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# MAXIM

## 250MHz, Low-Power, High-Output-Current, Differential Line Driver

MAX4142

### General Description

The MAX4142 differential line driver combines high-speed performance with fully symmetrical differential inputs and outputs. With an internally set +2V/V closed-loop gain, the MAX4142 is ideal for driving back-terminated cables and transmission lines.

This device utilizes laser-trimmed thin-film resistors and common-mode cancellation circuitry to deliver an outstanding 67dB at 10MHz common-mode rejection (CMR). Using current-feedback techniques, the MAX4142 achieves a 250MHz -3dB ( $A_v = +2V/V$ ) bandwidth, a 70MHz 0.1dB bandwidth, and a 1400V/ $\mu$ s slew rate. Excellent differential gain/phase error and noise specifications make this amplifier an excellent choice for a wide variety of video and RF signal-processing applications.

The MAX4142 operates from  $\pm 5V$  power supplies and requires only 12.5mA of quiescent current. The output stage is capable of driving a 100 $\Omega$  load to  $\pm 6V$  (differentially) or to  $\pm 3V$  (single-ended). The MAX4142 is available in a space-saving 14-pin SO package. For a pin-compatible, higher speed differential line driver, see the MAX4147 data sheet.

### Applications

- Video Twisted-Pair Driver
- Differential Pulse Amplifier
- High-Speed Instrumentation Amplifier
- Low-Noise Differential Receivers
- Differential ADC Driver

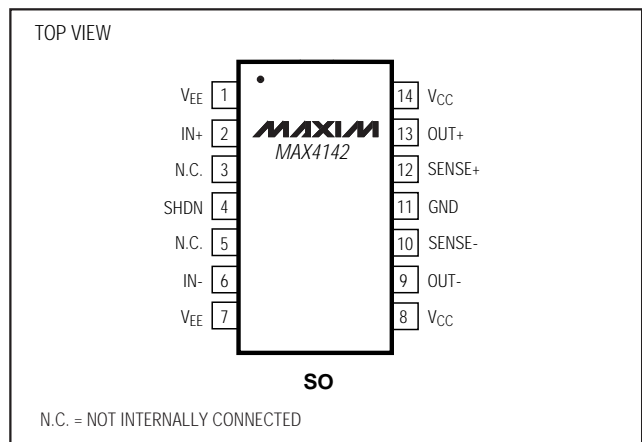
### Features

- ◆ 250MHz -3dB Bandwidth ( $A_v = +2V/V$ )
- ◆ 1400V/ $\mu$ s Slew Rate
- ◆ 67dB at 10MHz CMR
- ◆ 0.01%/0.01° Differential Gain/Phase
- ◆  $\pm 6V$  Differentially into 100 $\Omega$  Output Drive
- ◆ 1mA Shutdown Capability
- ◆ 12.5mA Quiescent Supply Current
- ◆ Available in 14-Pin Narrow SO Package

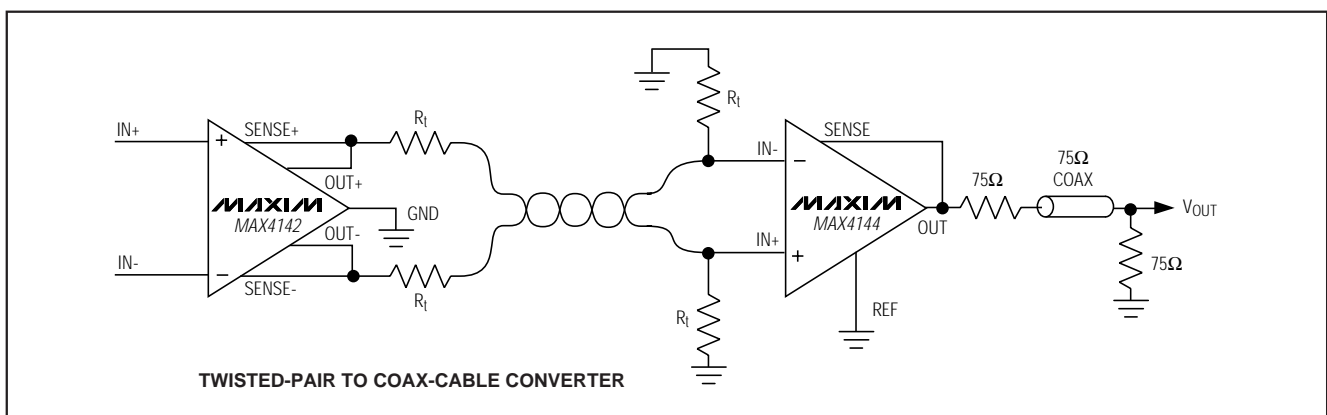
### Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX4142ESD	-40°C to +85°C	14 SO

### Pin Configuration



### Typical Application Circuit



MAXIM

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For small orders, phone 408-737-7600 ext. 3468.

