1.5µA Max, Single, Dual and Quad Over-The-Top Precision Rail-to-Rail Input and Output Op Amps

FEATURES

- **Low Supply Current: 1.5µA Max**
- **Rail-to-Rail Input and Output**
- **Low Offset Voltage: 375µV Max**
- **Operating Temperature Range: –40°C to 125°C**
- **Over-The-Top™ Inputs Operate Above V+**
- Wide Supply Range: 2.2V to 36V
- Single Supply Input Range: –0.3V to 36V
- Low Input Bias Current: 250pA
- Low Input Offset Current: 20pA
- High A_{VOL}: 100V/mV Minimum Driving 100kΩ Load
- Output Sources and Sinks 500µA Load Current
- Reverse Battery Protected to 18V

APPLICATIONS

- Battery- or Solar-Powered Systems
- Portable Instrumentation
- Remote Sensor Amplifier
- Micropower Filter

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Over-The-Top is a trademark of Linear Technology Corporation.

DESCRIPTION

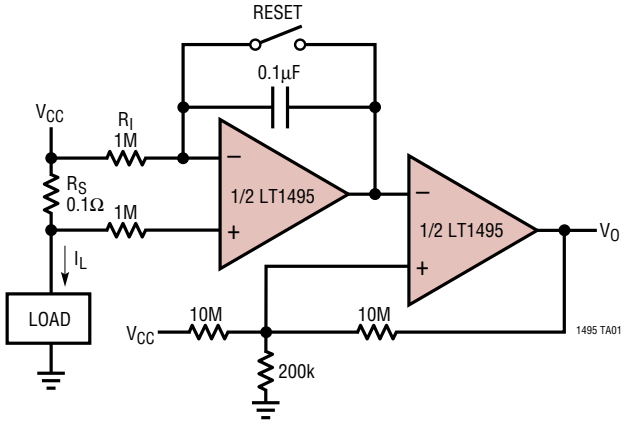
The LT®1494/LT1495/LT1496 are the lowest power ($I_S \leq 1.5\mu A$) op amps with precision specifications. The extremely low supply current is combined with excellent amplifier specifications: input offset voltage is 375µV maximum with a typical drift of only 0.4µV/°C, input offset current is 100pA maximum. A minimum open-loop gain (A_{VOL}) of 100V/mV ensures that gain errors are small. The device characteristics change little over the supply range of 2.2V to ±15V. Supply rejection is 90dB and the common mode rejection ratio is 90dB. Operation is specified for 3V, 5V and ±15V supplies. Reverse battery protection (–18V min) and inputs that operate above the positive supply make the LT1494/LT1495/LT1496 easy to use in harsh environments.

The low bias currents and offset current of the amplifier permit the use of megohm level source resistors without introducing significant errors. Voltage noise at $4\mu V_{P-P}$ is remarkably low considering the low supply current.

The LT1494 is available in the 8-Pin MSOP, PDIP and SO packages.The LT1495 is available in plastic 8-Pin PDIP and SO packages with the standard dual op amp pinout. The LT1496 is available in 14-Pin SO and PDIP packages.

TYPICAL APPLICATION

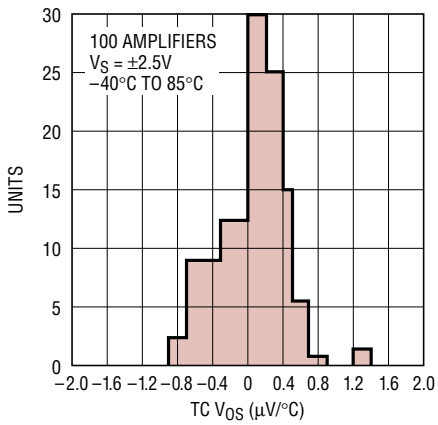
Micropower Integrating Current Sense



OUTPUT SWITCHES
WHEN $\int I_L dt = 0.98\ V_{CC} \left(\frac{R_I}{R_S}\right) C = (4.9A)(SEC)$ FOR $V_{CC} = 5V$

$I_S = 3\mu A$ DURING INTEGRATION; $I_S = 5\mu A$ END OF INTEGRATION

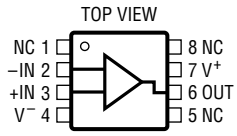
TC V_{OS} Distribution



ABSOLUTE MAXIMUM RATINGS (Note 1)

Total Supply Voltage (V^+ to V^-) 36V
Differential Input Voltage 36V
Input Current ..... ±10mA
Output Short-Circuit Duration ..... Continuous
Operating Temperature Range (Note 2)
LT1494C/LT1495C/LT1496C ..... –40°C to 85°C
LT1494I/LT1495I/LT1496I ..... –40°C to 85°C
LT1494H/LT1495H/LT1496H ..... –40°C to 125°C
Specified Temperature Range (Note 3)
LT1494C/LT1495C/LT1496C ..... –40°C to 85°C
LT1494I/LT1495I/LT1496I ..... –40°C to 85°C
LT1494H/LT1495H/LT1496H ..... –40°C to 125°C
Storage Temperature Range ..... –65°C to 150°C
Junction Temperature ..... 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

PACKAGE/ORDER INFORMATION



MS8 PACKAGE
8-LEAD PLASTIC MSOP

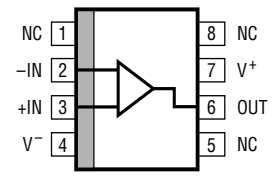
T_{JMAX} = 150°C, θ_{JA} = 250°C/W

ORDER PART NUMBER

LT1494CMS8
LT1494IMS8

MS8 PART MARKING

LTFF
LTFG



N8 PACKAGE
8-LEAD PDIP

S8 PACKAGE
8-LEAD PLASTIC SO

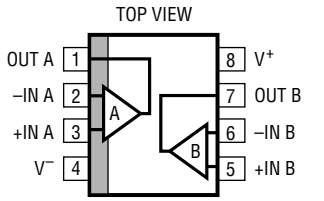
T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 190°C/W (S8)

ORDER PART NUMBER

LT1494CN8
LT1494CS8
LT1494IN8
LT1494IS8
LT1494HS8

S8 PART MARKING

1494
1494I
1494H



N8 PACKAGE
8-LEAD PDIP

S8 PACKAGE
8-LEAD PLASTIC SO

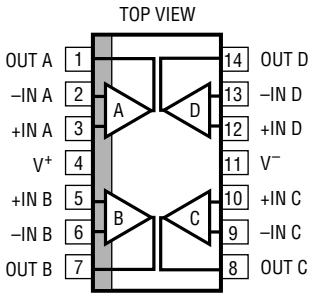
T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N8)
T_{JMAX} = 150°C, θ_{JA} = 190°C/W (S8)

ORDER PART NUMBER

LT1495CN8
LT1495CS8
LT1495IN8
LT1495IS8
LT1495HS8

S8 PART MARKING

1495
1495I
1495H



N PACKAGE
14-LEAD PDIP

S PACKAGE
14-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 130°C/W (N)
T_{JMAX} = 150°C, θ_{JA} = 160°C/W (S)

