19-4763; Rev 0; 7/98

EVALUATION KIT AVAILABLE

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

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/µs 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 ±5V power supplies and requires only 12.5mA of quiescent current. The output stage is capable of driving a 100Ω load to ±6V (differentially) or to ±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

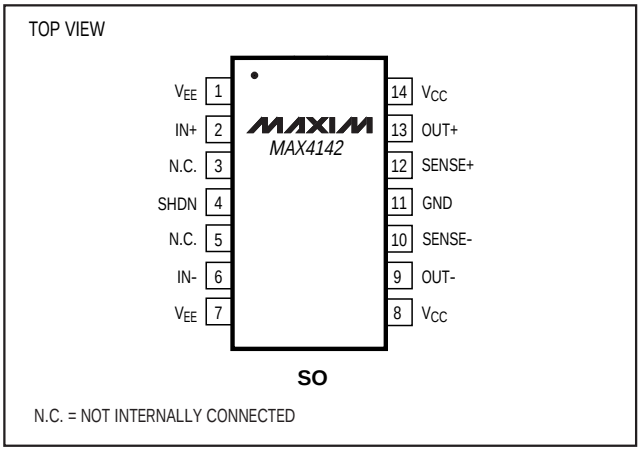
Features

- **250MHz -3dB Bandwidth (A_V = +2V/V)**
- **1400V/µs Slew Rate**
- **67dB at 10MHz CMR**
- **0.01%/0.01° Differential Gain/Phase**
- **±6V Differentially into 100Ω Output Drive**
- **1mA Shutdown Capability**
- **12.5mA Quiescent Supply Current**
- **Available in 14-Pin Narrow SO Package**

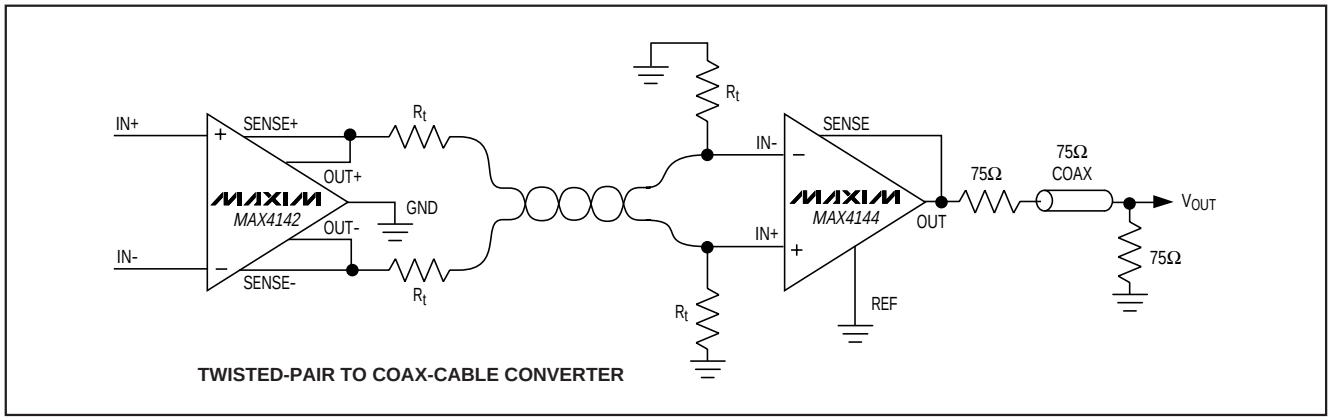
Ordering Information

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

Pin Configuration



Typical Application Circuit



TWISTED-PAIR TO COAX-CABLE CONVERTER

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 (IN_).....±10mA
Short-Circuit Duration (V_{OUT} to GND) 10sec
Continuous Power Dissipation (T_A = +70°C)
Plastic SO (derate 8.3mW/°C above +70°C) 667mW