# 250MHz, Low-Power, High-Output-Current, Differential Line Driver

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage ( $V_{CC}$  to  $V_{EE}$ ) ..... +12V  
 Voltage on Any Pin to Ground ..... ( $V_{EE} - 0.3V$ ) to ( $V_{CC} + 0.3V$ )  
 Input Current ( $I_{IN}$ ) .....  $\pm 10mA$   
 Short-Circuit Duration ( $V_{OUT}$  to GND) ..... 10sec  
 Continuous Power Dissipation ( $T_A = +70^\circ C$ )  
   Plastic SO (derate 8.3mW/ $^\circ C$  above  $+70^\circ C$ ) ..... 667mW

Operating Temperature Range .....  $-40^\circ C$  to  $+85^\circ C$   
 Storage Temperature Range .....  $-65^\circ C$  to  $+150^\circ C$   
 Lead Temperature (soldering, 10sec) .....  $+300^\circ C$

*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

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ , SHDN = 0,  $R_L = \infty$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values specified at  $T_A = +25^\circ C$ .)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage		Guaranteed by PSR test	$\pm 4.5$		$\pm 5.5$	V
Input Offset Voltage	$V_{OS}$	$V_{IN} = 0$		0.4	8	mV
Input Offset Voltage Drift	$TC_{VOS}$	$V_{IN} = 0$		3		$\mu V/^\circ C$
Input Bias Current	$I_B$	$V_{IN} = 0$		10	25	$\mu A$
Input Offset Current	$I_{OS}$	$V_{IN} = 0$		0.2	2.5	$\mu A$
Input Capacitance	$C_{IN}$			1		pF
Differential Input Resistance	$R_{IN}$			1		M $\Omega$
Differential Input Voltage Range		Guaranteed by output voltage swing test	-3.0		3.0	V
Common-Mode Input Voltage Range	$V_{CM}$	Guaranteed by CMR test	-1.7		1.7	V
Gain	$A_V$	$-1V \leq V_{OUT} \leq 1V$ , $R_L = 53\Omega$		2		V/V
Gain Error		$-1V \leq V_{OUT} \leq 1V$ , $R_L = 53\Omega$		0.3	2	%
Gain Drift		$R_L = 53\Omega$		20		ppm/ $^\circ C$
Common-Mode Rejection	CMR	$V_{CM} = \pm 1.7V$	55	80		dB
Power-Supply Rejection	PSR	$V_S = \pm 4.5V$ to $\pm 5.5V$	65	95		dB
Quiescent Supply Current	$I_{CC}$ , IEE	$V_{IN} = 0$		12.5	18	mA
Shutdown Supply Current	$I_{CC}$ , SHDN	$V_{SHDN} \geq 2V$ , $V_{IN} = 0$		1.0	2.0	mA
Output Voltage Swing	$ V_{OUT} $	Single-ended, $R_L = \infty$	3.0	3.4		V
		Differential, $R_L = \infty$	6.0	6.8		
		Single-ended, $R_L = 26.5\Omega$	2.0	2.4		
		Differential, $R_L = 53\Omega$	4.0	4.8		
Output Current Drive	$I_{OUT}$	$R_L = 20\Omega$	120	75		mA
Output Resistance	$R_{OUT}$			0.1		$\Omega$
SHDN Logic-High Threshold	$V_{IH}$				2.0	V
SHDN Logic-Low Threshold	$V_{IL}$		0.8			V
Enable Time from Shutdown	$t_{ON}$			500		ns
Disable Time to Shutdown	$t_{OFF}$			3.5		$\mu s$
SHDN Input Current	$I_{SHDN}$	$V_{SHDN} = 0$		66	150	$\mu A$

