



## Dual/Quad Single Supply Operational Amplifier

### OP292/OP492

#### FEATURES

Single Supply Operation: 4.5 V to 33 V  
Input Common Mode Includes Ground  
Output Swings to Ground  
High Slew Rate: 3 V/ $\mu$ s  
High Gain Bandwidth: 4 MHz  
Low Input Offset Voltage  
High Open-Loop Gain  
No Phase Inversion  
Low Cost

#### APPLICATIONS

Disk Drives  
Mobile Phones  
Servo Controls  
Modems and Fax Machines  
Pagers  
Power Supply Monitors and Controls  
Battery Operated Instrumentation

#### GENERAL DESCRIPTION

The OP292/OP492 are low cost general purpose dual and quad operational amplifiers designed for single supply applications and are ideal for +5 volt systems.

Fabricated on Analog Devices' CBCMOS process, the OP292/OP492 series has a PNP input stage that allows the input voltage range to include ground. A BiCMOS output stage enables the output to swing to ground while sinking current.

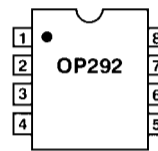
The OP292/OP492 series is unity-gain stable and features an outstanding combination of speed and performance for single or dual supply operation. The OP292/OP492 provide high slew rate, high bandwidth, with open-loop gain exceeding 40,000 and offset voltage under 800  $\mu$ V (OP292) and 1 mV (OP492). With these combinations of features and low supply current, the OP292/OP492 series is an excellent choice for battery operated applications.

The OP292/OP492 series performance is specified for single or dual supply voltage operation over the extended industrial temperature range ( $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ).

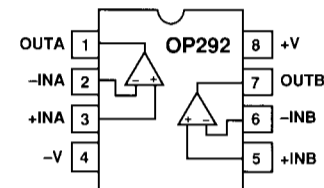
Package options for the OP292 and OP492 include plastic DIP, SO-8 (OP292) and SO-14.

#### PIN CONNECTIONS

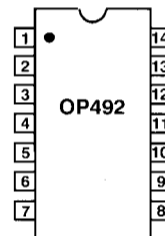
8-Lead Narrow-Body SO  
(S Suffix)



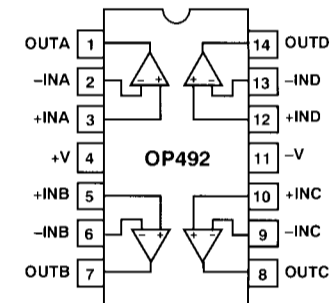
8-Lead Epoxy DIP  
(P Suffix)



14-Lead Narrow-Body SO  
(S Suffix)



14-Lead Epoxy DIP  
(P Suffix)



#### REV. 0

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# OP292/OP492—SPECIFICATIONS

## ELECTRICAL CHARACTERISTICS (@ $V_S = +5\text{ V}$ , $V_{CM} = 0\text{ V}$ , $V_O = +2\text{ V}$ , $T_A = +25^\circ\text{C}$ unless otherwise noted)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
<b>INPUT CHARACTERISTICS</b>						
Offset Voltage OP292	$V_{OS}$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		0.1	0.8	mV
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.3	1.2	mV
Offset Voltage OP492	$V_{OS}$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		0.5	2.5	mV
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.1	1	mV
Input Bias Current	$I_B$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		0.3	1.5	mV
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.5	2.5	mV
Input Offset Current	$I_{OS}$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$		450	700	nA
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.75	2.5	$\mu\text{A}$
Input Voltage Range Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0\text{ V to }4.0\text{ V}$	0	75	95	V
		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$	75	70	93	dB
Large Signal Voltage Gain	$A_{VO}$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	65	90	90	dB
		$R_L = 10\text{ k}\Omega$ , $V_O = 0.1\text{ V to }4\text{ V}$	25	200	200	V/mV
Offset Voltage Drift Long Term $V_{OS}$ Drift	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$	10	100	100	V/mV
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	5	50	50	V/mV
Bias Current Drift	$\Delta I_B/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$	2	10	10	$\mu\text{V}/^\circ\text{C}$
		Note 1	1			$\mu\text{V}/\text{Month}$
Offset Current Drift	$\Delta I_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$	6	400	400	$\text{pA}/^\circ\text{C}$
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	1.5	1.5	1.5	$\text{pA}/^\circ\text{C}$
<b>OUTPUT CHARACTERISTICS</b>						
Output Voltage Swing High	$V_{OUT}$	$R_L = 100\text{ k}\Omega$ to GND	4.0	4.3		V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	3.8	4.1		V
Output Voltage Swing Low	$V_{OUT}$	$R_L = 2\text{ k}\Omega$ to GND	3.7	3.9		V
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		8	20	mV
Short Circuit Current Limit	$I_{SC}$	$R_L = 100\text{ k}\Omega$ to $V+$		12	20	mV
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		280	450	mV
		$R_L = 2\text{ k}\Omega$ to $V+$		300	550	mV
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	5	8		mA
<b>POWER SUPPLY</b>						
Power Supply Rejection Ratio	PSRR	$V_S = 4.5\text{ V to }+30\text{ V}$ , $V_O = 2\text{ V}$	75	95		dB
Supply Current Per Amp OP292, OP492	$I_{SY}$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	70	90		dB
		$V_O = 2\text{ V}$		0.8	1.2	mA
<b>DYNAMIC PERFORMANCE</b>						
Slew Rate	SR	$R_L = 10\text{ k}\Omega$		3		V/ $\mu\text{s}$
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	1	2		V/ $\mu\text{s}$
Gain Bandwidth Product	GBP			4		MHz
Phase Margin	$\phi_m$			75		Degrees
Channel Separation	CS	$f_O = 1\text{ kHz}$		100		dB
<b>NOISE PERFORMANCE</b>						
Voltage Noise	$e_n$ p-p	0.1 Hz to 10 Hz		25		$\mu\text{V p-p}$
Voltage Noise Density	$e_n$	$f = 1\text{ kHz}$		15		$\text{nV}/\sqrt{\text{Hz}}$
Current Noise Density	$i_n$			0.7		$\text{pA}/\sqrt{\text{Hz}}$

### NOTES

<sup>1</sup>Long term offset voltage drift is guaranteed by 1000 hours life test performed on three independent wafer lots at  $+125^\circ\text{C}$  with LTPD of 1.3.

Specifications subject to change without notice.

OP292/OP492

**ELECTRICAL CHARACTERISTICS** (@  $V_S = \pm 15\text{ V}$ ,  $T_A = +25^\circ\text{C}$  unless otherwise noted)

Parameter	Symbol	Conditions	Min	Typ	Max	Units	
<b>INPUT CHARACTERISTICS</b>							
Offset Voltage	$V_{OS}$	$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		1.0	2.0	mV	
OP292				1.2	2.5	mV	
		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		1.5	3	mV	
OP492				1.4	2.5	mV	
		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		1.7	2.8	mV	
Input Bias Current				2	3	mV	
Input Offset Current	$I_{OS}$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		0.5	1	$\mu\text{A}$	
		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		7	50	nA	
		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		20	100	nA	
Input Voltage Range		Note 1	-11		11	V	
Common-Mode Rejection Ratio	CMRR	$V_{CM} = \pm 11\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	78	100		dB	
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	75	95		dB	
Large Signal Voltage Gain	$A_{VO}$	$R_L = 10\text{ k}\Omega$ , $V_O = \pm 10\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	25	120		V/mV	
		$-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	10	75		V/mV	
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	5	60		$\mu\text{V}/^\circ\text{C}$	
Bias Current Drift	$\Delta I_B/\Delta T$	$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		4	10	$\mu\text{A}/^\circ\text{C}$	
		$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$		3		$\text{pA}/^\circ\text{C}$	
<b>OUTPUT CHARACTERISTICS</b>							
Output Voltage Swing	$V_O$	$R_L = 2\text{ k}\Omega$ to GND $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	$\pm 11$	$\pm 12.2$		V	
			$R_L = 100\text{ k}\Omega$ to GND $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	$\pm 10$	$\pm 11$		V
			$-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	$\pm 13.8$	$\pm 14.3$		V
Short Circuit Current Limit	$I_{SC}$	Short Circuit to GND	$\pm 13.5$	$\pm 14.0$		mV	
			8	10.5		mA	
<b>POWER SUPPLY</b>							
Power Supply Rejection Ratio	PSRR	$V_S = \pm 2.25\text{ V}$ to $\pm 15\text{ V}$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	75	86		dB	
			70	83		dB	
Supply Current Per Amp	$I_{SY}$	$V_O = 0\text{ V}$		1	1.4	mA	
<b>DYNAMIC PERFORMANCE</b>							
Slew Rate	SR	$R_L = 10\text{ k}\Omega$ $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$	2.5	4		V/ $\mu\text{s}$	
			2	3		V/ $\mu\text{s}$	
Gain Bandwidth Product	GBP			4		MHz	
Phase Margin	$\phi_m$			75		Degrees	
Channel Separation	CS	$f_O = 1\text{ kHz}$		100		dB	
<b>NOISE PERFORMANCE</b>							
Voltage Noise	$e_n$ p-p	0.1 Hz to 10 Hz		25		$\mu\text{V p-p}$	
Voltage Noise Density	$e_n$	$f = 1\text{ kHz}$		15		$\text{nV}/\sqrt{\text{Hz}}$	
Current Noise Density	$i_n$			0.7		$\text{pA}/\sqrt{\text{Hz}}$	

NOTES

<sup>1</sup>Input voltage range is guaranteed by CMRR tests.

Specifications subject to change without notice.