Operating Temperature Range .....-40°C to +85°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10sec) .....+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_{CC} = +5V, V_{EE} = -5V, SHDN = 0, R_L = ∞, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values specified at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage		Guaranteed by PSR test	±4.5		±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		µV/°C
Input Bias Current	I_B	V_{IN} = 0		10	25	µA
Input Offset Current	I_{OS}	V_{IN} = 0		0.2	2.5	µA
Input Capacitance	C_{IN}			1		pF
Differential Input Resistance	R_{IN}			1		MΩ
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 ≤ V_{OUT} ≤ 1V, R_L = 53Ω		2		V/V
Gain Error		-1V ≤ V_{OUT} ≤ 1V, R_L = 53Ω		0.3	2	%
Gain Drift		R_L = 53Ω		20		ppm/°C
Common-Mode Rejection	CMR	V_{CM} = ±1.7V	55	80		dB
Power-Supply Rejection	PSR	V_S = ±4.5V to ±5.5V	65	95		dB
Quiescent Supply Current	I_{CC}, I_{EE}	V_{IN} = 0		12.5	18	mA
Shutdown Supply Current	$I_{CC, SHDN}$	V_{SHDN} ≥ 2V, V_{IN} = 0		1.0	2.0	mA
Output Voltage Swing	$\lvert V_{OUT} \rvert$	Single-ended, R_L = ∞	3.0	3.4		V
		Differential, R_L = ∞	6.0	6.8		
		Single-ended, R_L = 26.5Ω	2.0	2.4		
		Differential, R_L = 53Ω	4.0	4.8		
Output Current Drive	I_{OUT}	R_L = 20Ω	120	75		mA
Output Resistance	R_{OUT}			0.1		Ω
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		µs
SHDN Input Current	I_{SHDN}	V_{SHDN} = 0		66	150	µA

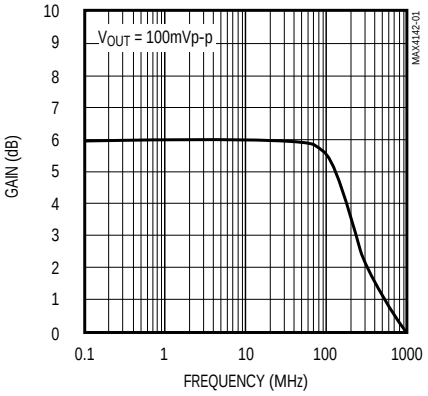
AC ELECTRICAL CHARACTERISTICS

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
-3dB Bandwidth	$BW_{(-3dB)}$	$V_{OUT} \le 0.1V_{RMS}$			250		MHz
Full-Power Bandwidth	FPBW	V_{OUT} = 2Vp-p			180		MHz
0.1dB Bandwidth	$BW_{(0.1dB)}$	$V_{OUT} \le 0.1V_{RMS}$			70		MHz
Common-Mode Rejection	CMR	f = 10MHz, V_{CM} = ±2V			67		dB
Slew Rate	SR	Differential, -2V ≤ V_{OUT} ≤ +2V			1400		V/µs
Settling Time	t_S	-1V ≤ V_{OUT} ≤ +1V	to 0.1%		25		ns
			to 0.01%		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		μV_{RMS}
Input Current Noise	i_n	f = 10kHz			2		$pA\sqrt{Hz}$
		f = 1MHz to 100MHz			20		nA_{RMS}
Spurious-Free Dynamic Range	SFDR	f_C = 500kHz, V_{OUT} = 1Vp-p, R_S = 50Ω, Figure1			-84		dBc
		f_C = 10MHz, V_{OUT} = 1Vp-p, R_S = 50Ω, Figure1			-76		

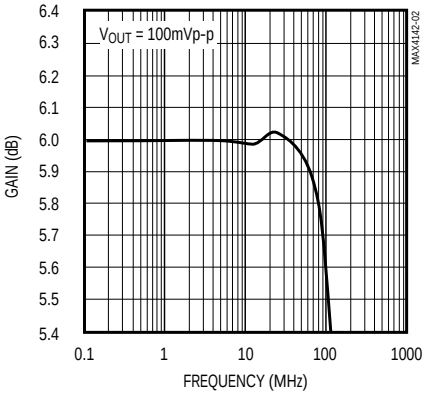
Typical Operating Characteristics

(V_{CC} = +5V, V_{EE} = -5V, SHDN = 0, R_L = 150Ω differential, T_A = +25°C, unless otherwise noted.)

