Not Recommended for New Designs

The MAX495 was manufactured for Maxim by an outside wafer foundry using a process that is no longer available. It is not recommended for new designs. A Maxim replacement or an industry second-source may be available. The data sheet remains available for existing users. **The other parts on the following data sheet are not affected.**

For further information, please see the QuickView data sheet for this part or contact technical support for assistance.

19-0265; Rev 2; 9/96

Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

General Description

The dual MAX492, quad MAX494, and single MAX495 operational amplifiers combine excellent DC accuracy with rail-to-rail operation at the input and output. Since the common-mode voltage extends from V_{CC} to V_{EE}, the devices can operate from either a single supply (+2.7V to +6V) or split supplies (±1.35V to ±3V). Each op amp requires less than 150µA supply current. Even with this low current, the op amps are capable of driving a 1kΩ load, and the input referred voltage noise is only 25nV/√Hz. In addition, these op amps can drive loads in excess of 1nF.

The precision performance of the MAX492/MAX494/MAX495, combined with their wide input and output dynamic range, low-voltage single-supply operation, and very low supply current, makes them an ideal choice for battery-operated equipment and other low-voltage applications. The MAX492/MAX494/MAX495 are available in DIP and SO packages in the industry-standard op-amp pin configurations. The MAX495 is also available in the smallest 8-pin SO: the µMAX package.

Applications

- Portable Equipment
- Battery-Powered Instruments
- Data Acquisition
- Signal Conditioning
- Low-Voltage Applications

Features

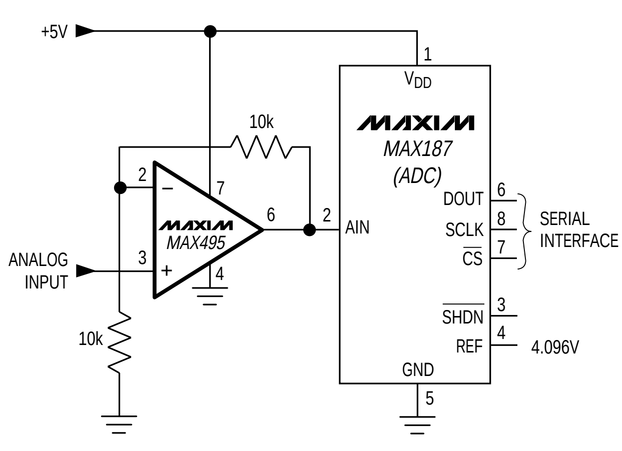
- ♦ **Low-Voltage Single-Supply Operation (+2.7V to +6V)**
- ♦ **Rail-to-Rail Input Common-Mode Voltage Range**
- ♦ **Rail-to-Rail Output Swing**
- ♦ **500kHz Gain-Bandwidth Product**
- ♦ **Unity-Gain Stable**
- ♦ **150µA Max Quiescent Current per Op Amp**
- ♦ **No Phase Reversal for Overdriven Inputs**
- ♦ **200µV Offset Voltage**
- ♦ **High Voltage Gain (108dB)**
- ♦ **High CMRR (90dB) and PSRR (110dB)**
- ♦ **Drives 1kΩ Load**
- ♦ **Drives Large Capacitive Loads**
- ♦ **MAX495 Available in µMAX Package—8-Pin SO**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX492CPA	0°C to +70°C	8 Plastic DIP
MAX492CSA	0°C to +70°C	8 SO
MAX492C/D	0°C to +70°C	Dice*
MAX492EPA	-40°C to +85°C	8 Plastic DIP
MAX492ESA	-40°C to +85°C	8 SO
MAX492MJA	-55°C to +125°C	8 CERDIP

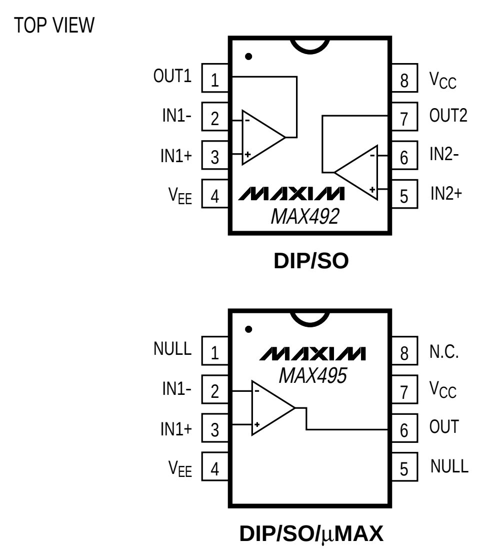
Ordering Information continued at end of data sheet.
**Dice are specified at T_A = +25°C, DC parameters only.*

Typical Operating Circuit



INPUT SIGNAL CONDITIONING FOR LOW-VOLTAGE ADC

Pin Configurations



Pin Configurations continued at end of data sheet.

Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

ABSOLUTE MAXIMUM RATINGS

Supply Voltage (V_{CC} to V_{EE}) 7V
Common-Mode Input Voltage..........(V_{CC} + 0.3V) to (V_{EE} - 0.3V)
Differential Input Voltage ....±(V_{CC} - V_{EE})
Input Current (IN+, IN-, NULL1, NULL2) ....±10mA
Output Short-Circuit Duration ....Indefinite short circuit to either supply
Voltage Applied to NULL Pins ....V_{CC} to V_{EE}
Continuous Power Dissipation (T_A = +70°C)
- 8-Pin Plastic DIP (derate 9.09mW/°C above +70°C) 727mW
- 8-Pin SO (derate 5.88mW/°C above +70°C).................471mW
- 8-Pin CERDIP (derate 8.00mW/°C above +70°C).........640mW
- 8-Pin µMAX (derate 4.1mW/°C above +70°C) 330mW
- 14-Pin Plastic DIP (derate 10.00mW/°C above +70°C)...800mW
- 14-Pin SO (derate 8.33mW/°C above +70°C)...............667mW
- 14-Pin CERDIP (derate 9.09mW/°C above +70°C).......727mW

Operating Temperature Ranges
- MAX49_C_ _ ....0°C to +70°C
- MAX49_E_ _...-40°C to +85°C
- MAX49_M_ _...-55°C to +125°C

Junction Temperatures
- MAX49_C_ _/E_ _..+150°C
- MAX49_M_ _...+175°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} = 2.7V to 6V, V_{EE} = GND, V_{CM} = 0V, V_{OUT} = V_{CC} / 2, T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Offset Voltage	V_{CM} = V_{EE} to V_{CC}			±200	±500	µV
Input Bias Current	V_{CM} = V_{EE} to V_{CC}			±25	±60	nA
Input Offset Current	V_{CM} = V_{EE} to V_{CC}			±0.5	±6	nA
Differential Input Resistance				2		MΩ
Common-Mode Input Voltage Range			V_{EE} - 0.25		V_{CC} + 0.25	V
Common-Mode Rejection Ratio	(V_{EE} - 0.25V) ≤ V_{CM} ≤ (V_{CC} + 0.25V)		74	90		dB
Power-Supply Rejection Ratio	V_{CC} = 2.7V to 6V		88	110		dB
Large-Signal Voltage Gain (Note 1)	V_{CC} = 2.7V, R_L = 100kΩ, V_{OUT} = 0.25V to 2.45V	Sourcing	90	104		dB
		Sinking	90	102		
	V_{CC} = 2.7V, R_L = 1kΩ, V_{OUT} = 0.5V to 2.2V	Sourcing	94	105		
		Sinking	78	90		
	V_{CC} = 5.0V, R_L = 100kΩ, V_{OUT} = 0.25V to 4.75V	Sourcing	98	108		
		Sinking	92	100		
	V_{CC} = 5.0V, R_L = 1kΩ, V_{OUT} = 0.5V to 4.5V	Sourcing	98	110		
		Sinking	86	98		
Output Voltage Swing (Note 1)	R_L = 100kΩ	V_{OH}	V_{CC} - 0.075	V_{CC} - 0.04		V
		V_{OL}		V_{EE} + 0.04	V_{EE} + 0.075	
	R_L = 1kΩ	V_{OH}	V_{CC} - 0.20	V_{CC} - 0.15		
		V_{OL}		V_{EE} + 0.15	V_{EE} + 0.20	
Output Short-Circuit Current				30		mA
Operating Supply Voltage Range			2.7		6.0	V
Supply Current (per amplifier)	V_{CM} = V_{OUT} = V_{CC} / 2	V_{CC} = 2.7V		135	150	µA
		V_{CC} = 5V		150	170	

