Dual and Quad Micropower Rail-to-Rail Input and Output Op Amps

FEATURES

- **Rail-to-Rail Input and Output**
- **Single Supply Input Range: –0.4V to 44V**
- **Micropower: 50µA/Amplifier Max**
- **MSOP Package**
- Specified on 3V, 5V and ±15V Supplies
- High Output Current: 20mA
- Output Drives 10,000pF with Output Compensation
- Reverse Battery Protection to 18V
- No Supply Sequencing Problems
- High Voltage Gain: 1500V/mV
- High CMRR: 98dB
- No Phase Reversal
- Gain Bandwidth Product: 200kHz

APPLICATIONS

- Battery- or Solar-Powered Systems
  - Portable Instrumentation
  - Sensor Conditioning
- Supply Current Sensing
- Battery Monitoring
- Micropower Active Filters
- 4mA to 20mA Transmitters

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DESCRIPTION

The dual LT®1490 and quad LT1491 op amps operate on all single and split supplies with a total voltage of 2V to 44V drawing only 40µA of quiescent current per amplifier. These amplifiers are reverse supply protected; they draw no current for reverse supply up to 18V. The input range of the LT1490/LT1491 includes both supplies and the output swings to both supplies. Unlike most micropower op amps, the LT1490/LT1491 can drive heavy loads; their rail-to-rail outputs drive 20mA. The LT1490/LT1491 are unity-gain stable and drive all capacitive loads up to 10,000pF when optional 0.22µF and 150Ω compensation is used.

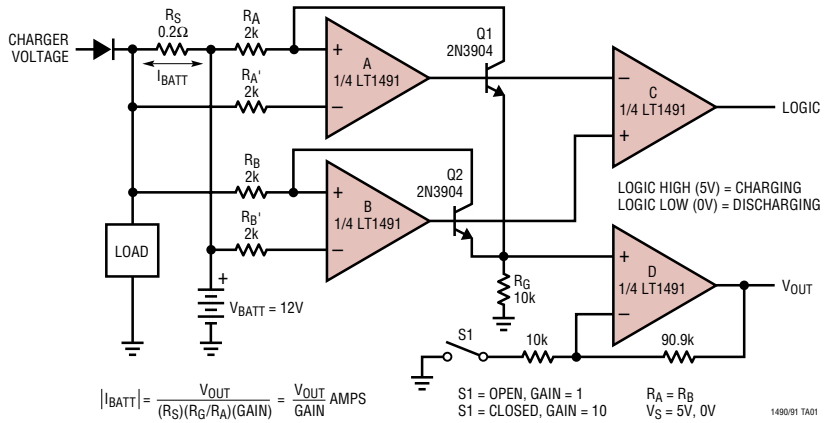
The LT1490/LT1491 have a unique input stage that operates and remains high impedance when above the positive supply. The inputs take 44V both differential and common mode even when operating on a 3V supply. Built-in resistors protect the inputs for faults below the negative supply up to 22V. There is no phase reversal of the output for inputs 22V below V^- or 44V above V^-, independent of V^+.

The LT1490 dual op amp is available in the 8-pin MSOP, SO and PDIP packages. The quad LT1491 is available in the 14-pin SO and PDIP packages.

For new designs it is recommended that the LT1490A/LT1491A be used instead of the LT1490/LT1491. See the LT1490A/LT1491A data sheet for details.

TYPICAL APPLICATION

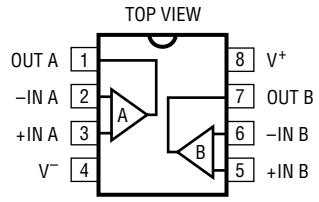
Battery Monitor



ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-) 44V
Input Differential Voltage 44V
Input Current ..... ±25mA
Output Short-Circuit Duration (Note 2) ..... Continuous
Operating Temperature Range ..... –40°C to 85°C
Junction Temperature ..... 150°C
Specified Temperature Range (Note 3) .. –40°C to 85°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

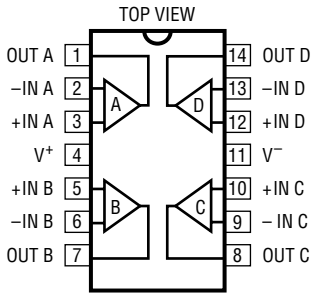
PACKAGE/ORDER INFORMATION (For new designs, use the LT1490A or LT1491A)



MS8 PACKAGE
8-LEAD MSOP
N8 PACKAGE
8-LEAD PDIP
S8 PACKAGE
8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 250°C/W (MS8)
T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 190°C/W (S8)

ORDER PART NUMBER
LT1490CMS8 LT1490CN8 LT1490CS8 LT1490IN8 LT1490IS8
MS8 PART MARKING
LTBB
S8 PART MARKING
1490 1490I



N PACKAGE
14-LEAD PDIP
S PACKAGE
14-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 110°C/W (N)
T_{JMAX} = 150°C, θ_{JA} = 150°C/W (S)

ORDER PART NUMBER
LT1491CN LT1491CS LT1491IN LT1491IS

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 3V, 0V; V_S = 5V, 0V; V_{CM} = V_{OUT} = half supply, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1490 N Package			220	800	µV
		0°C ≤ T_A ≤ 70°C	●			1000	µV
		–40°C ≤ T_A ≤ 85°C	●			1100	µV
		LT1490 S Package			220	950	µV
		0°C ≤ T_A ≤ 70°C	●			1200	µV
		–40°C ≤ T_A ≤ 85°C	●			1300	µV
		LT1491 N Package			300	1100	µV
		0°C ≤ T_A ≤ 70°C	●			1350	µV
		–40°C ≤ T_A ≤ 85°C	●			1450	µV
		LT1490CMS8 Package, LT1491 S Package			350	1450	µV
		0°C ≤ T_A ≤ 70°C	●			1650	µV
		–40°C ≤ T_A ≤ 85°C	●			1750	µV
V_{OS} TC	Input Offset Voltage Drift	0°C ≤ T_A ≤ 70°C (Note 7)	●		2	4	µV/°C
		–40°C ≤ T_A ≤ 85°C (Note 7)	●		2	4	µV/°C
I_{OS}	Input Offset Current		●		0.2	0.8	nA
		V_{CM} = 44V (Note 4)	●			0.8	µA
I_B	Input Bias Current		●		4	8	nA
		V_{CM} = 44V (Note 4)	●		4	10	µA
		V_S = 0V			0.1		nA
	Input Noise Voltage	0.1Hz to 10Hz			1		μV_{P-P}