ORDER PART NUMBER

LT1496CN
LT1496CS
LT1496IN
LT1496IS
LT1496HS

Consult LTC Marketing for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

T_A = 25°C, V_S = 5V, 0V; V_S = 3V, 0V; V_{CM} = V_O = half supply, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	V_S = 5V V_S = 3V V_S = 5V, MS8 Package V_S = 3V, MS8 Package		150 200 150 200	375 475 475 575	µV µV µV µV
I_B	Input Bias Current	(Note 5) V_{CM} = 10V (Note 6)		250 180	1000 360	pA nA
I_{OS}	Input Offset Current	(Note 5)		20	100	pA
	Input Noise Voltage	0.1Hz to 10Hz		4		μV_{P-P}
e_n	Input Noise Voltage Density	f = 100Hz		185		$nV/\sqrt{Hz}$
i_n	Input Noise Current Density	f = 100Hz		10		$fA/\sqrt{Hz}$
A_{VOL}	Large-Signal Voltage Gain	V_S = 5V, V_O = 0.25V to 4.5V, R_L = 100k V_S = 3V, V_O = 0.25V to 2.5V, R_L = 100k	100 50	500 250		V/mV V/mV
	Input Voltage Range		0		36	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0V to 4V, V_S = 5V V_{CM} = 0V to 10V, V_S = 5V	90 74	106 95		dB dB
PSRR	Power Supply Rejection Ratio	V_S = 2.2V to 12V, V_{CM} = V_O = 0.5V	90	99		dB
	Minimum Operating Supply Voltage			2.1	2.2	V
V_{OL}	Output Voltage Swing LOW	No Load I_{SINK} = 100µA		50 210	100 410	mV mV
V_{OH}	Output Voltage Swing HIGH	No Load I_{SOURCE} = 100µA	V^+ – 0.07 V^+ – 0.32	V^+ – 0.035 V^+ – 0.160		V V
I_{SC}	Short-Circuit Current	(Note 5)	0.7	1.3		mA
I_S	Supply Current per Amplifier	(Note 6)		1.0	1.5	µA
	Reverse Supply Voltage	I_S = 10µA per Amplifier	–18			V
SR	Slew Rate	A_V = –1, V_S = ±5V	0.4	1.0		V/ms
GBW	Gain Bandwidth Product	f = 100Hz		2.7		kHz

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the temperature range of 0°C ≤ T_A ≤ 70°C, V_S = 5V, 0V; V_S = 3V, 0V; V_{CM} = V_O = half supply, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	V_S = 5V	●		175	425	µV
		V_S = 3V	●		225	525	µV
		V_S = 5V, MS8 Package	●		175	525	µV
		V_S = 3V, MS8 Package	●		225	625	µV
V_{OS} TC	Input Offset Voltage Drift	(Note 4)	●		0.4	2	µV/°C
I_B	Input Bias Current	(Note 5)	●		250	1200	pA
		V_{CM} = 10V (Note 6)	●		240	500	nA
I_{OS}	Input Offset Current	(Note 5)	●		20	120	pA
A_{VOL}	Large-Signal Voltage Gain	V_S = 5V, V_O = 0.25V to 4.5V, R_L = 100k	●	75	280		V/mV
		V_S = 3V, V_O = 0.25V to 2.5V, R_L = 100k	●	40	150		V/mV
	Input Voltage Range		●	0.2		36	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0.2V to 4V, V_S = 5V	●	89	106		dB
		V_{CM} = 0.2V to 10V, V_S = 5V	●	64	85		dB
PSRR	Power Supply Rejection Ratio	V_S = 2.4V to 12V, V_{CM} = V_O = 0.5V	●	89	99		dB
	Minimum Operating Supply Voltage		●		2.3	2.4	V
V_{OL}	Output Voltage Swing LOW	No Load	●		55	110	mV
		I_{SINK} = 100µA	●		225	450	mV
V_{OH}	Output Voltage Swing HIGH	No Load	●	V^+ – 0.08	V^+ – 0.04		V
		I_{SOURCE} = 100µA	●	V^+ – 0.36	V^+ – 0.18		V
I_{SC}	Short-Circuit Current	(Note 5)	●	0.6	1.1		mA
I_S	Supply Current per Amplifier	(Note 6)	●		1.2	1.8	µA

The ● denotes the specifications which apply over the temperature range of –40°C ≤ T_A ≤ 85°C, V_S = 5V, 0V; V_S = 3V, 0V; V_{CM} = V_O = half supply, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	V_S = 5V	●		200	475	µV
		V_S = 3V	●		250	575	µV
		V_S = 5V, MS8 Package	●		200	575	µV
		V_S = 3V, MS8 Package	●		250	675	µV
V_{OS} TC	Input Offset Voltage Drift	(Note 4)	●		0.4	2	µV/°C
I_B	Input Bias Current	(Note 5)	●		250	1700	pA
		V_{CM} = 10V (Note 6)	●		275		nA
I_{OS}	Input Offset Current	(Note 5)	●		20	170	pA
A_{VOL}	Large-Signal Voltage Gain	V_S = 5V, V_O = 0.25V to 4.5V, R_L = 100k	●	55	215		V/mV
		V_S = 3V, V_O = 0.25V to 2.5V, R_L = 100k	●	30	115		V/mV
	Input Voltage Range		●	0.2		36	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0.2V to 4V, V_S = 5V	●	88	106		dB
		V_{CM} = 0.2V to 10V, V_S = 5V	●		75		dB
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 12V, V_{CM} = V_O = 0.5V	●	88	99		dB
	Minimum Operating Supply Voltage		●		2.6	2.7	V
V_{OL}	Output Voltage Swing LOW	No Load	●		60	120	mV
		I_{SINK} = 100µA	●		245	490	mV
V_{OH}	Output Voltage Swing HIGH	No Load	●	V^+ – 0.10	V^+ – 0.05		mV
		I_{SOURCE} = 100µA	●	V^+ – 0.38	V^+ – 0.19		mV
I_{SC}	Short-Circuit Current	(Note 5)	●	0.4	0.9		mA
I_S	Supply Current per Amplifier	(Note 6)	●		1.5	2.3	µA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the temperature range of –40°C ≤ T_A ≤ 125°C. V_S = 5V, 0V; V_S = 3V, 0V; V_{CM} = V_O = half supply, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		LT1494H/LT1495H/LT1496H MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	V_S = 5V	●		225	875	µV
		V_S = 3V	●		275	975	µV
V_{OS} TC	Input Offset Voltage Drift	(Note 4)	●		0.4	3	µV/°C
I_B	Input Bias Current	(Note 5)	●		3.8	10	nA
		V_{CM} = 10V (Note 6)	●		0.300	2	µA
I_{OS}	Input Offset Current	(Note 5)	●		0.3	2	nA
A_{VOL}	Large-Signal Voltage Gain	V_S = 5V, V_O = 0.25V to 4.5V, R_L = 100k	●	4	25		V/mV
		V_S = 3V, V_O = 0.25V to 2.5V, R_L = 100k	●	2	17		V/mV
	Input Voltage Range		●	0.5		36	V
CMRR	Common Mode Rejection Ratio	V_{CM} = 0.5V to 4V, V_S = 5V	●	72	95		dB
		V_{CM} = 0.5V to 10V, V_S = 5V	●		85		dB
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 12V, V_{CM} = V_O = 0.5V	●	86	105		dB
	Minimum Operating Supply Voltage		●			2.7	V
V_{OL}	Output Voltage Swing LOW	No Load	●		70	160	mV
		I_{SINK} = 100µA	●		275	550	mV
V_{OH}	Output Voltage Swing HIGH	No Load	●	V^+ – 140	V^+ – 45		mV
		I_{SOURCE} = 100µA	●	V^+ – 450	V^+ – 225		mV
I_S	Supply Current per Amplifier	(Note 6)	●		2	5	µA

T_A = 25°C, V_S = ±15V, V_{CM} = V_O = 0V, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage			200	575	µV
		MS8 Package		200	675	µV
I_B	Input Bias Current			25	1000	pA
I_{OS}	Input Offset Current			20	100	pA
A_{VOL}	Large-Signal Voltage Gain	V_O = ±10V, R_L = 100k	100	360		V/mV
	Input Voltage Range		–15		21	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –15V to 14V	100	120		dB
PSRR	Power Supply Rejection Ratio	V_S = ±5V to ±15V	96	120		dB
V_{OL}	Output Voltage Swing LOW	R_L = 1M		–14.85	–14.70	V
		R_L = 100k		–14.75	–14.50	V
V_{OH}	Output Voltage Swing HIGH	R_L = 1M	14.78	14.89		V
		R_L = 100k	14.62	14.81		V
I_{SC}	Short-Circuit Current		0.7	1.5		mA
I_S	Supply Current per Amplifier			1.4	2.0	µA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the temperature range of 0°C ≤ T_A ≤ 70°C, V_S = ±15V, V_{CM} = V_O = 0V, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage		●		225	625	µV
		MS8 Package	●		225	725	µV
I_B	Input Bias Current		●		250	1200	pA
I_{OS}	Input Offset Current		●		20	120	pA
A_{VOL}	Large-Signal Voltage Gain	V_O = ±10V, R_L = 100k	●	60	240		V/mV
	Input Voltage Range		●	–14.8		21	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –14.8V to 14V	●	98	120		dB
PSRR	Power Supply Rejection Ratio	V_S = ±5V to ±15V	●	94	120		dB
V_{OL}	Output Voltage Swing LOW	R_L = 1M	●		–14.84	–14.67	V
		R_L = 100k	●		–14.73	–14.46	V
V_{OH}	Output Voltage Swing HIGH	R_L = 1M	●	14.76	14.88		V
		R_L = 100k	●	14.58	14.79		V
I_{SC}	Short-Circuit Current		●	0.6	1.3		mA
I_S	Supply Current per Amplifier		●		1.6	2.4	µA

