19-0443; Rev 0; 9/95

500MHz, Low-Power, Current-Mode Feedback Amplifiers

General Description

The MAX4112/MAX4113 current-mode feedback amplifiers combine high-speed performance with low-power operation. The MAX4112 is optimized for closed-loop gains of 2V/V or greater, while the MAX4113 is optimized for gains of 8V/V or greater.

The MAX4112/MAX4113 require only 5mA of supply current and deliver bandwidths of 500MHz ($A_V \geq$ 2V/V) and 275MHz ($A_V \geq$ 8V/V), respectively. The high slew rates (1200V/µs and 1800V/µs) provide exceptional full-power bandwidths (300MHz and 250MHz), making these amplifiers ideal for high-performance pulse and RGB video applications.

These high-speed op amps have a wide output voltage swing of ±3.5V into 100Ω and a high current-drive capability of 80mA.

Features

- **500MHz -3dB Bandwidth (MAX4112)**
  275MHz -3dB Bandwidth (MAX4113)
- **0.1dB Gain Flatness to 30MHz (MAX4112)**
- **1200V/µs Slew Rate (MAX4112)**
  1800V/µs Slew Rate (MAX4113)
- **300MHz Full-Power Bandwidth (V_O = 2Vp-p, MAX4112)**
  250MHz Full-Power Bandwidth (V_O = 2Vp-p, MAX4113)
- **High Output Drive: 80mA**
- **Low Power: 5mA Supply Current**

Applications

Broadcast and High-Definition TV Systems

RGB Video

Pulse/RF Amplifier

Ultrasound

Active Filters

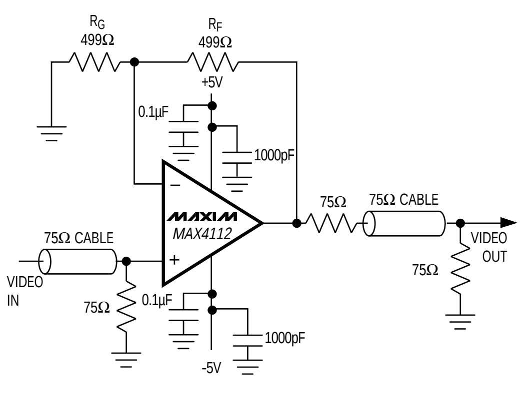
ADC Buffers

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX4112ESA	-40°C to +85°C	8 SO
MAX4112EUA	-40°C to +85°C	8 µMAX*
MAX4113ESA	-40°C to +85°C	8 SO

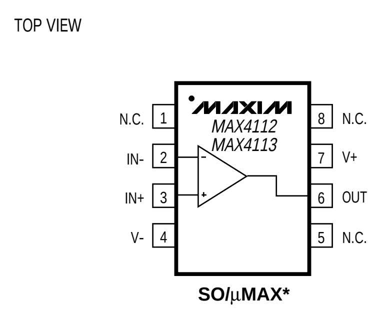
** Contact factory for µMAX package availability.*

Typical Application Circuit



VIDEO LINE DRIVER

Pin Configuration



** Contact factory for MAX4112 µMAX package availability.*

500MHz, Low-Power, Current-Mode Feedback Amplifiers

ABSOLUTE MAXIMUM RATINGS

Power Supply Voltage (V_{CC} to V_{EE})......................................12V
Voltage on Any Pin to Ground or Any Other Pin.........V_{CC} to V_{EE}
Short-Circuit Duration (V_{OUT} to GND)
V_{IN} < 1.5V ....Continuous
V_{IN} > 1.5V...0sec
Continuous Power Dissipation (T_A = +70°C)
SO (derate 5.88mW/C above +70°C) 471mW
µMAX (derate 4.10mW/C above +70°C).......................330mW
Operating Temperature Range
MAX4112E_A/MAX4113E_A.............................-40°C to +85°C
Storage Temperature Range.............................-65°C to +160°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.

ELECTRICAL CHARACTERISTICS

(V_{CC} = 5V, V_{EE} = -5V, T_A = T_{MIN} to T_{MAX}, typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
DC SPECIFICATIONS							
Input Offset Voltage	V_{OS}	V_{OUT} = 0V			1	8	mV
Input Offset Voltage Drift	TCV_{OS}	V_{OUT} = 0V			10		µV/°C
Positive Input Bias Current	I_{B+}	V_{OUT} = 0V, V_{IN} = $-V_{OS}$			3.5	20	µA
Negative Input Bias Current	I_{B-}	V_{OUT} = 0V, V_{IN} = $-V_{OS}$			3.5	20	µA
Input Resistance		IN+			500		kΩ
		IN-			30		Ω
Input Capacitance		IN+			2		pF
Input Voltage Noise	e_n	f = 10kHz			2.2		nV/√Hz
Integrated Voltage Noise	E_{nRMS}	f = 1MHz to 100MHz			27		$µV_{RMS}$
Positive Input Current Noise	i_{n+}	f = 10kHz	MAX4112		13		pA/√Hz
			MAX4113		9		
Negative Input Current Noise	i_{n-}	f = 10kHz			14		pA/√Hz
Common-Mode Input Voltage	V_{CM}			-2.5		2.5	V
Common-Mode Rejection	CMR	V_{CM} = ±2.5V		45	50		dB
Power-Supply Rejection	PSR	V_S = ±4.5V to ±5.5V		60	80		dB
Open-Loop Transimpedance	Z_{OL}	V_{OUT} = ±2.0V, V_{CM} = 0V, R_L = 100Ω		250	500		kΩ
Quiescent Supply Current	I_{SY}	V_{IN} = 0V			5	6.5	mA
Output Voltage Swing	V_{OUT}	R_L = ∞		±3.5	±3.8		V
		R_L = 100Ω		±3.1	±3.5		
Output Current Drive	I_{OUT}	R_L = 30Ω, T_A = 0°C to +85°C		65	80		mA

ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = 5V, V_{EE} = -5V, T_A = T_{MIN} to T_{MAX}, typical values are at T_A = +25°C, unless otherwise noted.)