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = 3V, 0V; V_S = 5V, 0V; V_{CM} = V_{OUT} = half supply, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
e_n	Input Noise Voltage Density	f = 1kHz			50		nV/√Hz
i_n	Input Noise Current Density	f = 1kHz			0.03		pA/√Hz
R_{IN}	Input Resistance	Differential Common Mode, V_{CM} = 0V to 44V	 	6 4	17 11		MΩ MΩ
C_{IN}	Input Capacitance				4.6		pF
	Input Voltage Range		●	0		44	V
CMRR	Common Mode Rejection Ratio (Note 4)	V_{CM} = 0V to V_{CC} – 1V V_{CM} = 0V to 44V	● ●	84 80	98 98		dB dB
A_{VOL}	Large-Signal Voltage Gain	V_S = 3V, V_O = 500mV to 2.5V, R_L = 10k 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	 ● ●	200 133 100	1500		V/mV V/mV V/mV
		V_S = 5V, V_O = 500mV to 4.5V, R_L = 10k 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	 ● ●	400 250 200	1500		V/mV V/mV V/mV
V_{OL}	Output Voltage Swing Low	V_S = 3V, No Load V_S = 3V, I_{SINK} = 5mA	● ●		22 250	50 450	mV mV
		V_S = 5V, No Load V_S = 5V, I_{SINK} = 5mA V_S = 5V, I_{SINK} = 10mA	● ● 		22 250 330	50 500 500	mV mV mV
V_{OH}	Output Voltage Swing High	V_S = 3V, No Load V_S = 3V, I_{SOURCE} = 5mA	● ●	2.95 2.55	2.978 2.6		V V
		V_S = 5V, No Load V_S = 5V, I_{SOURCE} = 10mA	● ●	4.95 4.30	4.978 4.6		V V
I_{SC}	Short-Circuit Current (Note 2)	V_S = 3V, Short to GND V_S = 3V, Short to V_{CC}	 	10 10	15 30		mA mA
		V_S = 5V, Short to GND V_S = 5V, Short to V_{CC}	 	15 15	25 30		mA mA
PSRR	Power Supply Rejection Ratio	V_S = 2.5V to 12.5V, V_{CM} = V_O = 1V	●	84	98		dB
	Minimum Operating Supply Voltage		●		2	2.5	V
	Reverse Supply Voltage	I_S = –100µA per Amplifier	●	18	27		V
I_S	Supply Current per Amplifier (Note 5)		 ●		40	50 55	µA µA
GBW	Gain Bandwidth Product (Note 4)	f = 1kHz 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	 ● ●	110 100 90	180		kHz kHz kHz
SR	Slew Rate (Note 6)	A_V = –1, R_L = ∞ 0°C ≤ T_A ≤ 70°C –40°C ≤ T_A ≤ 85°C	 ● ●	0.035 0.031 0.030	0.06		V/µs V/µs V/µs

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_S = ±15V, V_{CM} = 0V, V_{OUT} = 0V, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	LT1490 N, S Package			250	1200	µV
		0°C ≤ T_A ≤ 70°C	●			1400	µV
		–40°C ≤ T_A ≤ 85°C	●			1500	µV
		LT1491 N Package			350	1250	µV
		0°C ≤ T_A ≤ 70°C	●			1500	µV
		–40°C ≤ T_A ≤ 85°C	●			1600	µV
		LT1490CMS8 Package, LT1491 S Package			400	1600	µV
		0°C ≤ T_A ≤ 70°C	●			1850	µV
		–40°C ≤ T_A ≤ 85°C	●			1950	µV
V_{OS} TC	Input Offset Voltage Drift	0°C ≤ T_A ≤ 70°C (Note 7)	●		3	6	µV/°C
		–40°C ≤ T_A ≤ 85°C (Note 7)	●		3	6	µV/°C
I_{OS}	Input Offset Current		●		0.2	0.8	nA
I_B	Input Bias Current		●		4	8	nA
	Input Noise Voltage	0.1Hz to 10Hz			1		μV_{P-P}
e_n	Input Noise Voltage Density	f = 1kHz			50		$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	f = 1kHz			0.03		$pA/\sqrt{Hz}$
R_{IN}	Input Resistance	Differential		6	17		MΩ
		Common Mode, V_{CM} = –15V to 14V			15000		MΩ
C_{IN}	Input Capacitance				4.6		pF
	Input Voltage Range		●	–15		29	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –15V to 29V	●	80	98		dB
A_{VOL}	Large-Signal Voltage Gain	V_O = ±14V, R_L = 10k		100	250		V/mV
		0°C ≤ T_A ≤ 70°C	●	75			V/mV
		–40°C ≤ T_A ≤ 85°C	●	50			V/mV
V_O	Output Voltage Swing	No Load	●	±14.9	±14.978		V
		I_{OUT} = ±5mA	●	±14.5	±14.750		V
		I_{OUT} = ±10mA		±14.5	±14.670		V
I_{SC}	Short-Circuit Current (Note 2)	Short to GND		±20	±25		mA
		0°C ≤ T_A ≤ 70°C	●	±15			mA
		–40°C ≤ T_A ≤ 85°C	●	±10			mA
PSRR	Power Supply Rejection Ratio	V_S = ±1.25V to ±22V	●	88	98		dB
I_S	Supply Current per Amplifier				50	70	µA
			●			85	µA
GBW	Gain Bandwidth Product	f = 1kHz		125	200		kHz
		0°C ≤ T_A ≤ 70°C	●	110			kHz
		–40°C ≤ T_A ≤ 85°C	●	100			kHz
SR	Slew Rate	A_V = –1, R_L = ∞, V_O = ±10V, Measure at V_O = ±5V		0.0375	0.07		V/µs
		0°C ≤ T_A ≤ 70°C	●	0.0330			V/µs
		–40°C ≤ T_A ≤ 85°C	●	0.0300			V/µs

Note 1: Absolute Maximum Ratings are those values beyond which the life of the device may be impaired.

Note 2: A heat sink may be required to keep the junction temperature below absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted.

Note 3: The LT1490C/LT1491C are guaranteed to meet specified performance from 0°C to 70°C. The LT1490C/LT1491C are designed, characterized and expected to meet specified performance from –40°C to 85°C but are not tested or QA sampled at these temperatures. The LT1490I/LT1491I are guaranteed to meet specified performance from –40°C to 85°C.

Note 4: V_S = 5V limits are guaranteed by correlation to V_S = 3V and V_S = ±15V tests.

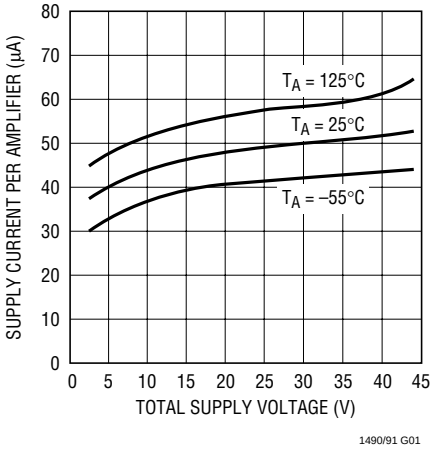
Note 5: V_S = 3V limits are guaranteed by correlation to V_S = 5V and V_S = ±15V tests.