# 250MHz, Low-Power, High-Output-Current, Differential Line Driver

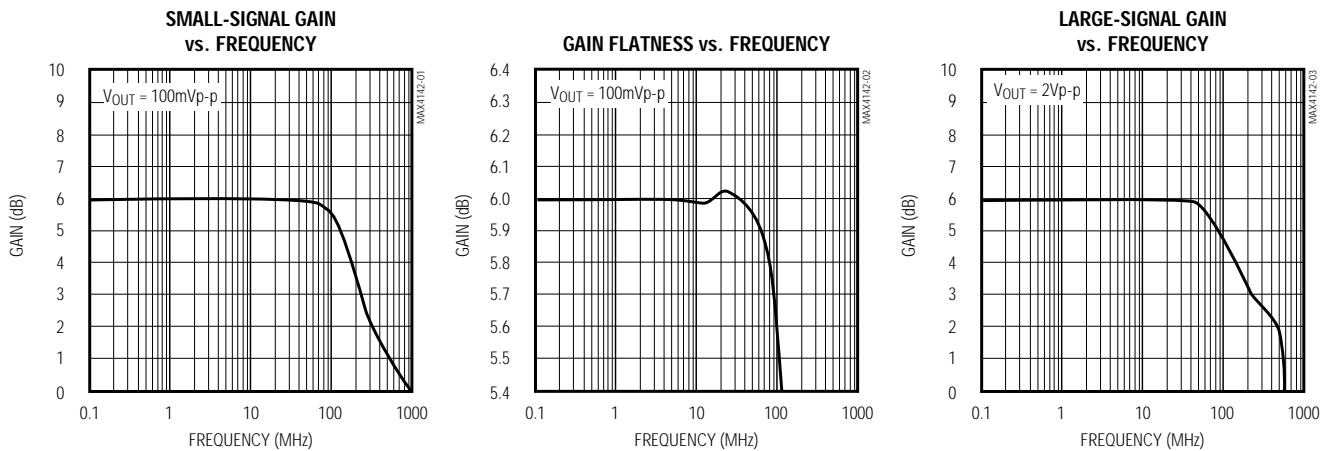
MAX4142

## AC ELECTRICAL CHARACTERISTICS

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
-3dB Bandwidth	BW(-3dB)	$V_{OUT} \leq 0.1V_{RMS}$		250		MHz
Full-Power Bandwidth	FPBW	$V_{OUT} = 2V_{p-p}$		180		MHz
0.1dB Bandwidth	BW(0.1dB)	$V_{OUT} \leq 0.1V_{RMS}$		70		MHz
Common-Mode Rejection	CMR	$f = 10MHz, V_{CM} = \pm 2V$		67		dB
Slew Rate	SR	Differential, $-2V \leq V_{OUT} \leq +2V$		1400		V/ $\mu s$
Settling Time	$t_S$	$-1V \leq V_{OUT} \leq +1V$		25		ns
				45		
Differential Gain	DG	$f = 3.58MHz$		0.01		%
Differential Phase	DP	$f = 3.58MHz$		0.01		degrees
Input Voltage Noise	$e_n$	$f = 10kHz$		8		$nV/\sqrt{Hz}$
		$f = 1MHz$ to $100MHz$		80		$\mu V_{RMS}$
Input Current Noise	$i_n$	$f = 10kHz$		2		$pA/\sqrt{Hz}$
		$f = 1MHz$ to $100MHz$		20		nARMS
Spurious-Free Dynamic Range	SFDR	$f_C = 500kHz, V_{OUT} = 1V_{p-p}, R_S = 50\Omega$ , Figure1		-84		dBc
		$f_C = 10MHz, V_{OUT} = 1V_{p-p}, R_S = 50\Omega$ , Figure1		-76		

## Typical Operating Characteristics

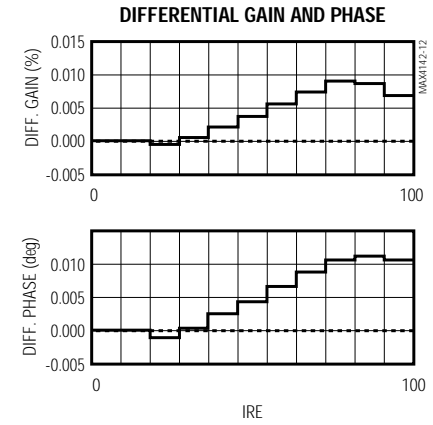
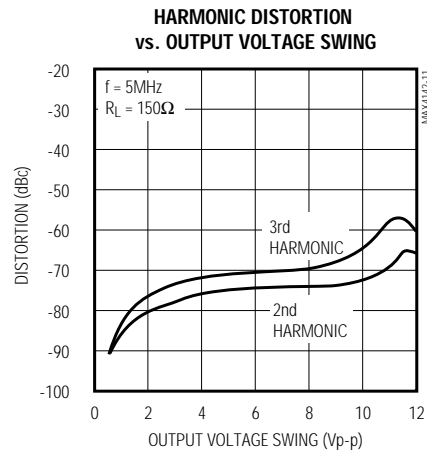
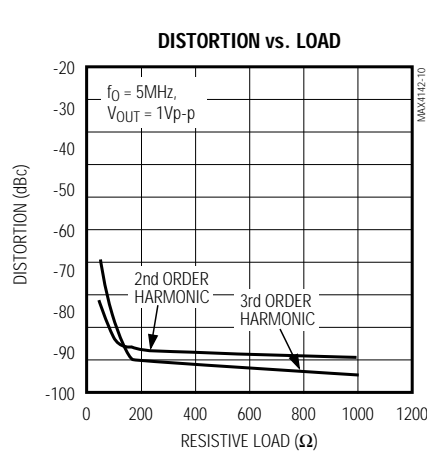
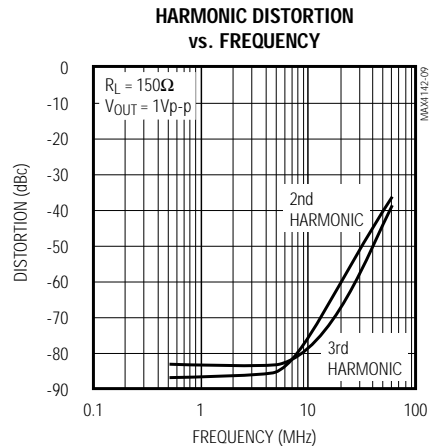
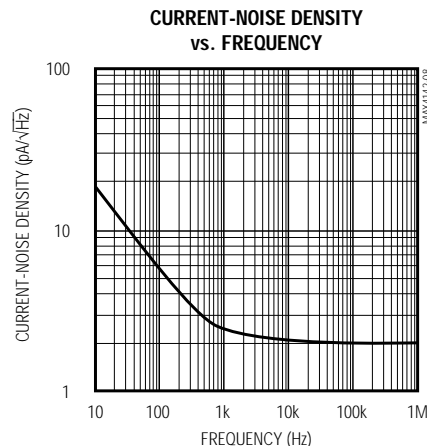
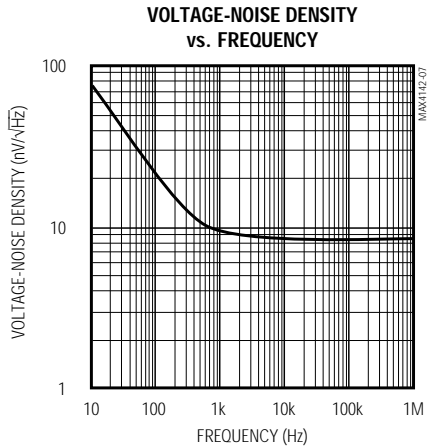
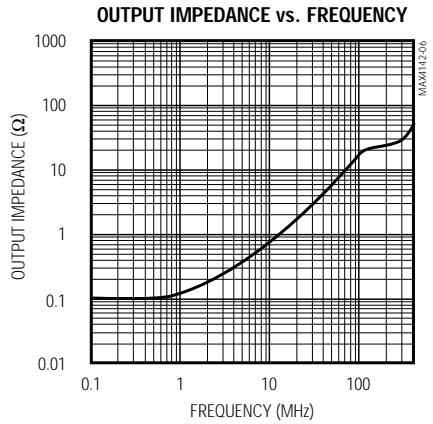
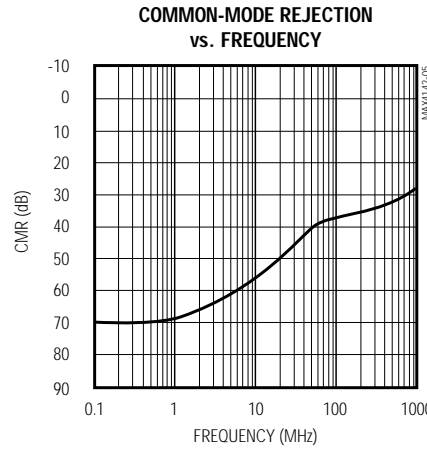
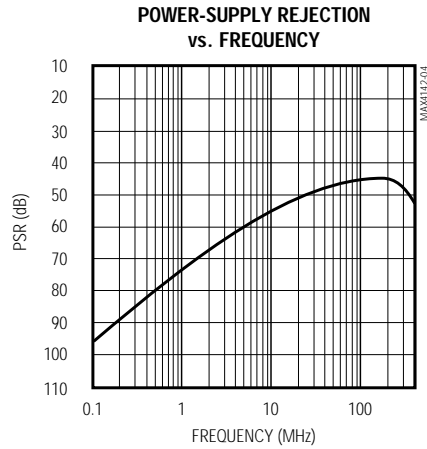
( $V_{CC} = +5V, V_{EE} = -5V, SHDN = 0, R_L = 150\Omega$  differential,  $T_A = +25^\circ C$ , unless otherwise noted.)