## OP292/OP492

### WAFER TEST LIMITS (@ $V_S = +5.0\text{ V}$ , $V_{CM} = 2.5\text{ V}$ , $T_A = +25^\circ\text{C}$ unless otherwise noted)

Parameter	Symbol	Conditions	Limit	Units
Offset Voltage	$V_{OS}$		$\pm 600$	$\mu\text{V}$ max
Input Bias Current	$I_B$		700	nA max
Input Offset Current	$I_{OS}$		50	nA max
Input Voltage Range <sup>1</sup>	$V_{CM}$		0/4	V min/V max
Common-Mode Rejection	CMRR	$V_{CM} = 0\text{ V to } 4.0\text{ V}$	75	dB min
Power Supply Rejection Ratio	PSRR	$V = \pm 4.5\text{ V to } \pm 15\text{ V}$	75	dB min
Large Signal Voltage Gain	$A_{VO}$	$R_L = 10\text{ k}\Omega$ , $V_O = 0.1\text{ V to } 4\text{ V}$	25	V/mV min
Output Voltage	$V_O$	$R_L = 2\text{ k}\Omega$	3.8	V min
Supply Current per Amp OP292, OP492	$I_{SY}$	$V_O = 0\text{ V}$ , $R_L = \text{Open}$	1.2	mA max

#### NOTES

Electrical tests and wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualifications through sample lot assembly and testing.

<sup>1</sup>Guaranteed by CMR test.

Specifications subject to change without notice.

#### ABSOLUTE MAXIMUM RATINGS<sup>1</sup>

Supply Voltage	+33 V
Input Voltage <sup>2</sup>	-15 V to +14 V
Differential Input Voltage <sup>2</sup>	V
Output Short-Circuit Duration	UNLIMITED
Storage Temperature Range	
P, S Package	-65°C to +150°C
Operating Temperature Range	
OP292/OP492 P, S	-40°C to +125°C
Junction Temperature Range	
P, S Package	-65°C to +125°C
Lead Temperature Range (Soldering, 60 sec)	+300°C

Package Type	$\theta_{JA}$ <sup>3</sup>	$\theta_{JC}$	Units
8-Pin Plastic DIP (P)	103	43	°C/W
14-Pin Plastic DIP (P)	83	39	°C/W
8-Pin SO (S)	158	43	°C/W
14-Pin SO (S)	120	36	°C/W

#### NOTES

<sup>1</sup>Absolute maximum ratings apply to both DICE and packaged parts, unless otherwise noted.

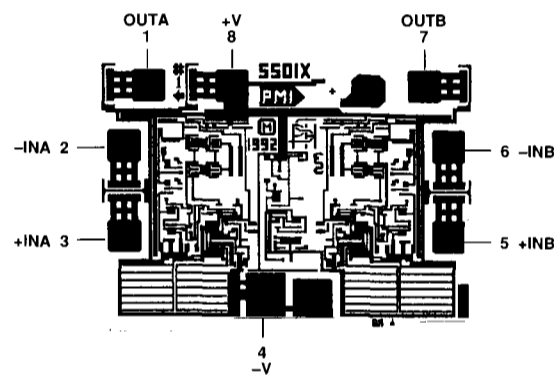
<sup>2</sup>For supply voltages less than +36 V, the absolute maximum input voltage is equal to the supply voltage.

<sup>3</sup> $\theta_{JA}$  is specified for the worst case conditions, i.e.,  $\theta_{JA}$  is specified for device in socket for P-DIP package;  $\theta_{JA}$  is specified for device soldered in circuit board for SOIC package.

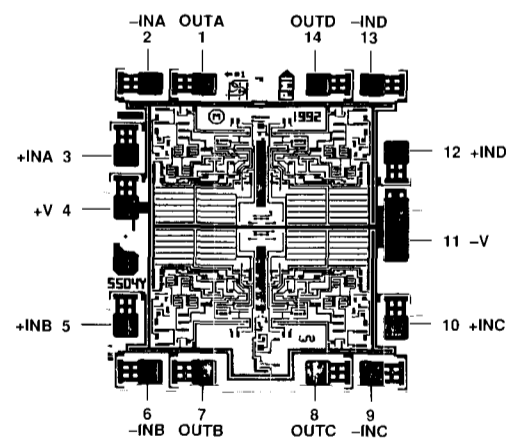
#### ORDERING GUIDE

Model	Temperature Range	Package Option
OP292GP	-40°C to +125°C	N-8
OP292GS	-40°C to +125°C	SO-8
OP492GP	-40°C to +125°C	N-14
OP492GS	-40°C to +125°C	SO-14
OP292/492GBC	+25°C	DICE

#### DICE CHARACTERISTICS



OP292 Die Size 0.040 × 0.057 Inch, 2,280 Sq. Mils  
Substrate Connected to V+, Number of Transistors:  
Bipolar 47, MOSFET 5.



OP492 Die Size 0.057 × 0.068 Inch, 3,876 Sq. Mils  
Substrate Connected to V+, Number of Transistors:  
Bipolar 91, MOSFET 9.

