

**EVALUATION KIT AVAILABLE**



# Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

MAX4444/MAX4445

## General Description

The MAX4444/MAX4445 differential line receivers offer unparalleled high-speed, low-distortion performance. Using a three op amp instrumentation amplifier architecture, these ICs have symmetrical differential inputs and a single-ended output. They operate from  $\pm 5V$  supplies and are capable of driving a  $100\Omega$  load to  $\pm 3.7V$ . The MAX4444 has an internally set closed-loop gain of  $+2V/V$ , while the MAX4445 is compensated for gains of  $+2V/V$  or greater, set by an external resistor. A low-power enable mode reduces current consumption to  $3.5mA$ .

Using current-feedback techniques, the MAX4444/MAX4445 achieve a  $550MHz$  bandwidth while maintaining up to a  $5000V/\mu s$  slew rate. Excellent differential gain/phase and noise specifications make these amplifiers ideal for a wide variety of video and RF signal-processing applications. An evaluation kit is available to speed design.

## Features

- ♦ **5000V/ $\mu s$  Slew Rate (MAX4444)**
- ♦  **$+2V/V$  Internally Fixed Gain (MAX4444)**
- ♦ **External Gain Selection (MAX4445,  $A_{VCL} \geq +2V/V$ )**
- ♦ **550MHz -3dB Bandwidth**
- ♦ **-60dB SFDR at 5MHz**
- ♦ **Low Differential Gain/Phase: 0.07%/0.05°**
- ♦ **Low Noise:  $25nV/\sqrt{Hz}$  at  $f_{IN} = 100kHz$**
- ♦ **Low-Power Disable Mode Reduces Quiescent Current to 3.5mA**

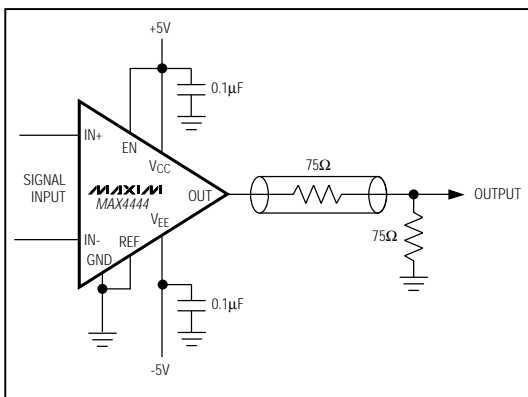
## Applications

- Differential-to-Single-Ended Conversion
- Twisted-Pair to Coaxial Converter
- High-Speed Instrumentation Amplifier
- Data Acquisition
- Medical Instrumentation
- High-Speed Differential Line Receiver

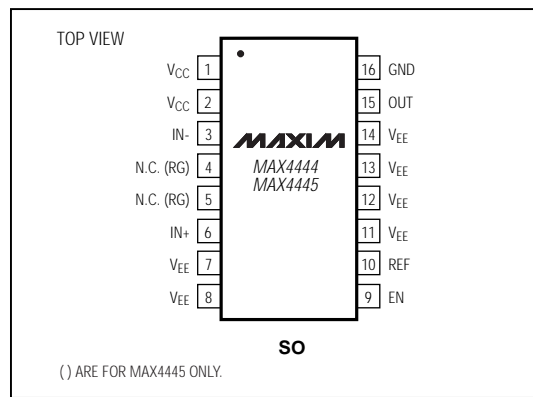
## Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX4444ESE	-40°C to +85°C	16 Narrow SO
MAX4445ESE	-40°C to +85°C	16 Narrow SO

## Typical Operating Circuit



## Pin Configuration



For free samples & the latest literature: <http://www.maxim-ic.com>, or phone 1-800-998-8800.  
For small orders, phone 1-800-835-8769.

# Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

## ABSOLUTE MAXIMUM RATINGS

$V_{CC}$ to $V_{EE}$ .....	+12V	Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )	
Voltage on $\text{IN}^+$ , $\text{IN}^-$ , $\text{EN}$ , $\text{OUT}^+$ , $\text{OUT}^-$ , $\text{RG}$ , $\text{REF}$ .....	( $V_{EE} - 0.3\text{V}$ ) to ( $V_{CC} + 0.3\text{V}$ )	16-Pin Narrow SO (derate 20mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) ...	1600mW
Current Into $\text{IN}^+$ , $\text{IN}^-$ , $\text{RG}$ , $\text{EN}$ .....	20mA	Operating Temperature Range .....	$-40^\circ\text{C}$ to $+85^\circ\text{C}$
Output Short-Circuit Duration .....	Indefinite to GND	Storage Temperature Range .....	$-65^\circ\text{C}$ to $+150^\circ\text{C}$
		Lead Temperature (soldering, 10sec) .....	$+300^\circ\text{C}$

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

( $V_{CC} = +5\text{V}$ ,  $V_{EE} = -5\text{V}$ ,  $V_{EN} = \geq 2\text{V}$ ,  $V_{CM} = 0$ ,  $R_L = \infty$ ,  $\text{REF} = \text{GND}$ ,  $\text{AVCL} = +2\text{V/V}$ ,  $T_A = T_{\text{MIN}}$  to  $T_{\text{MAX}}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage Range		Guaranteed by PSRR test	$\pm 4.5$		$\pm 5.5$	V
Input Common-Mode Voltage Range	$V_{CM}$	Guaranteed by CMRR test	-2.9		2.9	V
Differential Input Voltage Range	$V_{DIFF}$	Guaranteed by output swing test	-1.7		1.7	V
Input Offset Voltage	$V_{OS}$			15	65	mV
Input Offset-Voltage Temperature Coefficient	$\text{TC}_{VOS}$			12		$\mu\text{V}/^\circ\text{C}$
Input Bias Current	$I_B$			10	55	$\mu\text{A}$
Input Offset Current	$I_{OS}$			0.25	45	$\mu\text{A}$
Differential Input Resistance	$R_{IN}$	$-2.9\text{V} \leq V_{IN} \leq +2.9\text{V}$		82		k $\Omega$
		$-2.9\text{V} \leq V_{CM} \leq +2.9\text{V}$		170		
Gain	$A_V$	$-3\text{V} \leq V_{OUT} \leq +3\text{V}$	MAX4444	2		V/V
			MAX4445	$(1 + 600/R_G)$		
Gain Error		$-3\text{V} \leq V_{OUT} \leq +3\text{V}$ , $R_L = 100\Omega$	MAX4444	0.5	2	%
			MAX4445	2.6	8	
Gain-Error Drift		$R_L = 100\Omega$		0.003		$\%/^\circ\text{C}$
Output Voltage Swing	$V_{OUT}$	$R_L = 100\Omega$	$\pm 3.4$	$\pm 3.7$		V
		$R_L = 50\Omega$	$\pm 3.3$	$\pm 3.6$		
Output Current Drive	$I_{OUT}$	$R_L = 30\Omega$	90	120		mA
Power-Supply Rejection Ratio	PSRR	$V_S = \pm 4.5\text{V}$ to $\pm 5.5\text{V}$	53	70		dB
Common-Mode Rejection Ratio	CMRR	$-2.9\text{V} \leq V_{CM} \leq +2.9\text{V}$	40	55		dB
Disable Output Resistance	$R_{OUT(OFF)}$	$V_{EN} = 0$ , $-3.5\text{V} \leq V_{OUT} \leq +3.5\text{V}$ , MAX4444		1.8		k $\Omega$
EN Logic Low Threshold	$V_{IL}$				0.8	V
EN Logic High Threshold	$V_{IH}$		2			V
EN Logic Input Low Current	$I_{IL}$	$V_{EN} = 0$		2.2	10	$\mu\text{A}$
EN Logic Input High Current	$I_{IH}$	$V_{EN} = 5\text{V}$		2.6	10	$\mu\text{A}$
Quiescent Current	$I_Q$	$V_{IN} = 0$ , $V_{EN} = 5\text{V}$		41	55	mA
		$V_{IN} = 0$ , $V_{EN} = 0$		3.5	5.5	