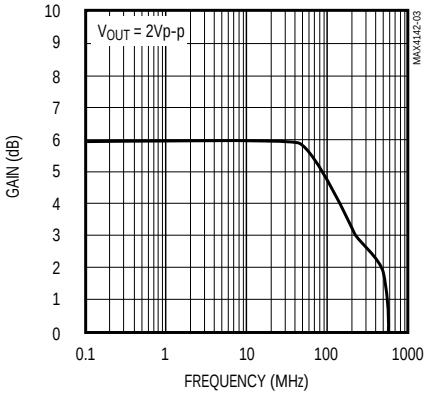
SMALL-SIGNAL GAIN vs. FREQUENCY



GAIN FLATNESS vs. FREQUENCY



LARGE-SIGNAL GAIN vs. FREQUENCY

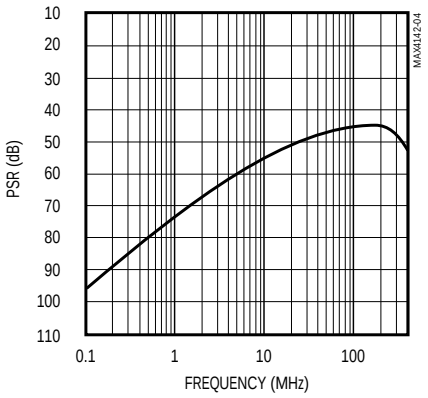


250MHz, Low-Power, High-Output-Current, Differential Line Driver

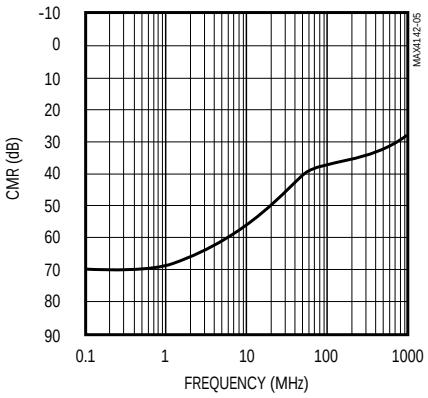
Typical Operating Characteristics (continued)

(V_{CC} = +5V, V_{EE} = -5V, SHDN = 0, R_L = 150Ω differential, T_A = +25°C, unless otherwise noted.)