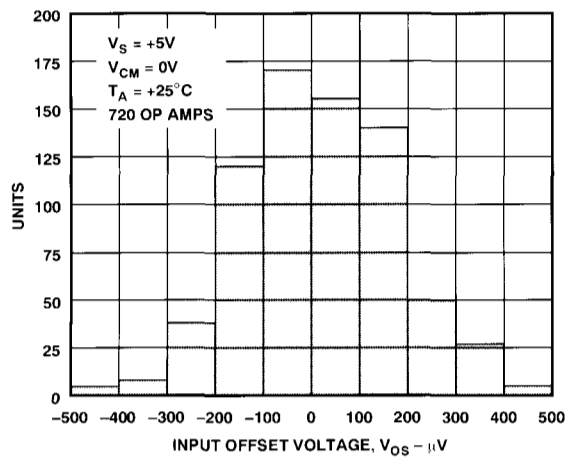


Figure 1. OP292 Input Offset Voltage Distribution @ +5 V

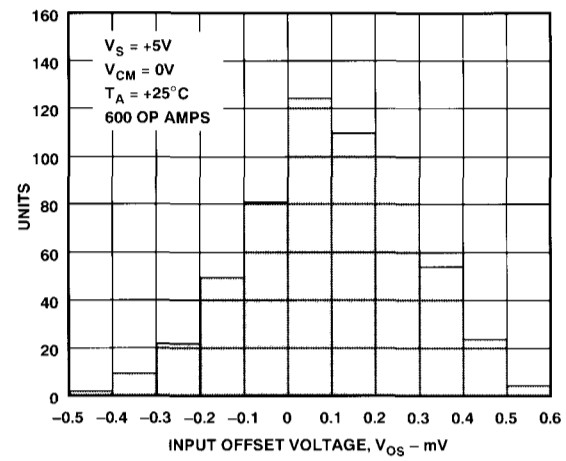


Figure 4. OP492 Input Offset Voltage Distribution @ +5 V

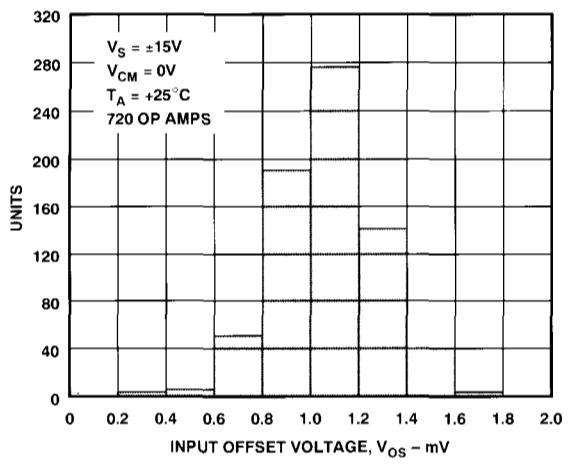


Figure 2. OP292 Input Offset Voltage Distribution @ ±15 V

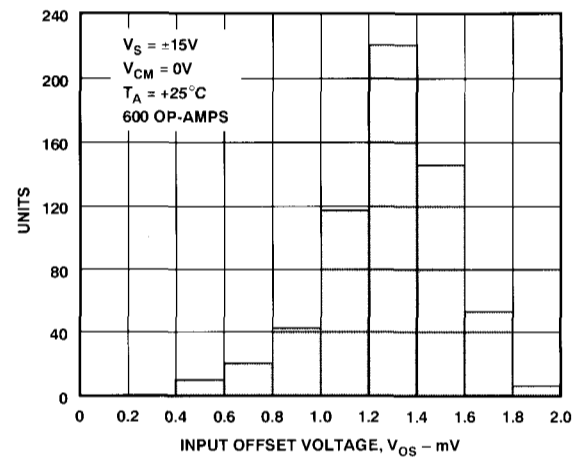


Figure 5. OP492 Input Offset Voltage Distribution @ ±15 V

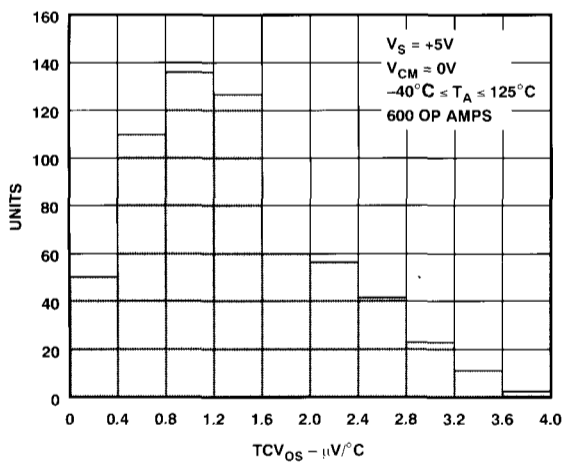


Figure 3. OP292 Temperature Drift ( $TCV_{OS}$ ) Distribution @ +5 V

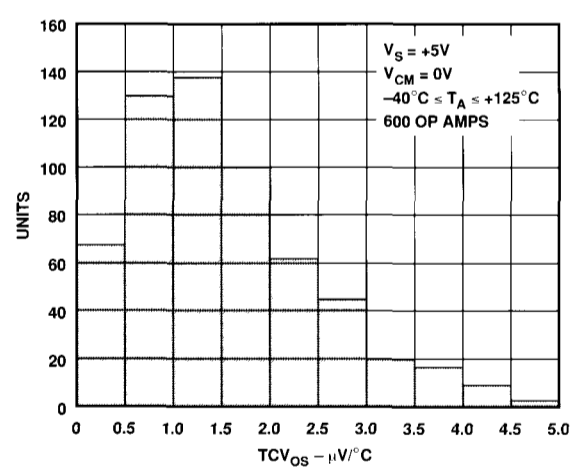


Figure 6. OP492 Temperature Drift ( $TCV_{OS}$ ) Distribution @ +5 V

## OP292/OP492

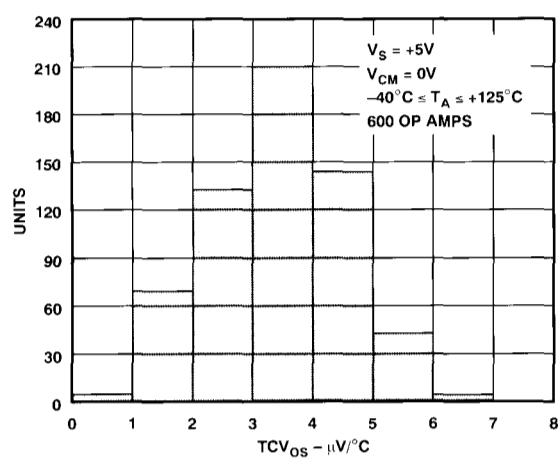


Figure 7. OP292 Temperature Drift ( $TCV_{OS}$ ) Distribution @  $\pm 15$  V

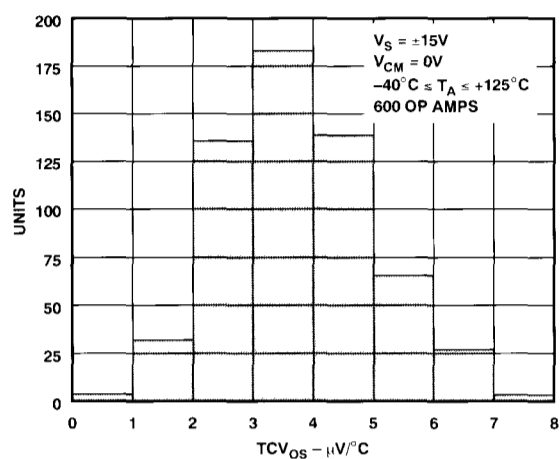


Figure 10. OP492 Temperature Drift ( $TCV_{OS}$ ) Distribution @  $\pm 15$  V

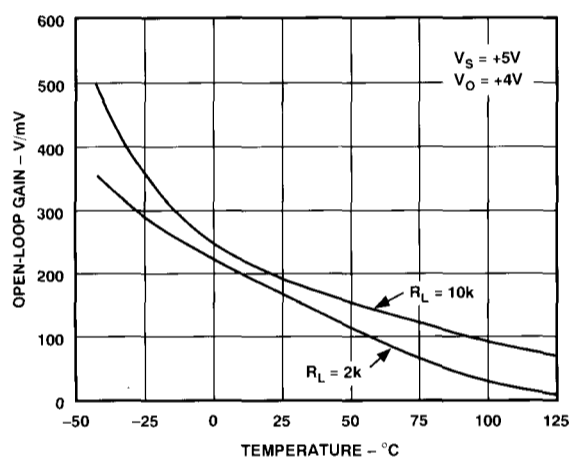


Figure 8. OP292 Open-Loop Gain vs. Temperature @ +5 V

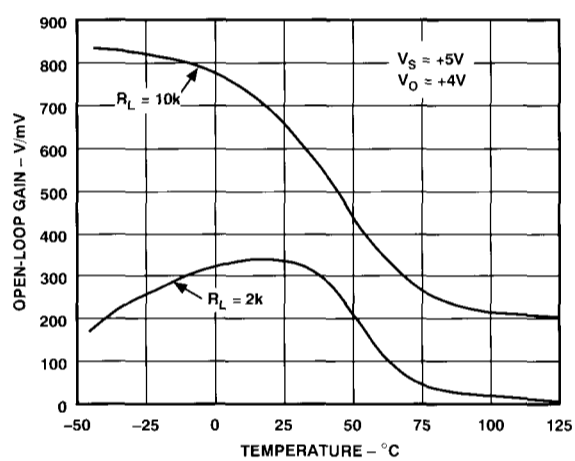


Figure 11. OP492 Open-Loop Gain vs. Temperature @ +5 V

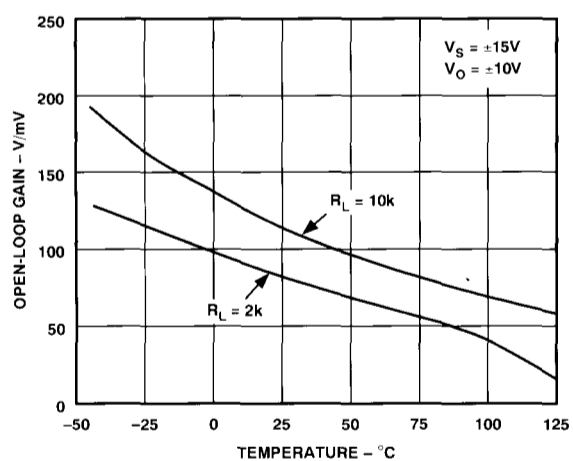


Figure 9. OP292 Open-Loop Gain vs. Temperature @  $\pm 15$  V

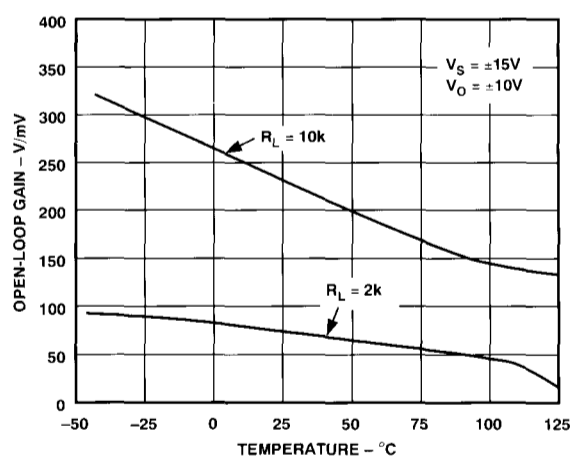


Figure 12. OP492 Open-Loop Gain vs. Temperature @  $\pm 15$  V

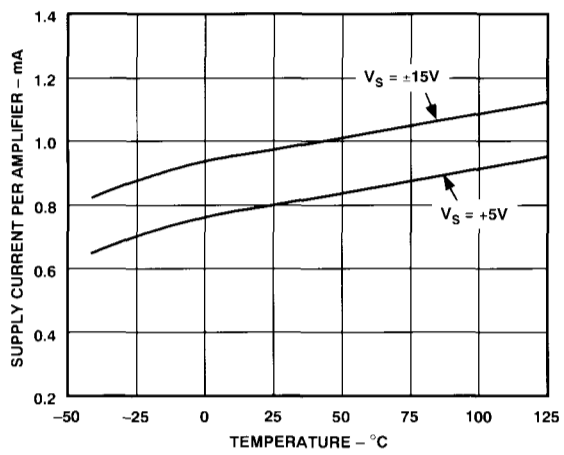


Figure 13. OP292 Supply Current per Amplifier vs. Temperature

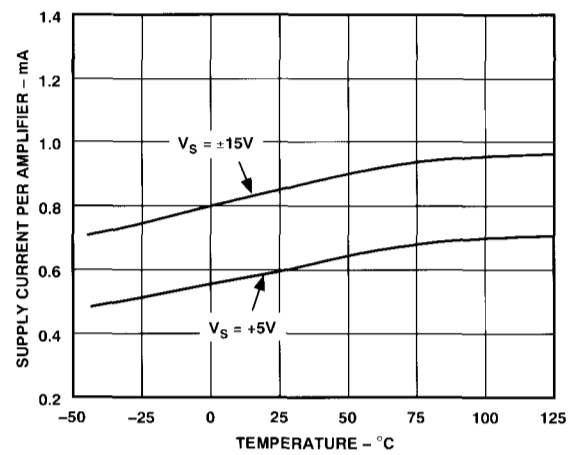


Figure 16. OP492 Supply Current per Amplifier vs. Temperature

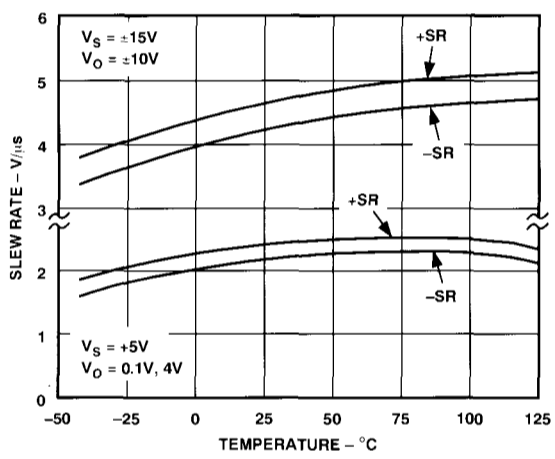


Figure 14. OP292 Slew-Rate vs. Temperature

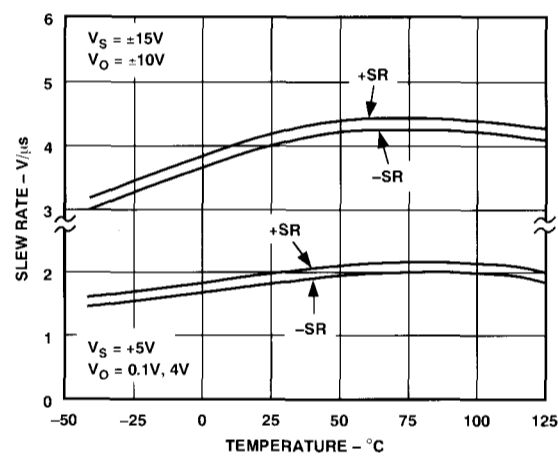


Figure 17. OP492 Slew-Rate vs. Temperature

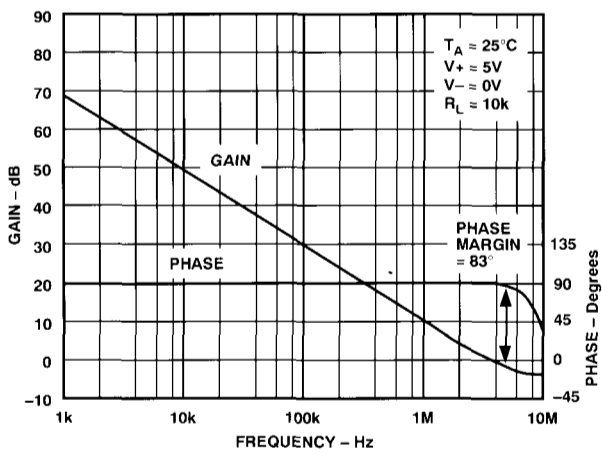


Figure 15. OP292/OP492 Open-Loop Gain and Phase vs. Frequency @ +5 V

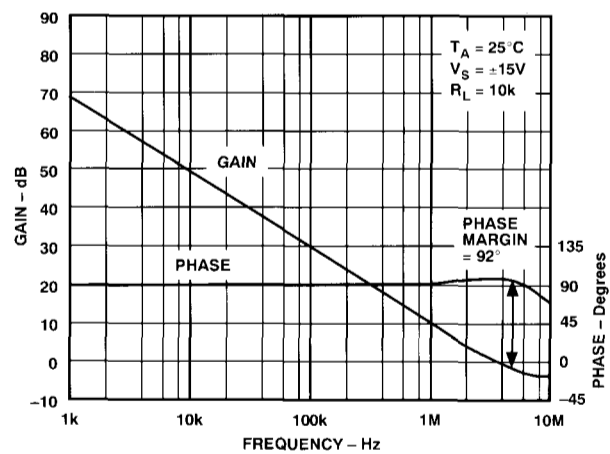


Figure 18. OP292/OP492 Open-Loop Gain/Phase vs. Frequency @ ±15 V