Note 6: Guaranteed by correlation to slew rate at V_S = ±15V and GBW at V_S = 3V and V_S = ±15V tests.

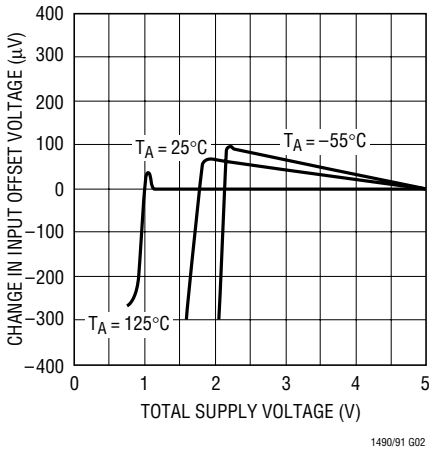
Note 7: This parameter is not 100% tested.

TYPICAL PERFORMANCE CHARACTERISTICS

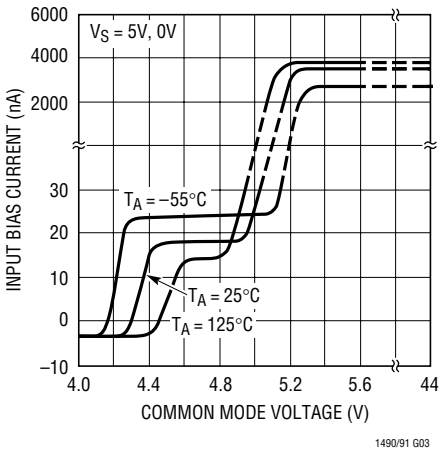
Supply Current vs Supply Voltage



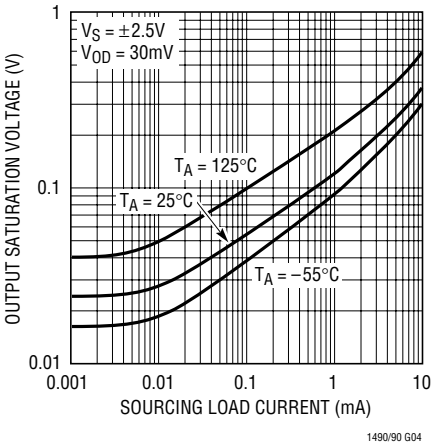
Minimum Supply Voltage



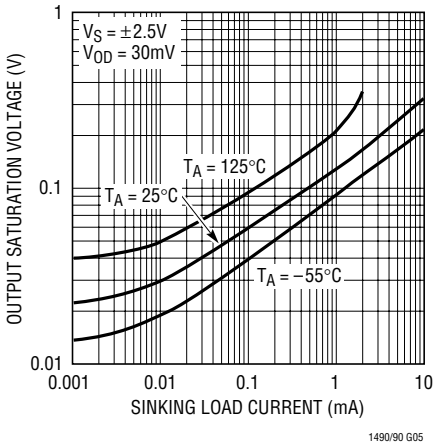
Input Bias Current vs Common Mode Voltage



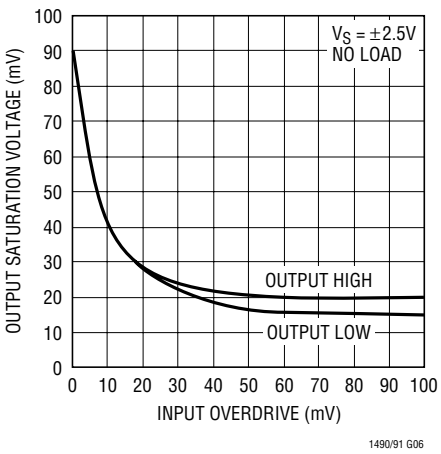
Output Saturation Voltage vs Load Current (Output High)



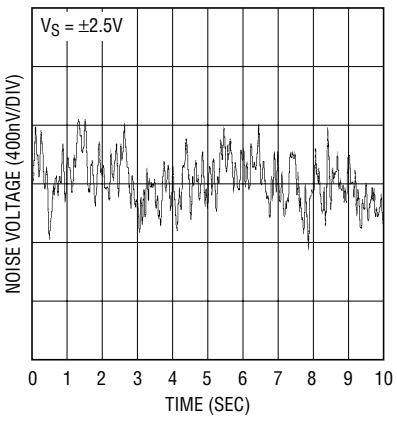
Output Saturation Voltage vs Load Current (Output Low)



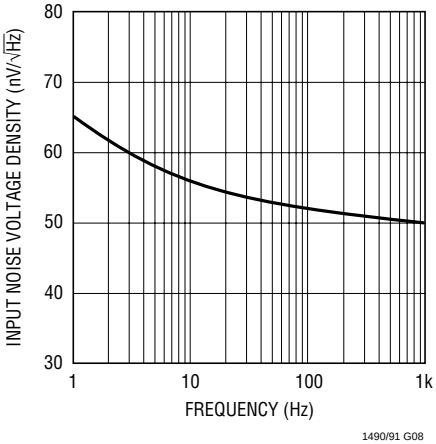
Output Saturation Voltage vs Input Overdrive



