19-3011; Rev 0; 1989

MAXIM

Single/Dual/Quad High-Speed, Fast-Settling, High Output Current Operational Amplifier

MAX408/428/448

General Description

The MAX408/428/448 are high speed general purpose monolithic operational amplifiers in a single, dual or quad package, that are useful for signal frequencies extending into the video range. These Op Amps function in gain configurations greater-than or equal-to 3. High output current allows large capacitive loads to be driven at high speeds.

Open-loop voltage gain of 10k V/V and high slew rate of 90V/μs make the MAX408/428/448 ideal for analog amplification and high speed signal processing. 100MHz gain bandwidth and a ±0.1% settling time of 150ns make each amplifier ideal for fast data conversion systems.

±50mA output current capability allows the amplifiers to drive terminated transmission lines of 50Ω with amplitudes of 5V peak-to-peak.

Along with the high speed and output drive capability, a 35nA offset current and trimmable offset voltage make the MAX408/428/448 optimal for signal conditioning applications where accuracy must be maintained.

Applications

Video Amplifiers
Test Equipment
Waveform Generators
Video Distribution
Pulse Amplifiers

Features

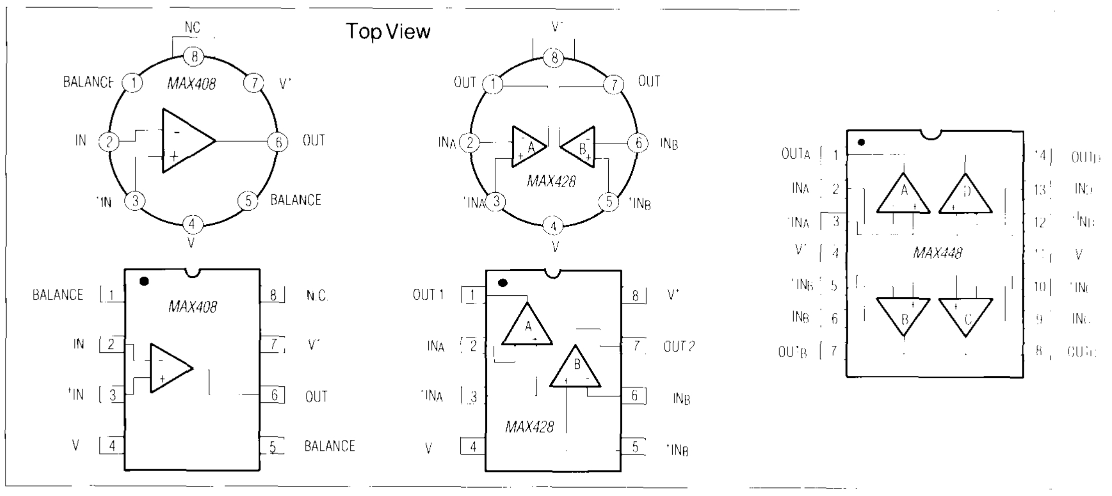
- ♦ **Fast Settling Time: ±0.1% in 150ns**
- ♦ **High Slew Rate: 90V/μs**
- ♦ **Large Gain Bandwidth: 100MHz**
- ♦ **Full Power Bandwidth: 4.8MHz at 6V p-p**
- ♦ **Ease of Use: Internally Compensated for $A_{CL} \geq 3$ with 50° - 60° Phase Margin**
- ♦ **Large Output Current: ±50mA**
- ♦ **Low Supply Voltage Operation: ±4V**
- ♦ **Wide Input Voltage Range: Within 1.5V of V⁺ and 0.5V of V⁻**
- ♦ **Minimal Crosstalk: >90dB Separation (MAX428/448)**
- ♦ **Short Circuit Protection**

Ordering Information

PART	TEMP. RANGE	PACKAGE*
MAX408ACPA	0°C to +70°C	8 Lead Plastic DIP
MAX408ACJA	0°C to +70°C	8 Lead CERDIP
MAX408ACSA	0°C to +70°C	8 Lead Small Outline
MAX408ACTV	0°C to +70°C	8 Lead TO-99 Metal Can
MAX408CPA	0°C to +70°C	8 Lead Plastic DIP
MAX408CJA	0°C to +70°C	8 Lead CERDIP
MAX408CSA	0°C to +70°C	8 Lead Small Outline
MAX408CTV	0°C to +70°C	8 Lead TO-99 Metal Can
MAX408C/D	0°C to 70°C	Dice
MAX408MJA	-55°C to +125°C	8 Lead CERDIP
MAX408MTV	-55°C to +125°C	8 Lead TO-99 Metal Can

(Ordering Information continued on last page.)
*Contact factory for availability of 20 Lead LCC

Pin Configurations



Call toll free 1-800-998-8800 for free samples or literature.

ABSOLUTE MAXIMUM RATINGS - MAX408

Supply Voltages .... ±6V
Differential Input Voltage .... ±9V
Common Mode Input Voltage .... |VS| -0.5V
Power Dissipation (Note 1) 450mW
Output Short Circuit Current Duration (Note 2) ...... Indefinite

Operating Temperature Range:
Commercial (MAX408AC, C) .... 0°C to +70°C
Military (MAX408M) .... -55°C to +125°C
Storage Temperature Range .... -65°C to +150°C
Lead Temperature (Soldering, 60 seconds) .... 300°C

Note 1: Power derating above T_A = 70°C to be based on a maximum junction temperature of 150°C and the thermal resistance factors in the chart below

PKG	θ_{JC}(°C/W)	θ_{JA} (°C/W)	T_C(°C)	T_A (°C)
DIP, CERDIP	75	180	110	70
SOIC	115	180	95	70
TO-99	115	150	95	30

Note 2: Continuous short circuit protection is allowed for the case and ambient temperatures in the chart below.