## OP292/OP492

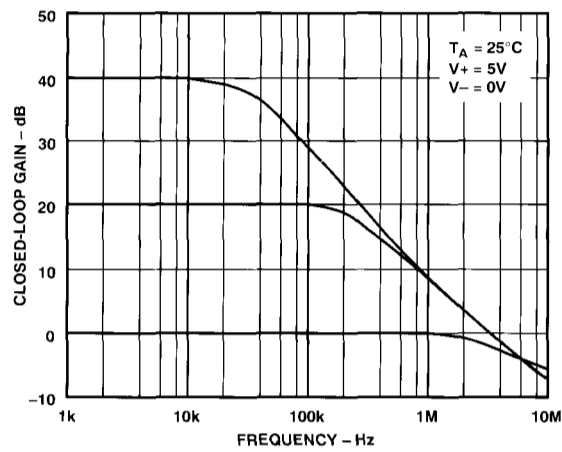


Figure 19. OP292/OP492 Closed-Loop Gain/Phase vs. Frequency @ +5 V

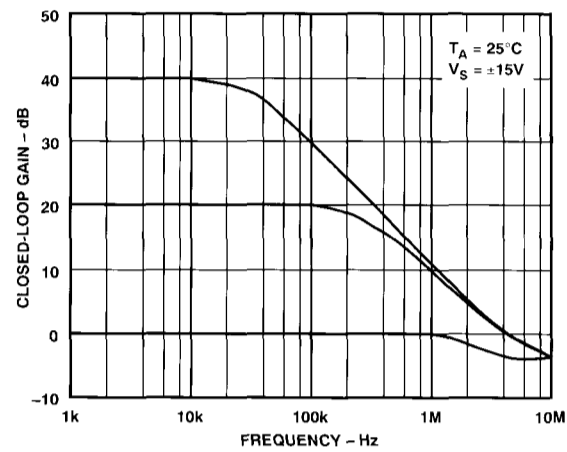


Figure 22. OP292/OP492 Closed-Loop Gain/Phase vs. Frequency @ ±15 V

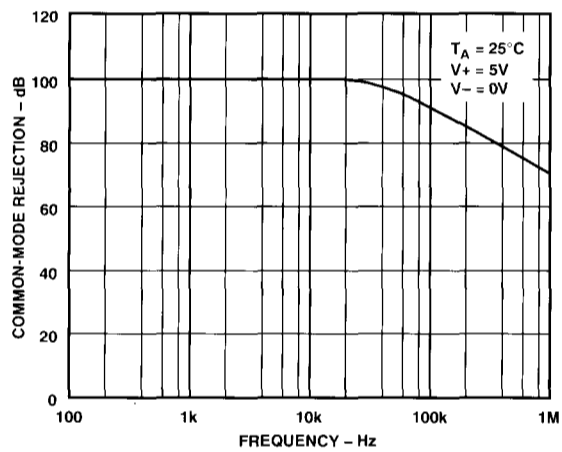


Figure 20. OP292/OP492 CMR vs. Frequency @ +5 V

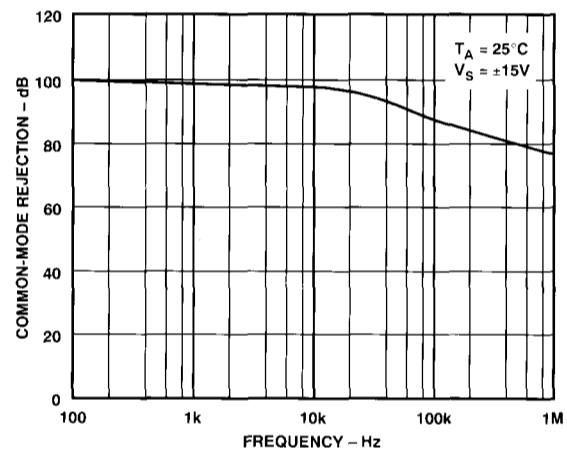


Figure 23. OP292/OP492 CMR vs. Frequency @ ±15 V

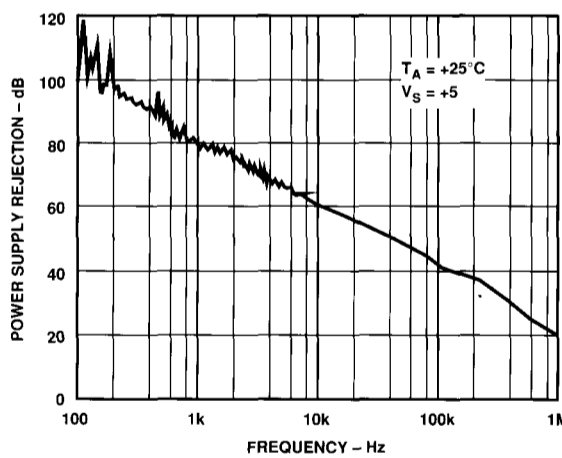


Figure 21. OP292/OP492 PSR vs. Frequency @ +5 V

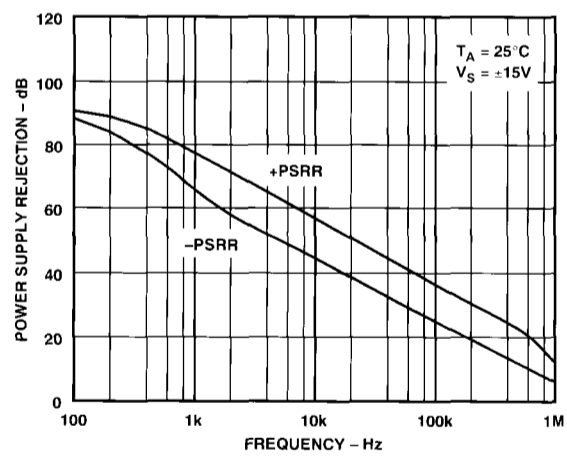


Figure 24. OP292/OP492 PSR vs. Frequency @ ±15 V



OP292/OP492

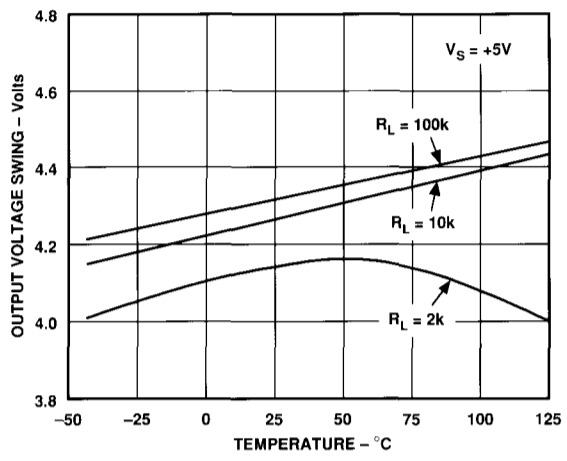


Figure 25. OP292/OP492  $V_{OUT}$  Swing vs. Temperature @ +5 V

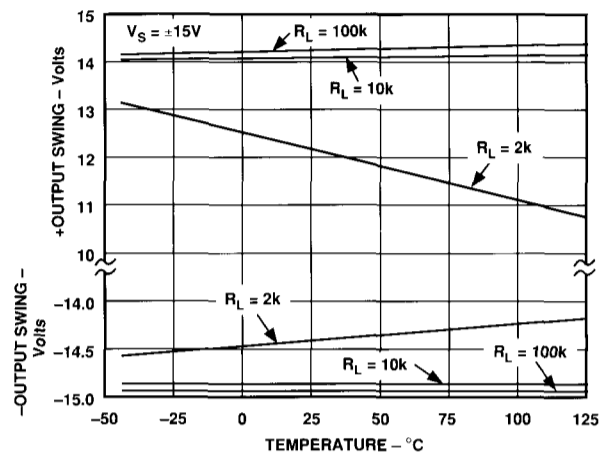


Figure 28. OP292/OP492  $V_{OUT}$  Swing vs. Temperature @ ±15 V

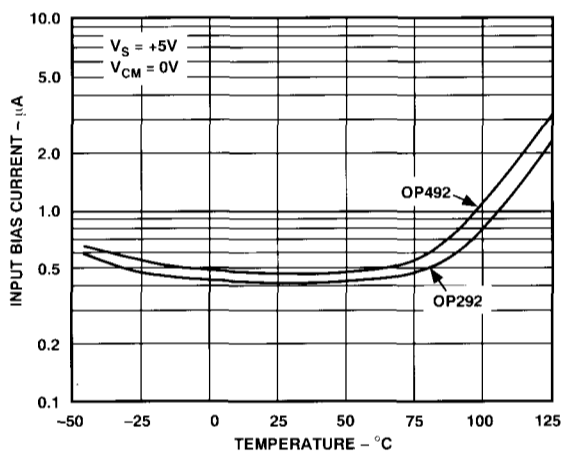


Figure 26. OP292/OP492 Input Bias Current vs. Temperature @ +5 V

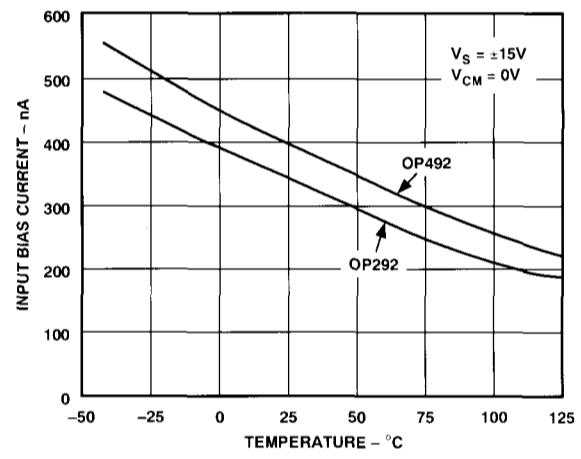


Figure 29. OP292/OP492 Input Bias Current vs. Temperature @ ±15 V

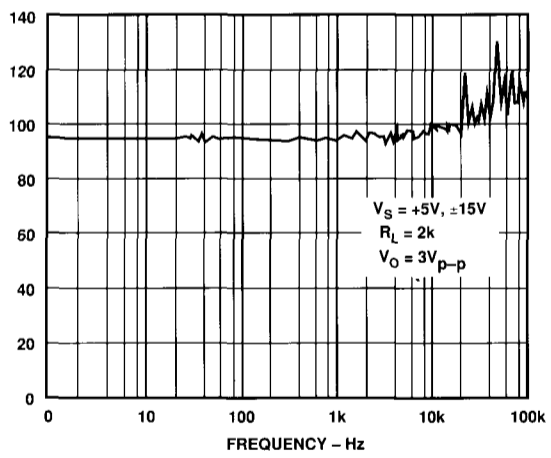


Figure 27. OP292/OP492 Channel Separation

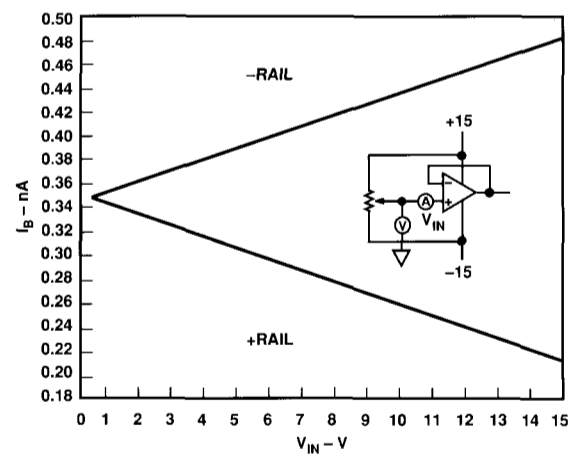


Figure 30. OP292/OP492  $I_B$  Current vs. Common Mode Voltage

## OP292/OP492

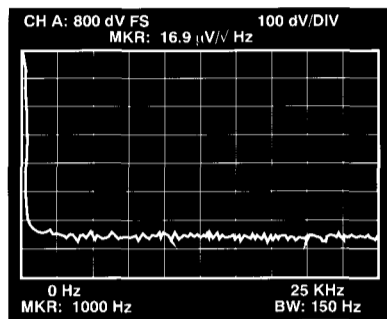


Figure 31. Voltage Noise Density

### APPLICATION INFORMATION

#### PHASE REVERSAL

The OP492 has built-in protection against phase reversal when the input voltage goes to either supply rail. In fact it is safe for the input to exceed either supply rail by up to 0.6 V with no risk of phase reversal. However, the input should not go beyond the positive supply rail by more than 0.9 V, otherwise the output will reverse phase. If this condition can occur, the problem can be fixed by adding a 5 k $\Omega$  current limiting resistor in series with the input pin. With this addition, the input can go to more than 5 V beyond the positive rail without phase reversal.

