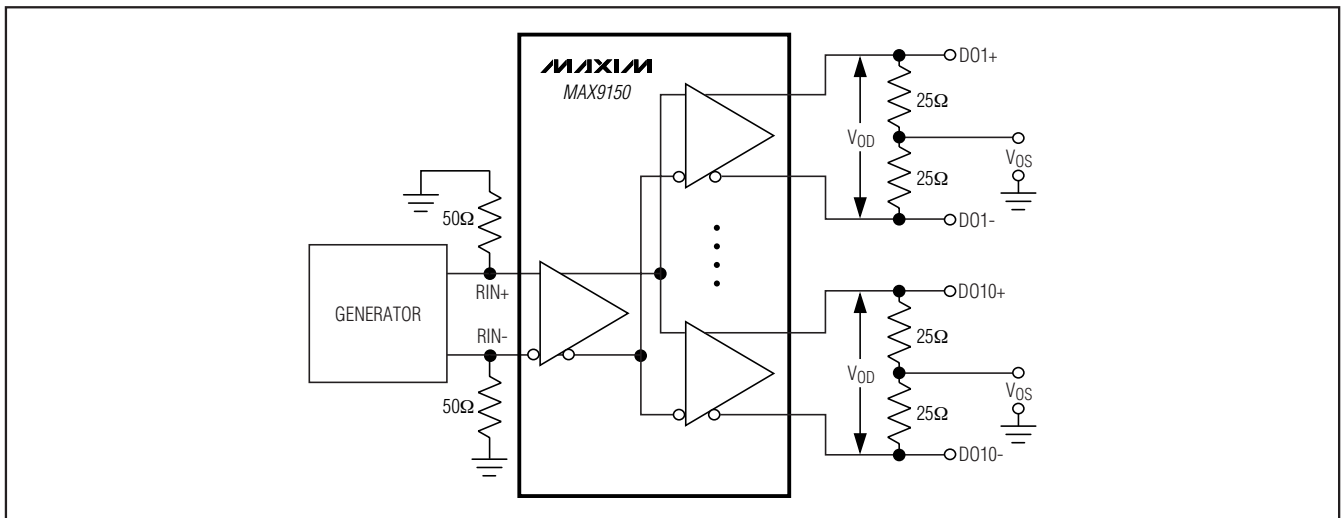


Figure 1. Driver-Load Test Circuit

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## Test Circuits and Timing Diagrams (continued)