AC ELECTRICAL CHARACTERISTICS

(V_{CC} = 2.7V to 6V, V_{EE} = GND, T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Gain-Bandwidth Product	R_L = 100kΩ, C_L = 100pF		500		kHz
Phase Margin	R_L = 100kΩ, C_L = 100pF		60		degrees
Gain Margin	R_L = 100kΩ, C_L = 100pF		10		dB
Total Harmonic Distortion	R_L = 10kΩ, C_L = 15pF, V_{OUT} = $2V_{p-p}$, A_V = +1, f = 1kHz		0.003		%
Slew Rate	R_L = 100kΩ, C_L = 15pF		0.20		V/µs
Time	To 0.1%, 2V step		12		µs
Turn-On Time	V_{CC} = 0V to 3V step, V_{IN} = V_{CC} / 2, A_V = +1		5		µs
Input Noise-Voltage Density	f = 1kHz		25		nV/√Hz
Input Noise-Current Density	f = 1kHz		0.1		pA/√Hz
Amp-Amp Isolation	f = 1kHz		125		dB

DC ELECTRICAL CHARACTERISTICS

(V_{CC} = 2.7V to 6V, V_{EE} = GND, V_{CM} = 0V, V_{OUT} = V_{CC} / 2, T_A = 0°C to +70°C, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Offset Voltage	V_{CM} = V_{EE} to V_{CC}				±650	µV
Input Offset Voltage Tempco				±2		µV/°C
Input Bias Current	V_{CM} = V_{EE} to V_{CC}				±75	nA
Input Offset Current	V_{CM} = V_{EE} to V_{CC}				±6	nA
Common-Mode Input Voltage Range			V_{EE} - 0.20		V_{CC} + 0.20	V
Common-Mode Rejection Ratio	(V_{EE} - 0.20) ≤ V_{CM} ≤ (V_{CC} + 0.20)		72			dB
Power-Supply Rejection Ratio	V_{CC} = 2.7V to 6V		86			dB
Large-Signal Voltage Gain (Note 1)	V_{CC} = 2.7V, R_L = 100kΩ, V_{OUT} = 0.25V to 2.45V	Sourcing	88			dB
		Sinking	84			
	V_{CC} = 2.7V, R_L = 1kΩ, V_{OUT} = 0.5V to 2.2V	Sourcing	92			
		Sinking	76			
	V_{CC} = 5.0V, R_L = 100kΩ, V_{OUT} = 0.25V to 4.75V	Sourcing	92			
		Sinking	88			
	V_{CC} = 5.0V, R_L = 1kΩ, V_{OUT} = 0.5V to 4.5V	Sourcing	96			
		Sinking	82			
Output Voltage Swing (Note 1)	R_L = 100kΩ	V_{OH}	V_{CC} - 0.075			V
		V_{OL}			V_{EE} + 0.075	
	R_L = 1kΩ	V_{OH}	V_{CC} - 0.20			
		V_{OL}			V_{EE} + 0.20	
Operating Supply Voltage Range			2.7		6.0	V
Supply Current (per amplifier)	V_{CM} = V_{OUT} = V_{CC} / 2	V_{CC} = 2.7V			175	µA
		V_{CC} = 5V			190	

DC ELECTRICAL CHARACTERISTICS

(V_{CC} = 2.7V to 6V, V_{EE} = GND, V_{CM} = 0V, V_{OUT} = V_{CC} / 2, T_A = -40°C to +85°C, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Offset Voltage	V_{CM} = V_{EE} to V_{CC}				±950	µV
Input Offset Voltage Tempco				±2		µV/°C
Input Bias Current	V_{CM} = V_{EE} to V_{CC}				±100	nA
Input Offset Current	V_{CM} = V_{EE} to V_{CC}				±8	nA
Common-Mode Input Voltage Range			V_{EE} - 0.15		V_{CC} + 0.15	V
Common-Mode Rejection Ratio	(V_{EE} - 0.15) ≤ V_{CM} ≤ (V_{CC} + 0.15)		68			dB
Power-Supply Rejection Ratio	V_{CC} = 2.7V to 6V, V_{CM} = 0V		84			dB
Large-Signal Voltage Gain (Note 1)	V_{CC} = 2.7V, R_L = 100kΩ, V_{OUT} = 0.25V to 2.45V	Sourcing	86			dB
		Sinking	84			
	V_{CC} = 2.7V, R_L = 1kΩ, V_{OUT} = 0.5V to 2.2V	Sourcing	92			
		Sinking	76			
	V_{CC} = 5.0V, R_L = 100kΩ, V_{OUT} = 0.25V to 4.75V	Sourcing	92			
		Sinking	86			
	V_{CC} = 5.0V, R_L = 1kΩ, V_{OUT} = 0.5V to 4.5V	Sourcing	96			
		Sinking	80			
Output Voltage Swing (Note 1)	R_L = 100kΩ	V_{OH}	V_{CC} - 0.075			V
		V_{OL}			V_{EE} + 0.075	
	R_L = 1kΩ	V_{OH}	V_{CC} - 0.20			
		V_{OL}			V_{EE} + 0.20	
Operating Supply-Voltage Range			2.7		6.0	V
Supply Current (per amplifier)	V_{CM} = V_{OUT} = V_{CC} / 2	V_{CC} = 2.7V			185	µA
		V_{CC} = 5V			200	

DC ELECTRICAL CHARACTERISTICS

(V_{CC} = 2.7V to 6V, V_{EE} = GND, V_{CM} = 0V, V_{OUT} = V_{CC} / 2, T_A = -55°C to +125°C, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Input Offset Voltage	V_{CM} = V_{EE} to V_{CC}				±1.2	mV
Input Offset Voltage Tempco				±2		µV/°C
Input Bias Current	V_{CM} = V_{EE} to V_{CC}				±200	nA
Input Offset Current	V_{CM} = V_{EE} to V_{CC}				±10	nA
Common-Mode Input Voltage Range			V_{EE} - 0.05		V_{CC} + 0.05	V
Common-Mode Rejection Ratio	(V_{EE} - 0.05V) ≤ V_{CM} ≤ (V_{CC} + 0.05V)		66			dB
Power-Supply Rejection Ratio	V_{CC} = 2.7V to 6V		80			dB
Large-Signal Voltage Gain (Note 1)	V_{CC} = 2.7V, R_L = 100kΩ, V_{OUT} = 0.25V to 2.45V	Sourcing	82			dB
		Sinking	80			
	V_{CC} = 2.7V, R_L = 1kΩ, V_{OUT} = 0.5V to 2.2V	Sourcing	90			
		Sinking	72			
	V_{CC} = 5.0V, R_L = 100kΩ, V_{OUT} = 0.25V to 4.75V	Sourcing	86			
		Sinking	82			
	V_{CC} = 5.0V, R_L = 1kΩ, V_{OUT} = 0.5V to 4.5V	Sourcing	94			
		Sinking	76			
Output Voltage Swing (Note 1)	R_L = 100kΩ	V_{OH}	V_{CC} - 0.075			V
		V_{OL}			V_{EE} + 0.075	
	R_L = 1kΩ	V_{OH}	V_{CC} - 0.250			
		V_{OL}			V_{EE} + 0.250	
Operating Supply-Voltage Range			2.7		6.0	V
Supply Current (per amplifier)	V_{CM} = V_{OUT} = V_{CC} / 2	V_{CC} = 2.7V			200	µA
		V_{CC} = 5V			225	

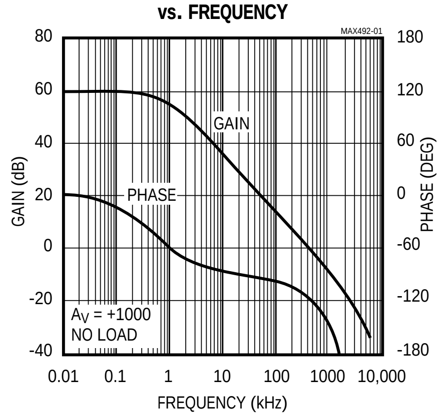
Note 1: R_L to V_{EE} for sourcing and V_{OH} tests; R_L to V_{CC} for sinking and V_{OL} tests.

Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

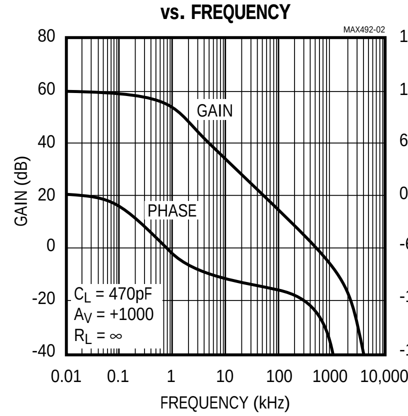
Typical Operating Characteristics

(T_A = +25°C, V_{CC} = 5V, V_{EE} = 0V, unless otherwise noted.)

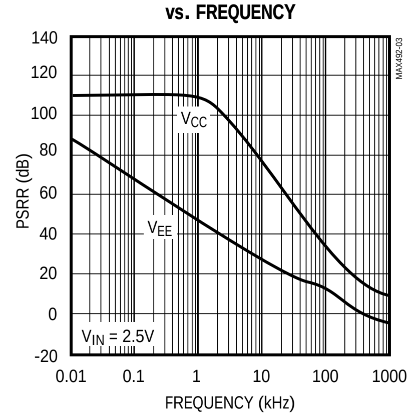
GAIN AND PHASE vs. FREQUENCY



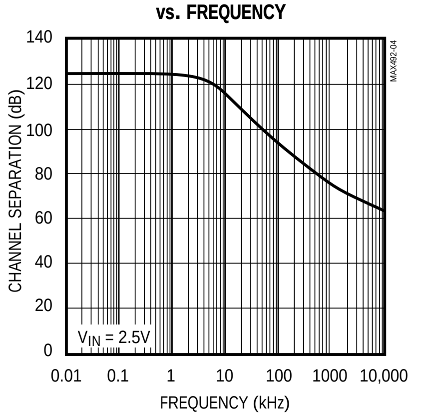
GAIN AND PHASE vs. FREQUENCY



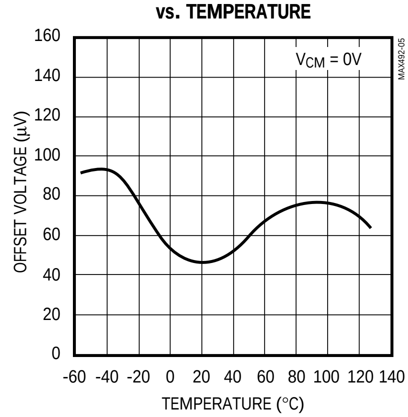
POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



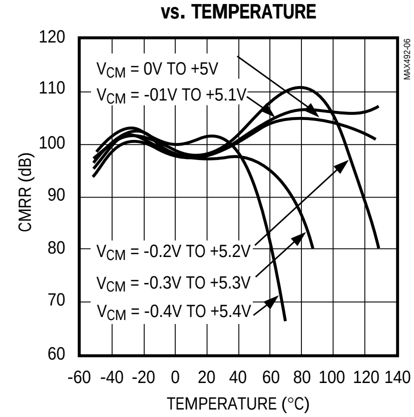
CHANNEL SEPARATION vs. FREQUENCY



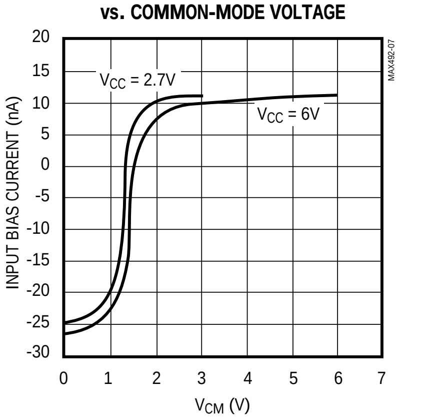
OFFSET VOLTAGE vs. TEMPERATURE



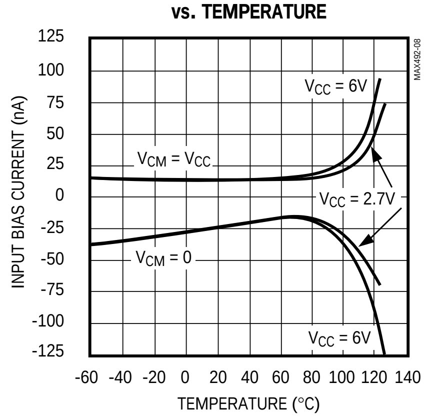
COMMON-MODE REJECTION RATIO vs. TEMPERATURE



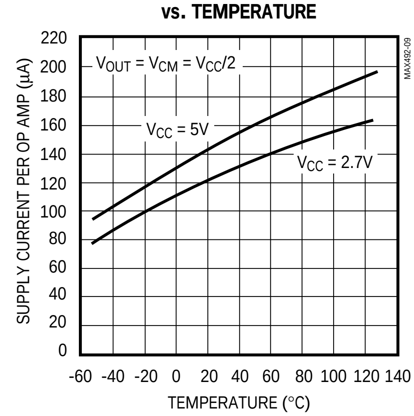
INPUT BIAS CURRENT vs. COMMON-MODE VOLTAGE



INPUT BIAS CURRENT vs. TEMPERATURE



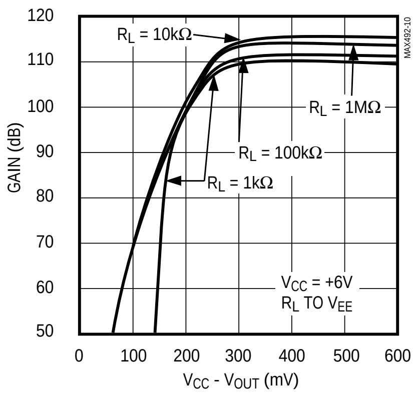
SUPPLY CURRENT PER AMPLIFIER vs. TEMPERATURE



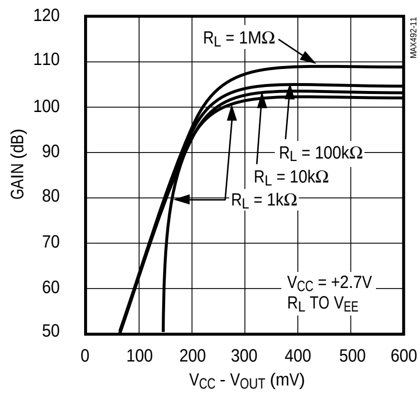
Typical Operating Characteristics (continued)

(T_A = +25°C, V_{CC} = 5V, V_{EE} = 0V, unless otherwise noted.)