An input voltage that is as much as 5 V below the negative rail will not result in phase reversal.

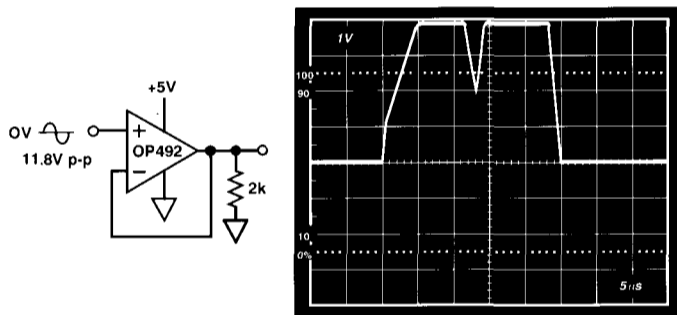


Figure 32. Output Can Reverse Phase If Input Exceeds the Positive Supply ( $V_+$ ) by More Than 0.9 V

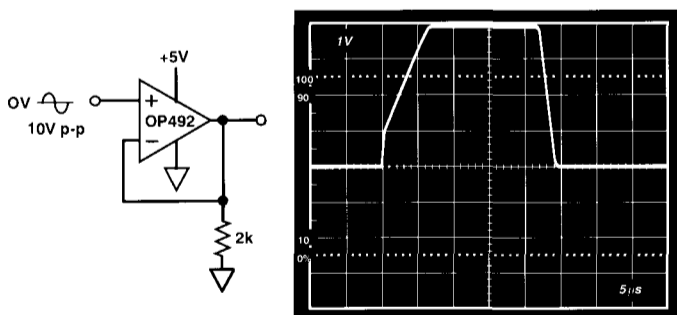


Figure 33. No Negative Rail Phase Reversal, Even with Input Signal at 5 V Below Ground

#### Power Supply Considerations

The OP292/OP492 are designed to operate equally well at single +5 V or  $\pm 15$  V supplies. The lowest supply voltage recommended is 4.5 V.

It is a good design practice to bypass the supply pins with a 0.1  $\mu$ F ceramic capacitor. It helps improve filtering of high frequency noise.

For dual supply operation, the negative supply ( $V_-$ ) must be applied at the same time, or before  $V_+$ . If  $V_+$  is applied before  $V_-$ , or in the case of a loss of  $V_-$  supply, while either input is connected to ground or other low impedance source, excessive input current may result. Potentially damaging levels of input current can destroy the amplifier. If this condition can exist, simply add a 1k or larger resistor in series with the input to eliminate the problem.

#### TYPICAL APPLICATIONS

##### Direct Access Arrangement for Telephone Line Interface

Figure 34 shows a +5 V-only transmit/receive telephone line interface for a modem circuit. It allows full duplex transmission of modem signals on a transformer-coupled 600  $\Omega$  line in a differential manner. The transmit section gain can be set for the specific modem device output. Similarly the receive amplifier gain can be appropriately selected based on the modem device input requirements. The circuit operates on a single +5 V supply. The standard value resistors allow the use of a SIP packaged resistor array; this, coupled with a quad op amp in a single package, offers a compact, low part-count solution.