# Ultra-High Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

MAX4444/MAX4445

## AC ELECTRICAL CHARACTERISTICS

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ ,  $V_{EN} = 5V$ ,  $R_L = 100\Omega$ ,  $REF = GND$ ,  $A_{VCL} = +2V/V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITION	MIN	TYP	MAX	UNITS
Small-Signal -3dB Bandwidth	$BW_{SS}$	$V_{OUT} = 100mVp-p$		550		MHz
Large-Signal -3dB Bandwidth	$BW_{LS}$	$V_{OUT} = 2Vp-p$		500		MHz
0.1dB Gain Flatness		$V_{OUT} = 100mVp-p$		80		MHz
Slew Rate (Note 1)	SR	$V_{OUT} = 4V$ step	MAX4444	5000		V/ $\mu s$
			MAX4445	3800		
		$V_{OUT} = 2V$ step	MAX4444	2400		
			MAX4445	2000		
		$V_{OUT} = 1V$ step		1200		
$V_{OUT} = 0.5V$ step		600				
Rise Time (Note 1)	$t_{RISE}$			650		ps
Fall Time (Note 1)	$t_{FALL}$	$V_{OUT} = 4V$ step		825		ps
		$V_{OUT} = 2V$ step		700		
		$V_{OUT} = 1V$ step		700		
		$V_{OUT} = 0.5V$ step		700		
Settling Time		Settle to 0.1% , $V_{OUT} = 2V$ step		12		ns
SFDR		$V_{OUT} = 2Vp-p$	$f_C = 100kHz$	-65		dBc
			$f_C = 5MHz$	-60		
			$f_C = 20MHz$	-55		
			$f_C = 100MHz$	-35		
2nd-Harmonic Distortion		$V_{OUT} = 2Vp-p$	$f_C = 100kHz$	-65		dBc
			$f_C = 5MHz$	-62		
			$f_C = 20MHz$	-50		
			$f_C = 100MHz$	-35		
3rd-Harmonic Distortion		$V_{OUT} = 2Vp-p$	$f_C = 100kHz$	-90		dBc
			$f_C = 5MHz$	-72		
			$f_C = 20MHz$	-62		
			$f_C = 100MHz$	-55		
Differential Phase Error	DP	NTSC, $R_L = 150\Omega$		0.05		degrees
Differential Gain Error	DG	NTSC, $R_L = 150\Omega$		0.07		%
Input Noise Voltage Density	$e_N$	$f = 100kHz$ (Note 2)		25		$nV/\sqrt{Hz}$
Input Noise Current Density	$i_N$	$f = 100kHz$		1.8		$pA/\sqrt{Hz}$
Output Impedance	$Z_{OUT}$	$f = 10MHz$		0.7		$\Omega$
Enable Time	$t_{SHDN(ON)}$	$V_{IN} = 1V$ , $V_{OUT}$ settle to within 10%		80		ns
Disable Time	$t_{SHDN(OFF)}$	$V_{IN} = 1V$ , $V_{OUT}$ settle to within 10%		200		ns
Power-Up Time	$t_{ON}$	$V_{IN} = 1V$ , $V_{OUT}$ settle to within 10%		0.5		$\mu s$
Power-Down Time	$t_{OFF}$	$V_{IN} = 1V$ , $V_{OUT}$ settle to within 10%		0.3		$\mu s$