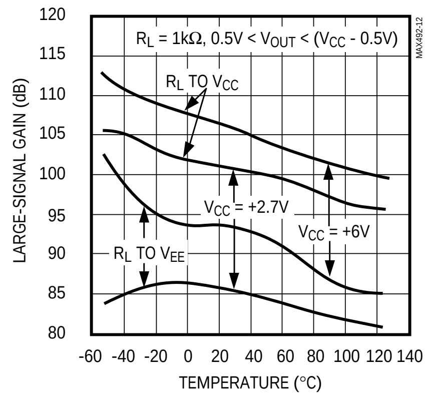
LARGE-SIGNAL GAIN vs. OUTPUT VOLTAGE



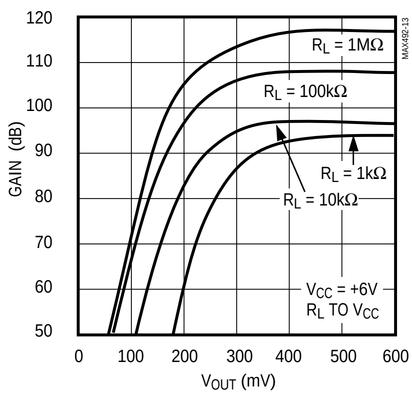
LARGE-SIGNAL GAIN vs. OUTPUT VOLTAGE



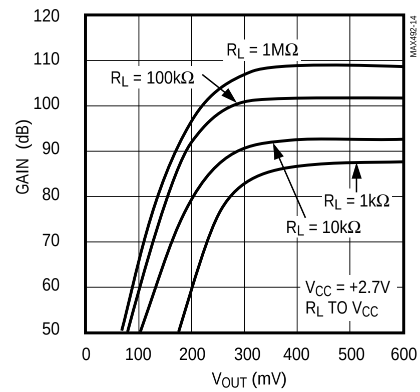
LARGE-SIGNAL GAIN vs. TEMPERATURE



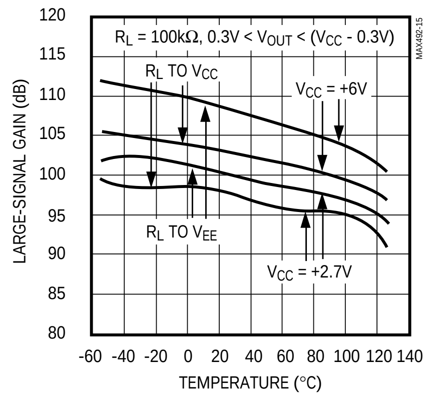
LARGE-SIGNAL GAIN vs. OUTPUT VOLTAGE



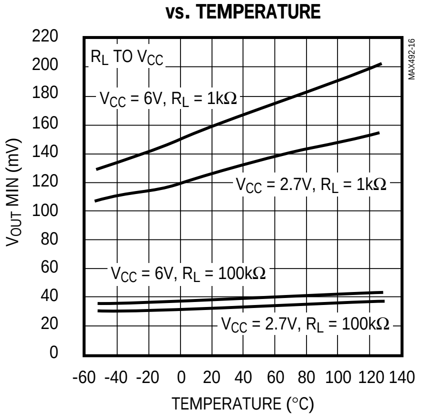
LARGE-SIGNAL GAIN vs. OUTPUT VOLTAGE



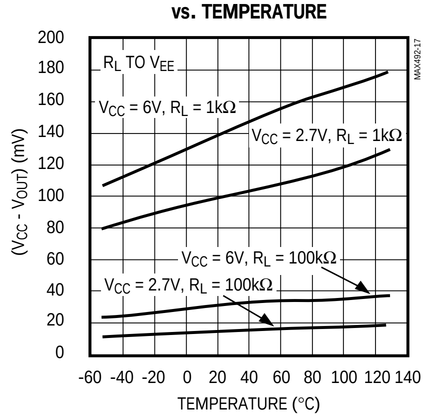
LARGE-SIGNAL GAIN vs. TEMPERATURE



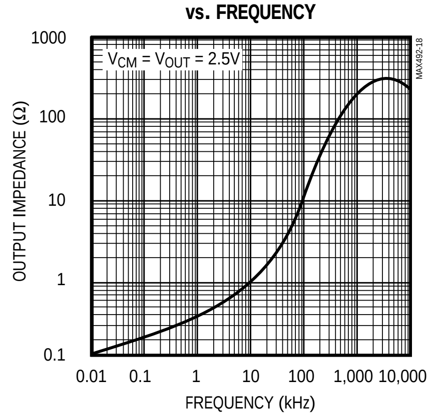
MINIMUM OUTPUT VOLTAGE vs. TEMPERATURE



MAXIMUM OUTPUT VOLTAGE vs. TEMPERATURE

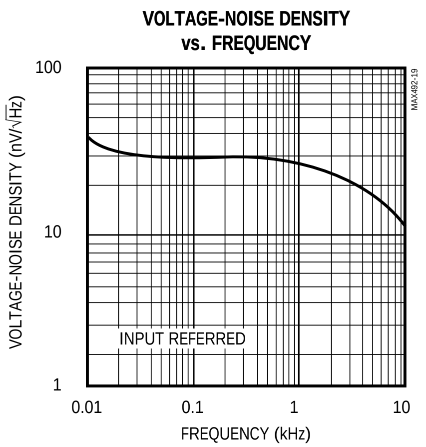


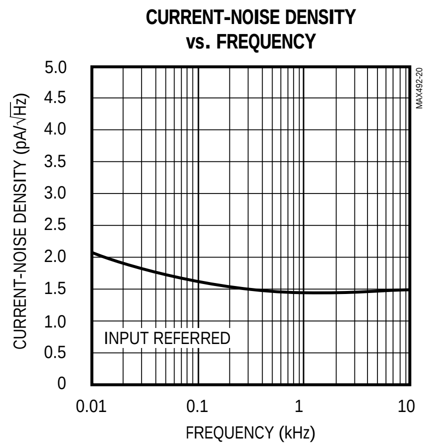
OUTPUT IMPEDANCE vs. FREQUENCY

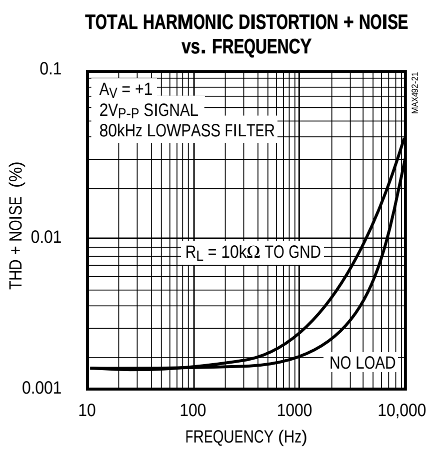


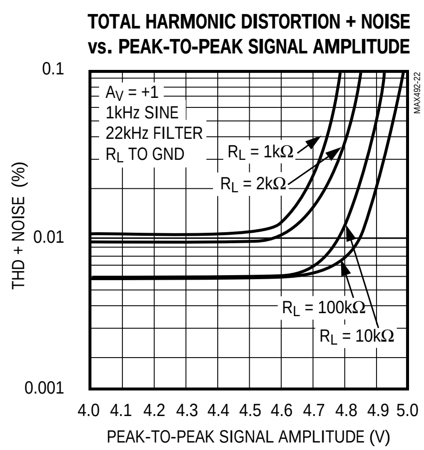
Typical Operating Characteristics (continued)

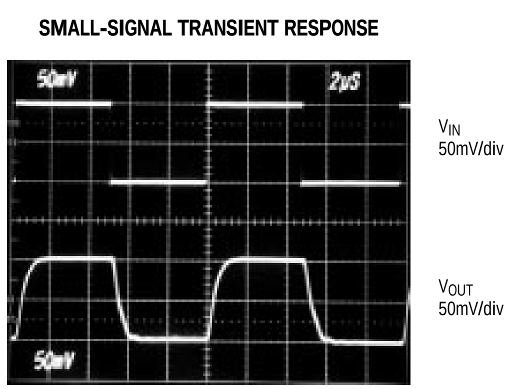
(T_A = +25°C, V_{CC} = 5V, V_{EE} = 0V, unless otherwise noted.)