The ● denotes the specifications which apply over the temperature range of –40°C ≤ T_A ≤ 85°C, V_S = ±15V, V_{CM} = V_O = 0V, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage		●		250	675	µV
		MS8 Package	●		250	775	µV
I_B	Input Bias Current		●		250	1700	pA
I_{OS}	Input Offset Current		●		20	170	pA
A_{VOL}	Large-Signal Voltage Gain	V_O = ±10V, R_L = 100k	●	50	200		V/mV
	Input Voltage Range		●	–14.8		21	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –14.8V to 14V	●	96	114		dB
PSRR	Power Supply Rejection Ratio	V_S = ±5V to ±15V	●	92	120		dB
V_{OL}	Output Voltage Swing LOW	R_L = 1M	●		–14.83	–14.66	V
		R_L = 100k	●		–14.72	–14.44	V
V_{OH}	Output Voltage Swing HIGH	R_L = 1M	●	14.74	14.87		V
		R_L = 100k	●	14.54	14.77		V
I_{SC}	Short-Circuit Current		●	0.4	1.1		mA
I_S	Supply Current per Amplifier		●		2.0	3.0	µA

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the temperature range of –40°C ≤ T_A ≤ 125°C. V_S = ±15V, V_{CM} = V_O = half supply, unless otherwise noted. (Note 3)

SYMBOL	PARAMETER	CONDITIONS		LT1494H/LT1495H/LT1496H MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage		●		275	1100	µV
I_B	Input Bias Current		●		3.8	10	nA
I_{OS}	Input Offset Current		●		0.3	2	nA
A_{VOL}	Large-Signal Voltage Gain	V_O = ±10V, R_L = 100k	●	21	70		V/mV
	Input Voltage Range		●	–14.5		21	V
CMRR	Common Mode Rejection Ratio	V_{CM} = –14.5V to 14V	●	69	90		dB
PSRR	Power Supply Rejection Ratio	V_S = ±5V to ±15V	●	89	115		dB
V_{OL}	Output Voltage Swing LOW	R_L = 1M R_L = 100k	● ●		–14.80 –14.69	–14.4 –14.2	V V
V_{OH}	Output Voltage Swing HIGH	R_L = 1M R_L = 100k	● ●	14.5 14.3	14.85 14.73		V V
I_S	Supply Current per Amplifier		●		3	6	µA

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

Note 2: The LT1494C/LT1495C/LT1496C and LT1494I/LT1495I/LT1496I are guaranteed functional over the operating temperature range of –40°C to 85°C. The LT1494H/LT1495H/LT1496H are guaranteed functional over the operating temperature range of –40°C to 125°C.

Note 3: The LT1494C/LT1495C/LT1496C are guaranteed to meet specified performance from 0°C to 70°C. The LT1494C/LT1495C/LT1496C 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 LT1494I/LT1495I/LT1496I are guaranteed to meet specified performance from –40°C to 85°C. The LT1494H/LT1495H/LT1496H are guaranteed to meet specified performance from –40°C to 125°C.

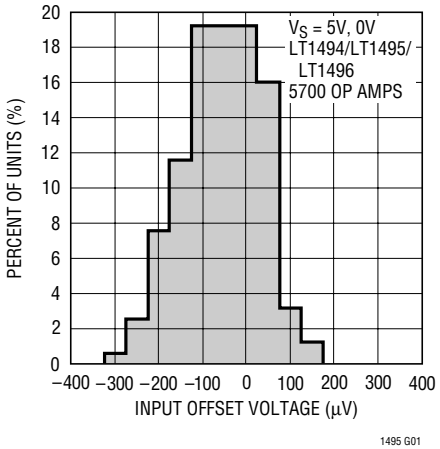
Note 4: This parameter is not 100% tested.

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

Note 6: V_S = 3V limits are guaranteed by correlation to V_S = 5V and V_S = ±15V tests.

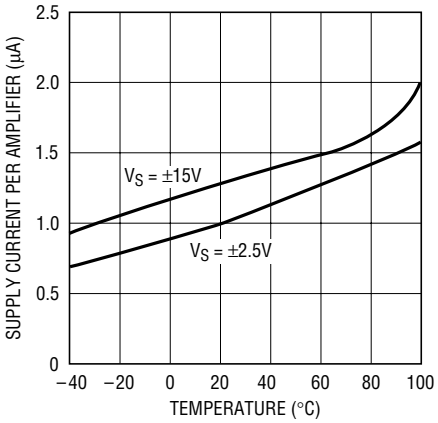
TYPICAL PERFORMANCE CHARACTERISTICS

Distribution of Input Offset Voltage



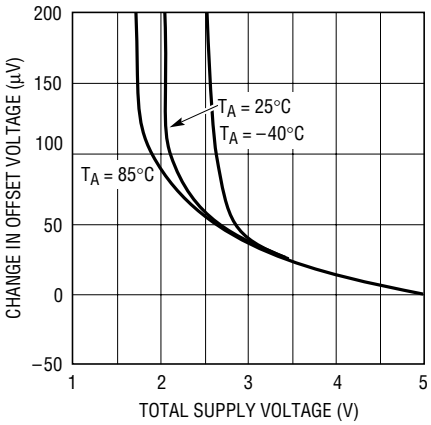
1495 G01

Supply Current vs Temperature



1495 G02

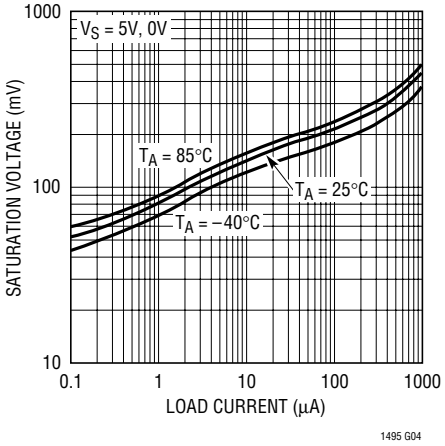
Minimum Supply Voltage



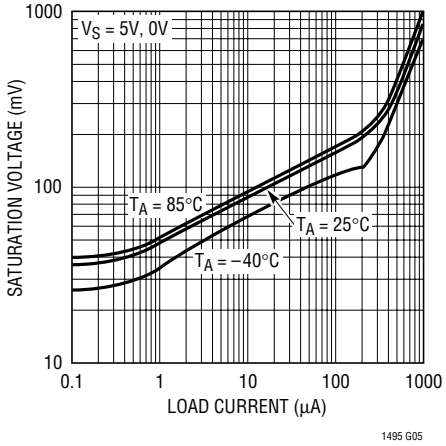
1495 G03

TYPICAL PERFORMANCE CHARACTERISTICS

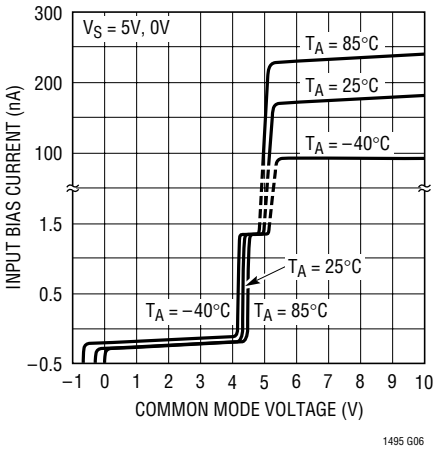
Output Saturation Voltage vs Load Current (Output Low)