# 250MHz, Low-Power, High-Output-Current, Differential Line Driver

## Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ , SHDN = 0,  $R_L = 150\Omega$  differential,  $T_A = +25^\circ C$ , unless otherwise noted.)

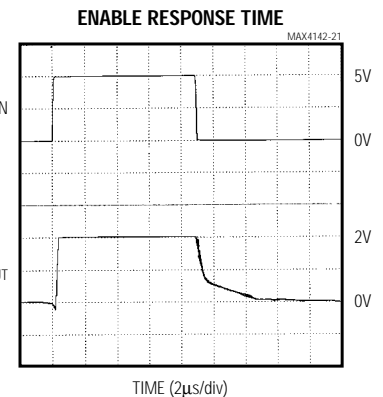
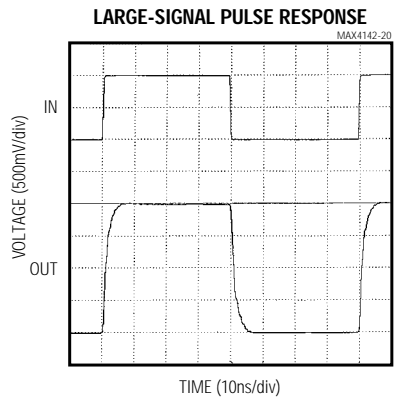
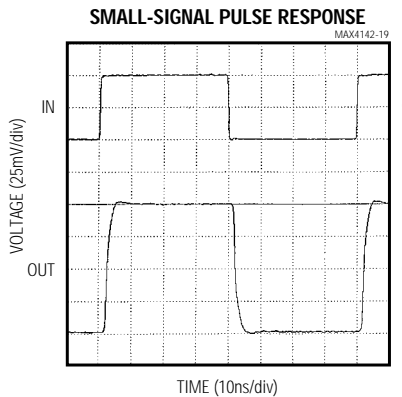
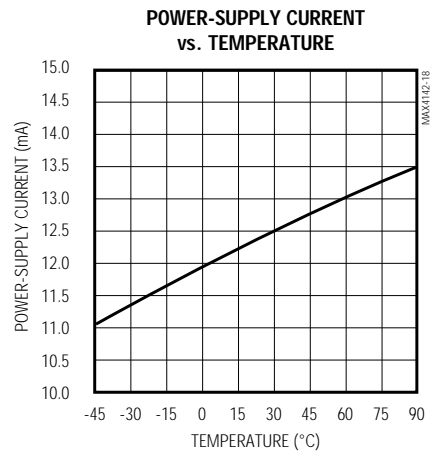
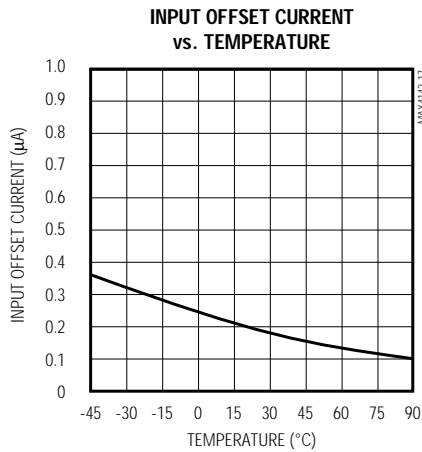
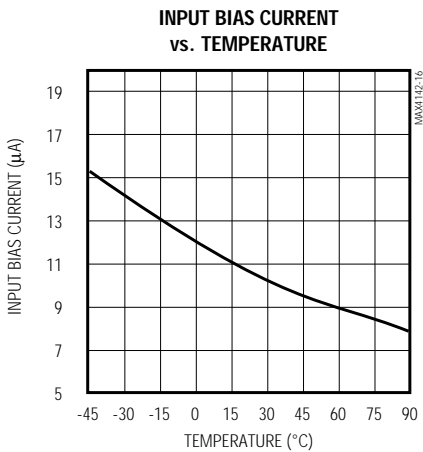
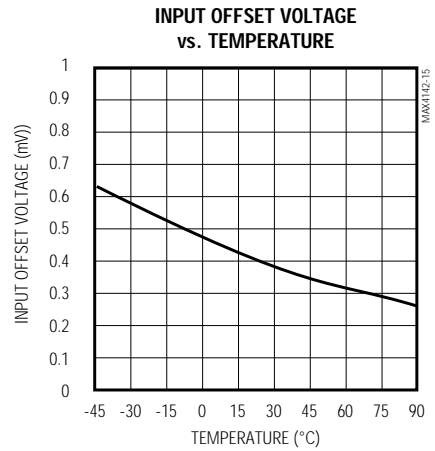
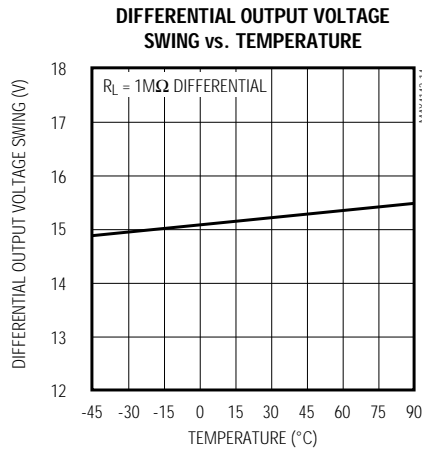
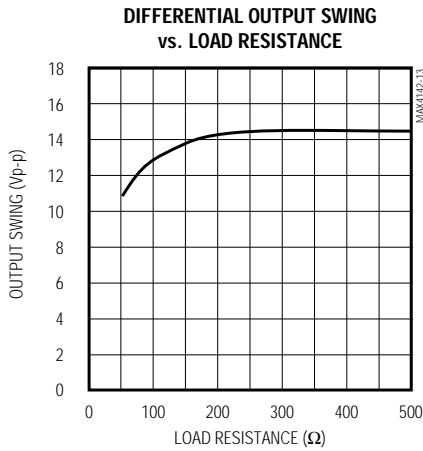