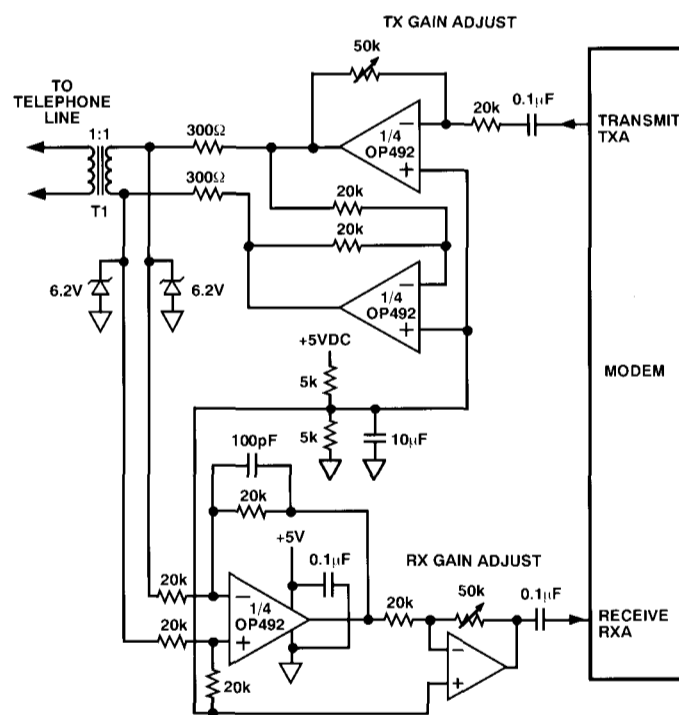


Figure 34. A Universal Direct Access Arrangement for Telephone Line Interface

## OP292/OP492

### A Single Supply Instrumentation Amplifier

A low cost single supply instrumentation amplifier can be built as shown in Figure 35. The circuit utilizes two op amps to form a high input impedance differential amplifier. Gain can be set by selecting resistor  $R_G$  which can be calculated using the transfer function equation. Normally,  $V_{REFERENCE}$  is set to 0 V. Then the output voltage is a function of the gain times the differential input voltage. However, the output can be offset by setting  $V_{REFERENCE}$  from 0 V to 4 V, as long as the input common-mode voltage of the amplifier is not exceeded.

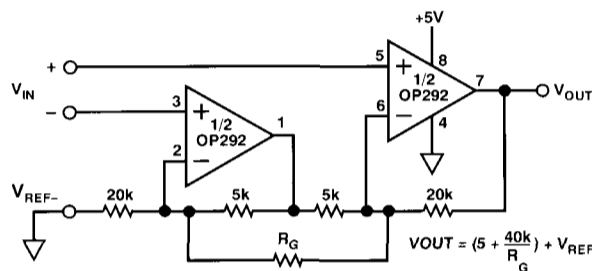


Figure 35. A Single Supply Instrumentation Amplifier

In this configuration, while the output can swing to near zero volts, one needs to be careful because the input's common-mode voltage range cannot operate to zero volts. This is because of the limitation of the circuit configuration where the first amplifier must be able to swing below ground in order to attain a 0 V common-mode voltage, which it cannot do. Depending on the gain of the instrumentation amplifier, the input common-mode extends to within about 0.3 V of zero. One can easily calculate the worst-case common-mode limit for a given gain.

### DAC Output Amplifier

The OP292/OP492 are ideal for buffering the output of single supply D/A converters. Figure 36 shows a typical amplifier used to buffer the output of a CMOS DAC that is connected for single supply operation. To do that, the normally current output 12-bit CMOS DAC (R-2R ladder type) is connected backward to produce a voltage output. This operating configuration necessitates a low voltage reference. In this case, a 1.235 V low power reference is used. The relatively high output impedance (10k) is buffered by the OP292 and at the same time gained up to a much more usable level. The potentiometer provides an accurate gain trim for a 4.095 V full-scale, allowing 1 mV increment per LSB of control resolution.

The DAC8043 device comes in an 8-pin DIP package providing a cost-effective, compact solution to a 12-bit analog channel.

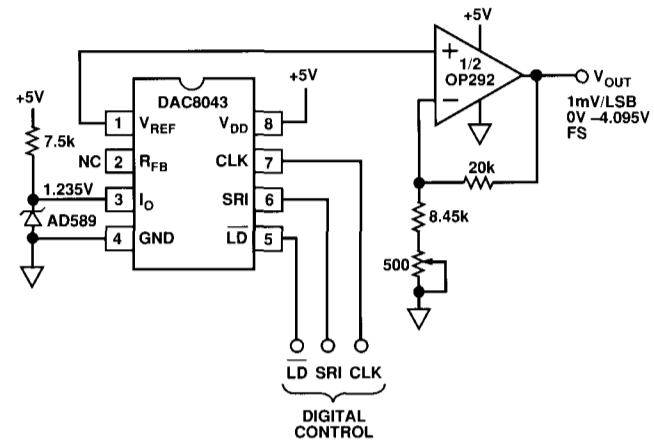


Figure 36. A 12-Bit Single-Supply DAC With Serial Bus Control

### A 50 Hz/60 Hz Single-Supply Notch Filter

Figure 37 shows a notch filter that achieves nearly 30 dB of 60 Hz rejection while powered by only a single 12 V supply. The circuit also works well on +5 V systems. The filter utilizes a twin-T configuration whose frequency selectivity depends heavily on the relative matching of the capacitors and resistors in the twin-T section. Mylar is a good choice for the twin-T's capacitors, and the relative matching of the capacitors and resistors determines the filter's passband symmetry. Using 1% resistors and 5% capacitors produces satisfactory results.

The amount of rejection and the Q of the filter is solely determined by one resistor, and is shown in the table. The bottom amplifier is used to split the supply to bias the amplifier to mid-level. The circuit can be modified to reject 50 Hz by simply changing the resistors in the twin-T section ( $R_1$  through  $R_4$ ) from 2.67k to 3.16k, and change  $R_5$  to 1/2 of 3.16k. For best results, the common value resistors can be from a resistor array for optimum matching characteristics.

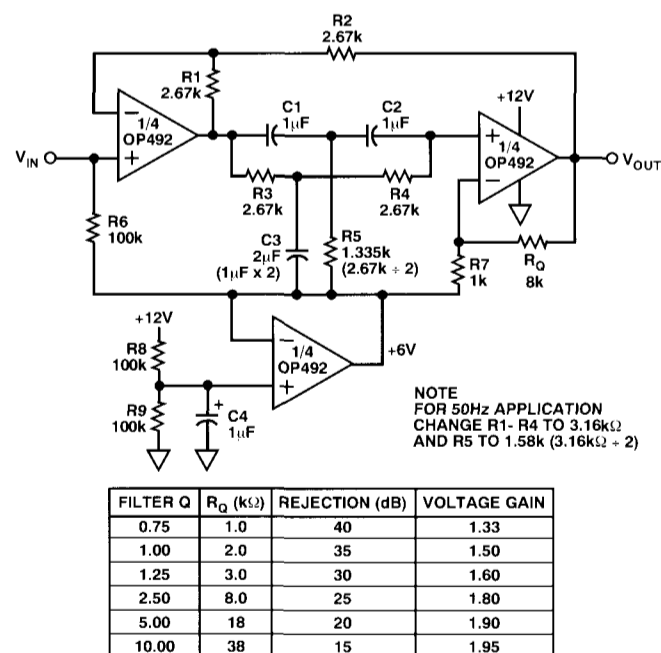


Figure 37. A Single-Supply 50 Hz/60 Hz Notch Filter

## OP292/OP492

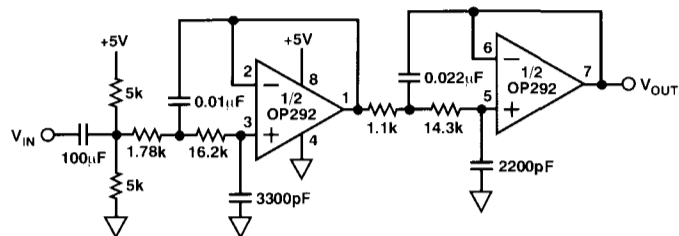


Figure 38. A 4-Pole Bessel Low Pass Filter Using Sallen-Key Topology

### A 4-Pole Bessel Low-Pass Filter

The linear phase filter in Figure 38 is designed to roll off at a voiceband cutoff frequency of 3.6 kHz. The 4 poles are formed by two cascading stages of two-pole Sallen-Key filters.

### A Low Cost, Linearized Thermistor Amplifier

An inexpensive thermometer amplifier circuit can be implemented using low cost thermistors. One such implementation is shown in Figure 39. The circuit measures temperature over the range of 0°C to +70°C to an accuracy of  $\pm 0.3^\circ\text{C}$  as the linearization circuit works well within a narrow temperature range.

However, it can measure higher temperature but at a slightly reduced accuracy. To achieve the aforementioned accuracy, the thermistor's nonlinearity must be corrected. This is done by connecting the thermistor in parallel with the 10k in the feedback loop of the first stage amplifier. A constant operating current of 281  $\mu\text{A}$  is supplied by the resistor R1 with the +5 V reference from the REF-195 such that the thermistor's self-heating error is kept below 0.1°C.

In many cases, the thermistor is placed some distance from the signal conditioning circuit. Under this condition, a 0.1  $\mu\text{F}$  capacitor placed across R2 will help to suppress noise pickup.

This linearization network creates an offset voltage which is corrected by summing a compensating current with potentiometer P1. The temperature dependent signal is amplified by the second stage, producing a transfer coefficient of  $-10 \text{ mV}/^\circ\text{C}$  at the output.

To calibrate, a precision decade box can be used in place of the thermistor. For 0°C trim, the decade box is set to 32.650k, and P1 is adjusted until the circuit's output reads 0 V. To trim the circuit at the full-scale temperature of 70°C, the decade box is then set to 1.752k and P2 is adjusted until the circuit reads  $-0.70 \text{ V}$ .