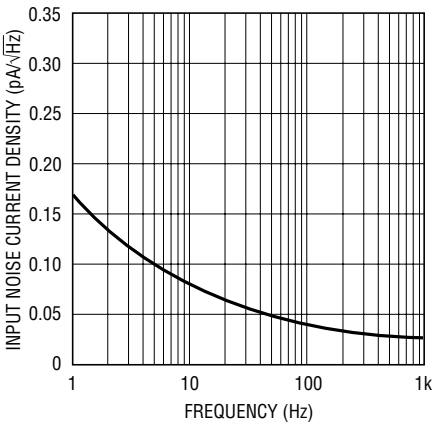
0.1Hz to 10Hz Noise Voltage



Noise Voltage Density vs Frequency

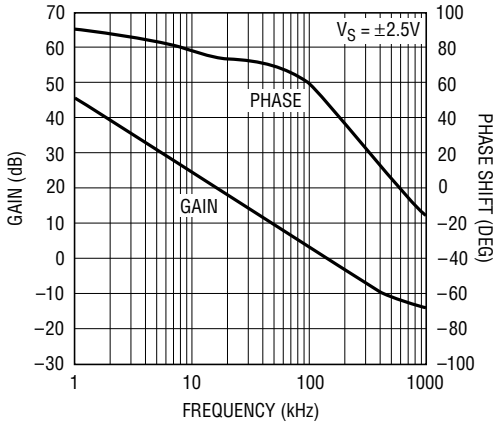


Input Noise Current vs Frequency



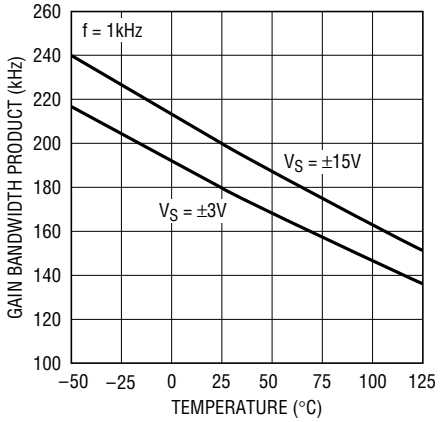
TYPICAL PERFORMANCE CHARACTERISTICS

Gain and Phase Shift vs Frequency



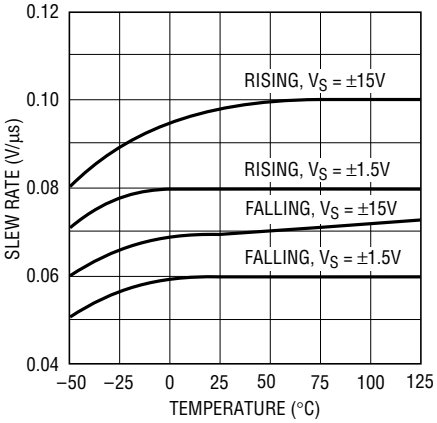
1490/91 G10

Gain Bandwidth Product vs Temperature



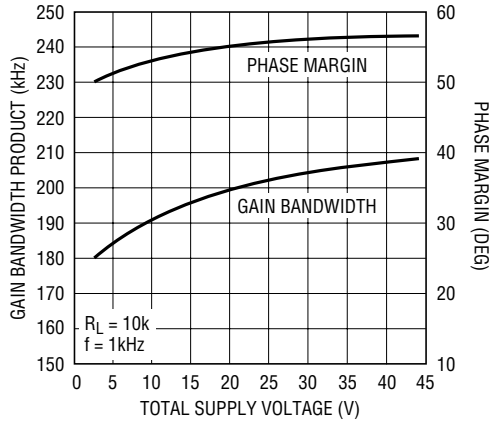
1490/91 G11

Slew Rate vs Temperature



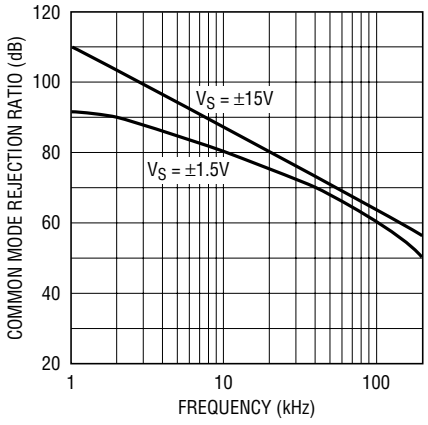
1490/91 G12

Gain Bandwidth Product and Phase Margin vs Supply Voltage



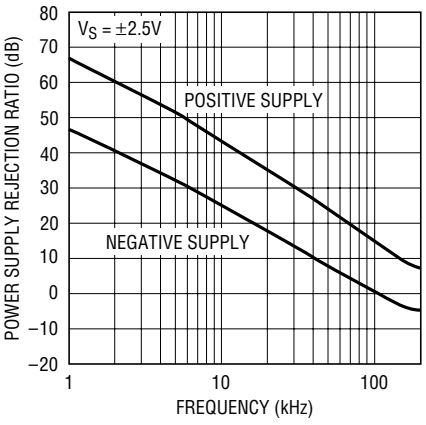
1490/91 G13

CMRR vs Frequency



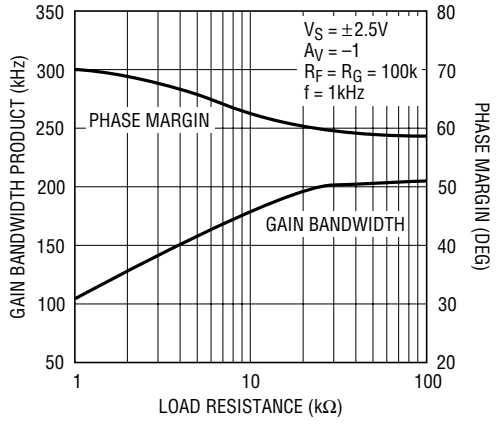
1490 G14

PSRR vs Frequency



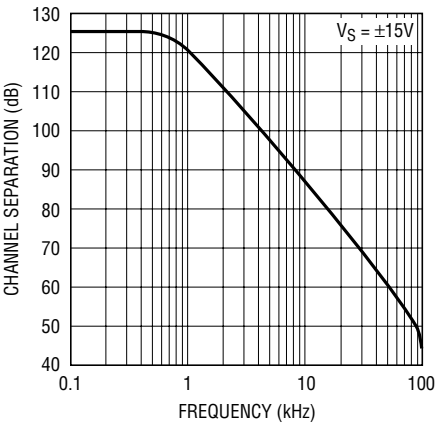
1490/91 G15

Gain Bandwidth Product and Phase Margin vs Load Resistance



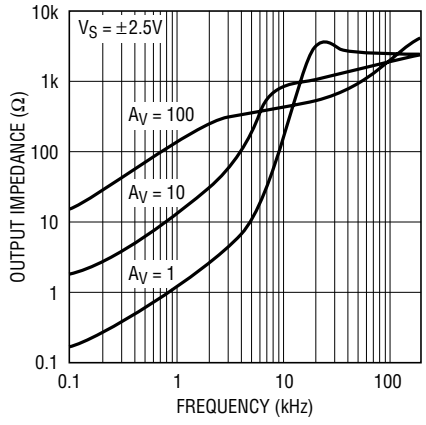
1490/91 G16

Channel Separation vs Frequency



1490/91 G17

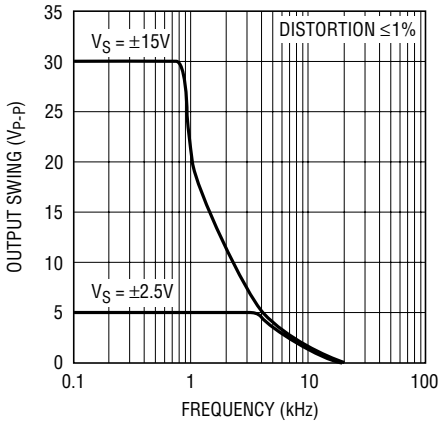
Output Impedance vs Frequency



1490/91 G18

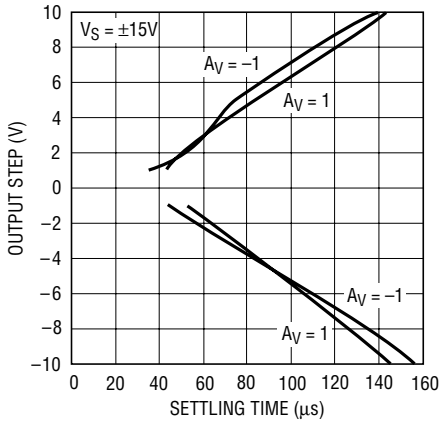
TYPICAL PERFORMANCE CHARACTERISTICS

Undistorted Output Swing vs Frequency



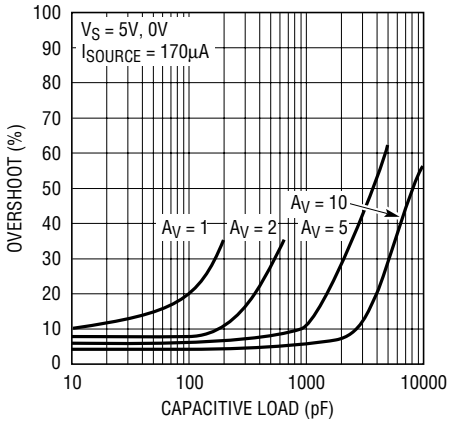
1490/91 G19

Settling Time to 0.1% vs Output Step



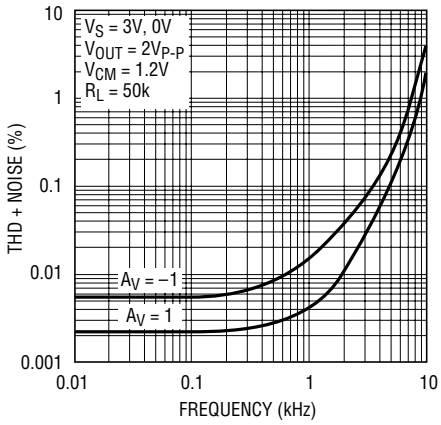
1490/91 F20

Capacitive Load Handling, Overshoot vs Capacitive Load



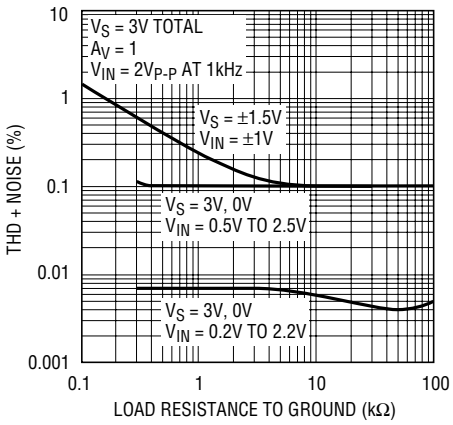
1490/91 G21

Total Harmonic Distortion + Noise vs Frequency



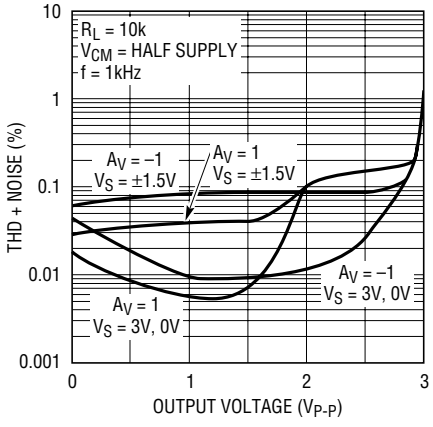
1490/91 G22

Total Harmonic Distortion + Noise vs Load Resistance



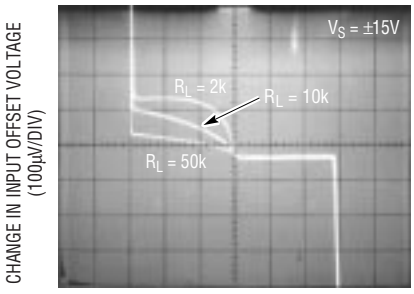
1490/91 G23

Total Harmonic Distortion + Noise vs Output Voltage



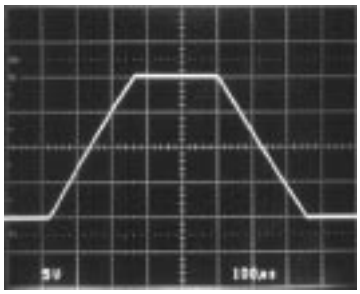
1490/91 G24

Open-Loop Gain



1490/91 G25

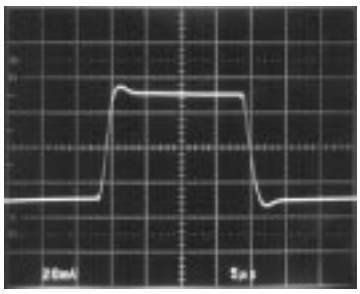
Large-Signal Response



V_S = ±15V
A_V = –1

1490/91 G26

Small-Signal Response



V_S = ±15V
A_V = 1

1490/91 G27

APPLICATIONS INFORMATION

Supply Voltage