ELECTRICAL CHARACTERISTICS - MAX408 (V_S = ±5V, T_A = 25°C unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX408C			MAX408AC			MAX408M			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}	T_A = 25°C 0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		5 8	12 16		3 5	6 10		3 6	6 12	mV
Average Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		20			20			 15		µV/°C
Input Bias Current	I_B			650	1100		650	1100		650	1100	nA
Input Offset Current	I_{OS}	T_A = 25°C 0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		35 70	120 200		35 70	120 200		35 70	120 300	nA
Input Common Mode Range	V_{CM}		+3 -4	+3.5 -4.5		+3 -4	+3.5 -4.5		+3 -4	+3.5 -4.5		V
Differential Input Resistance	R_{IND}	(Note 1)	3	10		3	10		3	10		MΩ
Common Mode Input Resistance	R_{INC}	(Note 1)	4	8		4	8		4	8		MΩ
Differential Input Capacitance	C_{IND}			2			2			2		pF
Common Mode Input Capaticance	C_{INC}			3			3			3		pF
Input Voltage Noise	e_N	BW = 10Hz to 100kHz		12			12			12		µVRMS
Open Loop Voltage Gain	A_V	V_{OUT} = ±3V, R_L = 2kΩ	2	5		5	10		5	10		V/mV
Output Voltage Swing	V_{OUT}	R_L = 2kΩ R_L = 51Ω	±3.5 ±2.0	 ±2.4		±3.5 ±2.5	 ±2.7		±3.5 ±2.5	 ±2.7		V
Power Supply Current	I_S	T_A = 25°C		7	10		7	10		7	10	mA
Common Mode Rejection Ratio	CMRR	V_{CM} = ±2V	60	70		60	70		60	70		dB
Power Supply Rejection Ratio	PSRR	ΔV_{PS} = ±0.5V	60	66		60	66		60	66		dB
Slew Rate (Note 1)	SR	10-90% of Leading Edge (Figure 1)	60	90		60	90		60	90		V/µs
Settling Time	t_S	To ±0.1% (±4mV) of Final Value (Figure 1) (Note 1)		150	200		150	200		150	200	ns
Gain Bandwidth Product	GBW			100			100			100		MHz

Note 1: Not tested, guaranteed by design.

ABSOLUTE MAXIMUM RATINGS - MAX428

Supply Voltages .... ±6V
Differential Input Voltage .... ±9V
Common Mode Input Voltage .... $|V_S|$ -0.5V
Power Dissipation (Note 1) 450mW
Output Short Circuit Current Duration (Note 2) ...... Indefinite

Note 1: Power derating above T_A = 70°C to be based on a maximum junction temperature of 150°C and the following thermal resistance factors:

PKG	θ_{JC}(°C/W)	θ_{JA} (°C/W)
DIP	75	180
TO-99	115	150

Operating Temperature Range:
Commercial (MAX428AC, C) .... 0°C to +70°C
Military (MAX428M) .... -55°C to +125°C
Storage Temperature Range .... -65°C to +150°C
Lead Temperature (Soldering, 60 seconds) .... 300°C

Note 2: Continuous short circuit protection is allowed on one amplifier per time up to the following case and ambient temperatures:

PKG	T_C(°C)	T_A (°C)
DIP	100	30
TO-99	75	(Note 3)

Note 3: Long duration shorts (>5 sec) will result in junction temperature exceeding 150°C which may result in part damage.

ELECTRICAL CHARACTERISTICS - MAX428 (V_S = ±5V, T_A = 25°C unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX428C			MAX428AC			MAX428M			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}	T_A = 25°C 0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		5 8	12 16		3 5	6 10		3 6	6 12	mV
Average Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		20			20			 15		μV/°C
Input Bias Current	I_B	T_A = 25°C 0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		650	1100 1700		650	1100 1700		650	1100 1700 2200	mA
Input Offset Current	I_{OS}			35	120		35	120		35	120	nA
Input Common Mode Range	V_{CM}		+3 -4	+3.5 -4.5		+3 -4	+3.5 -4.5		+3 -4	+3.5 -4.5		V
Differential Input Resistance	R_{IND}	(Note 1)	3	10		3	10		3	10		MΩ
Common Mode Input Resistance	R_{INC}	(Note 1)	4	8		4	8		4	8		MΩ
Differential Input Capacitance	C_{IND}			2			2			2		pF
Common Mode Input Capacitance	C_{INC}			3			3			3		pF
Input Voltage Noise	e_N	BW = 10Hz to 100kHz		12			12			12		μVRMS
Open Loop Voltage Gain	A_V	V_{OUT} = ±3V, R_L = 2kΩ	2	5		5	10		5	10		V/mV
Output Voltage Swing	V_{OUT}	R_L = 2kΩ R_L = 51Ω	±3.5 ±2.0	 ±2.4		±3.5 ±2.5	 ±2.7		±3.5 ±2.5	 +2.7		V
Power Supply Current	I_S	T_A = 25°C		15	20		15	20		15	20	mA
Common Mode Rejection Ratio	CMRR	V_{CM} = ±2V	60	70		60	70		60	70		dB
Power Supply Rejection Ratio	PSRR	ΔV_{PS} = ±0.5V	60	66		60	66		60	66		dB
Slew Rate (Note 1)	SR	10-90% of Leading Edge (Figure 1)	60	90		60	90		60	90		V/μs
Settling Time	t_S	To ±0.1% (±4mV) of Final Value (Figure 1) (Note 1)		150	200		150	200		150	200	ns
Gain Bandwidth Product	GBW			100			100			100		MHz

Note 1: Not tested, guaranteed by design.