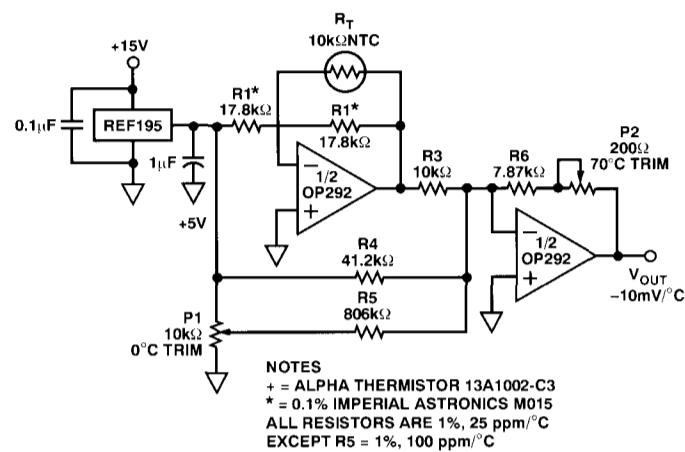


Figure 39. A Low Cost Linearized Thermistor Amplifier

### A Single-Supply Ultrasonic Clamping/Limiting Receiver Amplifier

Figure 40 shows an ultrasonic receiver amplifier using the non-linear impedance of low cost diodes to effectively control the gain for wide dynamic range. This circuit amplifies a 40 kHz ultrasonic signal through a pair of low cost clamping amplifiers before feeding a bandpass filter to extract a clean 40 kHz signal for processing.

The signal is ac-coupled into the false-ground bias node by virtue of the capacitive piezoelectric sensing element. Rather than using an amplifier to generate a supply splitting bias, the false ground voltage is generated by a low cost resistive voltage divider.

Each amplifier stage provides ac gain while passing on the dc self-bias. As long as the output signal at each stage is less than a diode's forward voltage, each amplifier has unrestricted gain to amplify low level signals. However, as the signal strength increases, the feedback diodes begin to conduct, shunting the feedback current, and thus reducing the gain. Although distorting the waveform, the diodes effectively maintain a relatively constant amplitude even with large signals that otherwise would saturate the amplifier. In addition, this design is considerably more stable than the feedback type AGC.

The overall circuit has a gain range from  $-2$  to  $-400$ , where the inversion comes from the bandpass filter stage. Operating with a Q of 5, the filter restores a clean, undistorted signal to the output. The circuit also work well with 5 V supply systems.

## OP292/OP492

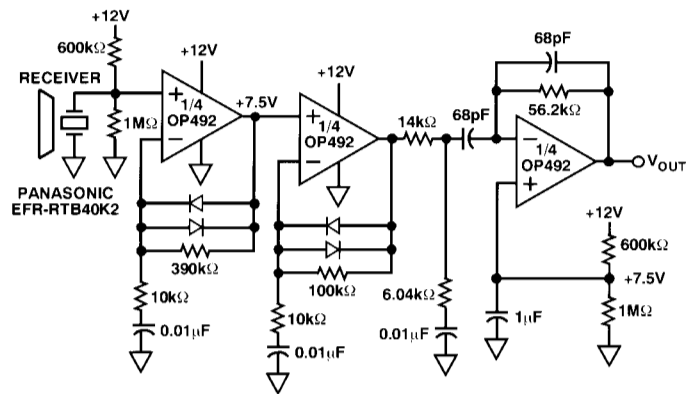


Figure 40. A 40 kHz Ultrasonic Clamping/Limiting Receiver Amplifier

### Precision Single-Supply Voltage Comparator

The OP292/OP492 have excellent overload recovery characteristics, making them suitable for precision comparator applications. Figure 41 shows the saturation recovery characteristics of the OP492. The amplifier exhibits very little propagation delay. The amplifier compares a signal precisely to less than 0.5 mV offset error.

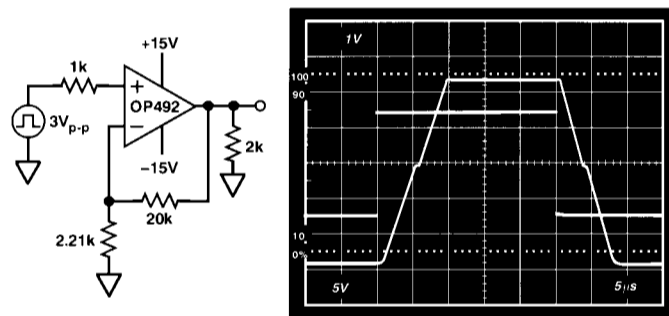


Figure 41. The OP492 Has Fast Overload Recovery for Comparator Applications

### Programmable Precision Window Comparator

The OP292/OP492 can be used for precise level detection such as in test equipment where a signal is measured within a range. Figure 42 shows such an implementation. The threshold voltage level is set by a pair of 12-bit D/A converters. The DACs have serial interface thus minimizing interconnection requirements. The DAC8512 has a control resolution of 1 mV/bit. Thus for 5 V supply operation, maximum DAC output is 4.095 V. However, the OP292 will accept a maximum input of 4.0 V.

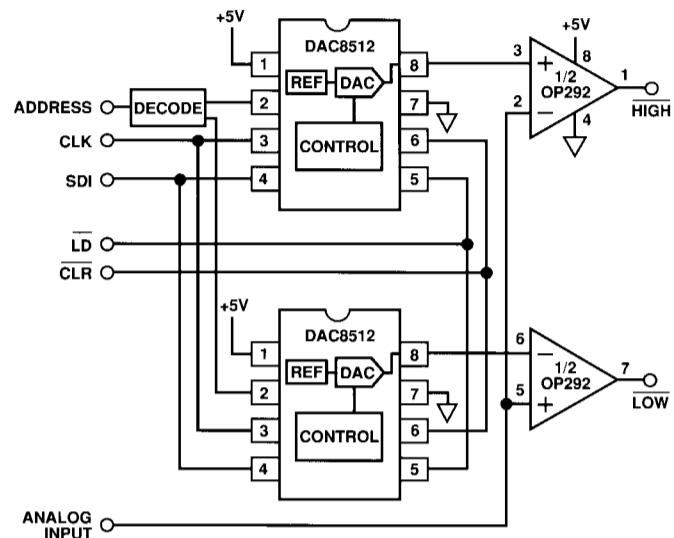


Figure 42. Programmable Window Comparator with 12-Bit Threshold Level Control



**OP292/OP492**

```
*
* POLE AT 100 MHz
*
G2  98  16  (15,30) 1
R12 16  98  1
C6   16  98  1.592E-9
*
* OUTPUT STAGE
*
RS1  99  30  1E6
RS2  30  50  1E6
ISY  99  50  .44E-3
G3   31  50  POLY(1) (16,30) -1.635E-6 4E-6
R16  31  50  1E6
DCL  50  31  DZ
I2   99  32  250E-6
RCL  33  50  56
M1   32  31  50  50  MN L=9E-6 W=1000E-6 AD=15E-9 AS=15E-9
M2   34  31  50  50  MN L=9E-6 W=1000E-6 AD=15E-9 AS=15E-9
CC   31  32  14E-12
Q3   99  32  34  QNA
Q4   33  32  34  QPA
Q5   31  33  50  QNA

.MODEL QNA NPN(IS=1.19E-16 BF=253 NF=0.99 VAF=193 IKF=2.76E-3
+ ISE=2.57E-13 NE=5 BR=0.4 NR=0.988 VAR=15 IKR=1.465E-4
+ ISC=6.9E-16 NC=0.99 RB=2.0E3 IRB=7.73E-6 RBM=132.8 RE=4 RC=209
+ CJE=2.1E-13 VJE=0.573 MJE=0.364 FC=0.5 CJC=1.64E-13 VJC=0.534 MJC=0.5
+ CJS=1.37E-12 VJS=0.59 MJS=0.5 TF=0.43E-9 PTF=30)
.MODEL QPA PNP(IS=5.21E-17 BF=131 NF=0.99 VAF=62 IKF=8.35E-4
+ ISE=1.09E-14 NE=2.61 BR=0.5 NR=0.984 VAR=15 IKR=3.96E-5
+ ISC=7.58E-16 NC=0.985 RB=1.52E3 IRB=1.67E-5 RBM=368.5 RE=6.31 RC=354.4
+ CJE=1.1E-13 VJE=0.745 MJE=0.33 FC=0.5 CJC=2.37E-13 VJC=0.762 MJC=0.4
+ CJS=7.11E-13 VJS=0.45 MJS=0.412 TF=1.0E-9 PTF=30)
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+ TOX=8.5E-8 LD=1.48E-6 WD=1E-6 NSUB=1.53E16 UO=650 DELTA=10 VMAX=2E5
+ XJ=1.75E-6 KAPPA=0.8 ETA=0.066 THETA=0.01 TPG=1 CJ=2.9E-4 PB=0.837
+ MJ=0.407 CJSW=0.5E-9 MJSW=0.33)
.MODEL QP PNP(BF=61.5)
.MODEL DX D
.MODEL DZ D(BV=3.6)
.ENDS OP292
```