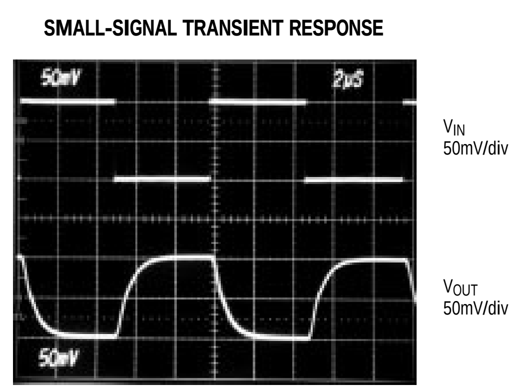








V_{CC} = +5V, A_V = +1, R_L = 10kΩ

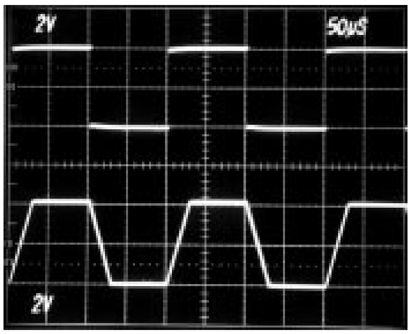


V_{CC} = +5V, A_V = -1, R_L = 10kΩ

Typical Operating Characteristics (continued)

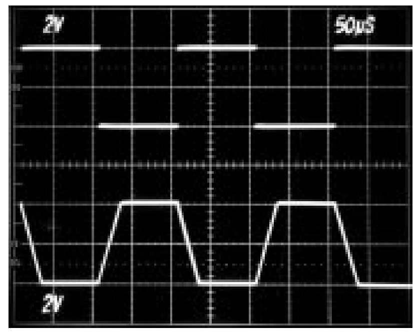
(T_A = +25°C, V_{CC} = 5V, V_{EE} = 0V, unless otherwise noted.)

LARGE-SIGNAL TRANSIENT RESPONSE



V_{CC} = +5V, A_V = +1, R_L = 10kΩ

LARGE-SIGNAL TRANSIENT RESPONSE



V_{CC} = +5V, A_V = -1, R_L = 10kΩ

Pin Description

PIN			NAME	FUNCTION
MAX492	MAX494	MAX495		
1	1	—	OUT1	Amplifier 1 Output
—	—	1, 5	NULL	Offset Null Input. Connect to a 10kΩ potentiometer for offset-voltage trimming. Connect wiper to V_{EE} (Figure 3).
—	—	2	IN-	Inverting Input
2	2	—	IN1-	Amplifier 1 Inverting Input
—	—	3	IN+	Noninverting Input
3	3	—	IN1+	Amplifier 1 Noninverting Input
4	11	4	V_{EE}	Negative Power-Supply Pin. Connect to ground or a negative voltage.
5	5	—	IN2+	Amplifier 2 Noninverting Input
—	—	6	OUT	Amplifier Output
6	6	—	IN2-	Amplifier 2 Inverting Input
7	7	—	OUT2	Amplifier 2 Output
8	4	7	V_{CC}	Positive Power-Supply Pin. Connect to (+) terminal of power supply.
—	8	—	OUT3	Amplifier 3 Output
—	9	—	IN3-	Amplifier 3 Inverting Input
—	10	—	IN3+	Amplifier 3 Noninverting Input
—	12	—	IN4+	Amplifier 4 Noninverting Input
—	13	—	IN4-	Amplifier 4 Inverting Input
—	14	—	OUT4	Amplifier 4 Output
—	—	8	N.C.	No Connect. Not internally connected.

Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

Applications Information

The dual MAX492, quad MAX494, and single MAX495 op amps combine excellent DC accuracy with rail-to-rail operation at both input and output. With their precision performance, wide dynamic range at low supply voltages, and very low supply current, these op amps are ideal for battery-operated equipment and other low-voltage applications.

Rail-to-Rail Inputs and Outputs

The MAX492/MAX494/MAX495's input common-mode range extends 0.25V **beyond** the positive and negative supply rails, with excellent common-mode rejection. Beyond the specified common-mode range, the outputs are guaranteed not to undergo phase reversal or latchup. Therefore, the MAX492/MAX494/MAX495 can be used in applications with common-mode signals at or even beyond the supplies, without the problems associated with typical op amps.

The MAX492/MAX494/MAX495's output voltage swings to within 50mV of the supplies with a 100kΩ load. This rail-to-rail swing at the input and output substantially increases the dynamic range, especially in low supply-voltage applications. Figure 1 shows the input and output waveforms for the MAX492, configured as a unity-gain noninverting buffer operating from a single +3V supply. The input signal is $3.0V_{p-p}$, 1kHz sinusoid centered at +1.5V. The output amplitude is approximately $2.95V_{p-p}$.

Input Offset Voltage

Rail-to-rail common-mode swing at the input is obtained by two complementary input stages in parallel, which feed a folded cascaded stage. The PNP stage is active for input voltages close to the negative rail, and the NPN stage is active for input voltages close to the positive rail.

The offsets of the two pairs are trimmed; however, there is some small residual mismatch between them. This mismatch results in a two-level input offset characteristic, with a transition region between the levels occurring at a common-mode voltage of approximately 1.3V. Unlike other rail-to-rail op amps, the transition region has been widened to approximately 600mV in order to minimize the slight degradation in CMRR caused by this mismatch.

To adjust the MAX495's input offset voltage (500µV max at +25°C), connect a 10kΩ trim potentiometer between the two NULL pins (pins 1 and 5), with the wiper connected to V_{EE} (pin 4) (Figure 2). The trim range of this circuit is ±6mV. External offset adjustment is not available for the dual MAX492 or quad MAX494.

The input bias currents of the MAX492/MAX494/MAX495 are typically less than 50nA. The bias current flows into the device when the NPN input stage is active, and it flows out when the PNP input stage is active. To reduce the offset error caused by input bias current flowing through external source resistances, match the effective resistance seen at each input. Connect resistor R3 between the noninverting input and ground when using

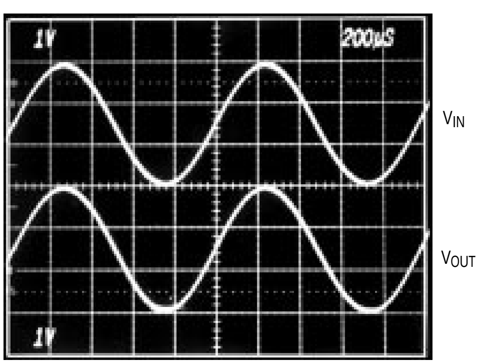


Figure 1. Rail-to-Rail Input and Output (Voltage Follower Circuit, V_{CC} = +3V, V_{EE} = 0V)

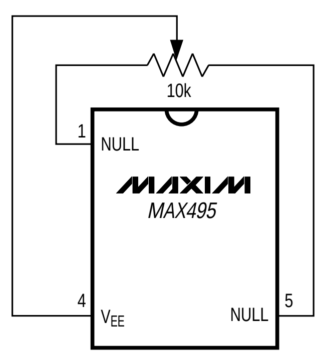


Figure 2. Offset Null Circuit

the op amp in an inverting configuration (Figure 3a); connect resistor R3 between the noninverting input and the input signal when using the op amp in a noninverting configuration (Figure 3b). Select R3 to equal the parallel combination of R1 and R2. High source resistances will degrade noise performance, due to the thermal noise of the resistor and the input current noise (which is multiplied by the source resistance).

Input Stage Protection Circuitry

The MAX492/MAX494/MAX495 include internal protection circuitry that prevents damage to the precision input stage from large differential input voltages. This protection circuitry consists of back-to-back diodes between IN+ and IN- with two 1.7kΩ resistors in series (Figure 4). The diodes limit the differential voltage applied to the amplifiers' internal circuitry to no more than V_F, where V_F is the diodes' forward-voltage drop (about 0.7V at +25°C).