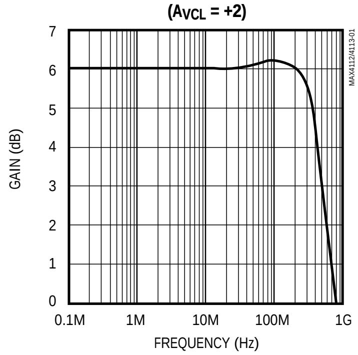
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
AC SPECIFICATIONS							
-3dB Bandwidth	BW_{-3dB}	$V_{OUT} \leq 0.1V_{RMS}$	MAX4112		500		MHz
			MAX4113		275		
0.1dB Bandwidth	$BW_{0.1dB}$	MAX4112, A_{VCL} = +2			30		MHz
		MAX4113, A_{VCL} = +8			90		
Full-Power Bandwidth	FPBW	V_O = 2Vp-p	MAX4112		300		MHz
			MAX4113		250		
Slew Rate	SR	$-2V \leq V_{OUT} \leq 2V$	MAX4112		1200		V/µs
			MAX4113		1800		
Settling Time	t_S	to 0.1%, $-1V \leq V_{OUT} \leq 1V$, R_L = 100Ω	MAX4112		15		ns
			MAX4113		10		
		to 0.01%, $-1V \leq V_{OUT} \leq 1V$, R_L = 100Ω	MAX4112		35		
			MAX4113		25		
Rise/Fall Times	t_R, t_F	10% to 90%, $-2V \leq V_{OUT} \leq 2V$, R_L = 100Ω			3		ns
		10% to 90%, $-50mV \leq V_{OUT} \leq 50mV$, R_L = 100Ω			0.8		
Differential Gain	DG	f = 3.58MHz	MAX4112, A_{VCL} = +2		0.02		%
			MAX4113, A_{VCL} = +8		0.02		
Differential Phase	DP	f = 3.58MHz	MAX4112, A_{VCL} = +2		0.03		degrees
			MAX4113, A_{VCL} = +8		0.04		
Input Capacitance	C_{IN}				2		pF
Output Impedance	Z_{OUT}	f = 10MHz, A_{VCL} = +2			0.9		Ω
Spurious-Free Dynamic Range	SFDR	f_C = 5MHz, V_{OUT} = 2Vp-p	MAX4112, A_{VCL} = +2		-68		dBc
			MAX4113, A_{VCL} = +8		-62		
Two-Tone Third-Order Intercept	IP3	f_C = 10MHz, A_{VCL} = +2			36		dB

500MHz, Low-Power, Current-Mode Feedback Amplifiers

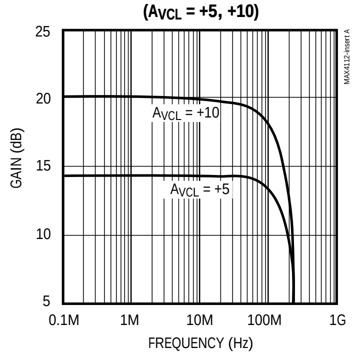
Typical Operating Characteristics

(V_{CC} = 5V, V_{EE} = -5V, R_F = 499Ω, R_L = 100Ω, T_A = +25°C, unless otherwise noted.)

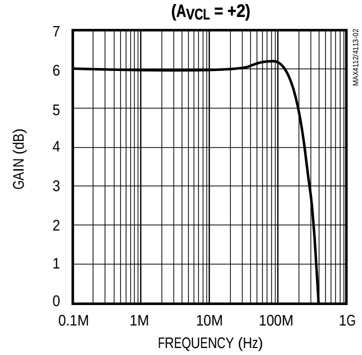
MAX4112
SMALL-SIGNAL GAIN vs. FREQUENCY
(A_{VCL} = +2)



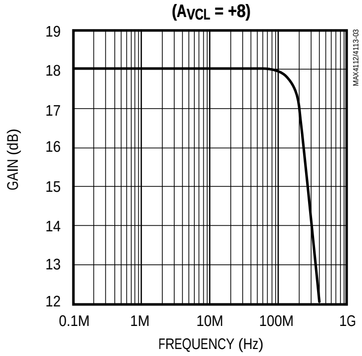
MAX4112
SMALL SIGNAL GAIN vs. FREQUENCY
(A_{VCL} = +5, +10)



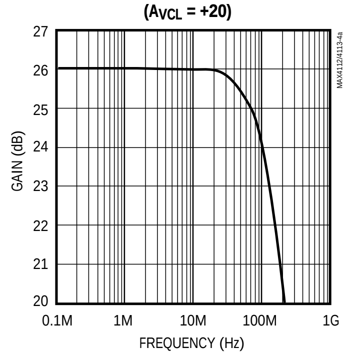
MAX4112
LARGE-SIGNAL GAIN vs. FREQUENCY
(A_{VCL} = +2)



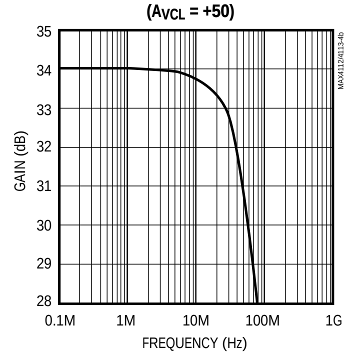
MAX4113
SMALL-SIGNAL GAIN vs. FREQUENCY
(A_{VCL} = +8)