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## Typical Operating Characteristics (continued)

( $V_{CC} = +5V$ ,  $V_{EE} = -5V$ , SHDN = 0,  $R_L = 150\Omega$  differential,  $T_A = +25^\circ C$ , unless otherwise noted.)



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## Pin Description

PIN	NAME	FUNCTION
1, 7	VEE	Negative Power Supply. Connect VEE to -5V.
2	IN+	Noninverting Input
3, 5	N.C.	No Connect. Not internally connected.
4	SHDN	Logic Input for Shutdown Circuitry. A logic low enables the amplifier. A logic high disables the amplifier.
6	IN-	Inverting Input
8, 14	VCC	Positive Power Supply. Connect VCC to +5V.
9	OUT-	Inverting Output
10	SENSE-	Inverting Output Sense. Connect to OUT- close to the pin for normal operation.
11	GND	Ground
12	SENSE+	Noninverting Output Sense. Connect to OUT+ close to the pin for normal operation.
13	OUT+	Noninverting Output

## Detailed Description

The MAX4142 differential line driver features 250MHz bandwidth and 67dB common-mode rejection (CMR) at 10MHz. This part achieves a 1400V/μs slew rate, and power dissipation is only 125mW. The MAX4142 has an internally set +2V/V closed-loop gain, making it ideal as a back-terminated line driver. The output stage can drive ±6V into a 100Ω load.

The MAX4142 utilizes a three-amplifier topology to provide differential inputs/outputs and common-mode feedback (Figure 1), making it ideal for applications with high common-mode noise, such as for driving T1 or xDSL transmissions over a twisted-pair cable. The MAX4142's differential noninverting structure uses two noninverting amplifiers (A1 and A2) to provide a single device with differential inputs and outputs. The use of two amplifiers effectively doubles the output voltage swing and bandwidth, and improves slew rate when compared to the single op-amp differential amplifier. Excellent gain and phase, along with low noise, also make the MAX4142 suitable for video applications and RF-signal processing.

For a complete differential transmission link, use the MAX4142 line driver with the MAX4144/MAX4146 line receivers, as shown in the *Typical Application Circuit*.