ABSOLUTE MAXIMUM RATINGS - MAX448

Supply Voltages .... ±6V
Differential Input Voltage .... ±9V
Common Mode Input Voltage .... $|V_S|$ -0.5V
Power Dissipation (Note 1) 550mW
Output Short Circuit Current Duration (Note 2) ...... Indefinite

Operating Temperature Range:
Commercial (MAX448AC, C) .... 0°C to +70°C
Military (MAX448M) .... -55°C to +125°C
Storage Temperature Range .... -65°C to +150°C
Lead Temperature (Soldering, 60 seconds) .... 300°C

Note 1: Power derating above T_A = 70°C to be based on a maximum junction temperature of 150°C and the thermal resistance factors of θ_{JC} = 75°C/W and θ_{JA} = 150°C/W.

Note 2: Continuous short circuit protection is allowed on one amplifier per time up to case temperatures of 85°C and ambient temperatures of 30°C.

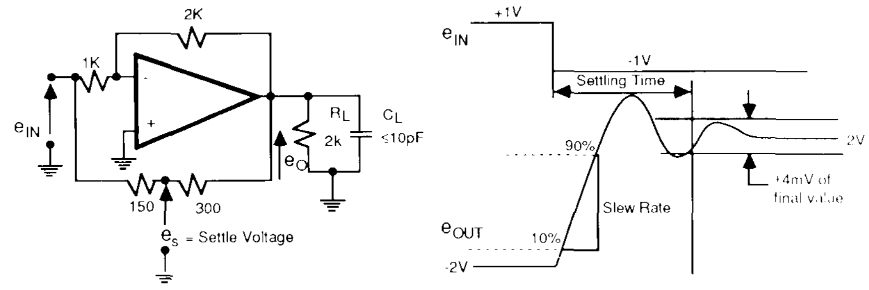
ELECTRICAL CHARACTERISTICS - MAX448 (V_S = ±5V, T_A = 25°C unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MAX448C			MAX448AC			MAX448M			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	V_{OS}	T_A = 25°C 0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		5 8	12 16		3 5	6 10		3 6	6 12	mV
Average Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		20			20			 15		μV/°C
Input Bias Current	I_B	T_A = 25°C 0°C ≤ T_A ≤ 70°C -55°C ≤ T_A ≤ 125°C		650	1100 1700		650	1100 1700		650	1100 2200	nA
Input Offset Current	I_{OS}			35	120		35	120		35	120	nA
Input Common Mode Range	V_{CM}		+3 -4	+3.5 -4.5		+3 -4	+3.5 -4.5		+3 -4	+3.5 -4.5		V
Differential Input Resistance	R_{IND}	(Note 1)	3	10		3	10		3	10		MΩ
Common Mode Input Resistance	R_{INC}	(Note 1)	4	8		4	8		4	8		MΩ
Differential Input Capacitance	C_{IND}			2						2		pF
Common Mode Input Capaticance	C_{INC}			3			3			3		pF
Input Voltage Noise	e_N	BW = 10Hz to 100kHz		12			12			12		μVRMS
Open Loop Voltage Gain	A_V	V_{OUT} = ±3V, R_L = 2kΩ	2	5		4	10		4	10		V/mV
Output Voltage Swing	V_{OUT}	R_L = 2kΩ R_L = 51Ω	±3.5 ±2.0	 ±2.4		±3.5 ±2.5	 ±2.7		+3.5 ±2.5	 ±2.7		V
Power Supply Current (All four amplifiers)	I_S	T_A = 25°C		30	40		30	40		30	40	mA
Power Supply Rejection Ratio	PSRR	ΔV_{PS} = ±0.5V	60	66		60	66		60	66		dB
Common Mode Rejection Ratio	CMRR	V_{CM} = ±2V	60	70		60	70		60	70		dB
Slew Rate (Note 1)	SR	10-90% of Leading Edge (Figure 1)	60	90		60	90		60	90		V/μs
Settling Time	t_S	To ±0.1% (±4mV) of Final Value (Figure 1) (Note 1)		150	200		150	200		150	200	ns
Gain Bandwidth Product	GBW			100			100			100		MHz

Note 1: Not tested, guaranteed by design.

AC CHARACTERISTICS - MAX408/428/448 (V_S = ±5V, T_A = 25 C unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	MAX4XXC MIN	MAX4XXC TYP	MAX4XXC MAX	MAX4XXAC MIN	MAX4XXAC TYP	MAX4XXAC MAX	MAX4XXM MIN	MAX4XXM TYP	MAX4XXM MAX	UNITS
Small Signal Rise/Fall Time	t_r/t_f	e_O = ±100mV 10-90% (Figure 1)		7			7			7		ns
Full Power Bandwidth	BW_{FP}	R_L = 2kΩ, C_L = 50pF V_{OUT} = 6Vp-p		4.8			4.8			4.8		MHz
Amp-Amp Crosstalk (MAX428/448)		Input Referenced f = 10kHz		-96			-96			-96		dB



Note that to properly measure e_S, amplifier and settle resistor ratios should be matched to 0.5% and probe capacitance <35pF