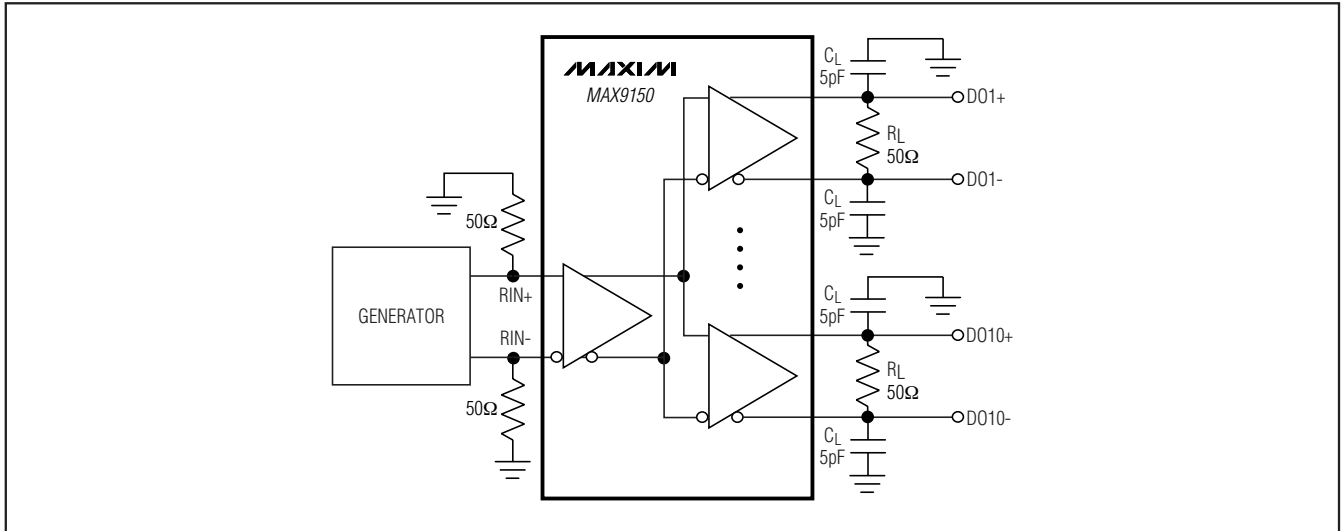


Figure 2. Repeater Propagation Delay and Transition Time Test Circuit

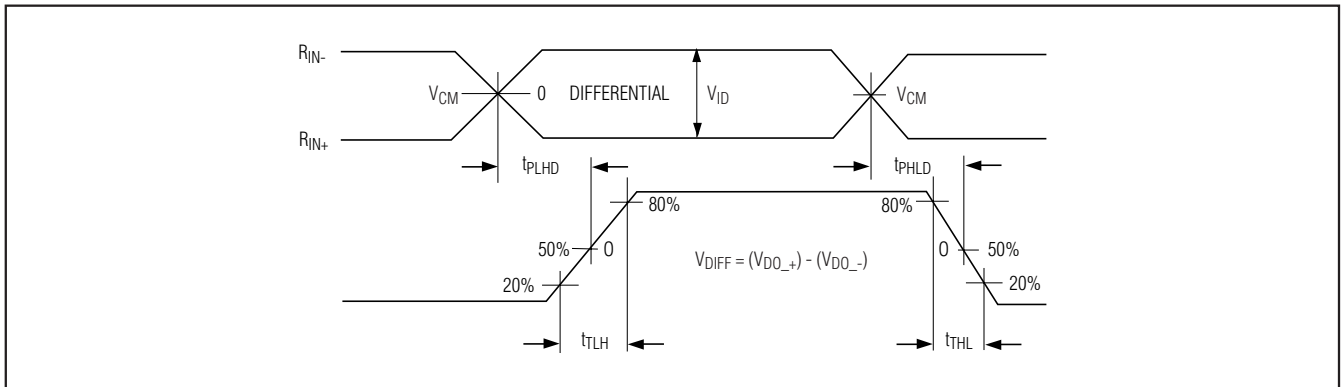


Figure 3. Propagation Delay and Transition Time Waveforms



# Low-Jitter, 10-Port LVDS Repeater

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## Test Circuits and Timing Diagrams (continued)