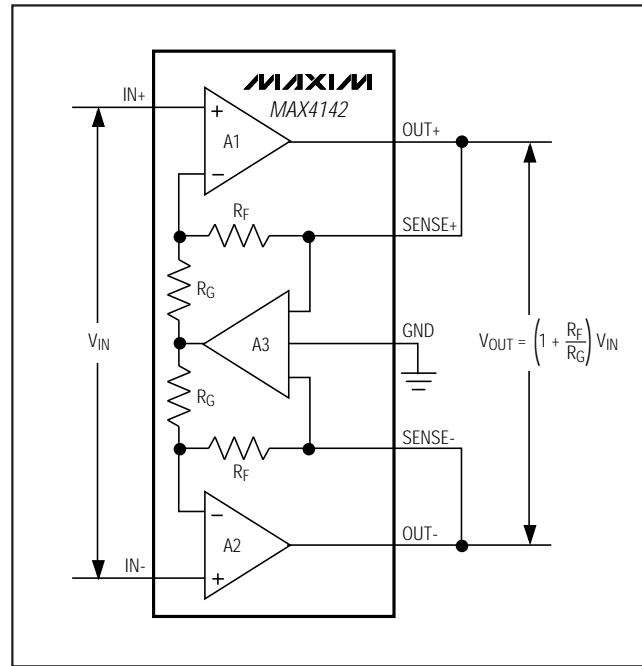


Figure 1. MAX4142 Functional Diagram

## Applications Information

### Balanced Transmission Lines

Differential (balanced) transmission lines use two conductors to transmit high-speed signals over low-cost cable or twisted-pair wire with minimal signal degradation. The transmit side of the balanced transmission line is driven by an amplifier with differential outputs, while the signal is received by an amplifier with differential inputs. In an ideal balanced system, each conductor has the same impedance from input to output and from the conductor to the system ground. Since the impedance from each conductor to ground is equivalent, any noise or other interference coupled into the transmission line will be equal in magnitude in each conductor, appearing as a common-mode signal to the amplifier at the receiving end of the transmission line. Since the receiving amplifier subtracts the signals on each side of the transmission line to obtain the desired information, common-mode signals are effectively canceled out by the receiving amplifier.

### Common-Mode Feedback

In nonideal balanced systems, impedance mismatches between the conductors of a transmission line can degrade system common-mode rejection (CMR) by converting a portion of any common-mode signal to a

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differential signal that is amplified by the receiver. The unique topology of the MAX4142 (Figure 1) utilizes two amplifiers (A1 and A2) to provide differential inputs and outputs, and a third amplifier (A3) to provide common-mode feedback. The common-mode feedback amplifier senses common-mode voltage at the MAX4142 output and forces this voltage to zero, effectively removing common-mode voltages from the transmission line. This technique improves CMR for systems with imperfectly balanced transmission-line impedances.

## Grounding, Bypassing, and PC Board Layout

Observe the following guidelines when designing your PC board:

- High-frequency design techniques must be followed when designing the PC board for the MAX4142.
- The printed circuit board should have at least two layers: the signal layer and the ground plane.
- Do not use wire-wrap boards; they are too inductive.
- Do not use IC sockets; they increase parasitic capacitance and inductance.
- Use surface-mount power-supply bypass capacitors instead of through-hole capacitors. Their shorter lead lengths reduce parasitic inductance, leading to superior high-frequency performance.
- Keep signal lines as short and as straight as possible. Do not make 90° turns; round all corners.
- The ground plane should be as free from voids as possible.

## Input Stage Circuitry

The MAX4142 includes internal protection circuitry that prevents damage to the precision input stage from large differential input voltages. This protection circuitry consists of five back-to-back Schottky protection diodes between IN+ and R<sub>G</sub>, and IN- and R<sub>G</sub> (Figure 2). The diodes limit the differential voltage applied to the amplifiers' internal circuitry to no more than 10V<sub>F</sub>, where V<sub>F</sub> is the diode's forward voltage drop (about 0.4V at +25°C).

For a large differential input voltage (exceeding 4V), the MAX4142 input bias current (at IN+ and IN-) increases according to the following equation:

$$\text{Input current} = [(V_{IN+} - V_{IN-}) - 10V_F] / 1.4k\Omega$$

A differential input voltage as high as 10V will cause only 2.1mA to flow—much less than the 10mA absolute maximum rating.

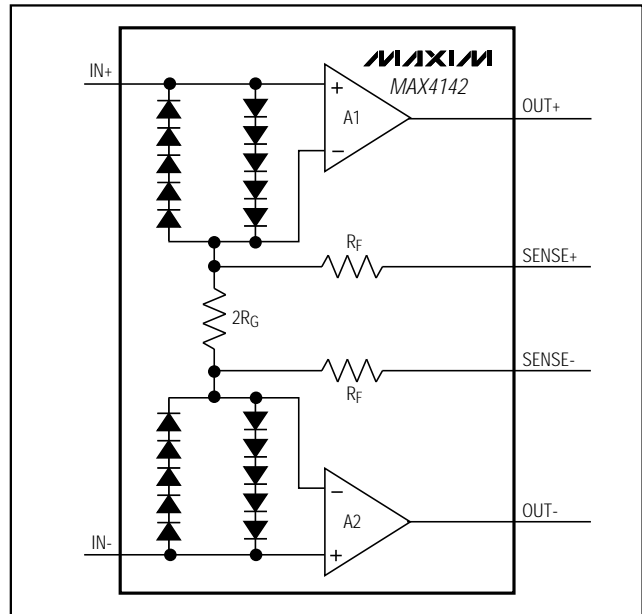


Figure 2. MAX4142 Input Protection Circuit

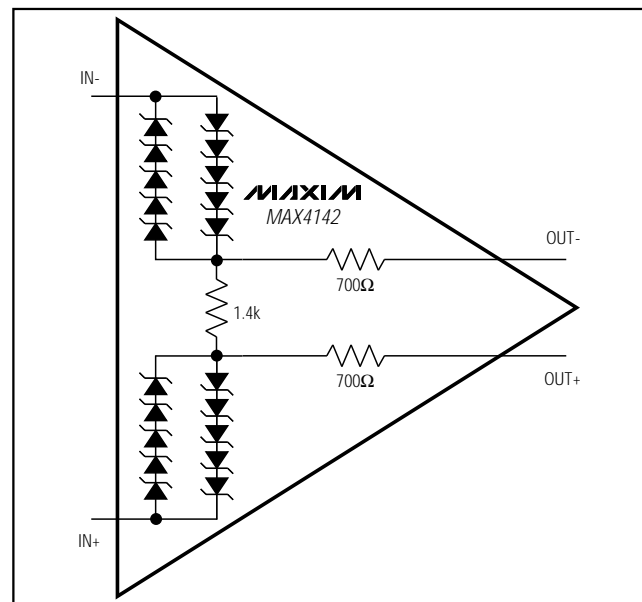


Figure 3. MAX4142 Shutdown Equivalent Circuit

## Shutdown Mode

The MAX4142 can be put into low-power shutdown mode by driving SHDN high. The amplifier output is high impedance in this mode; thus the impedance at OUT is that of the feedback resistors (2.8kΩ) (Figure 3).