Figure 1A. Settling Time and Slew Rate Test Circuit

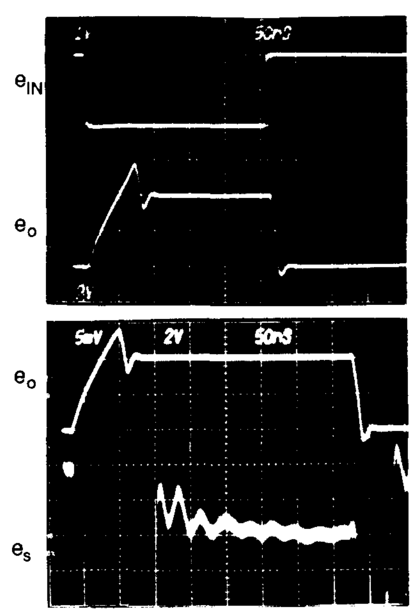


Figure 1B. Large Signal Response

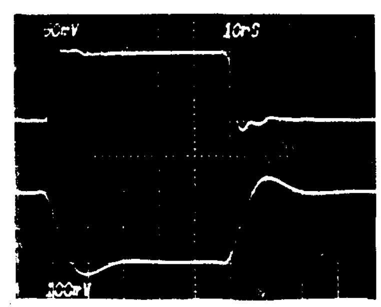


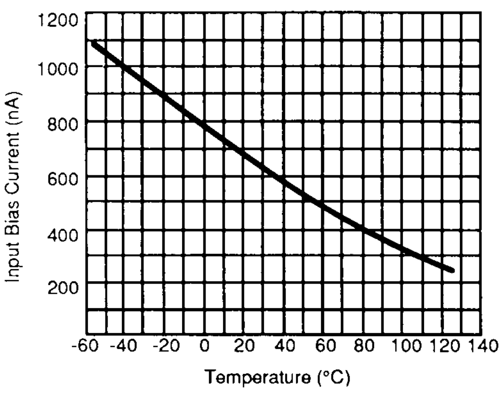
Figure 1C. Small Signal Response

Single/Dual/Quad High Speed, Fast Settling, High Output Current Operational Amplifier

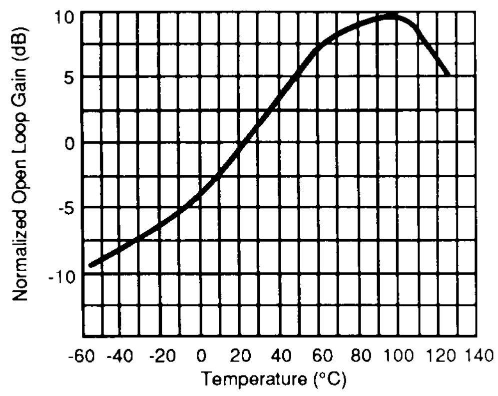
Typical Operating Characteristics

(V_S = ±5V, T_A = 25°C unless otherwise stated and apply for each individual op amp where applicable)

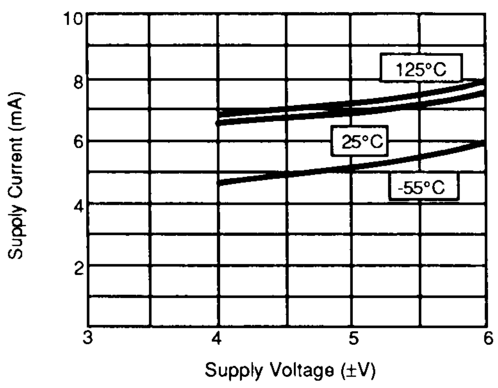
INPUT BIAS CURRENT vs TEMPERATURE



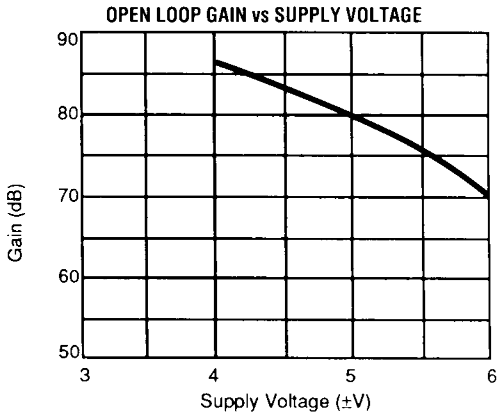
NORMALIZED OPEN LOOP GAIN vs TEMPERATURE