**Note 1:** Input step voltage has <100ps rise (fall) time. Measured at the output from 10% to 90% (90% to 10%) level.

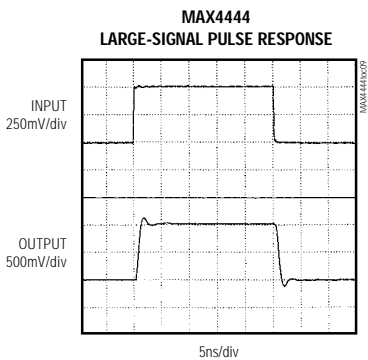
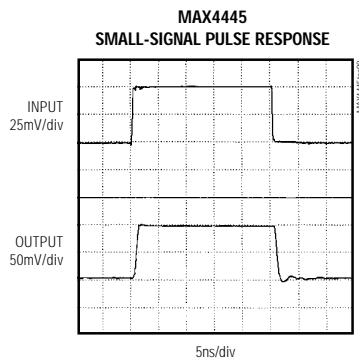
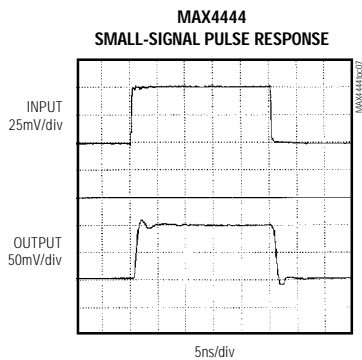
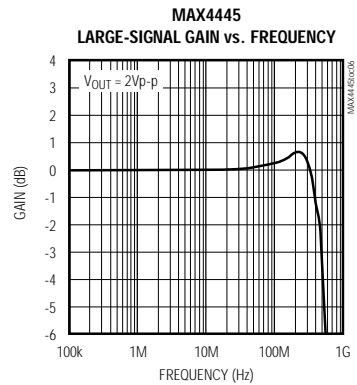
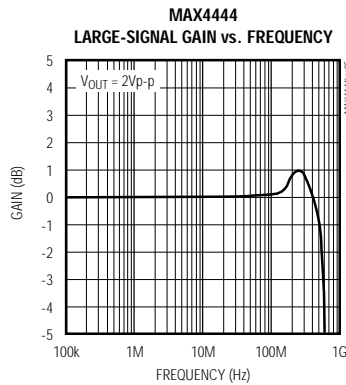
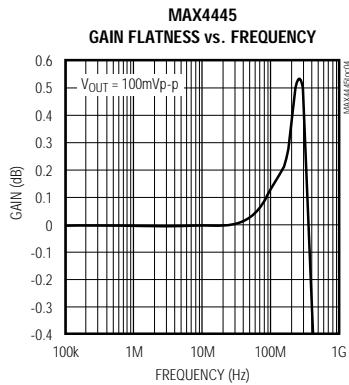
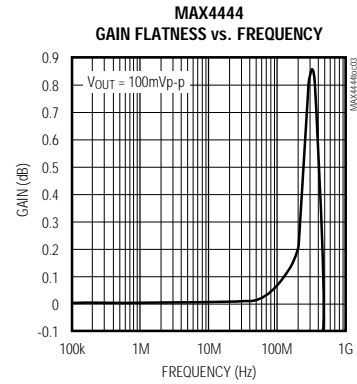
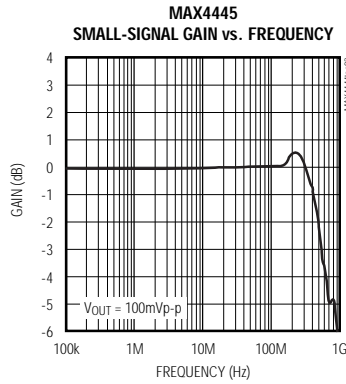
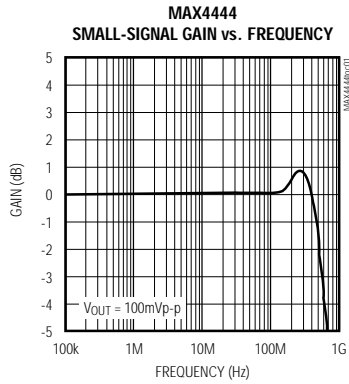
**Note 2:** Includes the current noise contribution through the on-die feedback resistor.

# Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

MAX4444/MAX4445

## Typical Operating Characteristics

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ ,  $V_{EN} = 5V$ ,  $V_{IN} = V_{IN+} - V_{IN-}$ ,  $R_L = 100\Omega$ ,  $REF = GND$ ,  $A_V = +2V/V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

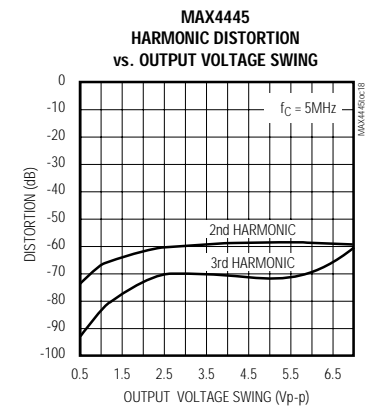
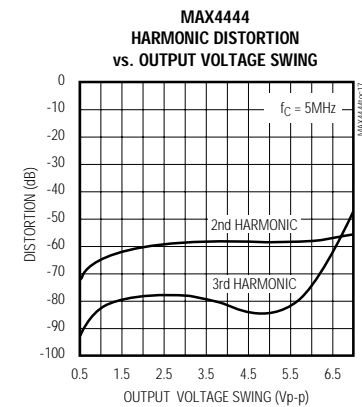
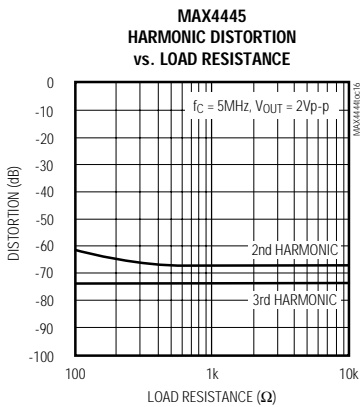
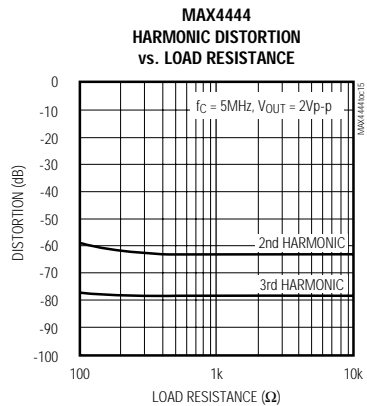
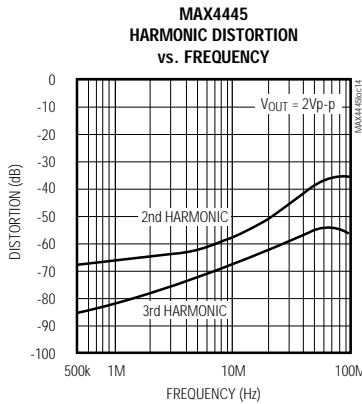
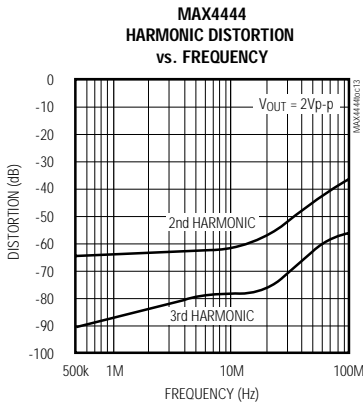
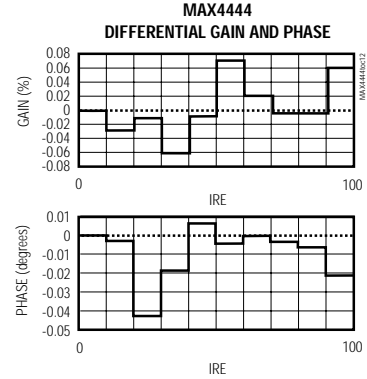
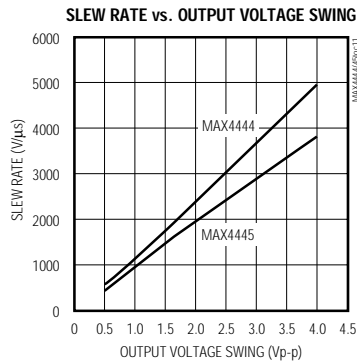
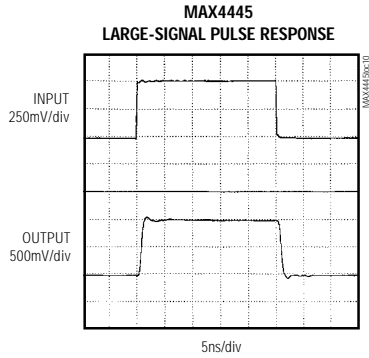


# Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

## Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ ,  $V_{EN} = 5V$ ,  $V_{IN} = V_{IN+} - V_{IN-}$ ,  $R_L = 100\Omega$ ,  $REF = GND$ ,  $A_V = +2V/V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

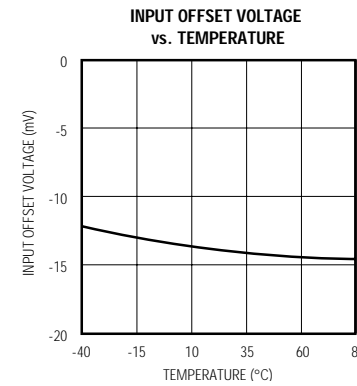
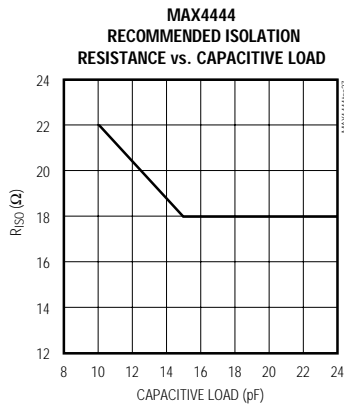
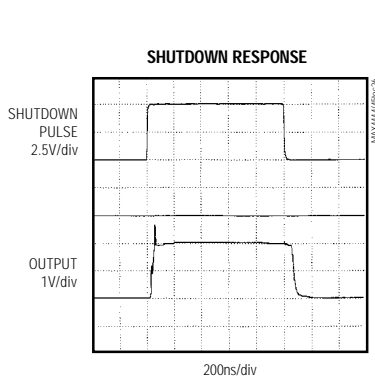
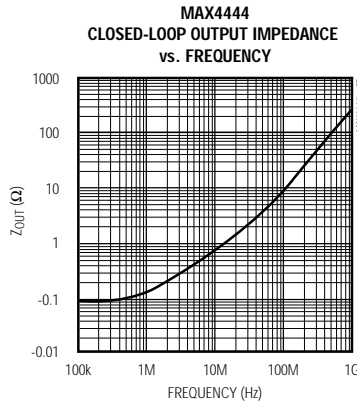
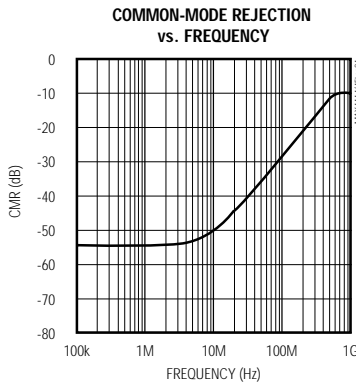
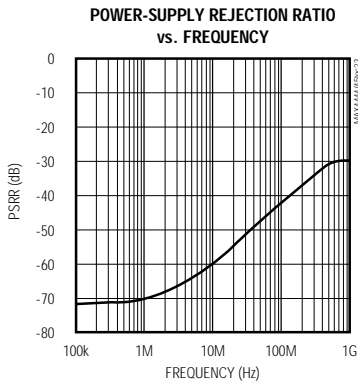
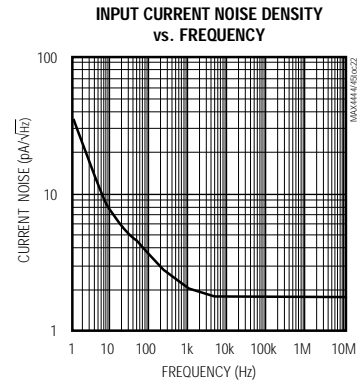
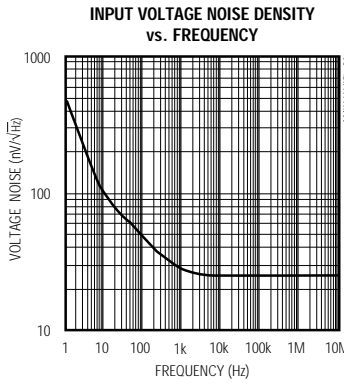
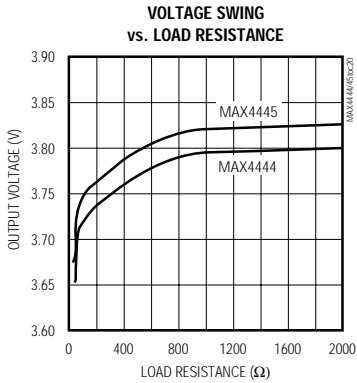
MAX4444/MAX4445



# Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

## Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ ,  $V_{EN} = 5V$ ,  $V_{IN} = V_{IN+} - V_{IN-}$ ,  $R_L = 100\Omega$ ,  $REF = GND$ ,  $A_V = +2V/V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

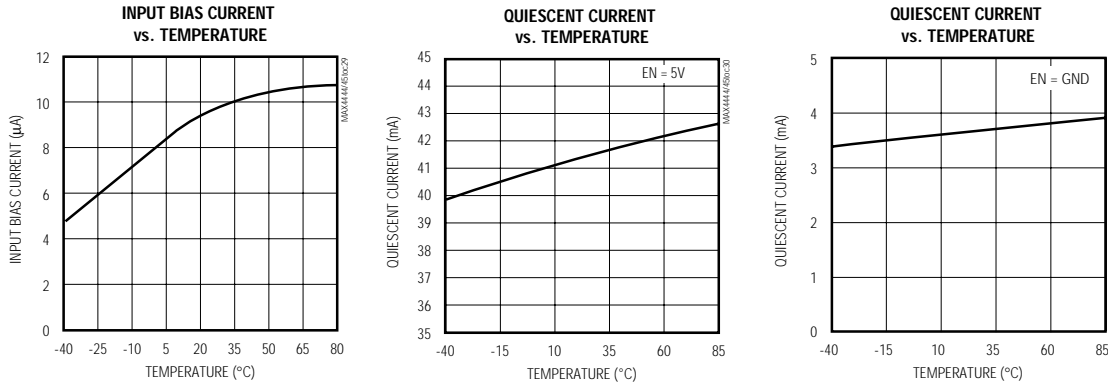


# Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

MAX4444/MAX4445

## Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ ,  $V_{EN} = 5V$ ,  $V_{IN} = V_{IN+} - V_{IN-}$ ,  $R_L = 100\Omega$ ,  $REF = GND$ ,  $A_V = +2V/V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

PIN		NAME	FUNCTION
MAX4444	MAX4445		
1, 2	1, 2	$V_{CC}$	Positive Power-Supply Input. Bypass with a $0.1\mu F$ capacitor to GND.
3	3	IN-	Inverting Amplifier Input
4, 5	—	N.C.	No Connection. Not internally connected. Connect to GND for best AC performance.
—	4, 5	RG	Resistor Gain Input. Connect a resistor between these pins to set closed-loop gain (Figure 1).
6	6	IN+	Noninverting Amplifier Input
7, 8, 11–14	7, 8, 11–14	$V_{EE}$	Negative Supply Input. Bypass with a $0.1\mu F$ capacitor.
9	9	EN	Active-High Enable Input. Connect to $V_{CC}$ for normal operation. Connect to GND for disable mode.
10	10	REF	Reference Input. Connect to midpoint of the two power supplies.
15	15	OUT	Amplifier Output
16	16	GND	Ground