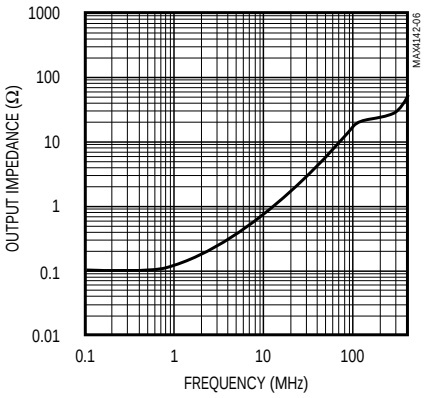
POWER-SUPPLY REJECTION vs. FREQUENCY



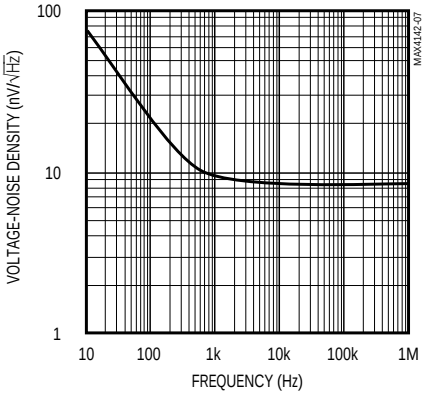
COMMON-MODE REJECTION vs. FREQUENCY



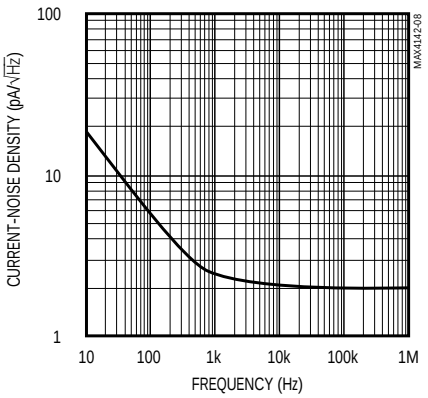
OUTPUT IMPEDANCE vs. FREQUENCY



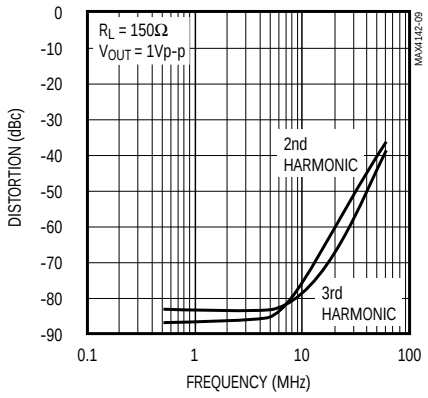
VOLTAGE-NOISE DENSITY vs. FREQUENCY



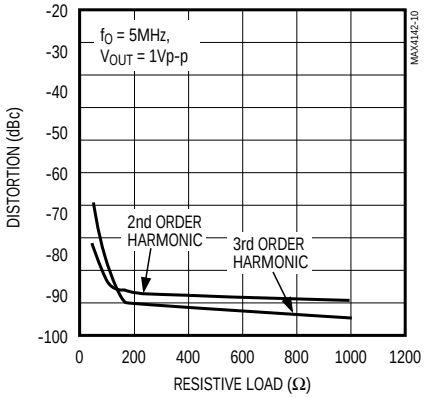
CURRENT-NOISE DENSITY vs. FREQUENCY



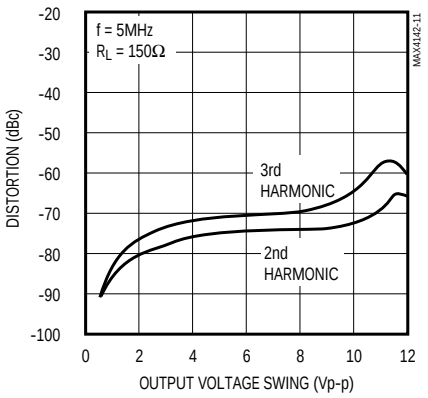
HARMONIC DISTORTION vs. FREQUENCY



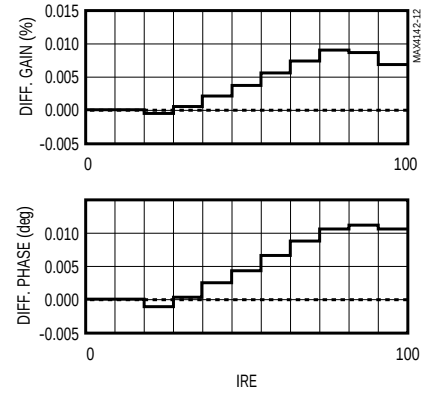
DISTORTION vs. LOAD



HARMONIC DISTORTION vs. OUTPUT VOLTAGE SWING



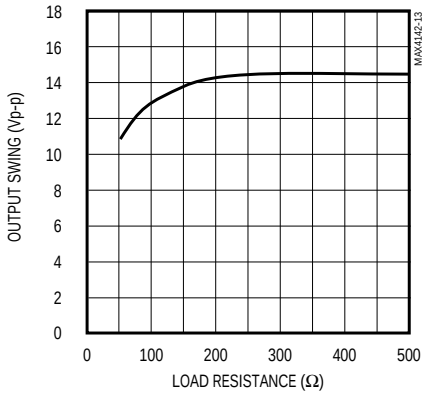
DIFFERENTIAL GAIN AND PHASE



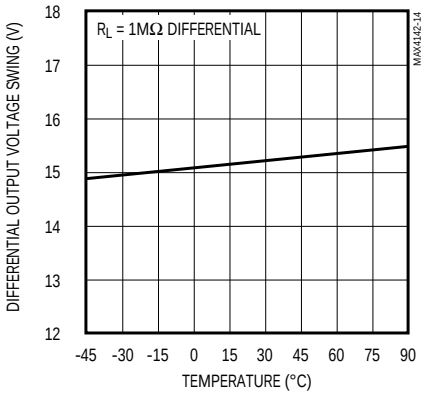
Typical Operating Characteristics (continued)

(V_{CC} = +5V, V_{EE} = -5V, SHDN = 0, R_L = 150Ω differential, T_A = +25°C, unless otherwise noted.)

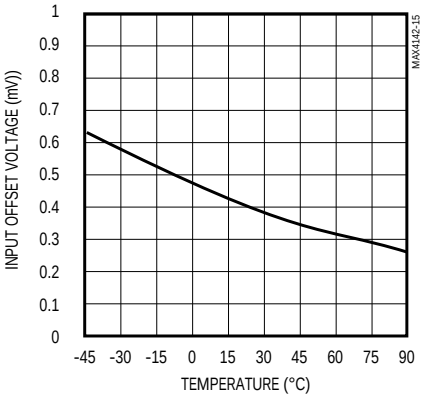
DIFFERENTIAL OUTPUT SWING vs. LOAD RESISTANCE