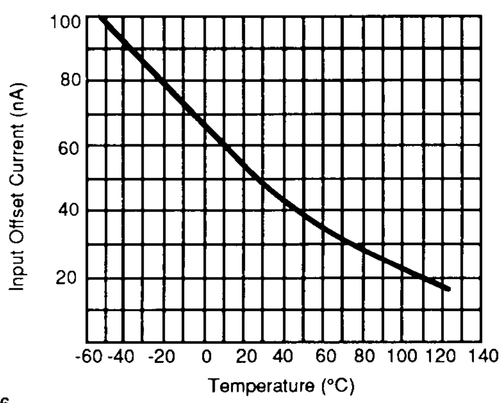
SUPPLY CURRENT vs SUPPLY VOLTAGE



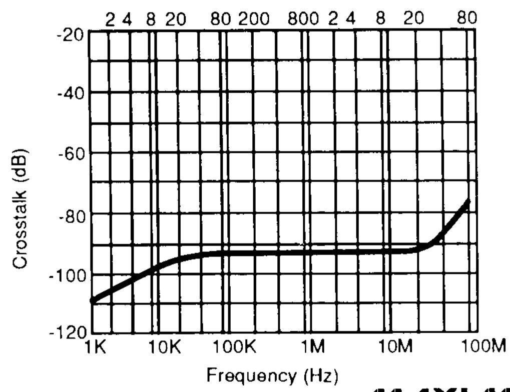
OPEN LOOP GAIN vs SUPPLY VOLTAGE



INPUT OFFSET CURRENT vs TEMPERATURE

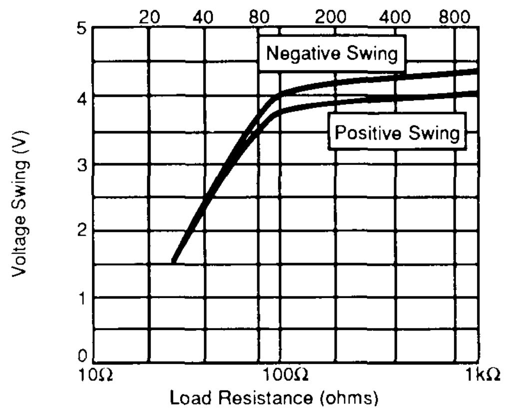


AMPLIFIER/AMPLIFIER CROSSTALK vs FREQUENCY (MAX428/448)

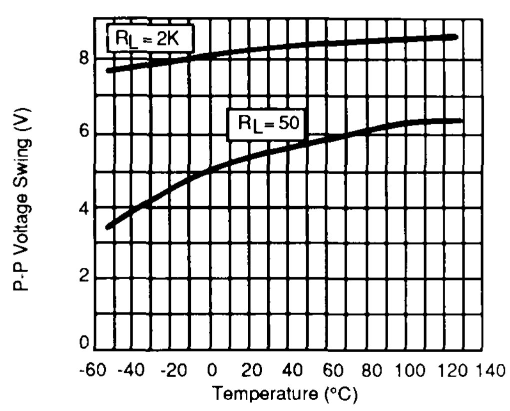


Typical Operating Characteristics (continued)

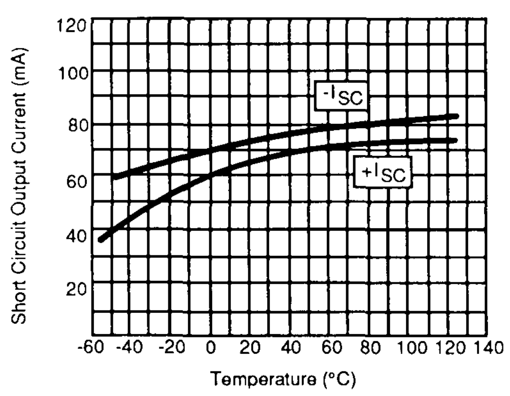
MAXIMUM OUTPUT VOLTAGE SWING vs LOAD RESISTANCE



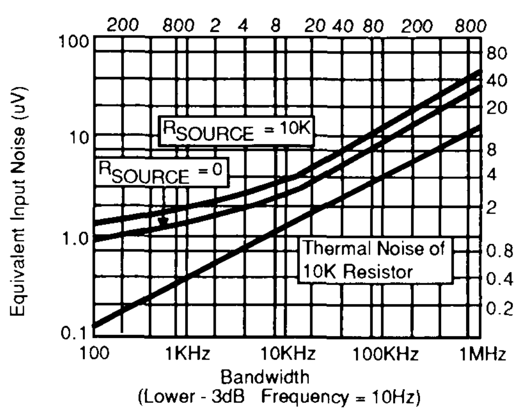
MAXIMUM OUTPUT VOLTAGE SWING vs TEMPERATURE



SHORT CIRCUIT OUTPUT CURRENT vs TEMPERATURE



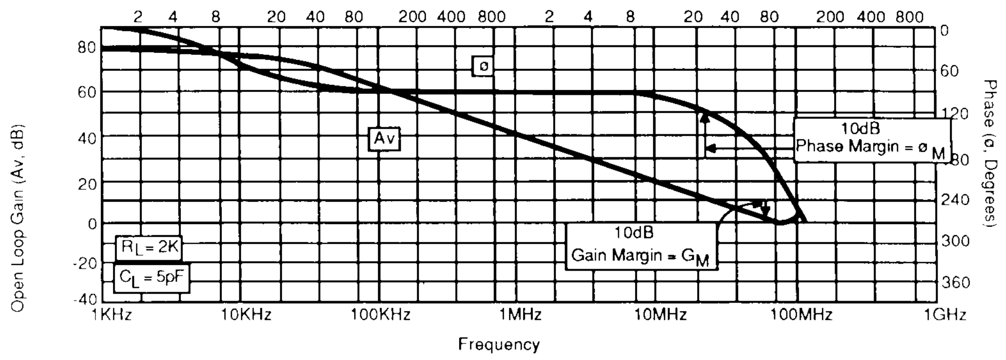
EQUIVALENT INPUT NOISE vs BANDWIDTH



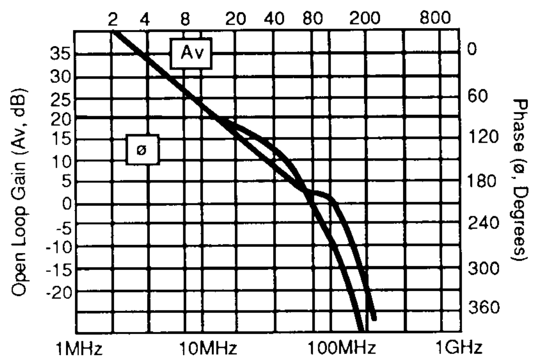
Single/Dual/Quad High-Speed, Fast-Settling, High Output Current Operational Amplifier