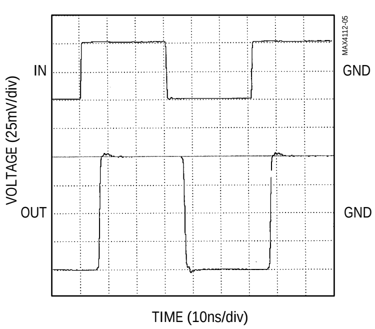
MAX4113
CLOSED-LOOP GAIN vs. FREQUENCY
(A_{VCL} = +20)



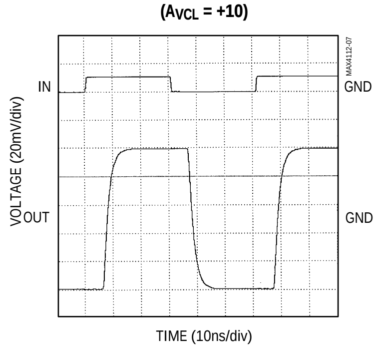
MAX4113
CLOSED-LOOP GAIN vs. FREQUENCY
(A_{VCL} = +50)



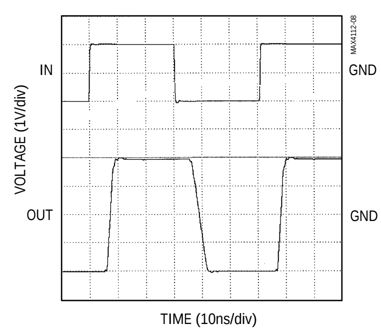
MAX4112
SMALL-SIGNAL PULSE RESPONSE
(A_{VCL} = +2)



MAX4112
SMALL-SIGNAL PULSE RESPONSE
(A_{VCL} = +10)



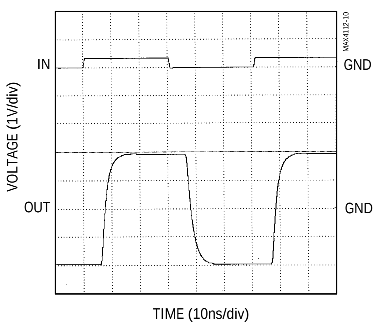
MAX4112
LARGE-SIGNAL PULSE RESPONSE
(A_{VCL} = +2)



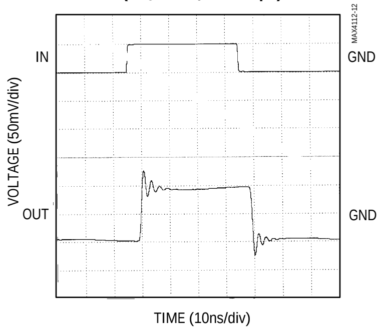
Typical Operating Characteristics (continued)

(V_{CC} = 5V, V_{EE} = -5V, R_F = 499Ω, R_L = 100Ω, T_A = +25°C, unless otherwise noted.)

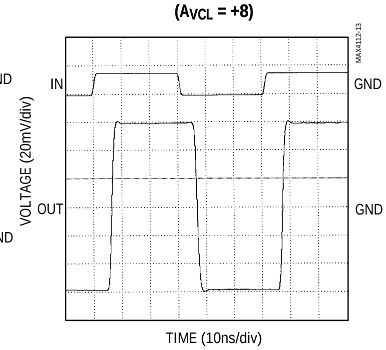
MAX4112
LARGE-SIGNAL PULSE RESPONSE
(A_{VCL} = +10)



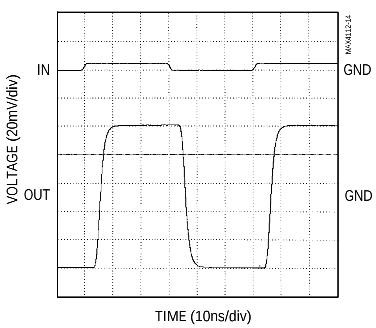
MAX4112
SMALL-SIGNAL PULSE RESPONSE
(A_{VCL} = +2, C_L = 10pF)



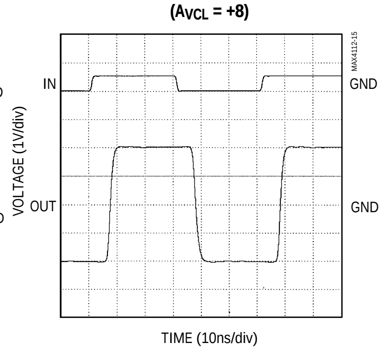
MAX4113
SMALL-SIGNAL PULSE RESPONSE
(A_{VCL} = +8)



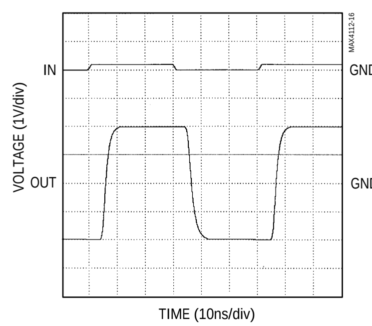
MAX4113
SMALL-SIGNAL PULSE RESPONSE
(A_{VCL} = +20)



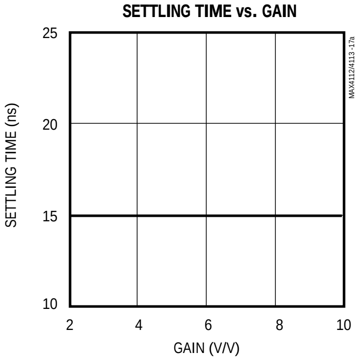
MAX4113
LARGE-SIGNAL PULSE RESPONSE
(A_{VCL} = +8)