Input bias current for the ICs (±25nA typical) is specified for the small differential input voltages. For large differential input voltages (exceeding V_F), this protection circuitry increases the input current at IN+ and IN-:

$$\text{Input Current} = \frac{(V_{IN+} - V_{IN-}) - V_F}{2 \times 1.7k\Omega}$$

For comparator applications requiring large differential voltages (greater than V_F), you can limit the input current that flows through the diodes with external resistors

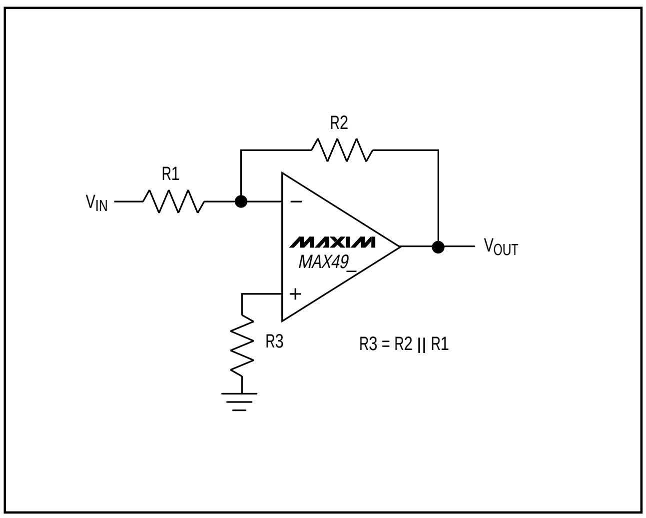


Figure 3a. Reducing Offset Error Due to Bias Current: Inverting Configuration

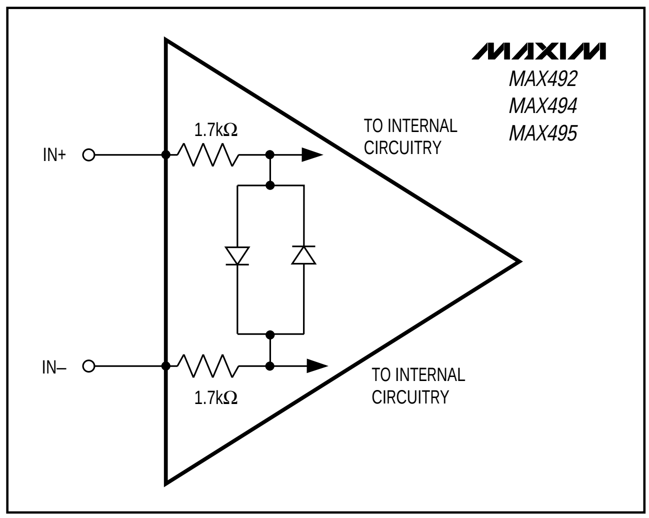


Figure 4. Input Stage Protection Circuitry

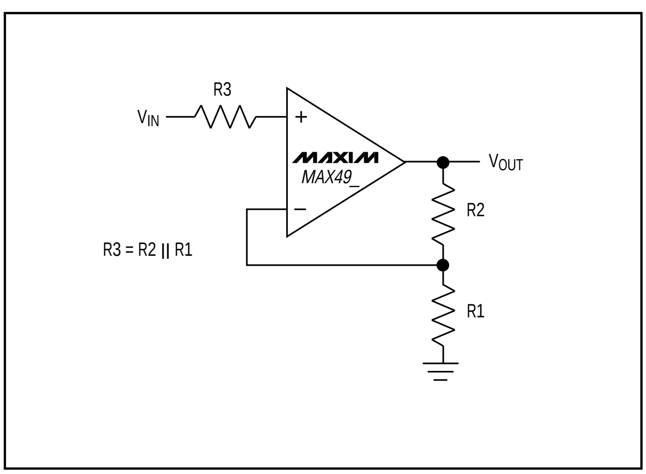


Figure 3b. Reducing Offset Error Due to Bias Current: Noninverting Configuration

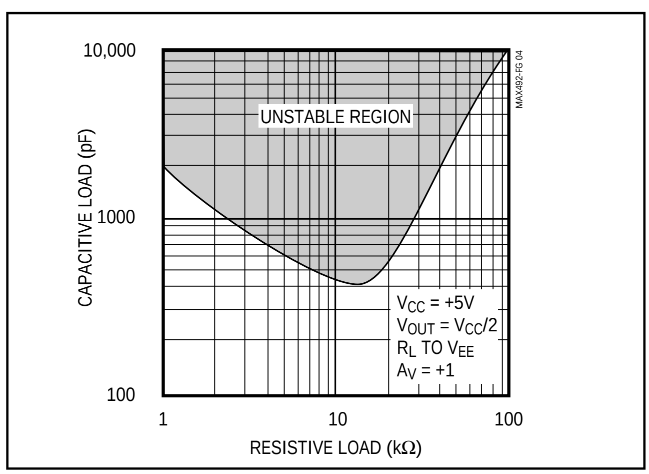


Figure 5. Capacitive-Load Stable Region Sourcing Current

Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

in series with IN-, IN+, or both. Series resistors are not recommended for amplifier applications, as they may increase input offsets and decrease amplifier bandwidth.

Output Loading and Stability

Even with their low quiescent current of less than 150µA per op amp, the MAX492/MAX494/MAX495 are well suited for driving loads up to 1kΩ while maintaining DC accuracy. Stability while driving heavy capacitive loads is another key advantage over comparable CMOS rail-to-rail op amps.

In op amp circuits, driving large capacitive loads increases the likelihood of oscillation. This is especially true for circuits with high loop gains, such as a unity-gain voltage follower. The output impedance and a capacitive load form an RC network that adds a pole to the loop response and induces phase lag. If the pole frequency is low enough—as when driving a large capacitive load—the circuit phase margin is degraded, leading to either an under-damped pulse response or oscillation.

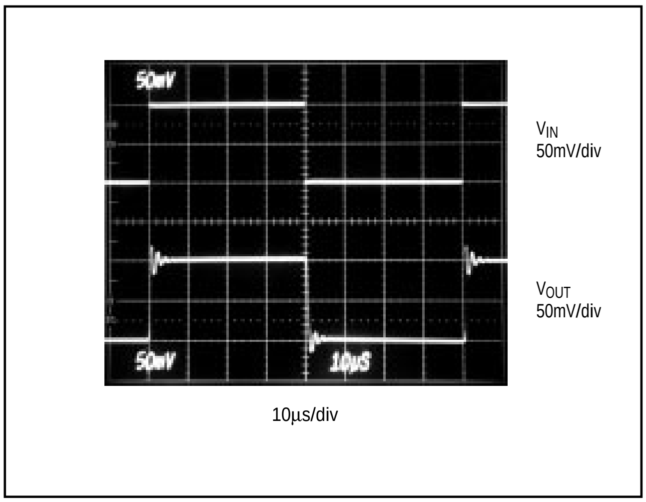


Figure 6. MAX492 Voltage Follower with 1000pF Load ($R_L = \infty$)