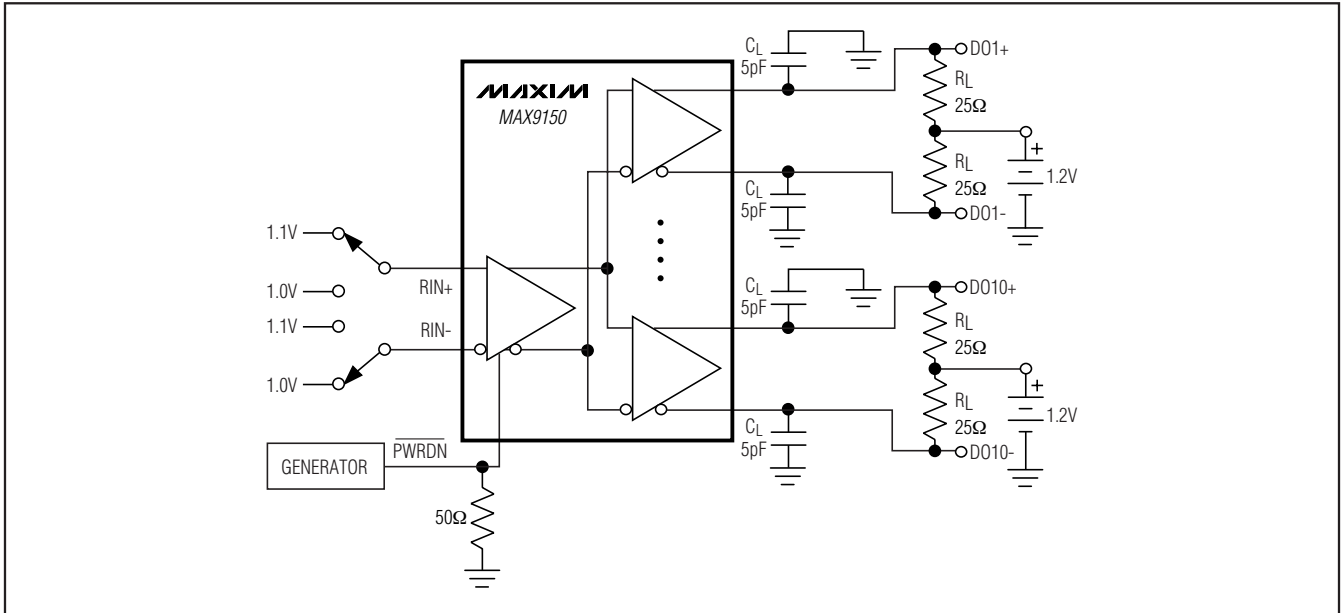


Figure 4. Power-Up/Down Delay Test Circuit

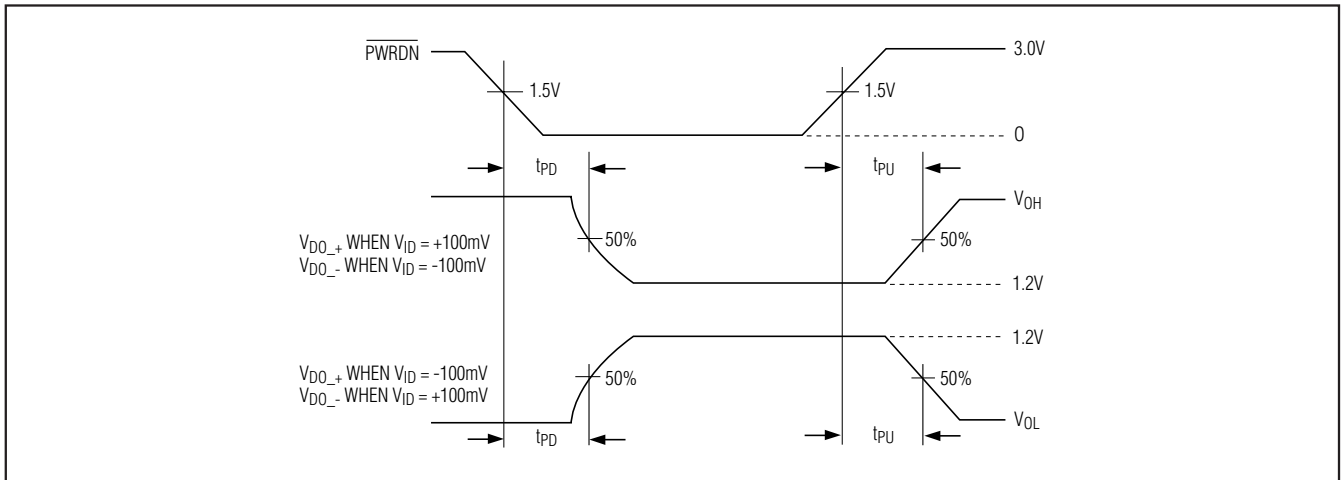


Figure 5. Power-Up/Down Delay Waveform

## 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.
28 TSSOP	U28-4	<a href="#">21-0066</a>

# Low-Jitter, 10-Port LVDS Repeater

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/00	Initial release	—
1	3/09	Replaced the obsolete Rev C package outline drawing with the <i>Package Information</i> table	9

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

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