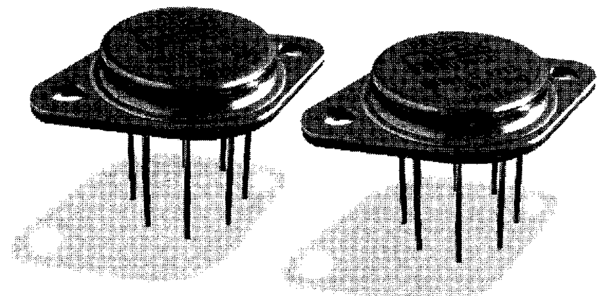
APEX POWER OPERATIONAL AMPLIFIERS

PA12 • PA12A

APEX MICROTECHNOLOGY CORPORATION • APPLICATIONS HOTLINE 800 546-APEX (800-546-2739)

FEATURES

- LOW THERMAL RESISTANCE — 1.4°C/W
- CURRENT FOLDOVER PROTECTION — NEW
- HIGH TEMPERATURE VERSION — PA12H
- EXCELLENT LINEARITY — Class A/B Output
- WIDE SUPPLY RANGE — ±10V to ±50V
- HIGH OUTPUT CURRENT — Up to ±15A Peak



APPLICATIONS

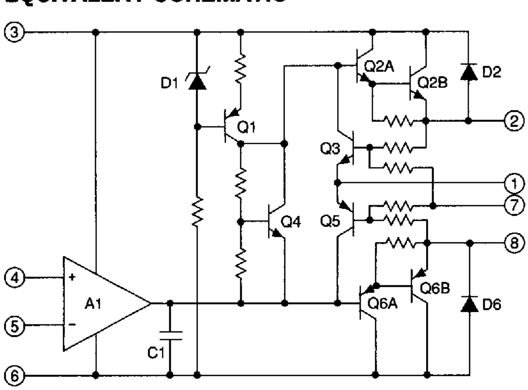
- MOTOR, VALVE AND ACTUATOR CONTROL
- MAGNETIC DEFLECTION CIRCUITS UP TO 10A
- POWER TRANSDUCERS UP TO 100kHz
- TEMPERATURE CONTROL UP TO 360W
- PROGRAMMABLE POWER SUPPLIES UP TO 90V
- AUDIO AMPLIFIERS UP TO 120W RMS

DESCRIPTION

The PA12 is a state of the art high voltage, very high output current operational amplifier designed to drive resistive, inductive and capacitive loads. The complementary darlington emitter follower output stage is protected against transient inductive kickback. For optimum linearity, especially at low levels, the output stage is biased for class A/B operation using a thermistor compensated base-emitter voltage multiplier circuit. The safe operating area (SOA) can be observed for all operating conditions by selection of user programmable current limiting resistors. For continuous operation under load, a heatsink of proper rating is recommended.

This hybrid integrated circuit utilizes thick film (cermet) resistors, ceramic capacitors and semiconductor chips to maximize reliability, minimize size and give top performance. Ultrasonically bonded aluminum wires provide reliable interconnections at all operating temperatures. The 8-pin TO-3 package is hermetically sealed and electrically isolated. The use of compressible isolation washers voids the warranty.

EQUIVALENT SCHEMATIC



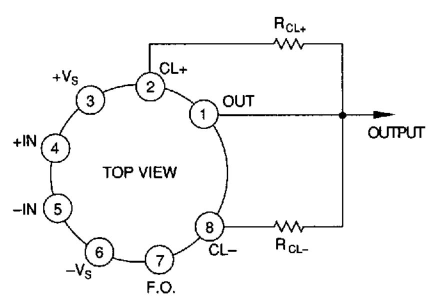
POWER RATING

Not all vendors use the same method to rate the power handling capability of a Power Op Amp. APEX rates the internal dissipation, which is consistent with rating methods used by transistor manufacturers and gives conservative results. Rating delivered power is highly application dependent and therefore can be misleading. For example, the 125W internal dissipation rating of the PA12 could be expressed as an output rating of 250W for audio (sine wave) or as 440W if using a single ended DC load. Please note that all vendors rate maximum power using an infinite heatsink.

THERMAL STABILITY

APEX has eliminated the tendency of class A/B output stages toward thermal runaway and thus has vastly increased amplifier reliability. This feature, not found in most other Power Op Amps, was pioneered by APEX in 1981 using thermistors which assure a negative temperature coefficient in the quiescent current. The reliability benefits of this added circuitry far outweigh the slight increase in component count.