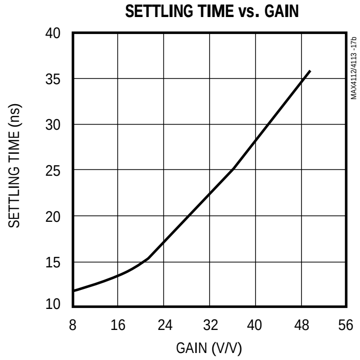
MAX4113
LARGE-SIGNAL PULSE RESPONSE
(A_{VCL} = +20)



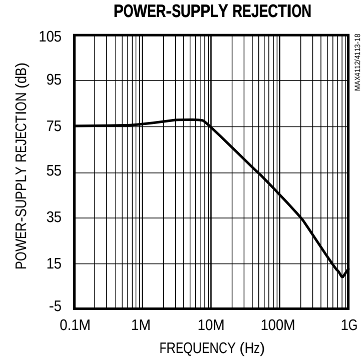
MAX4112
SETTLING TIME vs. GAIN



MAX4113
SETTLING TIME vs. GAIN



POWER-SUPPLY REJECTION

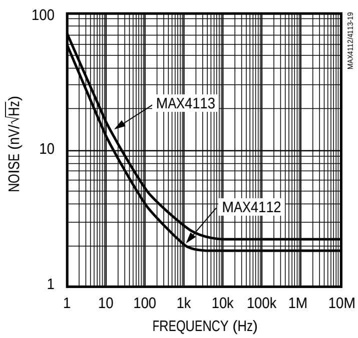


500MHz, Low-Power, Current-Mode Feedback Amplifiers

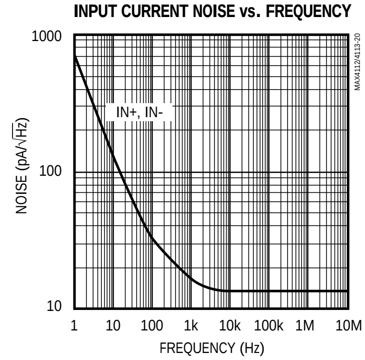
Typical Operating Characteristics (continued)

(V_{CC} = 5V, V_{EE} = -5V, R_F = 499Ω, R_L = 100Ω, T_A = +25°C, unless otherwise noted.)

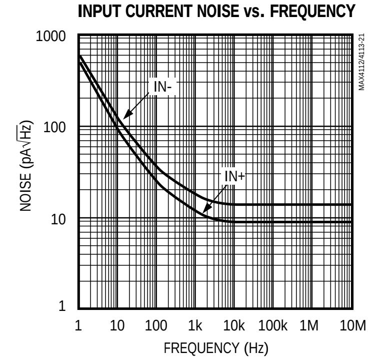
INPUT VOLTAGE NOISE vs. FREQUENCY



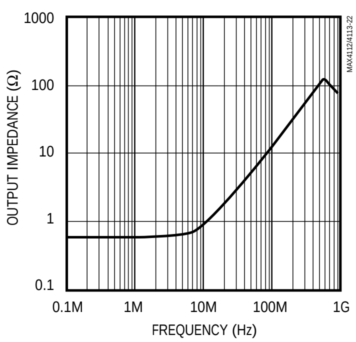
MAX4112 INPUT CURRENT NOISE vs. FREQUENCY



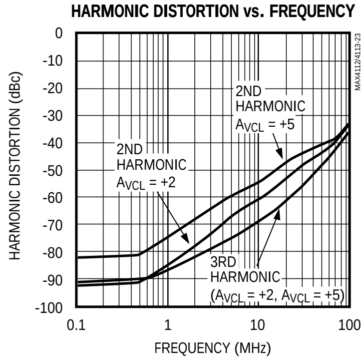
MAX4113 INPUT CURRENT NOISE vs. FREQUENCY



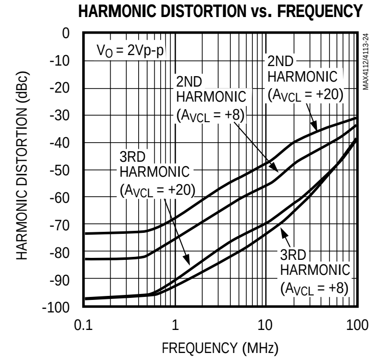
CLOSED-LOOP OUTPUT IMPEDANCE



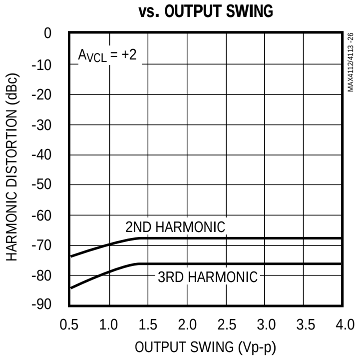
MAX4112 HARMONIC DISTORTION vs. FREQUENCY



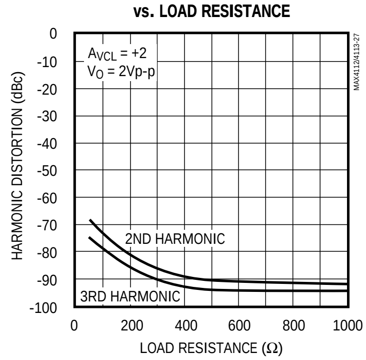
MAX4113 HARMONIC DISTORTION vs. FREQUENCY



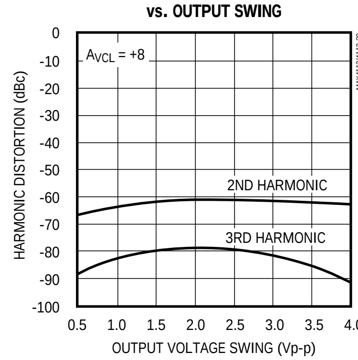
MAX4112 5MHz HARMONIC DISTORTION vs. OUTPUT SWING