Typical Operating Characteristics (continued)

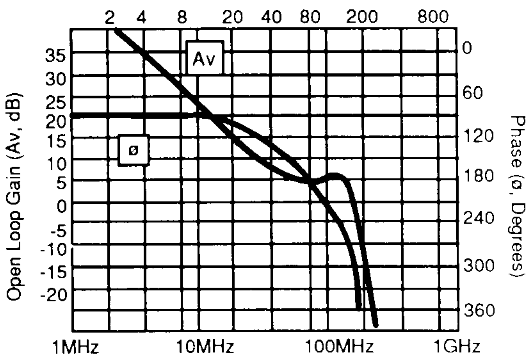
OPEN LOOP FREQUENCY RESPONSE



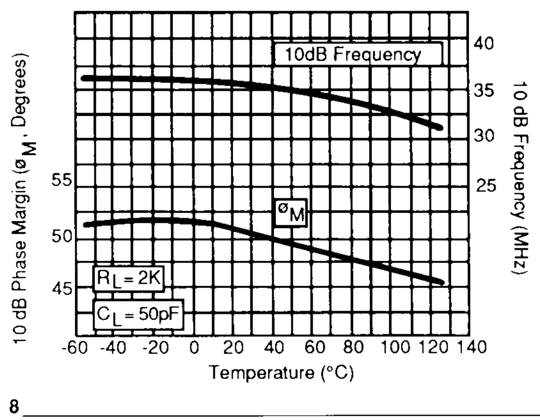
OPEN LOOP FREQ. RESPONSE, $R_L = 50\Omega$, $C_L = 50pF$



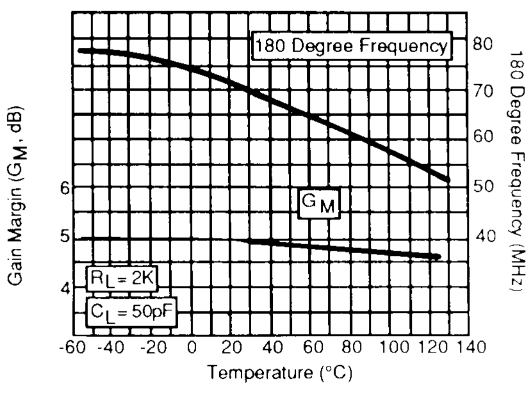
OPEN LOOP FREQ. RESPONSE, $R_L = 2K\Omega$, $C_L = 50pF$



10dB PHASE MARGIN AND 10dB FREQ. vs TEMP.



GAIN MARGIN AND 180 DEGREE FREQ. vs TEMP. $A_V = 10dB$



Application Information

AC Characteristics

The 35MHz 10dB crossover point of the MAX408/428/448 is achieved without feed forward compensation, a technique which can produce long tails in the recovery characteristic. The single pole rolloff follows the classic 20dB/decade slope to frequencies approaching 50MHz. The 10dB (3.2V/V) phase margin of 50°, even with a capacitive load of 50pF, gives stable and predictable performance down to non-inverting gain configurations of approximately 3V/V (inverting gains of -2V/V). At frequencies beyond 50MHz, the 20dB/decade slope is disturbed by an output stage zero, the damping factor of which is dependent upon the R_L, C_L load combination. This results in loss of gain margin (gain at loop phase = 360°) at frequencies of 70 to 100MHz which at a gain margin of 5dB (R_L = 2K, C_L = 5pF) results in a peak in the gain of 3 amplifier configurations as shown in Figures 3 and 4.

Figure 3 shows a blow up of the open loop characteristics in the 10MHz to 200MHz frequency range, as well as the corresponding closed loop characteristics for a gain of 3 non-inverting amplifier at similar load conditions. It should be noted that the open loop characteristic does not show the additional phase shift covered by the input capacitance pole. This is why the closed loop peaking at 30 to 40MHz is greater than what would be expected from the 50 to 60 degrees of phase margin indicated by the open loop characteristics. Corresponding small signal step response characteristics show well-behaved pulse waveforms with 16-33% overshoot.

The input capacitive pole can be neutralized by adding a feedback capacitor to R_2. The value of capacitance is selected according to $R_1 C_{IN} = R_2 C_{FB}$, where C_{IN} is the sum of the common mode and differential input capacitance ≈ 5pF. For $R_2 = 2R_1$, $C_{FB} = C_{IN/2} \approx 2.5$pF.

Figure 4 shows the results of this feedback capacitor addition. Neutralizing the input capacitance demonstrates the peaking that can result from the loss of gain margin at 70 to 100MHz. As the load time constant ($R_L C_L$) increases the peaking gets progressively worse ≈6dB at R_L = 2K, C_L = 50pF. The step response waveforms are as expected with a very strong 88MHz ring being exhibited at R_L = 2K, C_L = 50pF and no overshoot at R_L = 50Ω, C_L = 5pF.

Layout Considerations

As with any high-speed wideband amplifier, certain layout considerations are necessary to ensure stable operation. All connections to the amplifier should remain as short as possible, and the power supplies bypassed with 0.1µF capacitors to signal ground. It is suggested that a ground plane be considered as the best method for ensuring stability because it minimizes stray inductance and unwanted coupling in the ground signal paths.