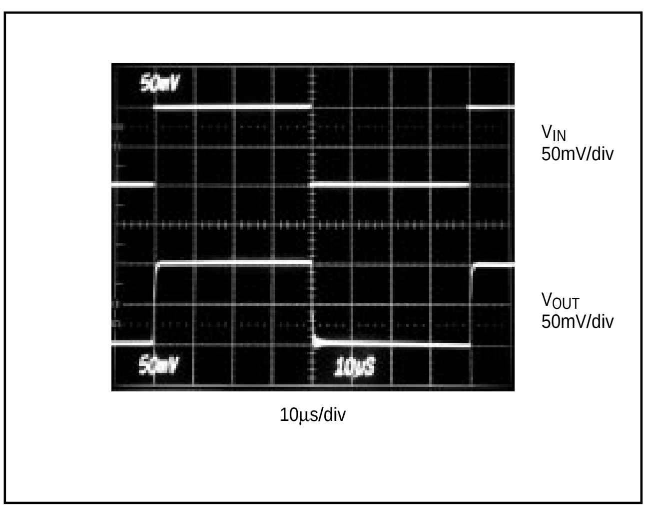


Figure 7a. MAX492 Voltage Follower with 500pF Load— $R_L = 5k\Omega$

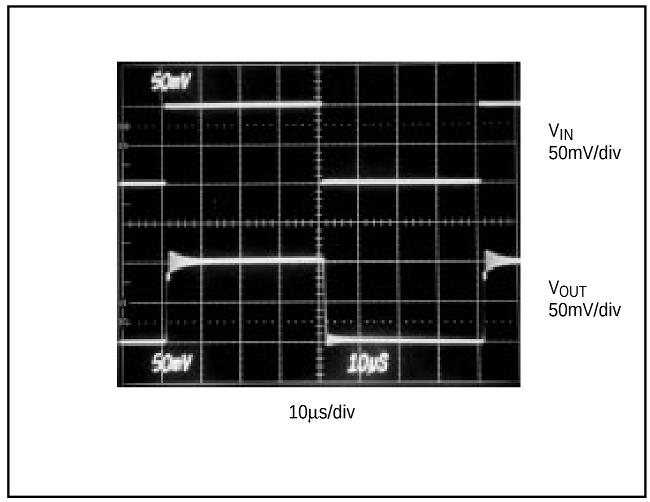


Figure 7b. MAX492 Voltage Follower with 500pF Load— $R_L = 20k\Omega$

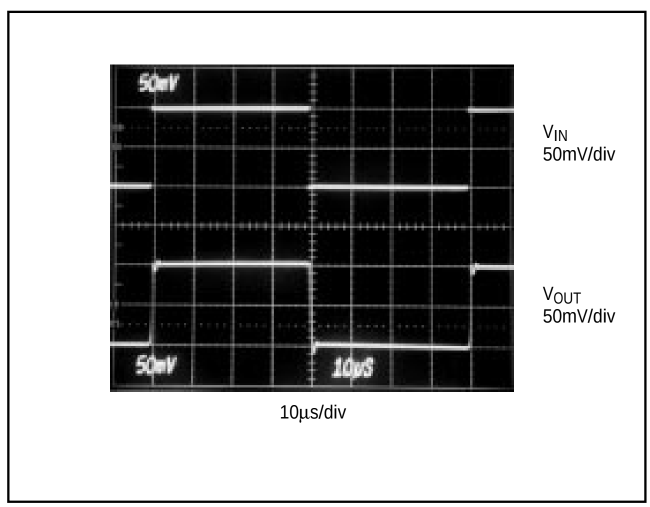


Figure 7c. MAX492 Voltage Follower with 500pF Load— $R_L = \infty$

The MAX492/MAX494/MAX495 can drive capacitive loads in excess of 1000pF under certain conditions (Figure 5). When driving capacitive loads, the greatest potential for instability occurs when the op amp is sourcing approximately 100µA. Even in this case, stability is maintained with up to 400pF of output capacitance. If the output sources either more or less current, stability is increased. These devices perform well with a 1000pF pure capacitive load (Figure 6). Figure 7 shows the performance with a 500pF load in parallel with various load resistors.

To increase stability while driving large capacitive loads, connect a pull-up resistor at the output to decrease the current that the amplifier must source. If the amplifier is made to sink current rather than source, stability is further increased.

Frequency stability can be improved by adding an output isolation resistor (R_S) to the voltage-follower circuit (Figure 8). This resistor improves the phase margin of the circuit by isolating the load capacitor from the op amp's output. Figure 9a shows the MAX492 driving 10,000pF ($R_L \geq 100k\Omega$), while Figure 9b adds a 47Ω isolation resistor.

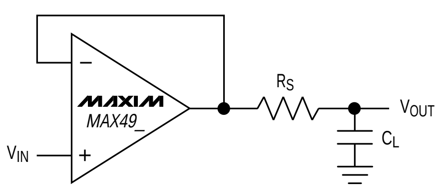


Figure 8. Capacitive-Load Driving Circuit

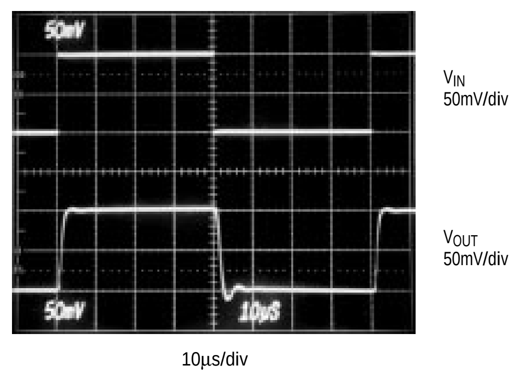


Figure 9b. Driving a 10,000pF Capacitive Load with a 47Ω Isolation Resistor

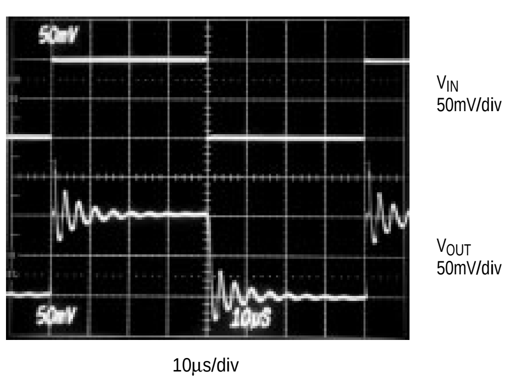


Figure 9a. Driving a 10,000pF Capacitive Load

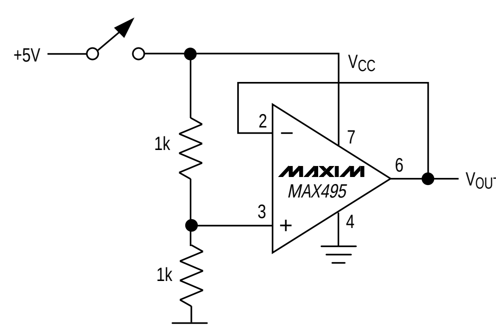


Figure 10. Power-Up Test Configuration

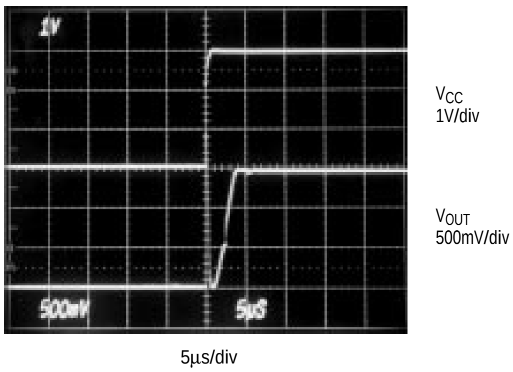


Figure 11a. Power-Up Settling Time (V_{CC} = +3V)

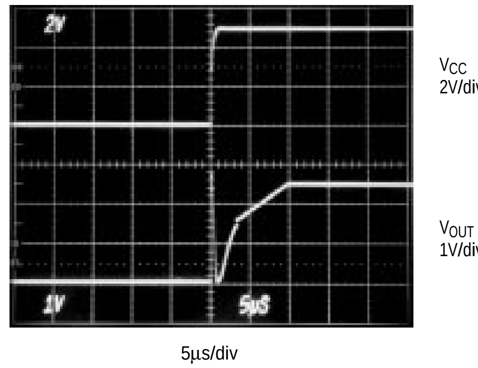


Figure 11b. Power-Up Settling Time (V_{CC} = +5V)

Because the MAX492/MAX494/MAX495 have excellent stability, no isolation resistor is required, except in the most demanding applications. This is beneficial because an isolation resistor would degrade the low-frequency performance of the circuit.

Power-Up Settling Time

The MAX492/MAX494/MAX495 have a typical supply current of 150µA per op amp. Although supply current is already low, it is sometimes desirable to reduce it further by powering down the op amp and associated ICs for periods of time. For example, when using a MAX494 to buffer the inputs to a multi-channel analog-to-digital converter (ADC), much of the circuitry could be powered down between data samples to increase battery life. If samples are taken infrequently, the op amps, along with the ADC, may be powered down most of the time.