MAX4112 5MHz HARMONIC DISTORTION vs. LOAD RESISTANCE



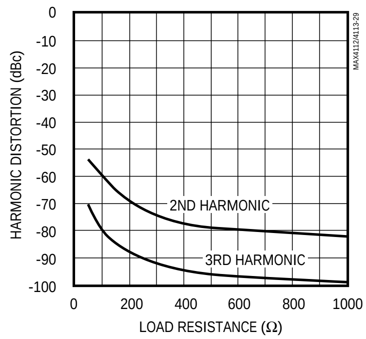
MAX4113 5MHz HARMONIC DISTORTION vs. OUTPUT SWING



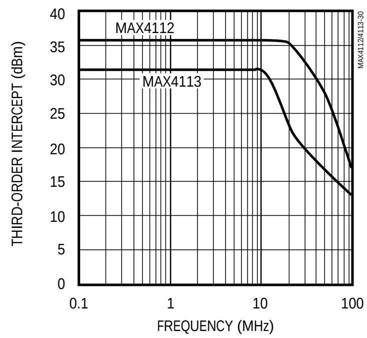
Typical Operating Characteristics (continued)

(V_{CC} = 5V, V_{EE} = -5V, R_F = 499Ω, R_L = 100Ω, T_A = +25°C, unless otherwise noted.)

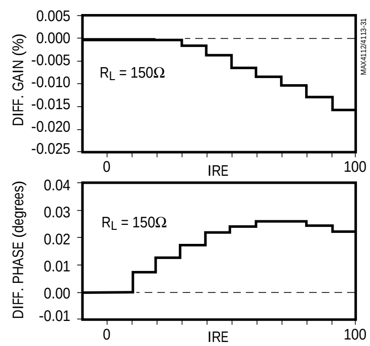
MAX4113
5MHz HARMONIC DISTORTION
vs. LOAD RESISTANCE



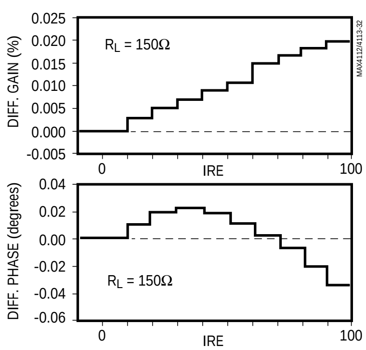
TWO-TONE THIRD-ORDER INTERCEPT
vs. FREQUENCY



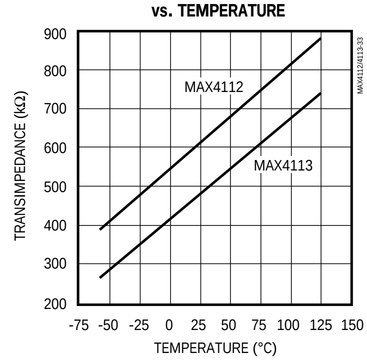
MAX4112
DIFFERENTIAL GAIN and PHASE



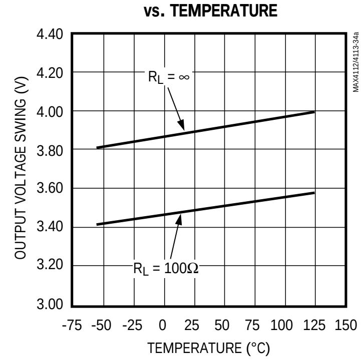
MAX4113
DIFFERENTIAL GAIN and PHASE



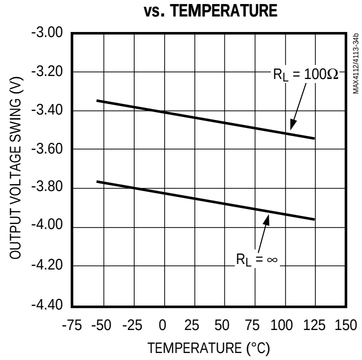
OPEN-LOOP TRANSIMPEDANCE
vs. TEMPERATURE



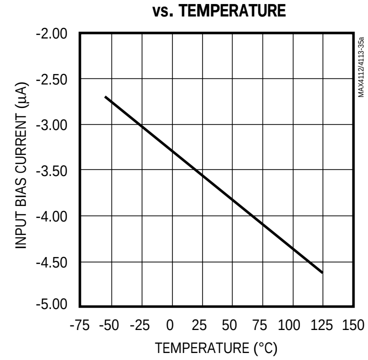
POSITIVE OUTPUT VOLTAGE SWING
vs. TEMPERATURE



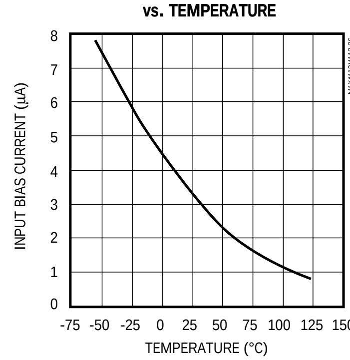
NEGATIVE OUTPUT VOLTAGE SWING
vs. TEMPERATURE



POSITIVE INPUT BIAS CURRENT
vs. TEMPERATURE



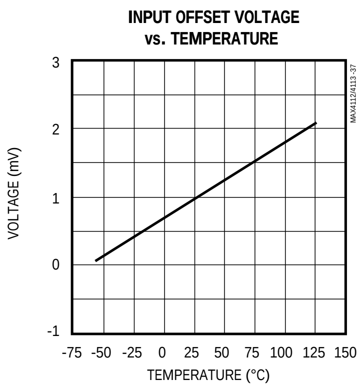
NEGATIVE INPUT BIAS CURRENT
vs. TEMPERATURE