## Ultra-High-Speed, Low-Distortion, Differential-to-Single-Ended Line Receivers with Enable

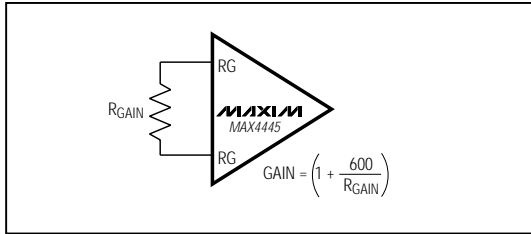


Figure 1. Setting the Amplifier Gain

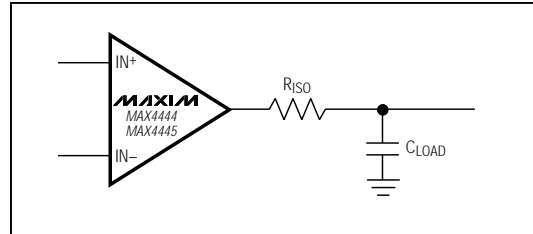


Figure 2. Using an Isolation Resistor for High Capacitive Loads

### Detailed Description

The MAX4444/MAX4445 differential-to-single-ended line receivers offer high-speed and low-distortion performance, and are ideally suited for video and RF signal-processing applications. These receivers offer a small-signal bandwidth of 550MHz and have a high slew rate of up to 5000V/μs. Their 120mA output capability allows them to be directly coupled to data acquisition systems.

### Applications Information

#### Grounding Bypassing

Use the following high-frequency design techniques when designing the PC board for the MAX4444/MAX4445.

- Use a multilayer board with one layer dedicated as the ground plane.
- Do not use wire wrap or breadboards due to high inductance.
- Avoid IC sockets due to high parasitic capacitance and inductance.
- Bypass supplies with a 0.1μF capacitor. Use surface-mount capacitors to minimize lead inductance.
- Keep signal lines as short and straight as possible. Do not make 90° turns. Use rounded corners. Do not cross signal paths if possible.
- Ensure that the ground plane is free from voids.

#### Low-Power Enable Mode

The MAX4444/MAX4445 are disabled when EN goes low. This reduces supply current to only 3.5mA. As the output becomes higher impedance, the effective impedance at the output for the MAX4444 is 1.8kΩ. The effective output impedance for the MAX4445 is 1.8kΩ plus RGAIN.

### Setting Gain (MAX4445)

The MAX4445 is stable with a minimum gain configuration of +2V/V. RGAIN, connected between the RG pins, sets the gain of this device as shown in Figure 1. Calculate the expected gain as follows:

$$\text{Gain} = (1 + 600 / \text{RGAIN})$$

### Driving Capacitive Loads

The MAX4444/MAX4445 are designed to drive capacitive loads. However, excessive capacitive loads may cause ringing or instability at the output as the phase margin of the device reduces. Adding a small series isolation resistor at the output helps reduce the ringing but slightly increases gain error (Figure 2). For recommended values, see *Typical Operating Characteristics*.

### Coaxial Line Driver

The MAX4444/MAX4445 are well suited to drive coaxial cables. Their high output current capability can easily drive the 75Ω characteristic impedance of common coaxial cables. Adjust the gain of the MAX4445 to compensate for cable losses to maintain the required levels at the input of the next stage.

### Chip Information

TRANSISTOR COUNT: 254

SUBSTRATE CONNECTED TO V<sub>EE</sub>

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.

8 Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600

© 1999 Maxim Integrated Products

Printed USA

MAXIM is a registered trademark of Maxim Integrated Products.