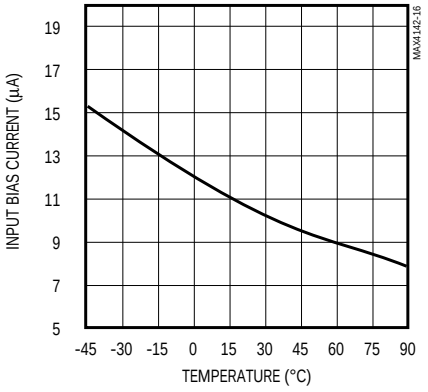
DIFFERENTIAL OUTPUT VOLTAGE SWING vs. TEMPERATURE



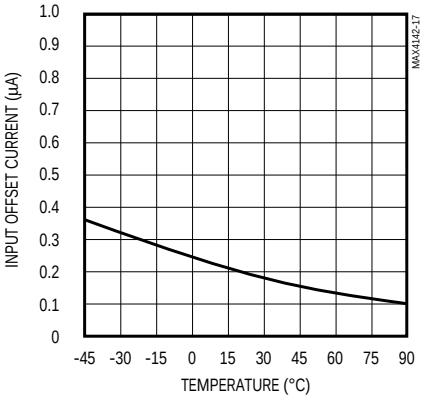
INPUT OFFSET VOLTAGE vs. TEMPERATURE



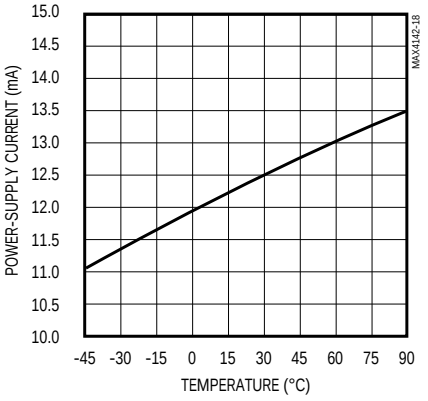
INPUT BIAS CURRENT vs. TEMPERATURE



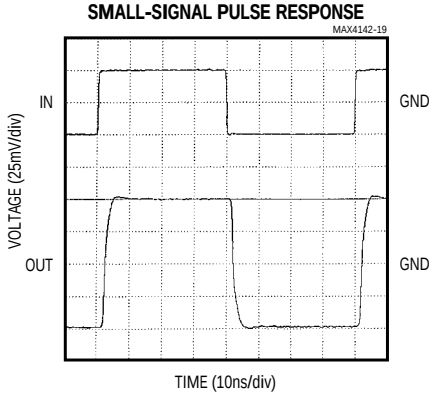
INPUT OFFSET CURRENT vs. TEMPERATURE



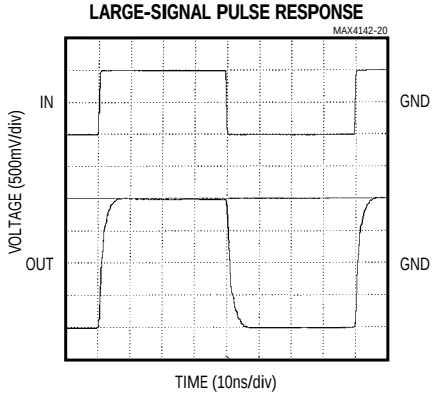
POWER-SUPPLY CURRENT vs. TEMPERATURE



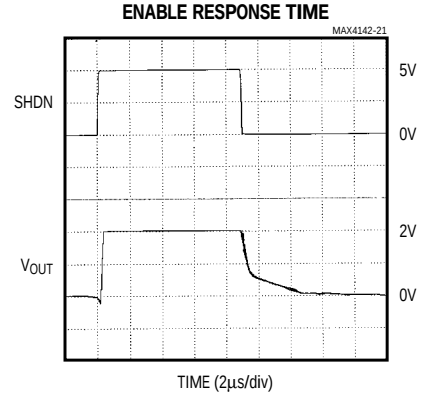
SMALL-SIGNAL PULSE RESPONSE



LARGE-SIGNAL PULSE RESPONSE



ENABLE RESPONSE TIME



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

Pin Description

PIN	NAME	FUNCTION
1, 7	V_{EE}	Negative Power Supply. Connect V_{EE} 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	V_{CC}	Positive Power Supply. Connect V_{CC} 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