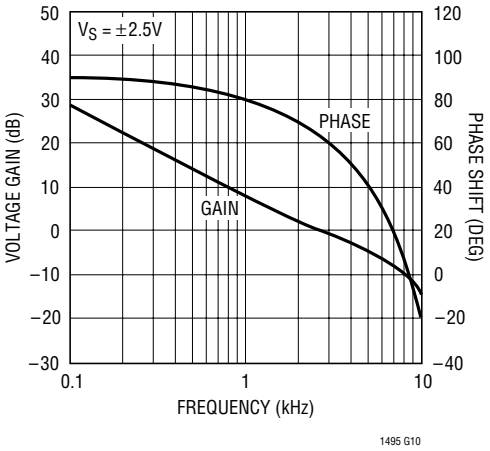
Output Saturation Voltage vs Load Current (Output High)



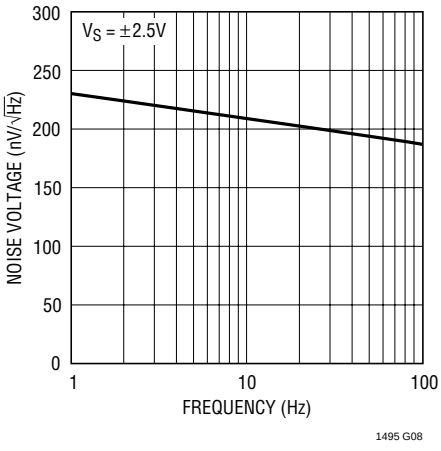
Input Bias Current vs Common Mode Voltage



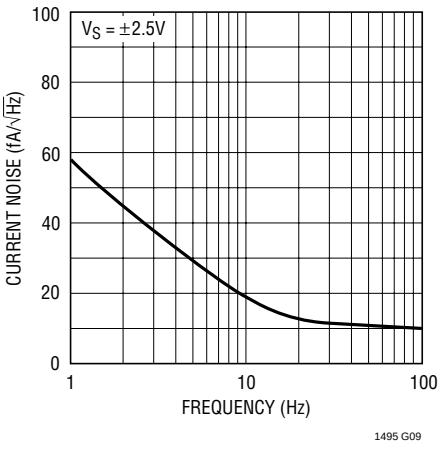
Gain and Phase Shift vs Frequency



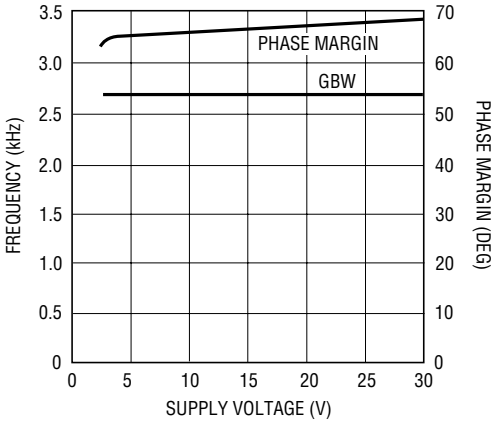
Noise Voltage Spectrum



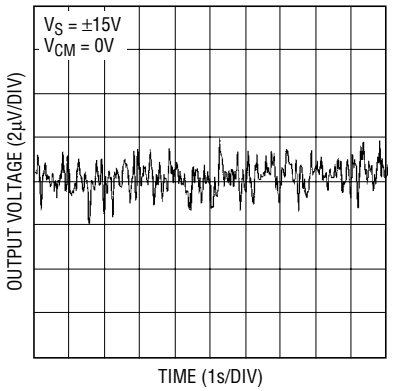
Noise Current Spectrum



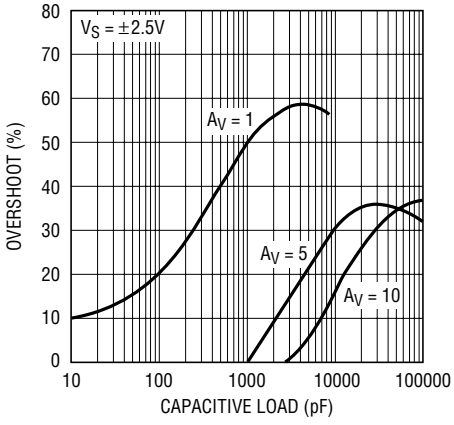
Gain Bandwidth and Phase Margin vs Supply Voltage