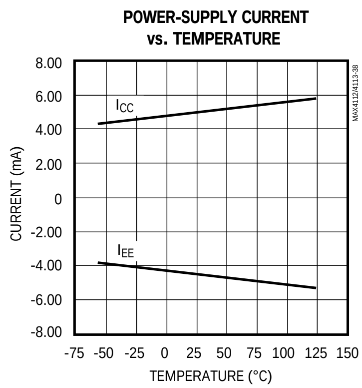


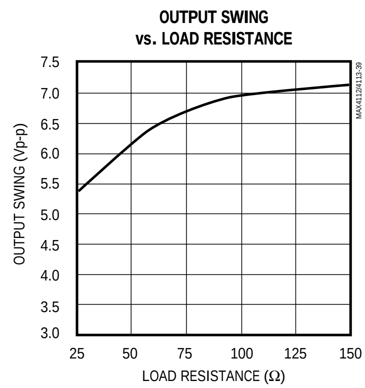
500MHz, Low-Power, Current-Mode Feedback Amplifiers

Typical Operating Characteristics (continued)

(V_{CC} = 5V, V_{EE} = -5V, R_F = 499Ω, R_L = 100Ω, T_A = +25°C, unless otherwise noted.)







Pin Description

PIN	NAME	FUNCTION
1, 5, 8	N.C.	No Connection, not internally connected
2	IN-	Inverting Input
3	IN+	Noninverting Input
4	V_{EE}	Negative Power Supply, connect to -5V
6	OUT	Amplifier Output
7	V_{CC}	Positive Power Supply, connect to +5V

Detailed Description

The MAX4112 is optimized for closed-loop gains (A_{VCL}) of 2V/V or greater, while the MAX4113 is optimized for closed-loop gains of 8V/V or greater. These low-power, high-speed current-mode feedback amplifiers operate from ±5V supplies. They are designed to drive video loads with excellent distortion characteristics. The MAX4112's differential gain and phase are 0.02% and 0.03°, respectively; the MAX4113 exhibits gain/phase error specifications of 0.02% and 0.04°, respectively. These characteristics, plus a wide 0.1dB bandwidth, make the MAX4112/MAX4113 ideal for use in broadcast and graphics video systems. The combination of ultra-high speed and low power makes these parts ideal for use in general-purpose high-speed applications, such as medical imaging, industrial instrumentation, and communications systems.

Applications Information

Theory of Operation

Since the MAX4112/MAX4113 are current-feedback amplifiers, their open-loop transfer function is expressed as a transimpedance, $\Delta V_{OUT}/\Delta I_{IN}$, or Z_{OL}. The frequency behavior of the open-loop transimpedance is similar to the open-loop gain of a voltage-mode feedback amplifier. That is, it has a large DC value and decreases at approximately 6dB/octave.

Analyzing the follower with gain, as shown in Figure 1, yields the following transfer function:

$$\frac{V_{OUT}}{V_{IN}} = G \times \frac{Z_{OL}(S)}{Z_{OL}(S) + G \times R_{IN} + R_F}$$

where $G = A_{VCL} = 1 + R_F / R_G$, and $R_{IN} = 1/g_M \cong 30\Omega$.

At low gains, $G \times R_{IN} << R_F$. Therefore, the closed-loop bandwidth is essentially independent of closed-loop gain. Similarly $Z_{OL} >> R_F$ at low frequencies, so that:

$$\frac{V_{OUT}}{V_{IN}} = G = 1 + R_F / R_G$$

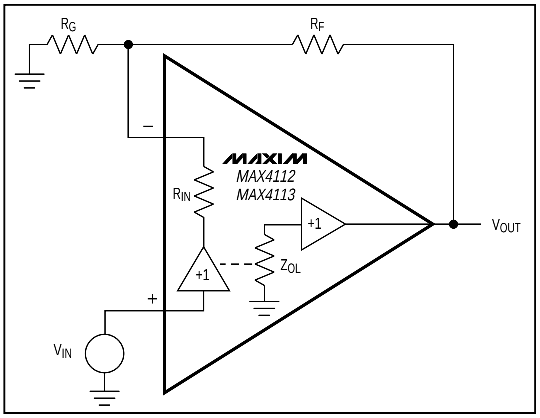


Figure 1. Current Feedback Amplifier

Layout and Power-Supply Bypassing

The MAX4112/MAX4113 have an RF bandwidth and, consequently, require careful board layout, including the possible use of constant-impedance Microstrip or Stripline techniques.

To realize the full AC performance of these high-speed amplifiers, pay careful attention to power-supply bypassing and board layout. The PC board should have at least two layers: a signal and power layer on one side, and a large, low-impedance ground plane on the other side. The ground plane should be as free of voids as possible. With multilayer boards, locate the ground plane on a layer that incorporates no signal or power traces.

Regardless of whether a constant-impedance board is used, it is best to observe the following guidelines when designing the board. Wire-wrap boards are much too inductive, and breadboards are much too capacitive; neither should be used. IC sockets increase parasitic capacitance and inductance, and should not be used. In general, surface-mount components give better high-frequency performance than through-hole components. They have shorter leads and lower parasitic reactances. Keep lines as short and as straight as possible. Do not make 90° turns; round all corners.

Observe high-frequency bypassing techniques to maintain the amplifier's accuracy. The bypass capacitors should include a 1000pF ceramic capacitor between each supply pin and the ground plane, located as close to the package as possible. Next, place a 0.01µF to 0.1µF ceramic capacitor in parallel with each 1000pF capacitor, and as close to them as possible. Then place a 10µF to 15µF low-ESR tantalum at the point of entry (to the PC board) of the power-supply pins. The power-supply trace should lead directly from the tantalum capacitor to the V_{CC} and V_{EE} pins. To minimize parasitic inductance, keep PC traces short and use surface-mount components.