EXTERNAL CONNECTIONS



PA12 • PA12A

ABSOLUTE MAXIMUM RATINGS
SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

	PA12/PA12A
SUPPLY VOLTAGE, +Vs to −Vs	100V
OUTPUT CURRENT, within SOA	15A
POWER DISSIPATION, internal	125W
INPUT VOLTAGE, differential	$\pm V_S$ −3V
INPUT VOLTAGE, common mode	$\pm V_S$
TEMPERATURE, pin solder -10s	300°C
TEMPERATURE, junction[1]	200°C
TEMPERATURE RANGE, storage	−65 to +150°C
OPERATING TEMPERATURE RANGE, case	−55 to +125°C

SPECIFICATIONS

PARAMETER	TEST CONDITIONS[2]	PA12 MIN	PA12 TYP	PA12 MAX	PA12A MIN	PA12A TYP	PA12A MAX	UNITS
INPUT								
OFFSET VOLTAGE, initial	T_C = 25°C		±2	±6		±1	±3	mV
OFFSET VOLTAGE, vs. temperature	Full temperature range		±10	±65		*	±40	µV/°C
OFFSET VOLTAGE, vs. supply	T_C = 25°C		±30	±200		*	*	µV/V
OFFSET VOLTAGE, vs. power	T_C = 25°C		±20			*		µV/W
BIAS CURRENT, initial	T_C = 25°C		±12	±30		10	20	nA
BIAS CURRENT, vs. temperature	Full temperature range		±50	±500		*	*	pA/°C
BIAS CURRENT, vs. supply	T_C = 25°C		±10			*		pA/V
OFFSET CURRENT, initial	T_C = 25°C		±12	±30		±5	±10	nA
OFFSET CURRENT, vs. temperature	Full temperature range		±50			*		pA/°C
INPUT IMPEDANCE, DC	T_C = 25°C		200			*		MΩ
INPUT CAPACITANCE	T_C = 25°C		3			*		pF
COMMON MODE VOLTAGE RANGE[3]	Full temperature range	$\pm V_S$−5	$\pm V_S$−3		*	*		V
COMMON MODE REJECTION, DC	Full temp. range, $V_{CM} = \pm V_S$ −6V	74	100		*	*		dB
GAIN								
OPEN LOOP GAIN at 10Hz	T_C = 25°C, 1KΩ load		110			*		dB
OPEN LOOP GAIN at 10Hz	Full temp. range, 8Ω load	96	108		*	*		dB
GAIN BANDWIDTH PRODUCT @ 1MHz	T_C = 25°C, 8Ω load		4			*		MHz
POWER BANDWIDTH	T_C = 25°C, 8Ω load	13	20		*	*		kHz
PHASE MARGIN	Full temp. range, 8Ω load		20			*		°
OUTPUT								
VOLTAGE SWING[3]	T_C = 25°C, PA12 = 10A, PA12A = 15A	$\pm V_S$−6			*			V
VOLTAGE SWING[3]	T_C = 25°C, I_O = 5A	$\pm V_S$−5			*			V
VOLTAGE SWING[3]	Full temp. range, I_O = 80mA	$\pm V_S$−5			*			V
CURRENT, peak	T_C = 25°C	10			15			A
SETTLING TIME to .1%	T_C = 25°C, 2V step		2			*		µs
SLEW RATE	T_C = 25°C	2.5	4		*	*		V/µs
CAPACITIVE LOAD	Full temperature range, A_V = 1			1.5			*	nF
CAPACITIVE LOAD	Full temperature range, A_V > 10			SOA			*	
POWER SUPPLY								
VOLTAGE	Full temperature range	±10	±40	±45	*	*	±50	V
CURRENT, quiescent	T_C = 25°C		25	50		*	*	mA
THERMAL								
RESISTANCE, AC, junction to case[4]	T_C = −55 to +125°C, F > 60Hz		.8	.9		*	*	°C/W
RESISTANCE, DC, junction to case	T_C = −55 to +125°C		1.25	1.4		*	*	°C/W
RESISTANCE, junction to air	T_C = −55 to +125°C		30			*		°C/W
TEMPERATURE RANGE, case	Meets full range specification	−25		+85	−55		+125	°C

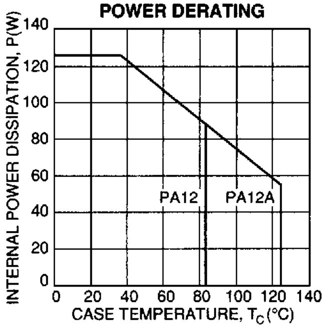
NOTES:
- * The specification of PA12A is identical to the specification for PA12 in applicable column to the left.
1. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.
2. The power supply voltage for all tests is ±40, unless otherwise noted as a test condition.
3. $+V_S$ and $-V_S$ denote the positive and negative supply rail respectively. Total V_S is measured from $+V_S$ to $-V_S$.
4. Rating applies if the output current alternates between both output transistors at a rate faster than 60Hz.