0.1Hz to 10Hz Output Voltage Noise

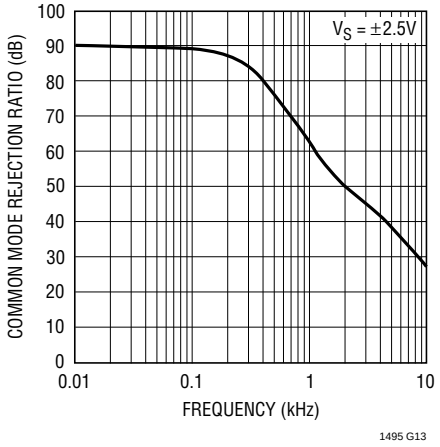


Capacitive Load Handling



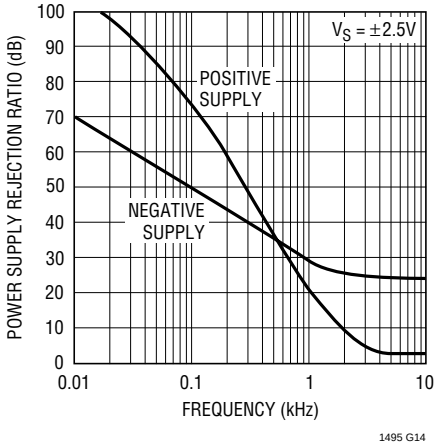
TYPICAL PERFORMANCE CHARACTERISTICS

Common Mode Rejection Ratio vs Frequency



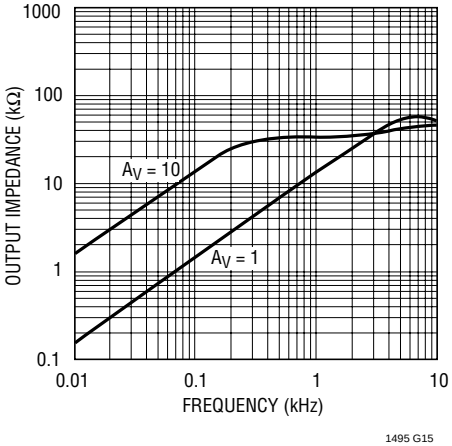
1495 G13

Power Supply Rejection Ratio vs Frequency



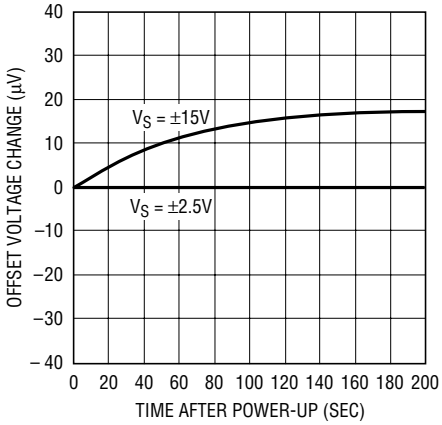
1495 G14

Output Impedance vs Frequency



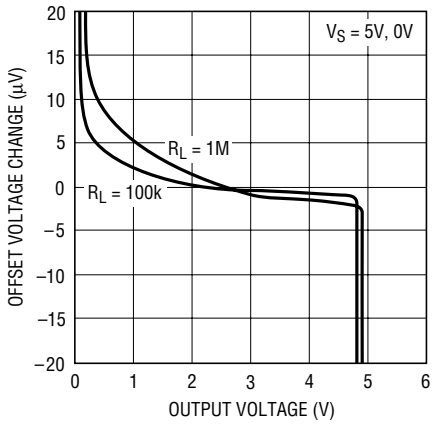
1495 G15

Warm-Up Drift vs Time



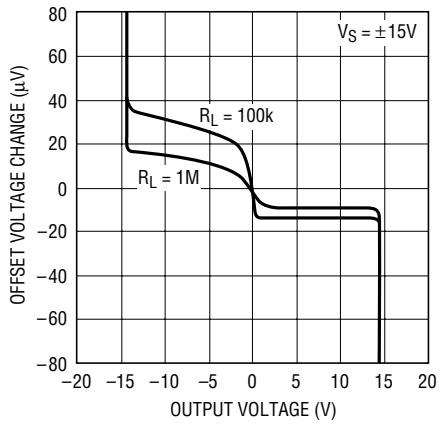
1495 G16

Open-Loop Gain V_S = 5V, 0V



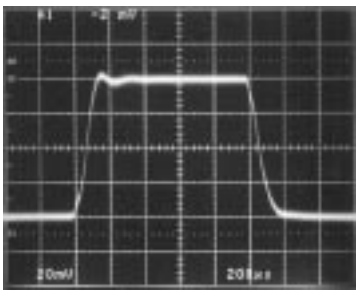
1495 G17

Open-Loop Gain $V_S = \pm 15V$



1495 G18

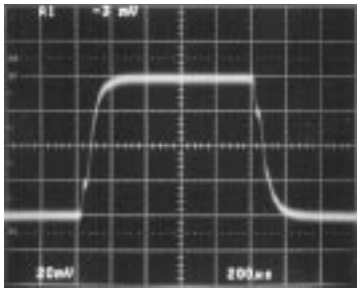
Small-Signal Response $V_S = \pm 15V$



1495 G19

$V_S = \pm 15V$
$R_L = 1M$
$C_L = 100pF$

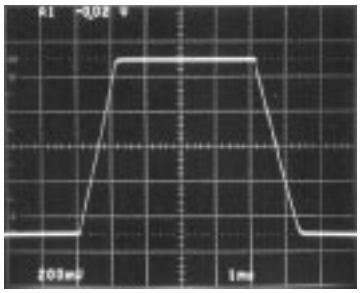
Small-Signal Response V_S = 5V, 0V



1495 G20

V_S = 5V, 0V
R_L = 1M
C_L = 100pF

Large-Signal Response V_S = 5V, 0V



1495 G21

V_S = 5V, 0V
R_L = 1M
C_L = 100pF

APPLICATIONS INFORMATION

Start-Up Characteristics

Micropower op amps are sometimes not micropower during start-up, wreaking havoc on low current supplies. In the worst case, there may not be enough supply current available to take the system up to nominal voltages. Figure 1 is a graph of LT1495 supply current vs supply voltage for the three limit cases of input offset that could occur during start-up. The circuits are shown in Figure 2. One circuit creates a positive offset, forcing the output to come up saturated high. Another circuit creates a negative offset, forcing the output to come up saturated low, while the last brings up the output at half supply. In all cases, the supply current is well behaved. Supply current is highest with the output forced high, so if one amplifier is unused, it is best to force the output low or at half supply.

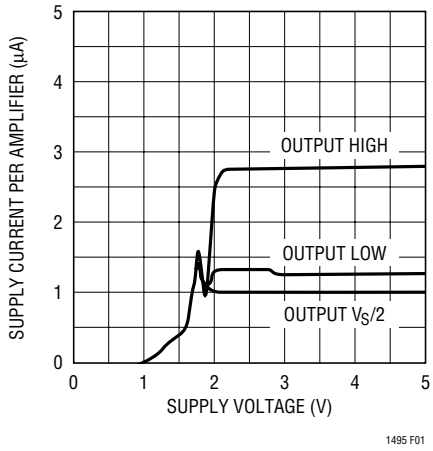


Figure 1. Start-Up Characteristics

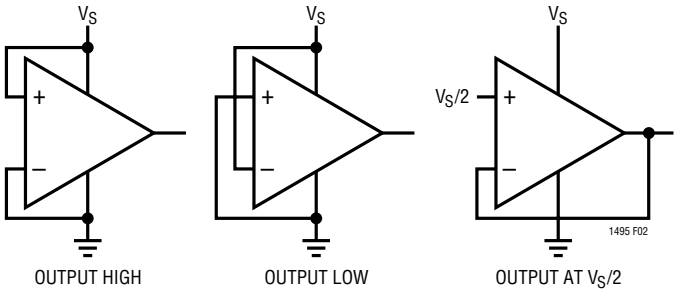


Figure 2. Circuits for Start-Up Characteristics

Reverse Battery

The LT1494/LT1495/LT1496 are protected against reverse battery voltages up to 18V. In the event a reverse battery condition occurs, the supply current is typically less than 100nA (inputs grounded and outputs open). For typical single supply applications with ground referred loads and feedback networks, no other precautions are required. If the reverse battery condition results in a negative voltage at either the input pins or output pin, the current into the pin should be limited by an external resistor to less than 10mA.

Inputs

While the LT1494/LT1495/LT1496 will function normally with its inputs taken above the positive supply, the common mode range does not extend beyond approximately 300mV below the negative supply at room temperature. The device will not be damaged if the inputs are taken lower than 300mV below the negative supply as long as the current out of the pin is limited to less than 10mA. However, the output phase is not guaranteed and the supply current will increase.

Output

The graph, Capacitive Load Handling, shows amplifier stability with the output biased at half supply. If the output is to be operated within about 100mV of the positive rail, the allowable load capacitance is less. With this output voltage, the worst case occurs at $A_V = 1$ and light loads, where the load capacitance should be less than 500pF with a 5V supply and less than 100pF with a 30V supply.

Rail-to-Rail Operation

The simplified schematic, Figure 3, details the circuit design approach of the LT1494/LT1495/LT1496. The amplifier topology is a three-stage design consisting of a rail-to-rail input stage, that continues to operate with the inputs above the positive rail, a folded cascode second stage that develops most of the voltage gain, and a rail-to-rail common emitter stage that provides the current gain.