Choosing Feedback and Gain Resistors

The MAX4112/MAX4113 are current-feedback amplifiers optimized for a 499Ω feedback resistor. Although a standard 5% value is sufficient, a 1% value is preferred to maintain consistency over a wide range of production lots. Changing feedback resistor value will reduce the bandwidth or cause excessive peaking. To change the magnitude of the gain, use the input resistor (R_F). Figure 2 shows the standard inverting and noninverting configurations. Notice that the gain of the noninverting circuit (Figure 2a) is 1 plus the magnitude of the inverting closed-loop gain. Otherwise the two circuits are identical and equivalent (see Table 1).

DC and Noise Errors

There are several major error sources to consider in any operational amplifier. These apply equally to the MAX4112/MAX4113. Offset-error terms are given by the equation below. Voltage and current noise errors are

Table 1. Recommended Component Values

COMPONENT	MAX4112				MAX4113				
	-2	+2	+10	+25	-8	+8	+10	+50	+100
R_F (Ω)	499	499	499	499	499	499	499	499	499
R_G (Ω)	247	499	56	20	62.5	69	56	10	5
R_O (Ω)	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9
R_S (Ω)	0	—	—	—	—	0	—	—	—
R_T (Ω)	62.5	49.9	49.9	49.9	250	49.9	49.9	49.9	49.9
Small-Signal Bandwidth (MHz)	180	500	100	50	325	275	235	50	23
0.1dB Flatness (MHz)	40	30	15	8	90	90	79	8	4

root-square summed and, therefore, computed separately. In Figure 3, the total output offset voltage is determined by:

a) The input offset voltage (V_{OS}) times the closed-loop gain (1 + R_F / R_G)

b) The positive input bias current (I_{B+}) times the source resistor (R_S) (usually 50Ω or 75Ω), plus the negative input bias current (I_{B-}), times the parallel combination of R_G and R_F. In current-mode feedback amplifiers, the input bias currents may flow into or out of the device; for this reason, there is no benefit to matching the resistance at both inputs.

The equation for total DC error is:

$$V_{OUT} = \left[(I_{B+})R_S + (I_{B-})(R_F \| R_G) + V_{OS}\right]\left(1\frac{R_F}{R_G}\right)$$

c) The total output referred noise voltage is:

$$e_{n(OUT)} = \left(1+\frac{R_F}{R_G}\right)\sqrt{\left[(i_{n+})R_S\right]^2 + \left[(i_{n-})R_F \| R_G\right]^2 + (e_n)^2}$$

The MAX4112 has a very low, $2nV/\sqrt{Hz}$ noise voltage. The current noise at the positive input (i_{n+}) is $13pA/\sqrt{Hz}$, and the current noise at the inverting input is $14pA/\sqrt{Hz}$.

An example of the DC error calculations, using the MAX4112 typical data and the typical operating circuit using R_F = R_G =500Ω (R_F || R_G = 250Ω) and R_S = 50Ω gives:

$V_{OUT} = (3.5 \times 10^{-6} \times 50 + 3.5 \times 10^{-6} \times 250 + 10^{-3})(1 + 1)$

V_{OUT} = 4.1mV

Calculating total output noise in a similar manner yields:

$$e_{n(OUT)} = (1+1)\sqrt{\left(13x10^{-12}x50\right)^2 + \left(14x10^{-12}x250\right)^2 + \left(2x10^{-9}\right)^2}$$

$$e_{n(OUT)} = 4nV/\sqrt{Hz}$$

With a 200MHz system bandwidth, this calculates to 56.6µV_{RMS} (approximately 340µVp-p, choosing the six-sigma value).

Resistor Types

Surface-mount resistors are the best choice for high-frequency circuits. They are of similar material to metal-film resistors, but are deposited using a thick-film process in a flat, linear manner that minimizes inductance. Their small size and lack of leads also minimizes parasitic inductance and capacitance, yielding more predictable performance.

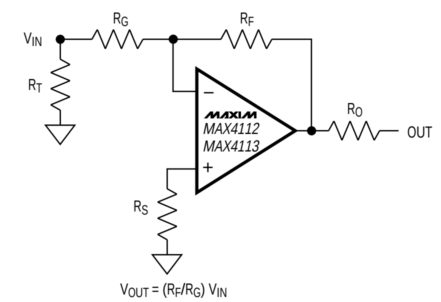


Figure 2a. Inverting Gain Configuration

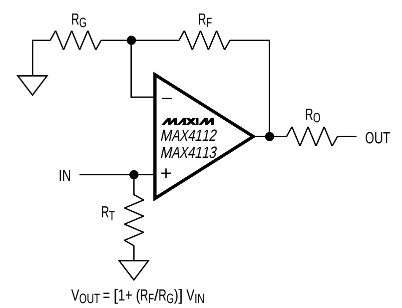


Figure 2b. Noninverting Gain Configuration

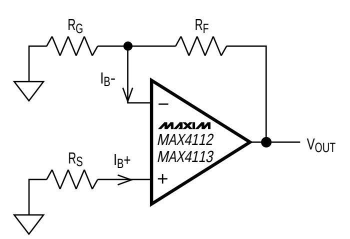


Figure 3. Output Offset Voltage

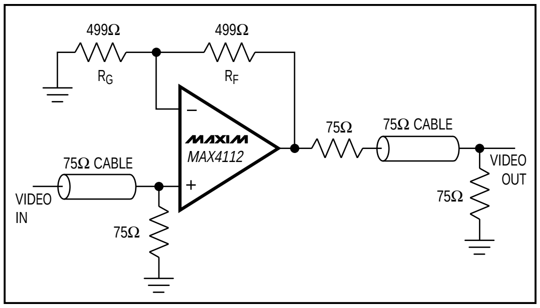


Figure 4. Video Line Driver

Metal-film resistors with leads are manufactured using a thin-film process where resistive material is deposited in a spiral layer around a ceramic rod. Although the materials used are noninductive, the spiral winding presents a small inductance (about 5nH) that may have an adverse effect on high-frequency circuits.