The positive supply pin of the LT1490/LT1491 should be bypassed with a small capacitor (about 0.01μF) within an inch of the pin. When driving heavy loads an additional 4.7μF electrolytic capacitor should be used. When using split supplies, the same is true for the negative supply pin.

The LT1490/LT1491 are protected against reverse battery voltages up to 18V. In the event a reverse battery condition occurs, the supply current is less than 1nA.

The LT1490/LT1491 can be shut down by removing V^+. In this condition the input bias current is less than 0.1nA, even if the inputs are 44V above the negative supply.

When operating the LT1490/LT1491 on total supplies of 30V or more, the supply must not be brought up faster than 1μs. This is especially true if low ESR bypass capacitors are used. A series RLC circuit is formed from the supply lead inductance and the bypass capacitor. 5Ω of resistance in the supply or the bypass capacitor will dampen the tuned circuit enough to limit the rise time.

Inputs

The LT1490/LT1491 have two input stages, NPN and PNP (see the Simplified Schematic), resulting in three distinct operating regions as shown in the Input Bias Current vs Common Mode typical performance curve.

For input voltages about 0.8V or more below V^+, the PNP input stage is active and the input bias current is typically –4nA. When the input voltage is about 0.5V or less from V^+, the NPN input stage is operating and the input bias current is typically 18nA. Increases in temperature will cause the voltage at which operation switches from the PNP stage to the NPN stage to move towards V^+. The input offset voltage of the NPN stage is untrimmed and is typically 600μV.

A Schottky diode in the collector of each NPN transistor of the NPN input stage allows the LT1490/LT1491 to operate with either or both of its inputs above V^+. At about 0.3V above V^+ the NPN input transistor is fully saturated and the input bias current is typically 4μA at room temperature. The input offset voltage is typically 700μV when operating above V^+. The LT1490/LT1491 will operate with its inputs 44V above V^- regardless of V^+.