APPLICATIONS INFORMATION

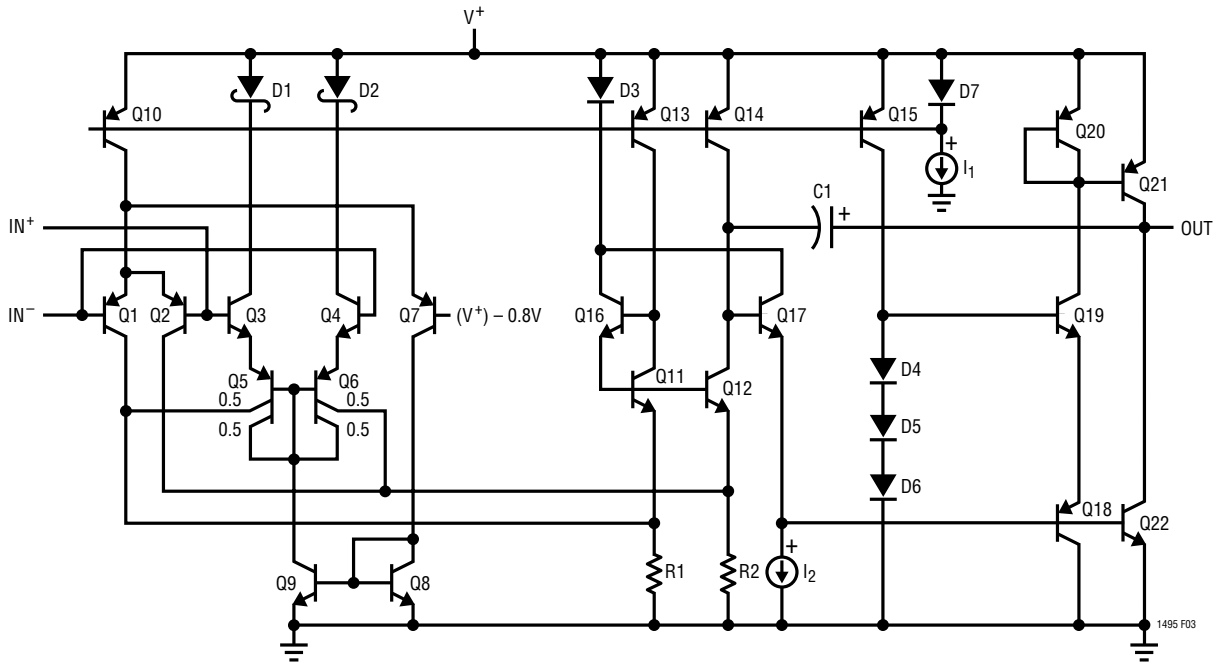


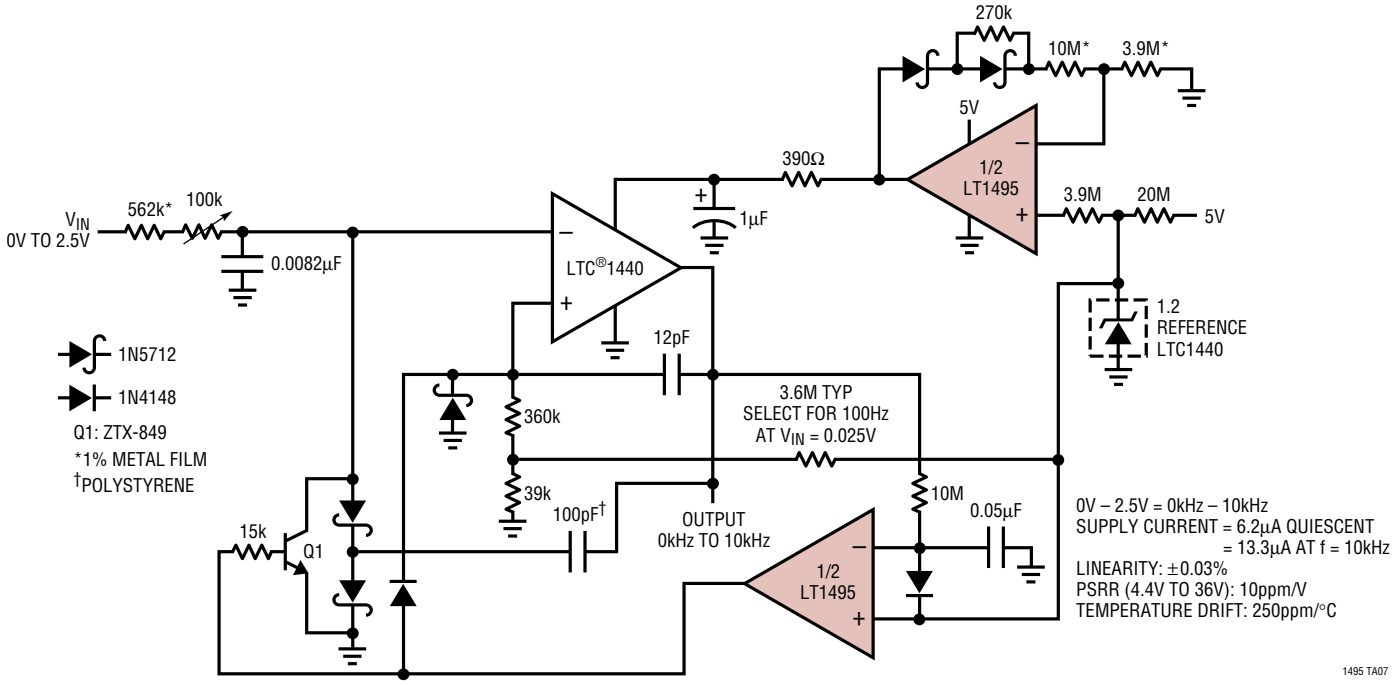
Figure 3. Simplified Schematic

The input stage is formed by two diff amps Q1-Q2 and Q3-Q6. For signals with a common mode voltage between V_{EE} and (V_{CC} – 0.8V), Q1 and Q2 are active. When the input common mode exceeds (V_{CC} – 0.8V), Q7 turns on, diverting the current from diff amp Q1-Q2 to current mirror Q8-Q9. The current from Q8 biases on the other diff amp consisting of PNP's Q5-Q6 and NPN's Q3-Q4. Though Q5-Q6 are driven from the emitters rather than the base, the basic diff amp action is the same. When the common mode voltage is between (V_{CC} – 0.8V) and V_{CC}, devices Q3 and Q4 act as followers, forming a buffer between the amplifier inputs and the emitters of the Q5-Q6. If the common mode voltage is taken above V_{CC}, Schottky diodes D1 and D2 reverse bias and devices Q3 and Q4 then act as diodes. The diff amp formed by Q5-Q6 operates normally, however, the input bias current increases to the emitter current of Q5-Q6, which is typically 180nA. The graph, Input Bias Current vs Common Mode Voltage found in the Typical Performance Characteristics section, shows these transitions at three temperatures.

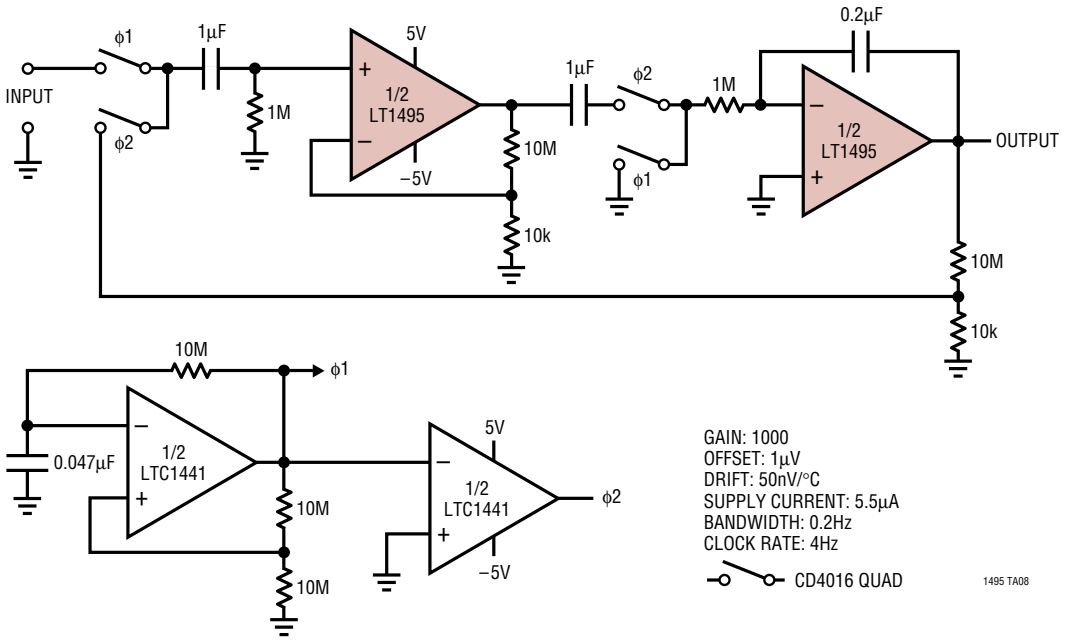
The collector currents of the two-input pairs are combined in the second stage consisting of Q11 to Q16, which furnishes most of the voltage gain. Capacitor C1 sets the amplifier bandwidth. The output stage is configured for maximum swing by the use of common emitter output devices Q21 and Q22. Diodes D4 to D6 and current source Q15 set the output quiescent current.