Carbon composition resistors with leads are manufactured by pouring the resistor material into a mold. This process yields relatively low-inductance resistors that are very useful in high-frequency applications, although they tend to cost more and have more thermal noise than other types. The ability of carbon composition resistors to self-heal after a large current overload makes them useful in high-power RF applications.

For general-purpose use, surface-mount metal-film resistors seem to have the best overall performance for low cost, low inductance, and low noise.

Video Line Driver

The MAX4112/MAX4113 are optimized (gain flatness) to drive coaxial transmission lines when the cable is terminated at both ends, as shown in Figure 4. Cable frequency response may cause variations in the flatness of the signal.

Driving Capacitive Loads

The MAX4112/MAX4113 are optimized for AC performance. They are not designed to drive highly capacitive loads. Reactive loads will decrease phase margin and may produce excessive ringing and oscillation. Figure 5 shows a circuit that eliminates this problem. The small (usually 5Ω to 20Ω) isolation resistor, R_S, placed before the reactive load will prevent ringing and oscillation. At higher capacitive loads, AC performance will be controlled by the interaction of the load capacitance and isolation resistor.

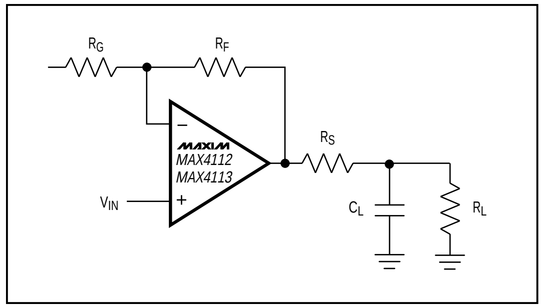


Figure 5a. Using an Isolation Resistor (R_S) for High Capacitive Loads

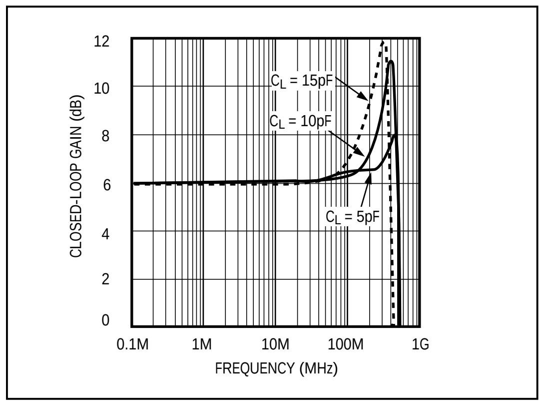


Figure 5b. Frequency Response vs. Capacitive Load—No Isolation Resistor

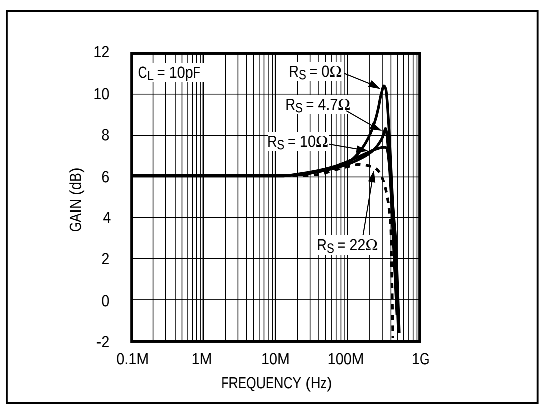
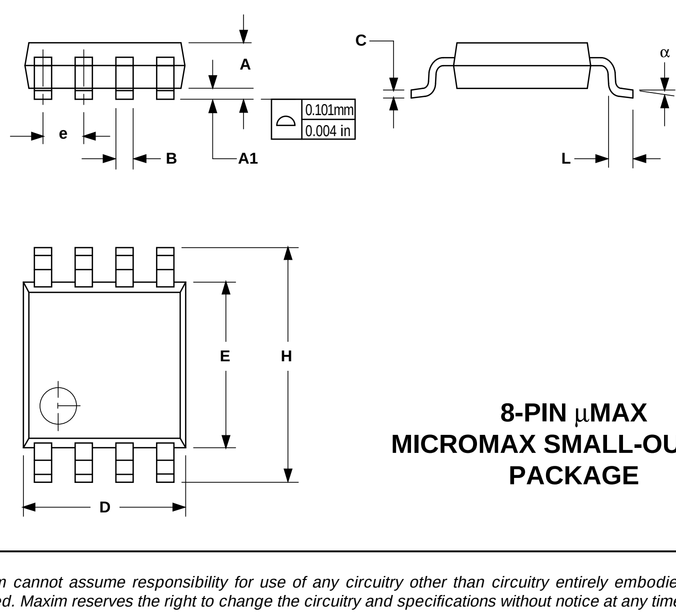


Figure 5c. Frequency Response vs. Isolation Resistance (see Figure 5a for circuit)

Chip Information

TRANSISTOR COUNT: 53

Package Information



DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.036	0.044	0.91	1.11
A1	0.004	0.008	0.10	0.20
B	0.010	0.014	0.25	0.36
C	0.005	0.007	0.13	0.18
D	0.116	0.120	2.95	3.05
E	0.116	0.120	2.95	3.05
e	0.0256		0.65	
H	0.188	0.198	4.78	5.03
L	0.016	0.026	0.41	0.66
α	0°	6°	0°	6°

21-0036D

8-PIN μMAX MICROMAX SMALL-OUTLINE PACKAGE