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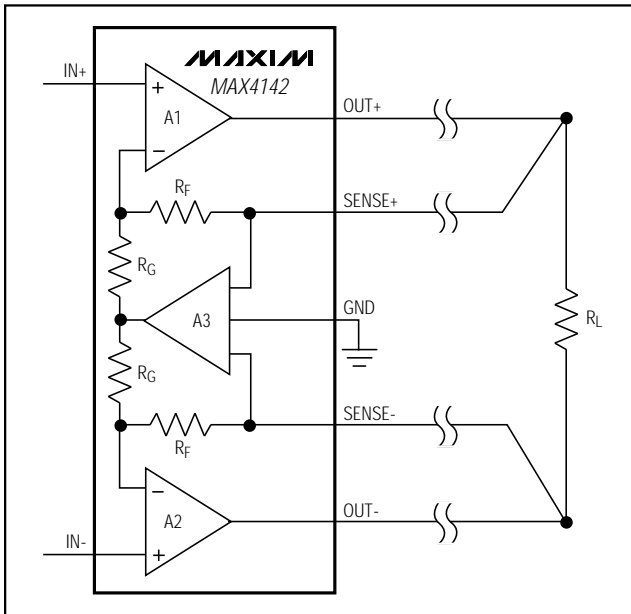


Figure 4. Connection of SENSE+ and SENSE- to a Remote Load

## Using SENSE+ and SENSE-

The MAX4142 has two output voltage-sense pins, SENSE+ and SENSE-. These pins are normally connected to the MAX4142'S OUT+ and OUT- pins. In some long-line applications, it may be desirable to connect SENSE+ to OUT+ and SENSE- to OUT- at the load, instead of the typical connection at the part (Figure 4). This compensates for the long line's resistance, which otherwise leads to an IR voltage error.

When using this technique, keep the sense lines' impedance low to minimize gain errors. Also, keep capacitance low to maximize frequency response. The gain of the MAX4142 is approximated by the following equation:

$$A_V = 1 + \left[ \frac{R_F + (\Delta R_{\text{SENSE}+}) + (\Delta R_{\text{SENSE}-})}{R_G} \right]$$

where  $\Delta R_{\text{SENSE}+}$  and  $\Delta R_{\text{SENSE}-}$  are the SENSE+ and SENSE- trace impedances, respectively. For the MAX4142,  $R_F$  is  $700\Omega$  and  $R_G$  is  $700\Omega$ .

Additionally, mismatches in the SENSE+ and SENSE- traces lead to common-mode gain errors. However, these errors are effectively eliminated by the MAX4142's common-mode feedback (see the *Common-Mode Feedback* section).

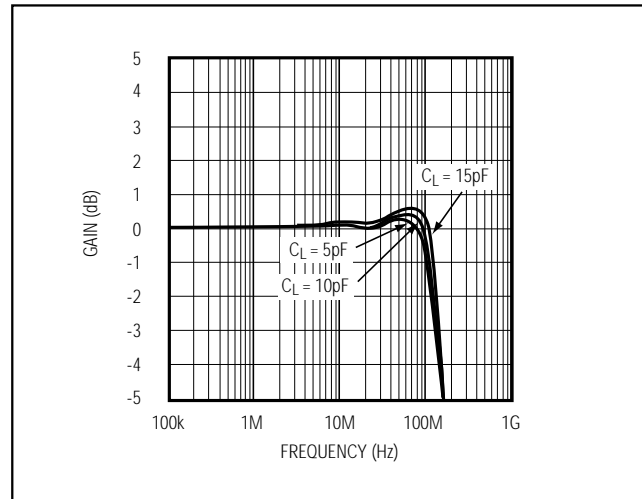


Figure 5. MAX4142 Small-Signal Response with Capacitive Load

## Driving Capacitive Loads

The MAX4142 provides maximum AC performance when driving no output load capacitance. This is the case when driving a correctly terminated transmission line (i.e., a back-terminated cable).

In most amplifier circuits, driving large-load capacitance increases the chance of oscillations. The amplifier's output impedance and the load capacitor combine to add a pole and excess phase to the loop response. If the pole's frequency is low enough and phase margin is degraded sufficiently, oscillations may occur. A second concern when driving capacitive loads results from the amplifier's output impedance, which looks inductive at high frequencies. The inductance forms an L-C resonant circuit with the capacitive load. This causes peaking in the frequency response and degrades the amplifier's phase margin.

The MAX4142 drives capacitive loads up to 25pF without oscillation. However, some peaking may occur in the frequency domain (Figure 5).

To drive larger-capacitance loads or to reduce ringing, add isolation resistors between the amplifier's outputs and the load (Figure 6).

The value of  $R_{\text{ISO}}$  depends on the capacitive load (Figure 7). With higher capacitive values, bandwidth is dominated by the RC network formed by  $R_{\text{ISO}}$  and  $C_L$ ; the bandwidth of the amplifier itself is much higher. Also note that the isolation resistor forms a divider that decreases the voltage delivered to the load.