TYPICAL APPLICATIONS

13μA, 0kHz to 10kHz Voltage to Frequency Converter

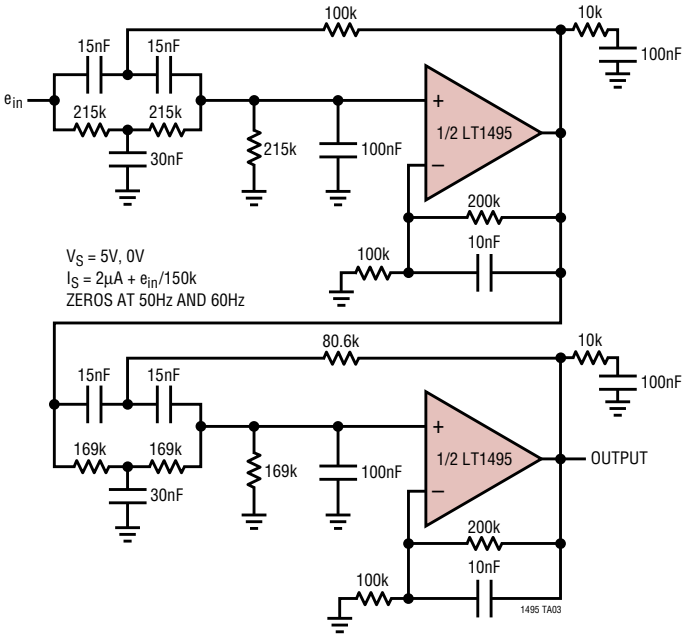


6μA, A_V = 1000, Chopper Stabilized Amplifier

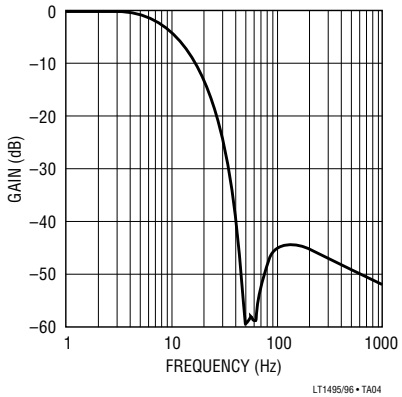


TYPICAL APPLICATIONS

6th Order 10Hz Elliptic Lowpass Filter

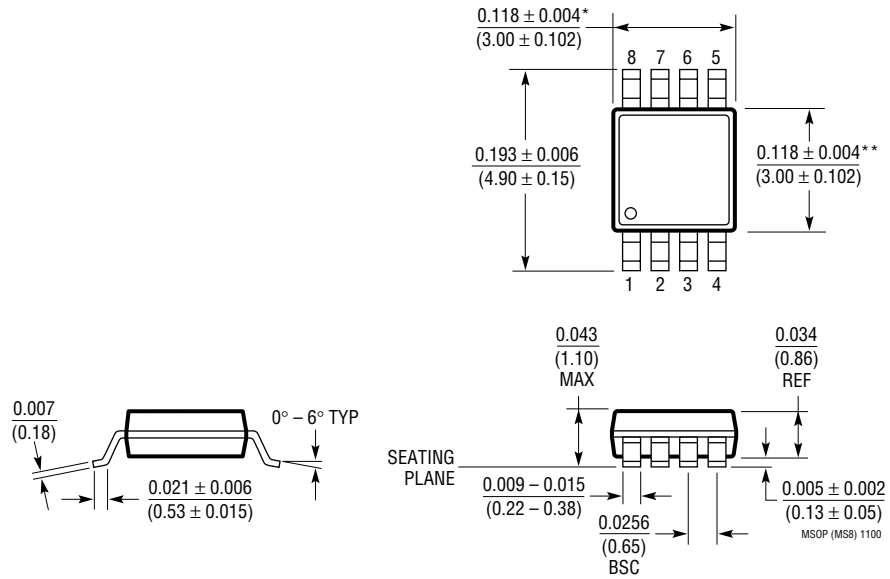


Filter Frequency Response



PACKAGE DESCRIPTION

MS8 Package
8-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1660)

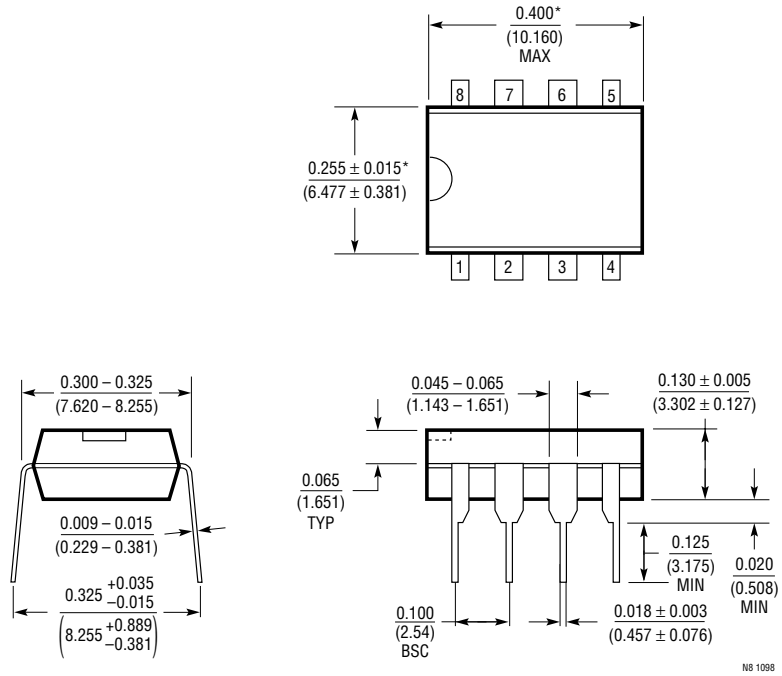


* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

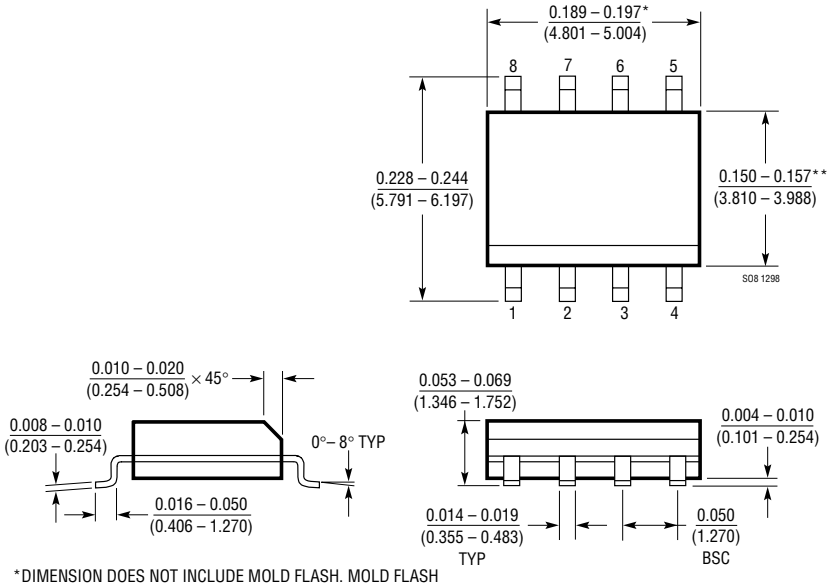
PACKAGE DESCRIPTION

N8 Package
8-Lead PDIP (Narrow .300 Inch)
(Reference 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 .150 Inch)
(Reference LTC DWG # 05-08-1610)