To minimize capacitive effects, resistor values should be kept as small as possible, consistent with the application.

MAX408 Offset Voltage Nulling

The configuration of Figure 2 will give a typical V_{OS} nulling range of ±15mV. If a smaller adjustment range is desired, resistor values R1 and R2 can be increased accordingly. For example, at R1 = 3.6kΩ, the adjustment range is ±5mV. Since pins 1 and 5 are not part of the signal path, AC characteristics are left undisturbed.

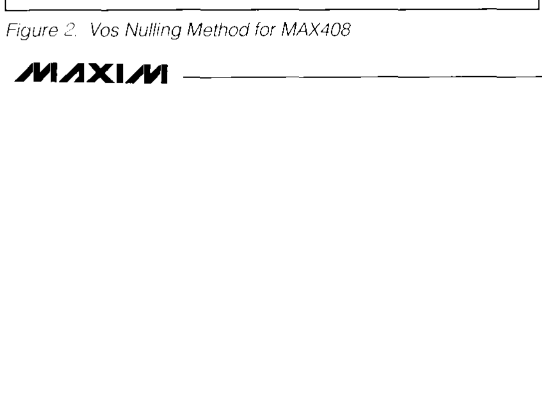
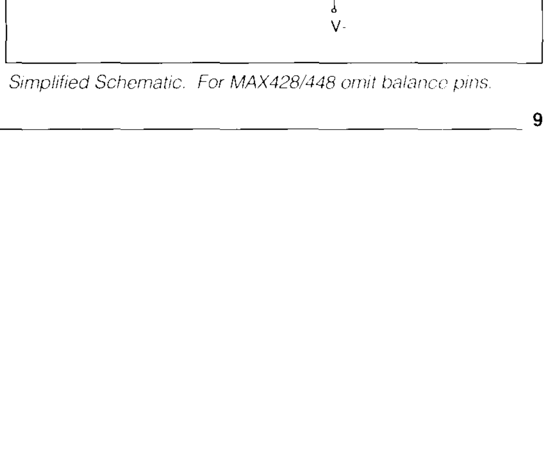


Figure 2. Vos Nulling Method for MAX408



Simplified Schematic. For MAX428/448 omit balance pins.

Single/Dual/Quad High-Speed, Fast-Settling, High Output Current Operational Amplifier

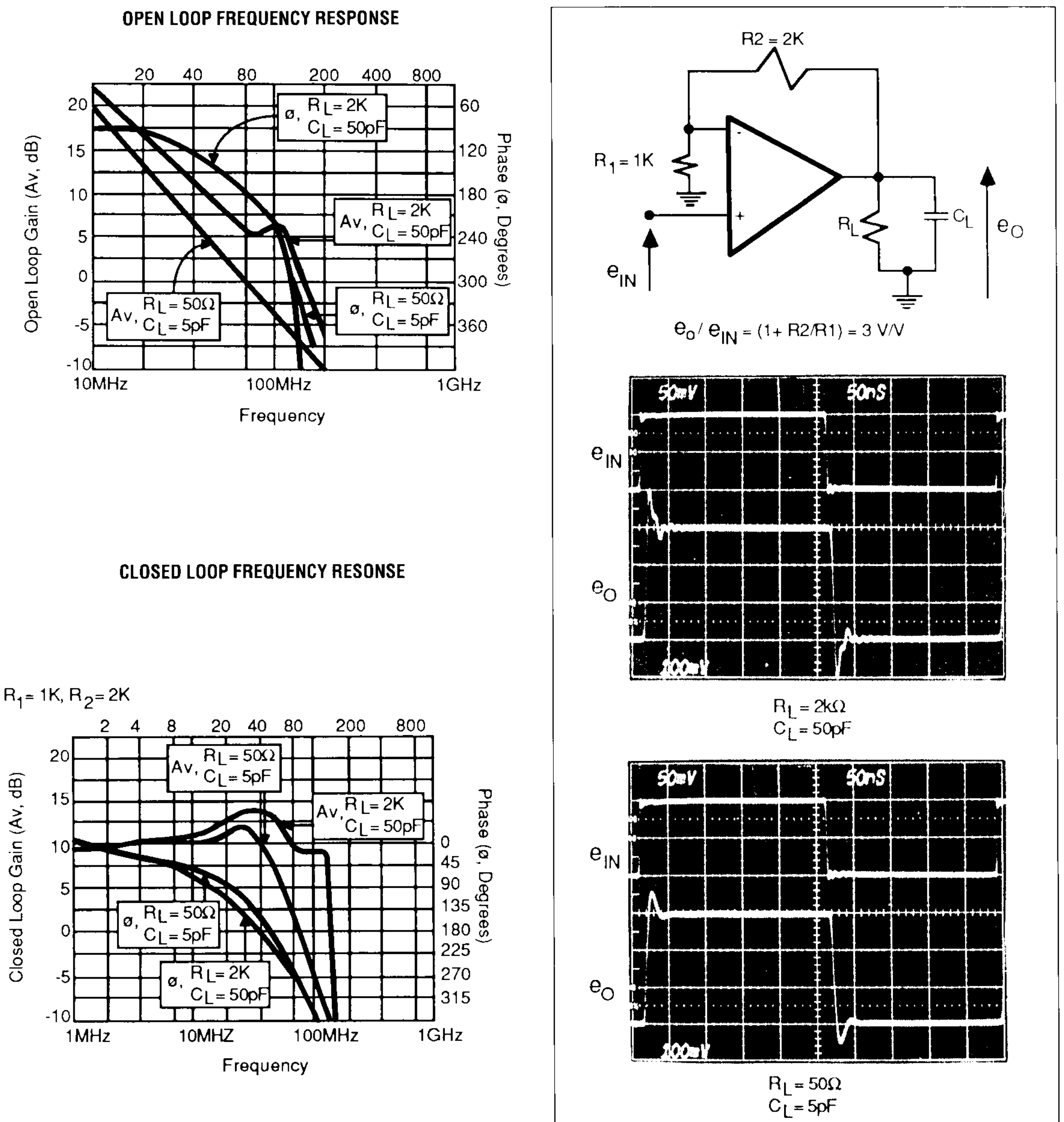
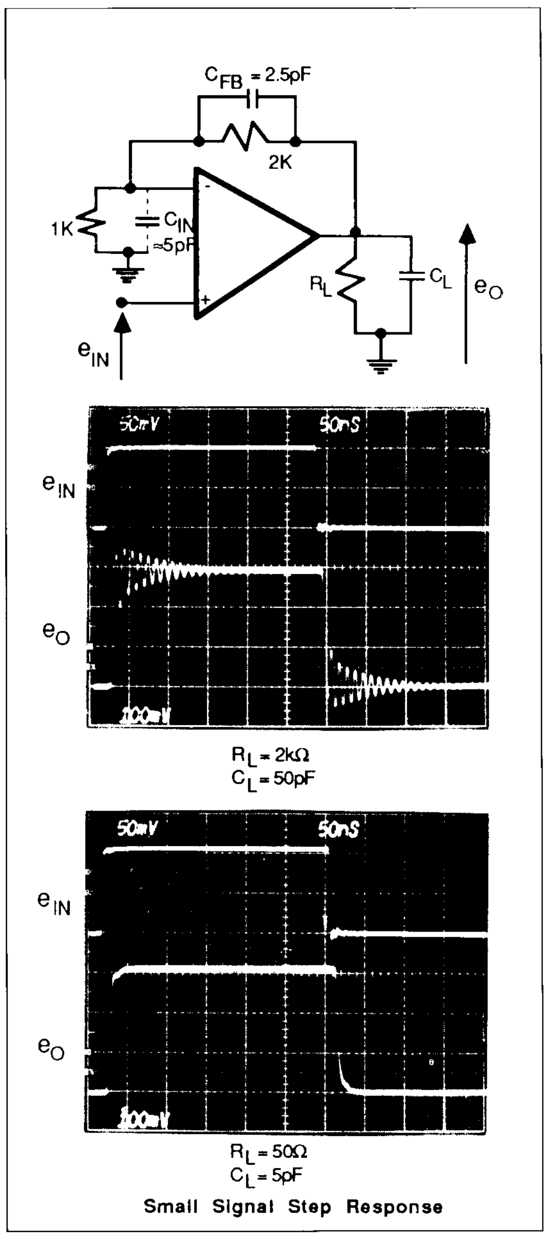