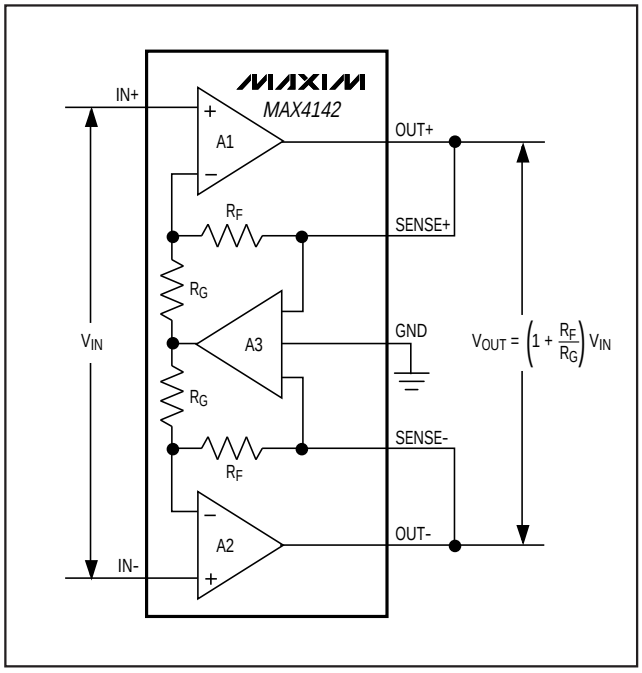


Figure 1. MAX4142 Functional Diagram

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.*

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

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_G, and IN- and R_G (Figure 2). The diodes limit the differential voltage applied to the amplifiers' internal circuitry to no more than $10V_F$, where V_F 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.

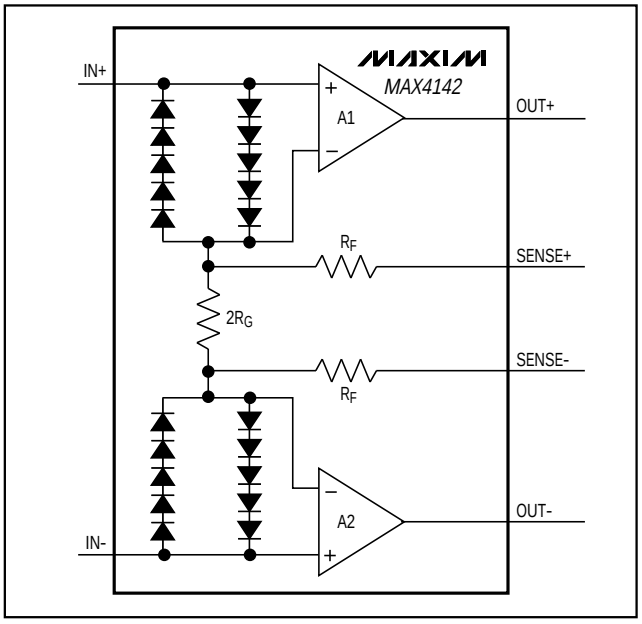


Figure 2. MAX4142 Input Protection Circuit

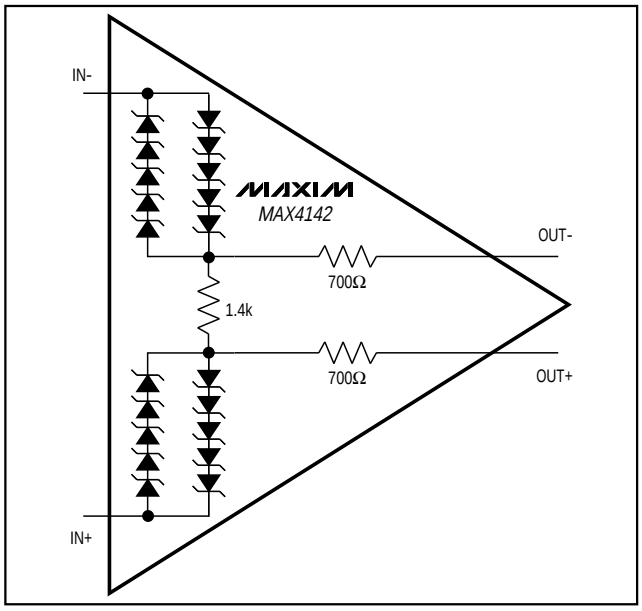


Figure 3. MAX4142 Shutdown Equivalent Circuit

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).