The inputs are protected against excursions as much as 22V below V^- by an internal 1k resistor in series with each input and a diode from the input to the negative supply. There is no output phase reversal for inputs up to 22V below V^-. There are no clamping diodes between the inputs and the maximum differential input voltage is 44V.

Output

The output voltage swing of the LT1490/LT1491 is affected by input overdrive as shown in the typical performance curves. When monitoring voltages within 100mV of either rail, gain should be taken to keep the output from clipping.

The output of the LT1490/LT1491 can be pulled up to 18V beyond V^+ with less than 1nA of leakage current, provided that V^+ is less than 0.5V.

The normally reverse-biased substrate diode from the output to V^- will cause unlimited currents to flow when the output is forced below V^-. If the current is transient and limited to 100mA, no damage will occur.

The LT1490/LT1491 is internally compensated to drive at least 200pF of capacitance under any output loading conditions. A 0.22μF capacitor in series with a 150Ω resistor between the output and ground will compensate these amplifiers for larger capacitive loads, up to 10,000pF, at all output currents.

Distortion

There are two main contributors of distortion in op amps: output crossover distortion as the output transitions from sourcing to sinking current and distortion caused by nonlinear common mode rejection. Of course, if the op amp is operating inverting there is no common mode induced distortion. When the LT1490 switches between input stages there is significant nonlinearity in the CMRR. Lower load resistance increases the output crossover distortion, but has no effect on the input stage transition distortion. For lowest distortion the LT1490/LT1491 should be operated single supply, with the output always sourcing current and with the input voltage swing between ground and (V^+ – 0.8V). See the Typical Performance Characteristics curves.

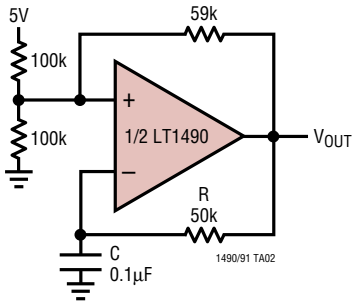
APPLICATIONS INFORMATION

Gain

The open-loop gain is almost independent of load when the output is sourcing current. This optimizes performance in single supply applications where the load is returned to ground. The typical performance photo of Open-Loop Gain for various loads shows the details.