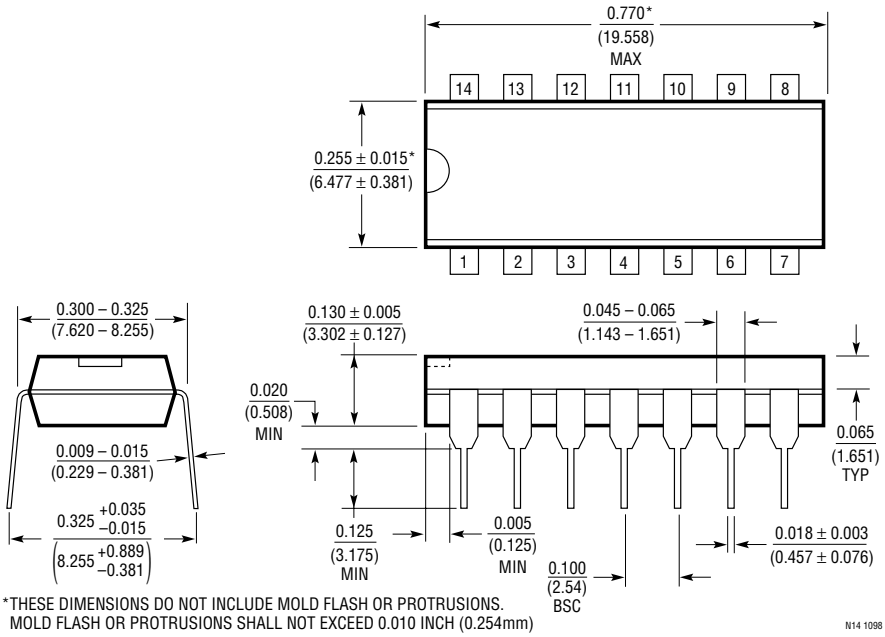


*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

PACKAGE DESCRIPTION

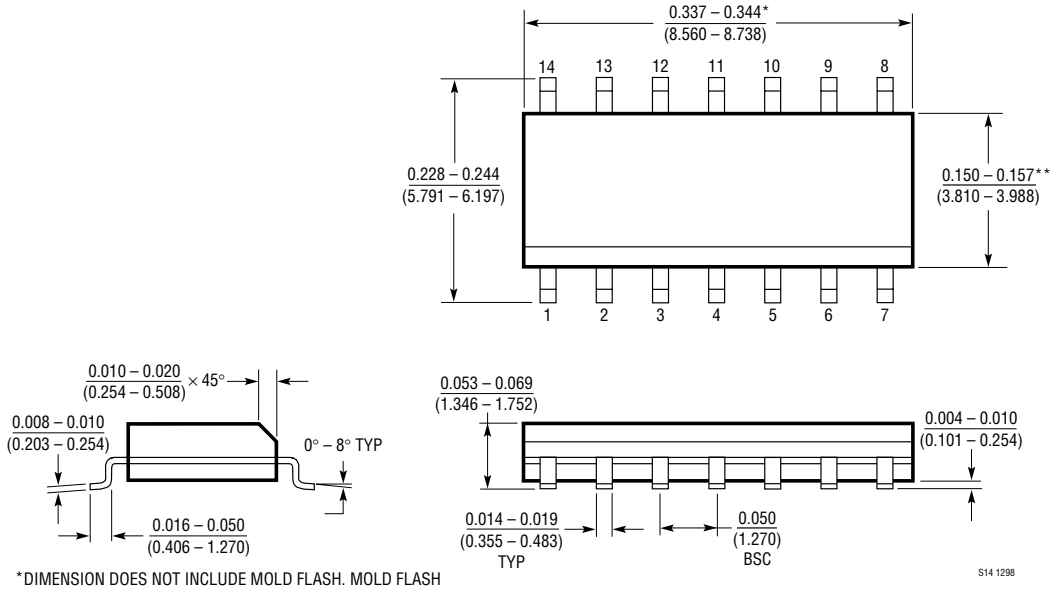
N Package
14-Lead PDIP (Narrow .300 Inch)
(Reference LTC DWG # 05-08-1510)



*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 .150 Inch)
(Reference LTC DWG # 05-08-1610)



S14 1298

*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

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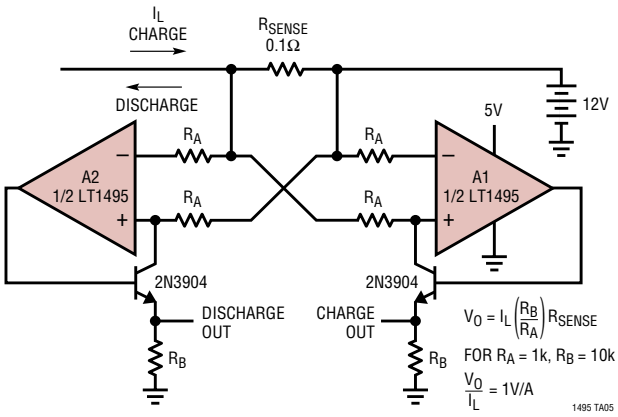
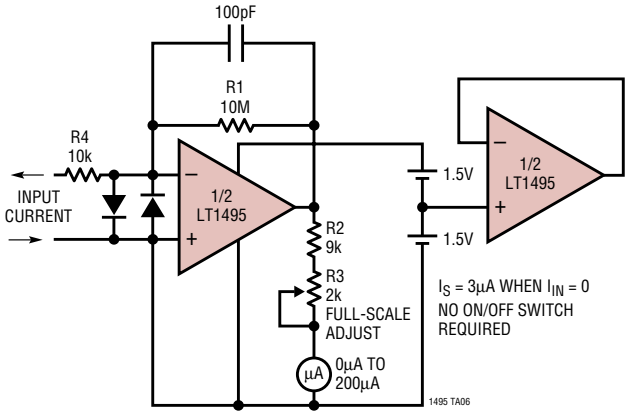
TYPICAL APPLICATIONS

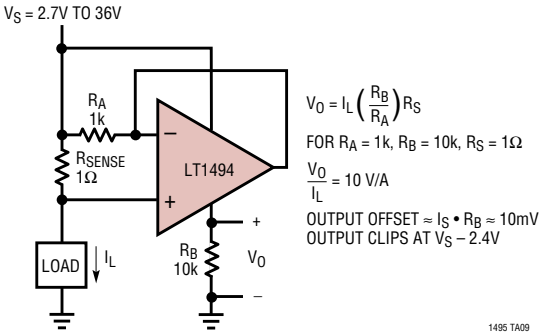
Battery Current Monitor



0nA to 200nA Current Meter



High Side Current Sense



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC®1440/41/42	Micropower Single/Dual Comparators with 1% Reference	LTC1440: Single, LTC1441/42: Dual
LTC1443/44/45	Micropower Quad Comparators with 1% Reference	LTC1443: 1.182 Reference LTC1444/45: 1.221V Reference and Adjustable Hysteresis
LT1466/LT1467	75μA Dual/Quad Rail-to-Rail Input and Output Op Amps	390μV $V_{OS(MAX)}$, Gain Bandwidth = 120kHz
LT1490A/LT1491A	50μA Dual/Quad Rail-to-Rail Input and Output Op Amps	950μV $V_{OS(MAX)}$, Gain Bandwidth = 200kHz
LTC1540	Nanopower Single Comparator with 1% Reference	350nA Supply Current
LT1636	Single Over-The-Top Micropower, Rail-to-Rail Input and Output Op Amp	225μV $V_{OS(MAX)}$, I_S = 55μA (MAX), Gain-Bandwidth = 200kHz Shutdown Pin, MSOP
LT1672/LT1673/LT1674	2μA MAX, $A_V \geq 5$ Single/Dual/Quad Over-The-Top Precision Rail-to-Rail Input and Output Op Amps	Decompensated Version of the LT1494/LT1495/LT1496 $A_V \geq 5$, Gain-Bandwidth = 12kHz
LT2078/LT2079	55μA Dual/Quad Single Supply Op Amps	120μV $V_{OS(MAX)}$, Gain Bandwidth = 200kHz
LT2178/LT2179	17μA Dual/Quad Single Supply Op Amps	120μV $V_{OS(MAX)}$, Gain Bandwidth = 60kHz
LT1782	Micropower, Over-The-Top, SOT-23, Rail-to-Rail Input and Output Op Amp	SOT-23, 800μV $V_{OS(MAX)}$, I_S = 55μA (Max), Gain-Bandwidth = 200kHz, Shutdown Pin
LT1783	1.2MHz, Over-The-Top, Micropower, Rail-to-Rail Input and Output Op Amp in SOT-23	SOT-23, 800μV $V_{OS(MAX)}$, I_S = 300μA (Max), Gain-Bandwidth = 1.2MHz, Shutdown Pin

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