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

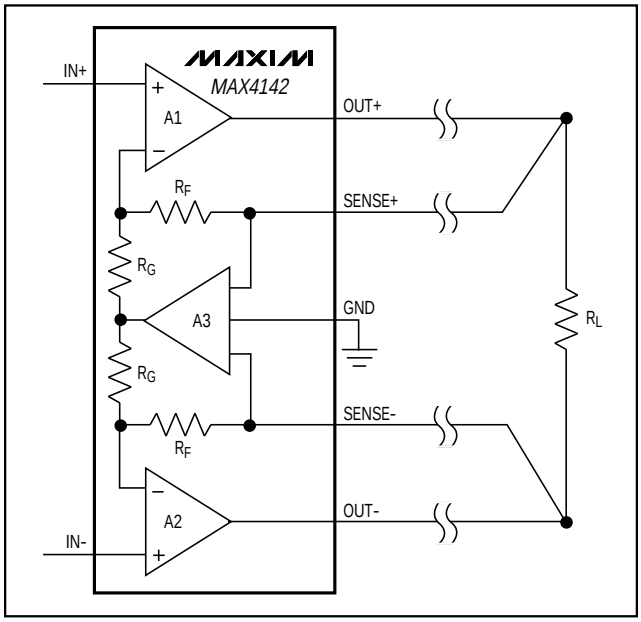


Figure 4. Connection of SENSE+ and SENSE- to a Remote Load

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:

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

where ΔR_{SENSE+} and ΔR_{SENSE-} are the SENSE+ and SENSE- trace impedances, respectively. For the MAX4142, R_F is 700Ω and R_G is 700Ω.

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).

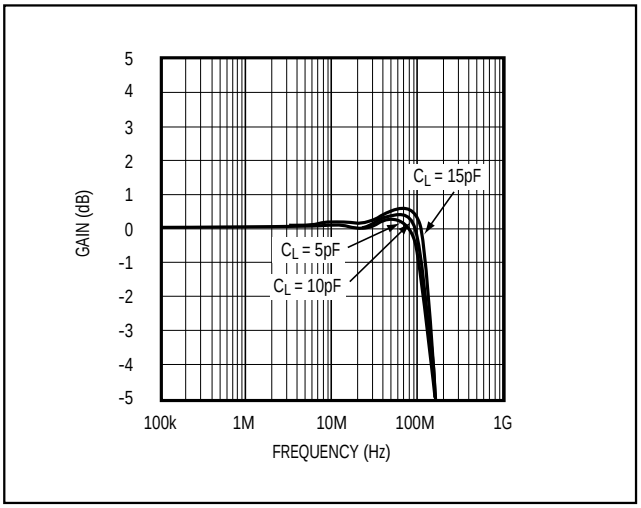


Figure 5. MAX4142 Small-Signal Response with Capacitive Load

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_{ISO} depends on the capacitive load (Figure 7). With higher capacitive values, bandwidth is dominated by the RC network formed by R_{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.