TYPICAL APPLICATIONS

Square Wave Oscillator



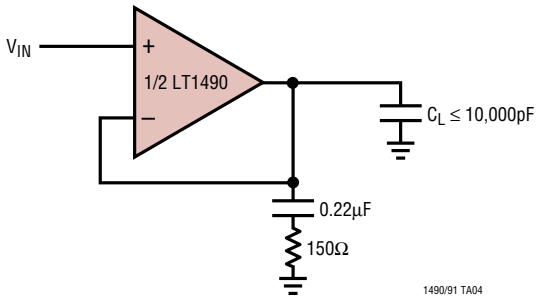
$f = \frac{1}{2RC}$

$V_{OUT} = 5V_{P-P}$ WITH 5V SUPPLY

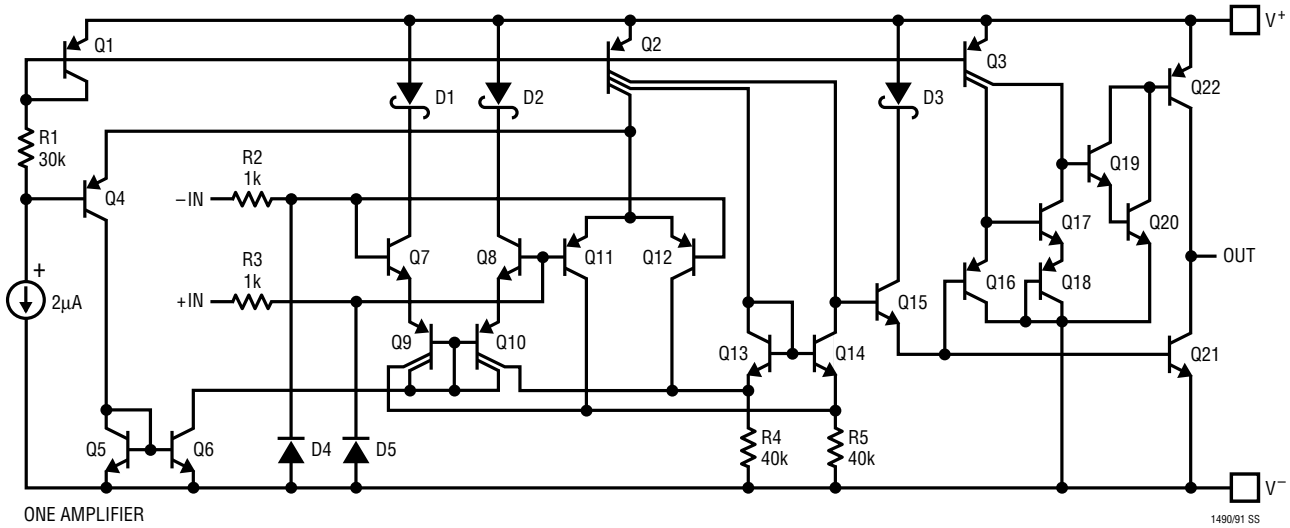
$I_S = 200\mu A$

AT $V_S = 5V$, R = 50k, C = 1nF
OUTPUT IS 5kHz SLEW LIMITED TRIANGLE WAVE

Optional Output Compensation for Capacitive Loads Greater Than 200pF



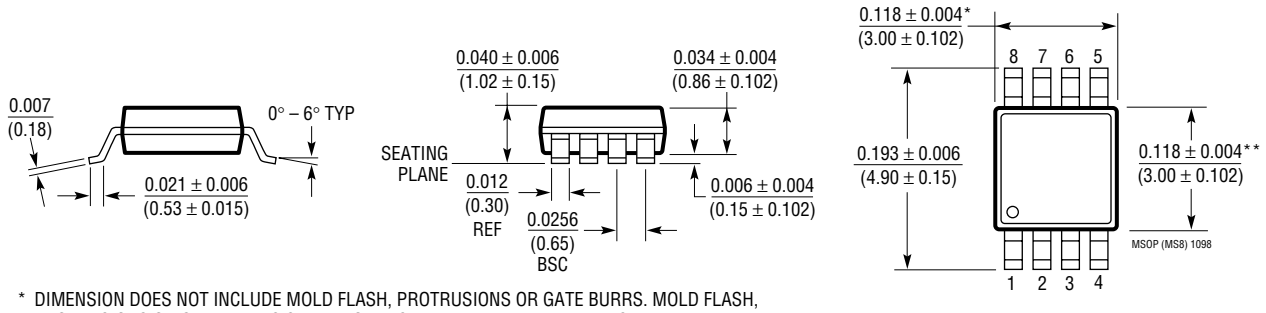
SIMPLIFIED SCHEMATIC



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

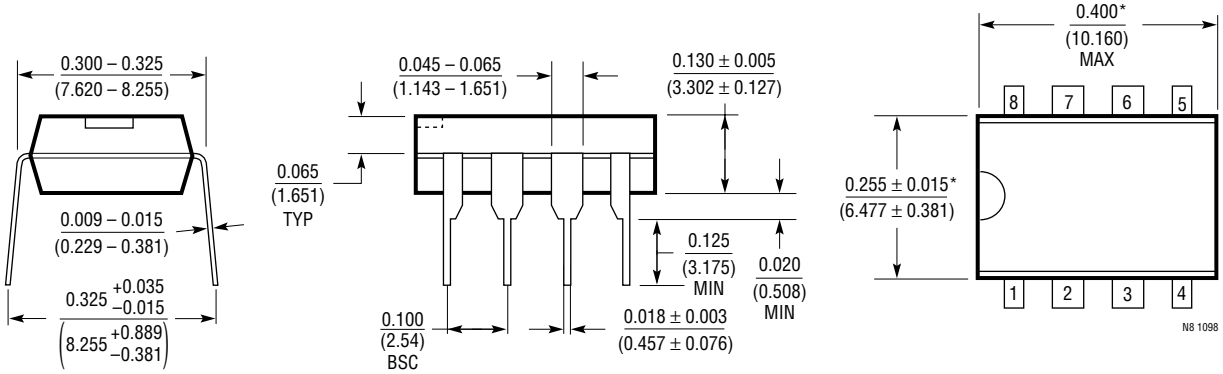
MS Package
8-Lead Plastic MSOP
(LTC DWG # 05-08-1660)



* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

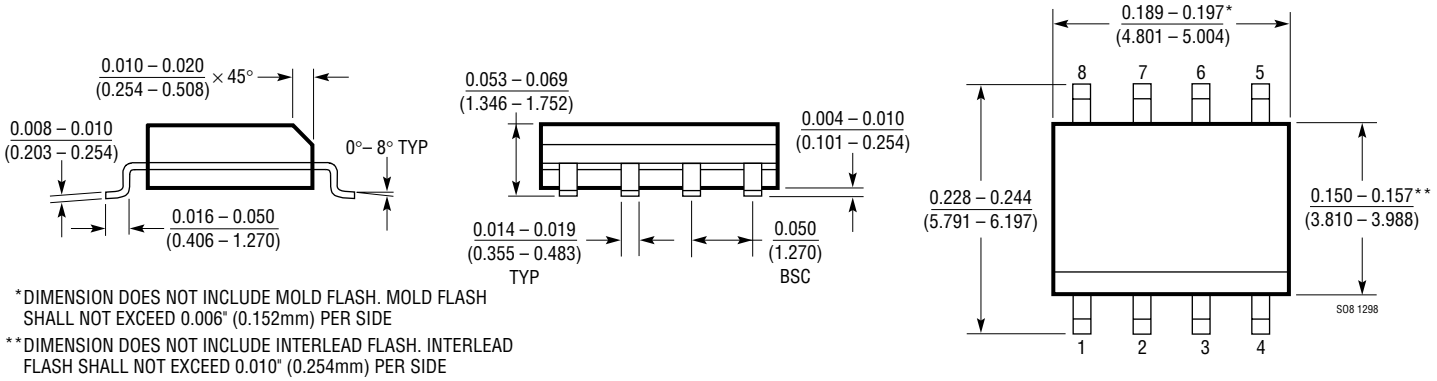
** DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS. INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

N8 Package
8-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

S8 Package
8-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)



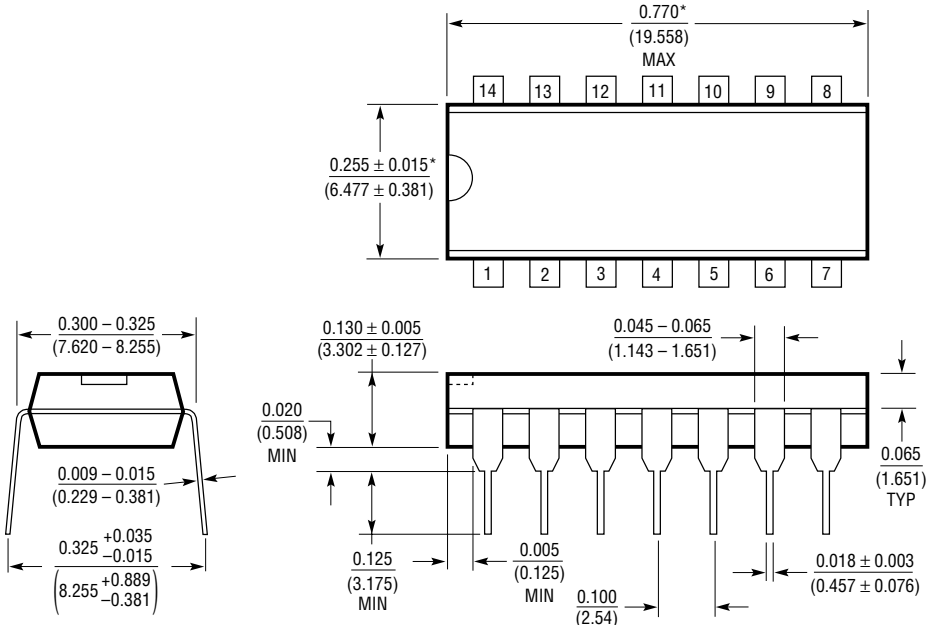
*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

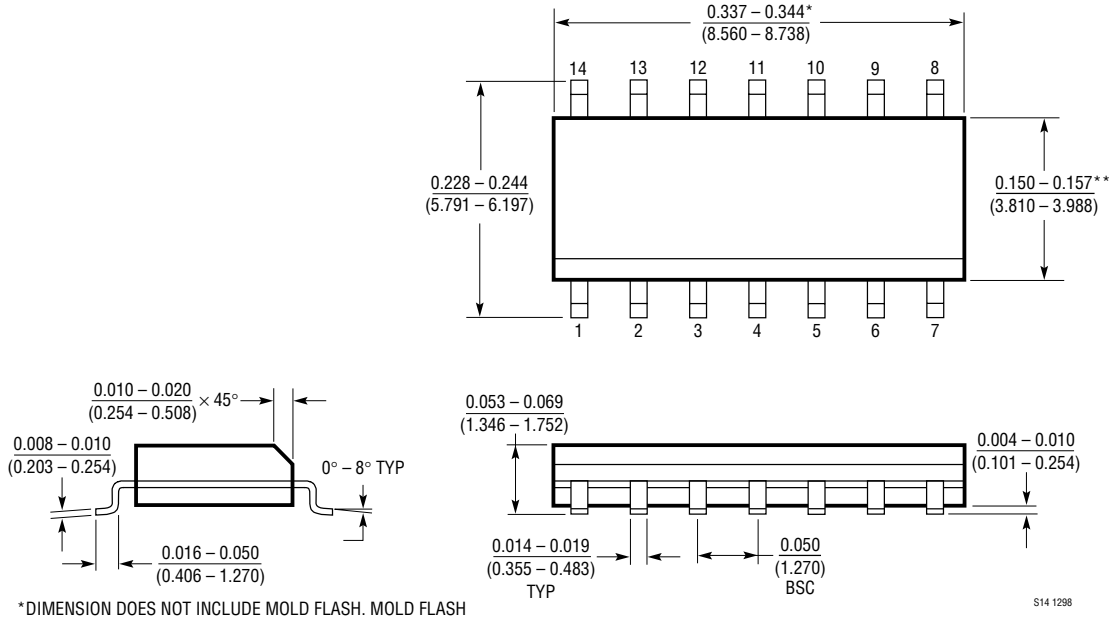
N Package
14-Lead PDIP (Narrow 0.300)
(LTC DWG # 05-08-1510)