When power is reapplied to the MAX492/MAX494/MAX495, it takes some time for the voltages on the supply pin and the output pin of the op amp to settle. Supply settling time depends on the supply voltage, the value of the bypass capacitor, the output impedance of the incoming supply, and any lead resistance or inductance between components. Op amp settling time depends primarily on the output voltage and is slew-rate limited. With the noninverting input to a voltage follower held at mid-supply (Figure 10), when the supply steps from 0V to V_{CC}, the output settles in approximately 4µs for V_{CC} = +3V (Figure 11a) or 10µs for V_{CC} = +5V (Figure 11b).

Power Supplies and Layout

The MAX492/MAX494/MAX495 operate from a single 2.7V to 6V power supply, or from dual supplies of ±1.35V to ±3V. For single-supply operation, bypass the power supply with a 1µF capacitor in parallel with a 0.1µF ceramic capacitor. If operating from dual supplies, bypass each supply to ground.

Good layout improves performance by decreasing the amount of stray capacitance at the op amp's inputs and output. To decrease stray capacitance, minimize both trace lengths and resistor leads and place external components close to the op amp's pins.

Rail-to-Rail Buffers

The *Typical Operating Circuit* shows a MAX495 gain-of-two buffer driving the analog input to a MAX187 12-bit ADC. Both devices run from a single 5V supply, and the converter's internal reference is 4.096V. The MAX495's typical input offset voltage is 200µV. This results in an error at the ADC input of 400µV, or less than half of one least significant bit (LSB). Without offset trimming, the op amp contributes negligible error to the conversion result.

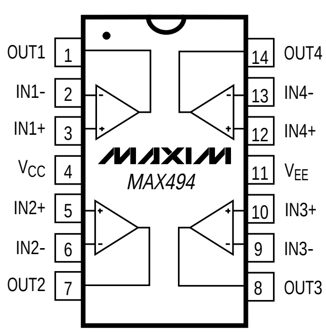
Ordering Information (continued)

PART	TEMP. RANGE	PIN-PACKAGE
MAX494CPD	0°C to +70°C	14 Plastic DIP
MAX494CSD	0°C to +70°C	14 SO
MAX494EPD	-40°C to +85°C	14 Plastic DIP
MAX494ESD	-40°C to +85°C	14 SO
MAX494MJD	-55°C to +125°C	14 CERDIP
MAX495CPA	0°C to +70°C	8 Plastic DIP
MAX495CSA	0°C to +70°C	8 SO
MAX495CUA	0°C to +70°C	8 µMAX
MAX495C/D	0°C to +70°C	Dice*
MAX495EPA	-40°C to +85°C	8 Plastic DIP
MAX495ESA	-40°C to +85°C	8 SO
MAX495MJA	-55°C to +125°C	8 CERDIP

Dice are specified at T_A = +25°C, DC parameters only.

Pin Configurations (continued)

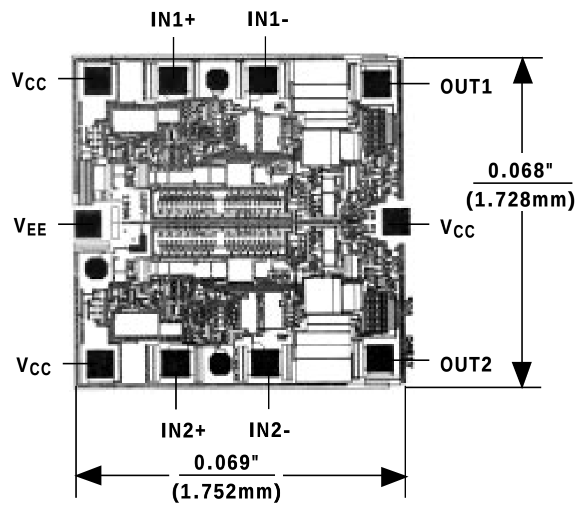
TOP VIEW



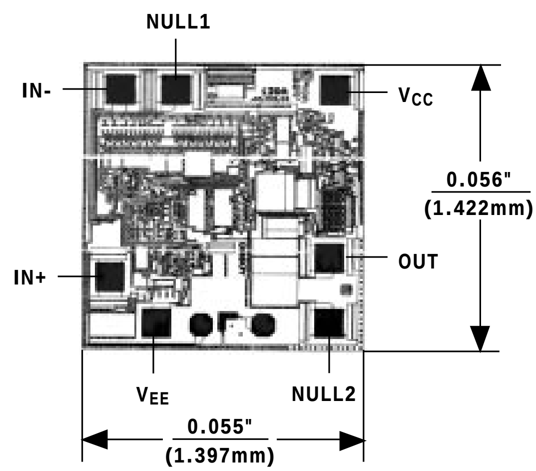
DIP/SO

Chip Topographies

MAX492



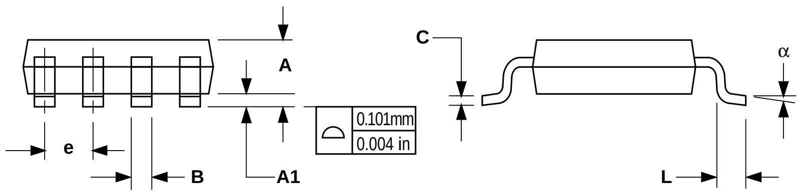
MAX495



TRANSISTOR COUNT: 134 (single MAX495)
268 (dual MAX492)
536 (quad MAX494)
SUBSTRATE CONNECTED TO V_{EE}

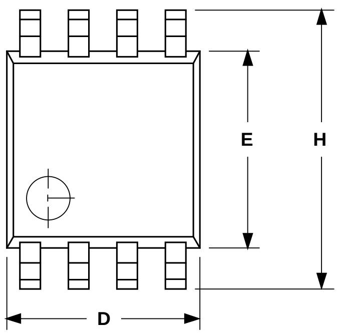
Single/Dual/Quad, Micropower, Single-Supply Rail-to-Rail Op Amps

Package Information

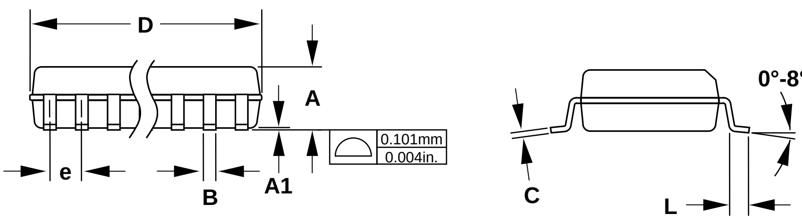


DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.036	0.044	0.91	1.11
A1	0.004	0.008	0.10	0.20
B	0.010	0.014	0.25	0.36
C	0.005	0.007	0.13	0.18
D	0.116	0.120	2.95	3.05
E	0.116	0.120	2.95	3.05
e	0.0256		0.65	
H	0.188	0.198	4.78	5.03
L	0.016	0.026	0.41	0.66
α	0°	6°	0°	6°

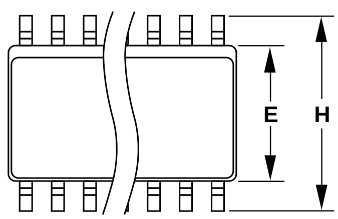
21-0036D



8-PIN μMAX MICROMAX SMALL-OUTLINE PACKAGE



DIM	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	0.150	0.157	3.80	4.00
e	0.050		1.27	
H	0.228	0.244	5.80	6.20
L	0.016	0.050	0.40	1.27



Narrow SO SMALL-OUTLINE PACKAGE (0.150 in.)

DIM	PINS	INCHES		MILLIMETERS	
		MIN	MAX	MIN	MAX
D	8	0.189	0.197	4.80	5.00
D	14	0.337	0.344	8.55	8.75
D	16	0.386	0.394	9.80	10.00

21-0041A