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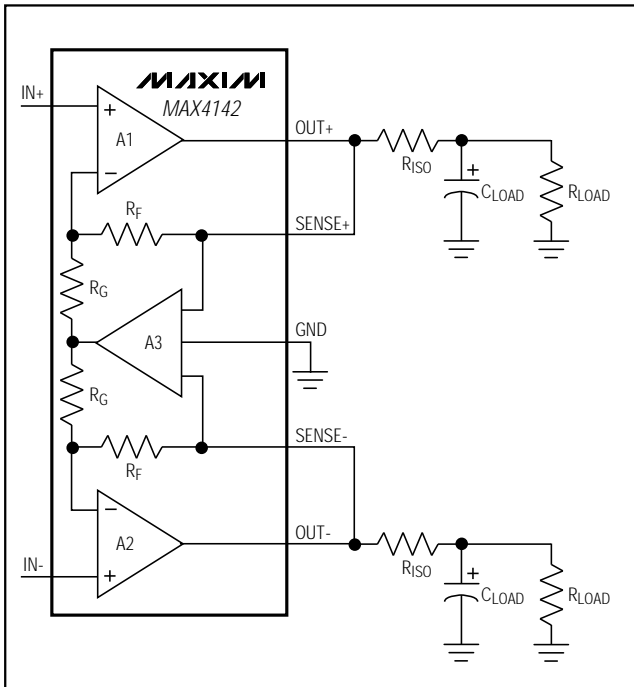


Figure 6. Addition of  $R_{ISO}$  to Amplifier Output

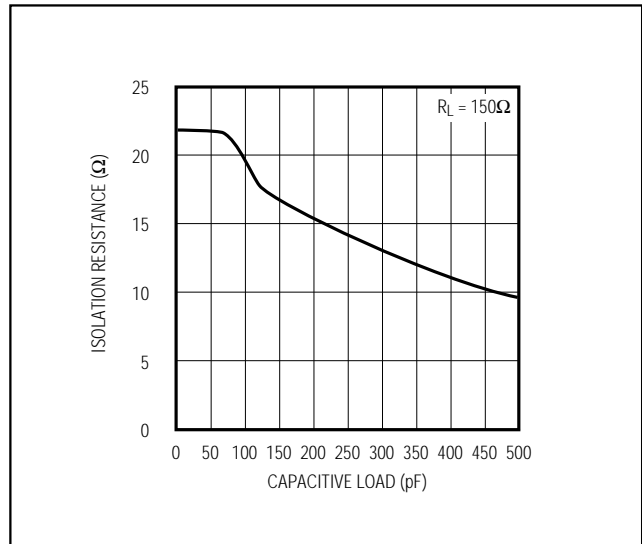


Figure 7. Isolation Resistance vs. Capacitive Load

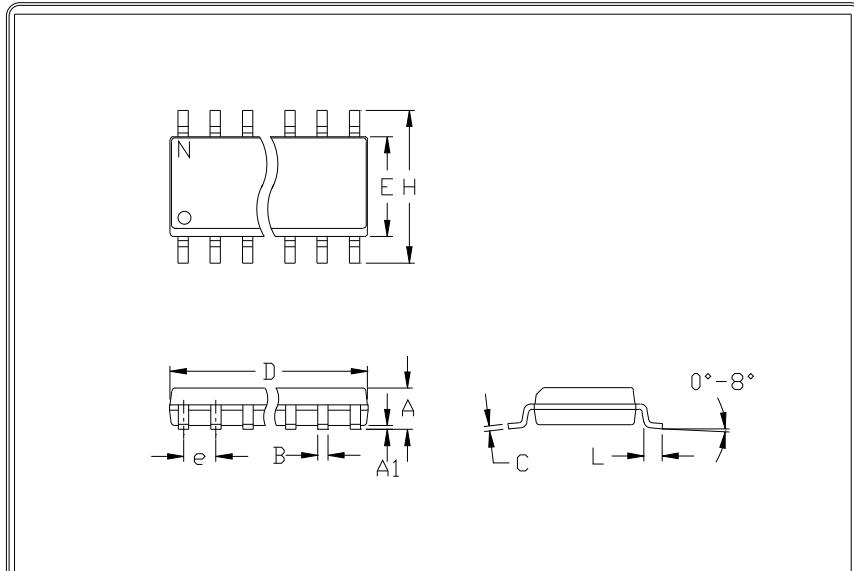
## Chip Information

TRANSISTOR COUNT: 243

SUBSTRATE CONNECTED TO VEE

# 250MHz, Low-Power, High-Output-Current, Differential Line Driver

## Package Information



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
e	0.050		1.27	
E	0.150	0.157	3.80	4.00
H	0.228	0.244	5.80	6.20
h	0.010	0.020	0.25	0.50
L	0.016	0.050	0.40	1.27

	INCHES		MILLIMETERS		N	MS012
	MIN	MAX	MIN	MAX		
D	0.189	0.197	4.80	5.00	8	A
D	0.337	0.344	8.55	8.75	14	B
D	0.386	0.394	9.80	10.00	16	C

- NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
  2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
  3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
  4. CONTROLLING DIMENSION: MILLIMETER
  5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
  6. N = NUMBER OF PINS



PACKAGE FAMILY OUTLINE: SOIC .150"



21-0041 A  
DOCUMENT CONTROL NUMBER REV

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## NOTES

MAX4142

# 250MHz, Low-Power, High-Output-Current, Differential Line Driver

## NOTES

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