## OP292/OP492

```
* OP492 SPICE Macro-model          Rev. A, 6/93
*                                  ARG / PMI
*
* Copyright 1993 by Analog Devices
*
* Refer to "README.DOC" file for License Statement. Use of
* this model indicates your acceptance of the terms and pro-
* visions in the License Statement.
*
* Node assignments
*
*          noninverting input
*          inverting input
*          positive supply
*          negative supply
*          output
*
.SUBCKT OP492 2 1 99 50 34
*
* INPUT STAGE AND POLE AT 40 MHz
*
I1      99  4  50E-6
IOS     2   1  10E-9
EOS     2   3  POLY(1) (21,30) 1.5E-3 75
CIN     1   2  3E-12
Q1      5   1  7   QP
Q2      6   3  8   QP
R3      5   50 2E3
R4      6   50 2E3
R5      4   7  966
R6      4   8  966
C1      5   6  .995E-12
*
* GAIN STAGE
*
EREF   98  0  (30,0) 1
G1     98  9  (5,6) 500E-6
R7     9   98 210.819E3
D1     9   10 DX
D2    11  9  DX
V1    99  10 .6
V2    11  50 .6
*
* ZERO/POLE AT 6 MHz/12 MHz
*
E1     12  98 (9,30) 2
R8     12  13 1
R9     13  98 1
C3     12  13 26.526E-9
*
* ZERO AT 15 MHz
*
E2     14  98 (13,30) 1E6
R10    14  15 1E6
R11    15  98 1
C4     14  15 10.610E-15
*
* COMMON MODE STAGE WITH ZERO AT 40 kHz
*
ECM    20  98 POLY(2) (1,30) (2,30) 0 0.5 0.5
R20    20  21 1E6
R21    21  98 1
C5     20  21 3.979E-12
```



```

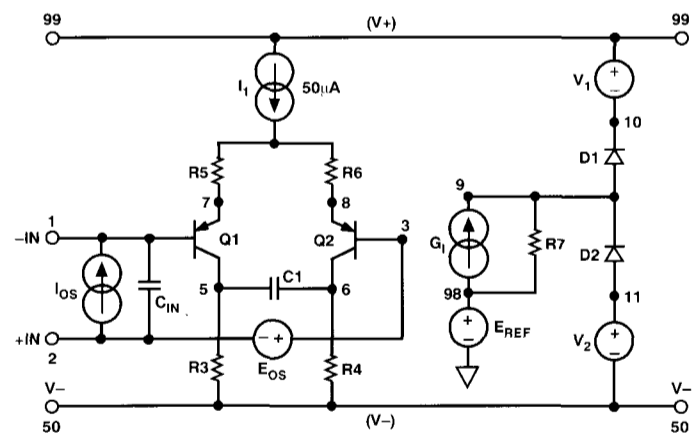
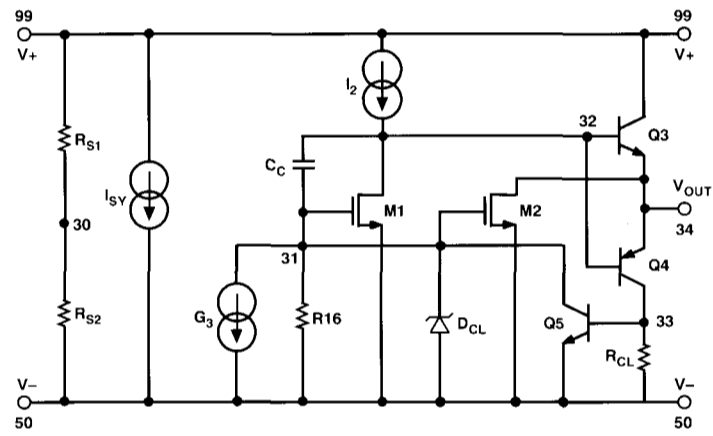
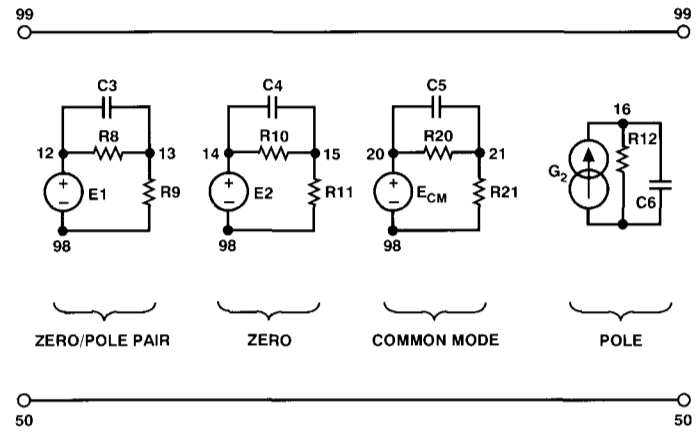
*
* POLE AT 100 MHz
*
G2    98  16  (15,30)  1
R12   16  98  1
C6    16  98  1.592E-9
*
* OUTPUT STAGE
*
RS1   99  30  1E6
RS2   30  50  1E6
ISY   99  50  .44E-3
G3    31  50  POLY(1) (16,30) -1.635E-6  4E-6
R16   31  50  1E6
DCL   50  31  DZ
I2    99  32  250E-6
RCL   33  50  56
M1    32  31  50  50  MN  L=9E-6  W=1000E-6  AD=15E-9  AS=15E-9
M2    34  31  50  50  MN  L=9E-6  W=1000E-6  AD=15E-9  AS=15E-9
CC    31  32  14E-12
Q3    99  32  34 QNA
Q4    33  32  34 QPA
Q5    31  33  50 QNA

.MODEL QNA NPN(IS=1.19E-16 BF=253 NF=0.99 VAF=193 IKF=2.76E-3
+ ISE=2.57E-13 NE=5 BR=0.4 NR=0.988 VAR=15 IKR=1.465E-4
+ ISC=6.9E-16 NC=0.99 RB=2.0E3 IRB=7.73E-6 RBM=132.8 RE=4 RC=209
+ CJE=2.1E-13 VJE=0.573 MJE=0.364 FC=0.5 CJC=1.64E-13 VJC=0.534 MJC=0.5
+ CJS=1.37E-12 VJS=0.59 MJS=0.5 TF=0.43E-9 PTF=30)
.MODEL QPA PNP(IS=5.21E-17 BF=131 NF=0.99 VAF=62 IKF=8.35E-4
+ ISE=1.09E-14 NE=2.61 BR=0.5 NR=0.984 VAR=15 IKR=3.96E-5
+ ISC=7.58E-16 NC=0.985 RB=1.52E3 IRB=1.67E-5 RBM=368.5 RE=6.31 RC=354.4
+ CJE=1.1E-13 VJE=0.745 MJE=0.33 FC=0.5 CJC=2.37E-13 VJC=0.762 MJC=0.4
+ CJS=7.11E-13 VJS=0.45 MJS=0.412 TF=1.0E-9 PTF=30)
.MODEL MN NMOS(LEVEL=3 VTO=1.3 RS=0.3 RD=0.3
+ TOX=8.5E-8 LD=1.48E-6 WD=1E-6 NSUB=1.53E16 UO=650 DELTA=10 VMAX=2E5
+ XJ=1.75E-6 KAPPA=0.8 ETA=0.066 THETA=0.01 TPG=1 CJ=2.9E-4 PB=0.837
+ MJ=0.407 CJSW=0.5E-9 MJSW=0.33)
.MODEL QP PNP(BF=61.5)
.MODEL DX D
.MODEL DZ D(BV=3.6)
.ENDS OP492

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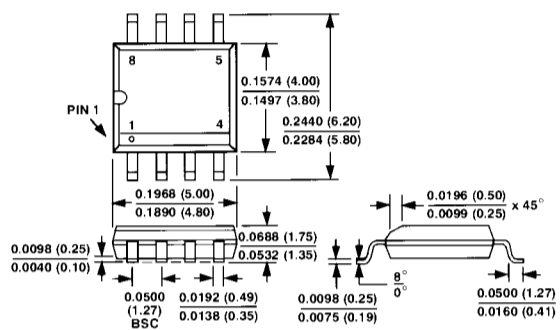
# OP292/OP492

## OP292/OP492 SPICE

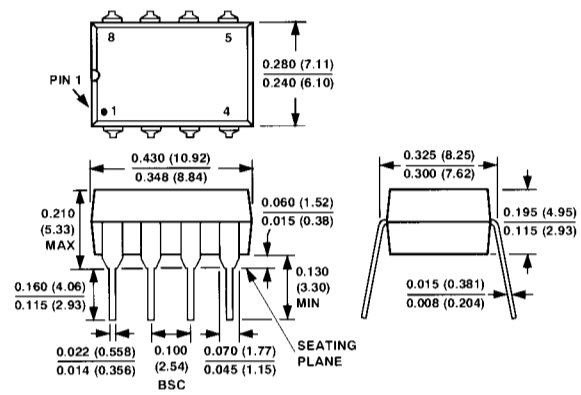


**OUTLINE DIMENSIONS**  
Dimensions shown in inches and (mm).

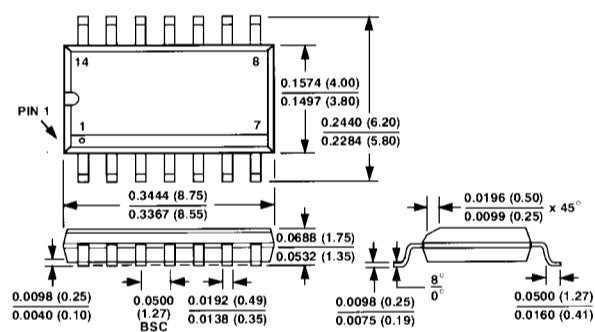
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**8-Lead Narrow-Body SOIC**  
(S Suffix)



**N-8**  
**8-Lead Epoxy DIP**  
(P Suffix)



**SO-14**  
**14-Lead Narrow-Body SOIC**  
(S Suffix)



**N-14**  
**14-Lead Epoxy DIP**  
(P Suffix)