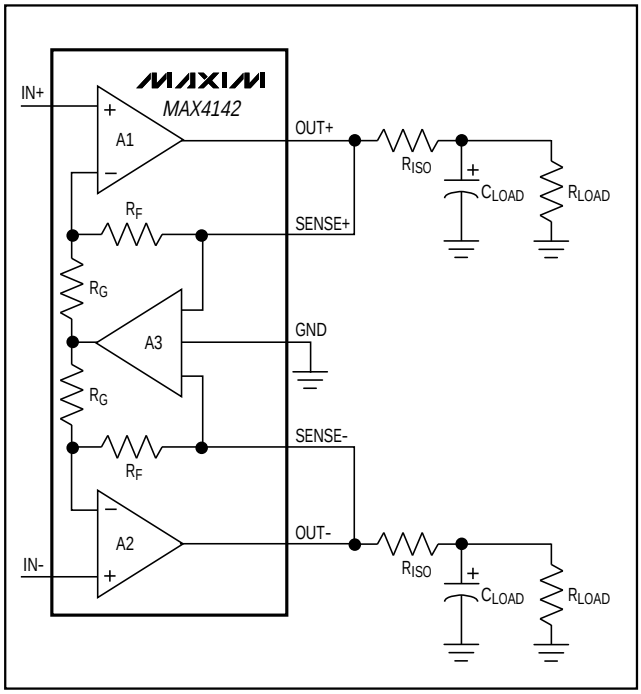


Figure 6. Addition of R_{ISO} to Amplifier Output

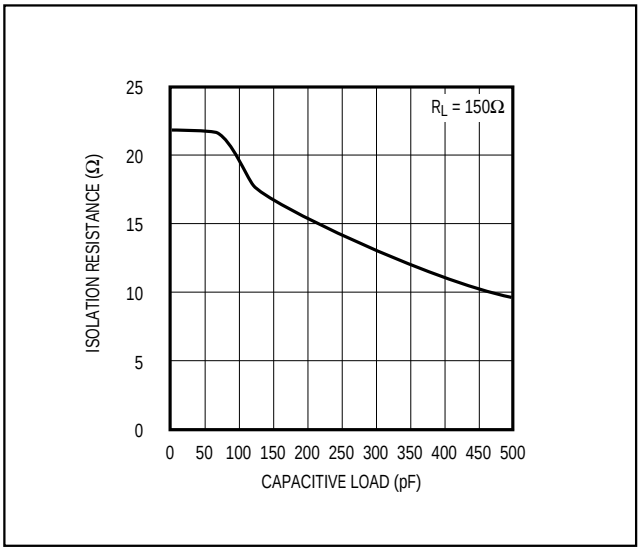


Figure 7. Isolation Resistance vs. Capacitive Load

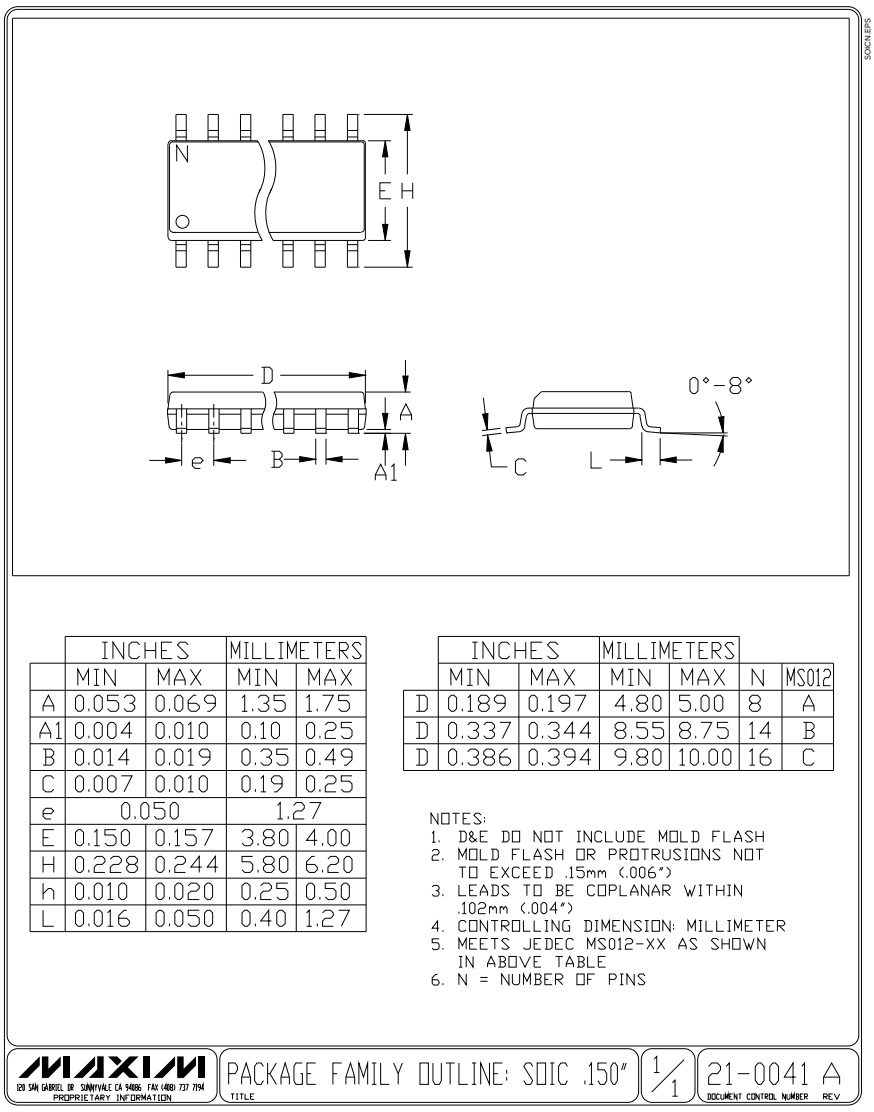
Chip Information

TRANSISTOR COUNT: 243

SUBSTRATE CONNECTED TO V_{EE}

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			
	MIN	MAX	MIN	MAX	N	MS012
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

MAXIM 120 SAN GABRIEL DR SUNNYVALE CA 94086 FAX (408) 737 7194 PROPRIETARY INFORMATION

PACKAGE FAMILY OUTLINE: SOIC .150" TITLE

1/1

21-0041 A DOCUMENT CONTROL NUMBER REV

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