*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

N14 1098

S Package
14-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)



*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

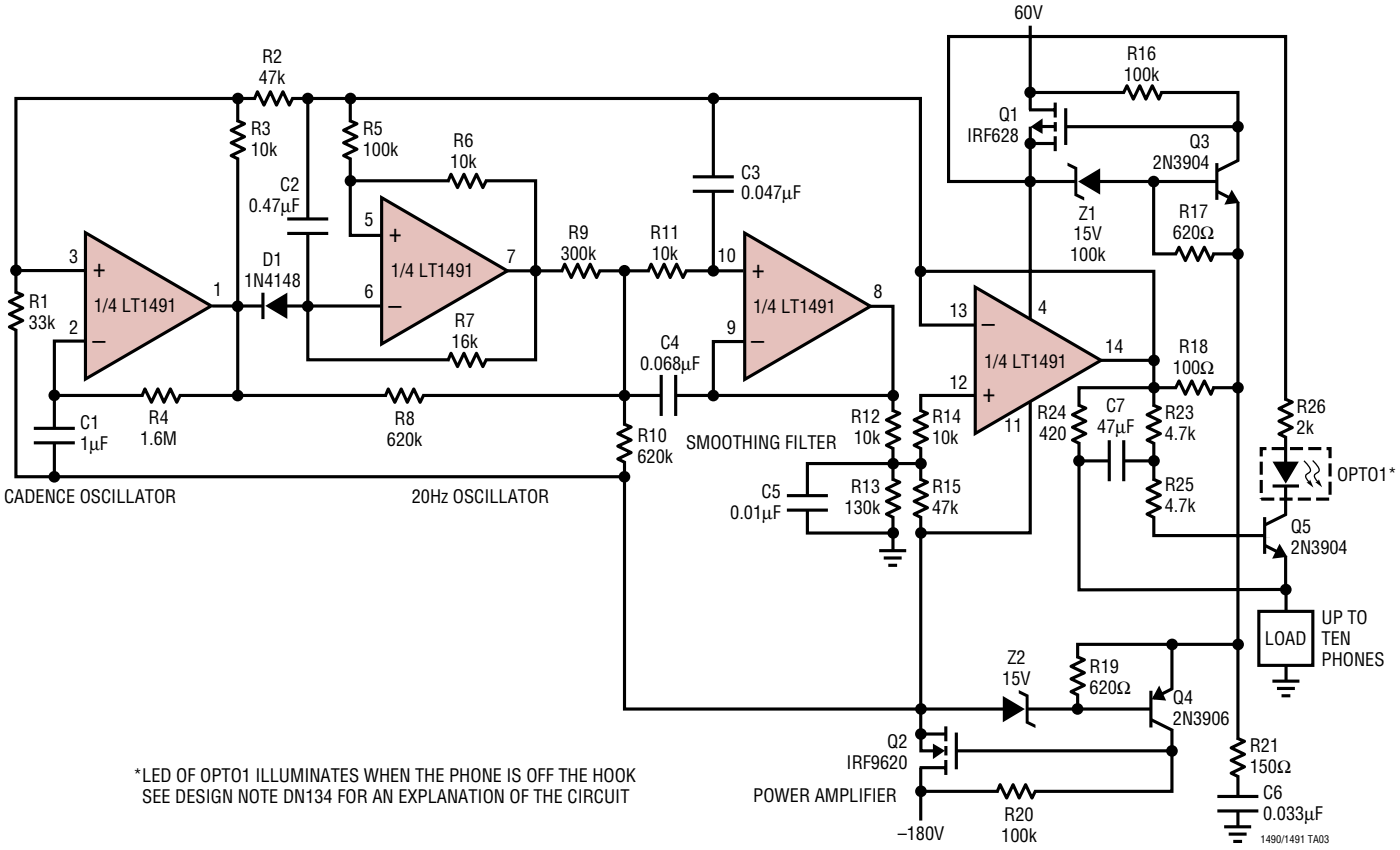
**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

S14 1298

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

TYPICAL APPLICATION

Ring-Tone Generator



*LED OF OPTO1 ILLUMINATES WHEN THE PHONE IS OFF THE HOOK
SEE DESIGN NOTE DN134 FOR AN EXPLANATION OF THE CIRCUIT

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1078/LT1079	Dual/Quad 55µA Max, Single Supply, Precision Op Amps	Input/Output Common Mode Includes Ground, 70µV $V_{OS(MAX)}$ and 2.5µV/°C Drift (Max), 200kHz GBW, 0.07V/µs Slew Rate
LTC1152	Rail-to-Rail Input, Rail-to-Rail Output, Zero-Drift Amplifier	High DC Accuracy, 10µV $V_{OS(MAX)}$, 100nV/°C, 1MHz GBW, 1V/µs Slew Rate, Supply Current 2.2mA (Max), Single Supply, Can Be Configured for C-Load™ Operation
LT1178/LT1179	Dual/Quad 17µA Max, Single Supply, Precison Op Amps	Input/Output Common Mode Includes Ground, 70µV $V_{OS(MAX)}$ and 4µV/°C Drift (Max), 85kHz GBW, 0.04V/µs Slew Rate
LT1366/LT1367	Dual/Quad Precision, Rail-to-Rail Input and Output Op Amps	475µV $V_{OS(MAX)}$, 500V/mV $A_{VOL(MIN)}$, 400kHz GBW
LT1490A/LT1491A	Dual/Quad Micropower Rail-to-Rail Precision Op Amps	500µV $V_{OS(MAX)}$, Improved Version of the LT1490/LT1491

C-Load is a trademark of Linear Technology Corporation.

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14901fb LT/LCG 0600 2K REV B • PRINTED IN USA
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