Figure 3. Frequency and Time Domain Response Characteristics, Av = 3



CLOSED LOOP FREQUENCY RESPONSE

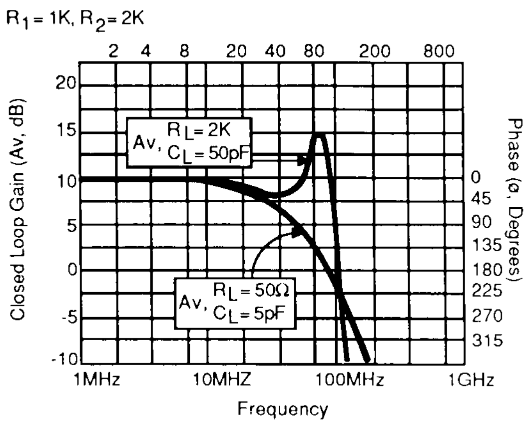


Figure 4. Response Characteristics with Input Pole Cancellation, Av = 3

Single/Dual/Quad High-Speed, Fast-Settling, High Output Current Operational Amplifier

Ordering Information (continued)

PART	TEMP. RANGE	PACKAGE*
MAX428ACPA	0°C to +70°C	8 Lead Plastic DIP
MAX428ACJA	0°C to +70°C	8 Lead CERDIP
MAX428ACSA	0°C to +70°C	8 Lead Small Outline
MAX428ACTV	0°C to +70°C	8 Lead TO-99 Metal Can
MAX428CPA	0°C to +70°C	8 Lead Plastic DIP
MAX428CJA	0°C to +70°C	8 Lead CERDIP
MAX428CSA	0°C to +70°C	8 Lead Small Outline
MAX428CTV	0°C to +70°C	8 Lead TO-99 Metal Can
MAX428C/D	0°C to +70°C	Dice
MAX428MJA	-55°C to +125°C	8 Lead CERDIP
MAX428MTV	-55°C to +125°C	8 Lead TO-99 Metal Can
MAX448ACPD	0°C to +70°C	14 Lead Plastic DIP
MAX448ACJD	0°C to +70°C	14 Lead CERDIP
MAX448ACSD	0°C to +70°C	14 Lead Small Outline
MAX448CPD	0°C to +70°C	14 Lead Plastic DIP
MAX448CJD	0°C to +70°C	14 Lead CERDIP
MAX448CSD	0°C to +70°C	14 Lead Small Outline
MAX448C/D	0°C to +70°C	Dice
MAX448MJD	-55°C to +125°C	14 Lead CERDIP

*Contact factory for availability of 20 Lead LCC