CAUTION The internal substrate contains beryllia (BeO). Do not break the seal. If accidentally broken, do not crush, machine, or subject to temperatures in excess of 850°C to avoid generating toxic fumes.

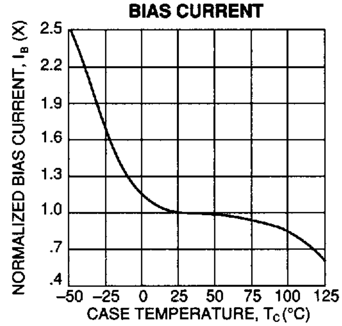
TYPICAL PERFORMANCE GRAPHS

PA12 • PA12A

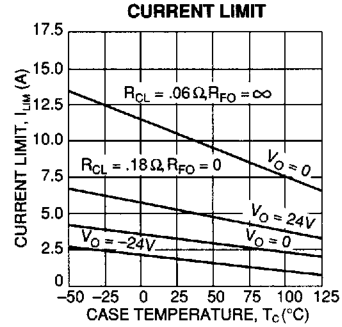
POWER DERATING



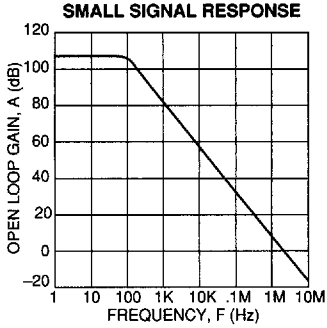
BIAS CURRENT



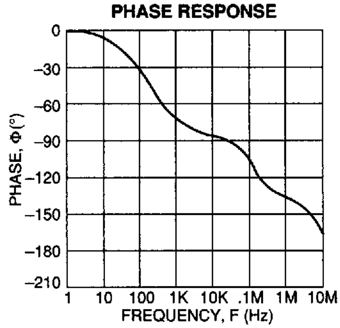
CURRENT LIMIT



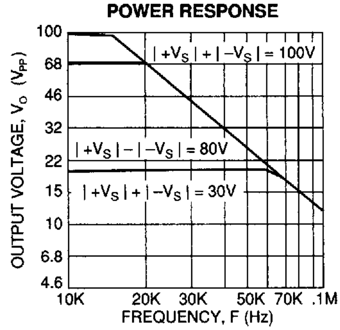
SMALL SIGNAL RESPONSE



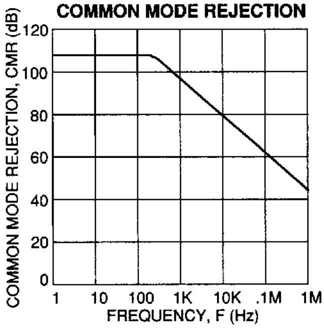
PHASE RESPONSE



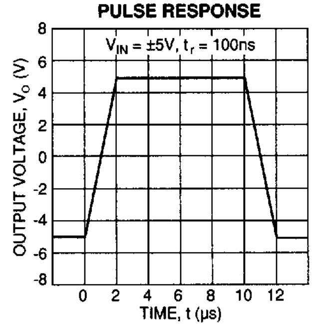
POWER RESPONSE



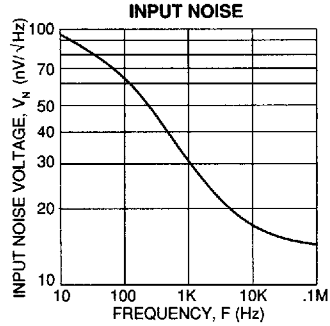
COMMON MODE REJECTION



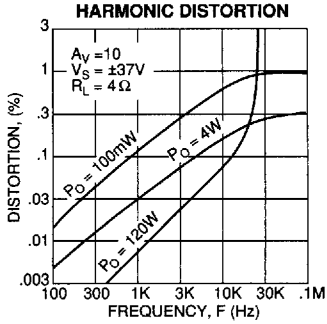
PULSE RESPONSE



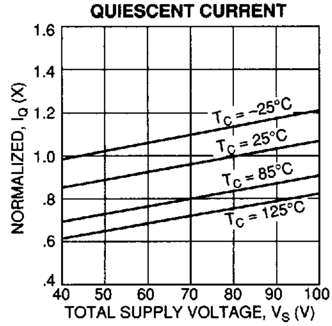
INPUT NOISE



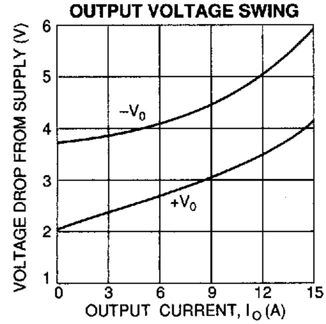
HARMONIC DISTORTION



QUIESCENT CURRENT



OUTPUT VOLTAGE SWING



PA12 • PA12A

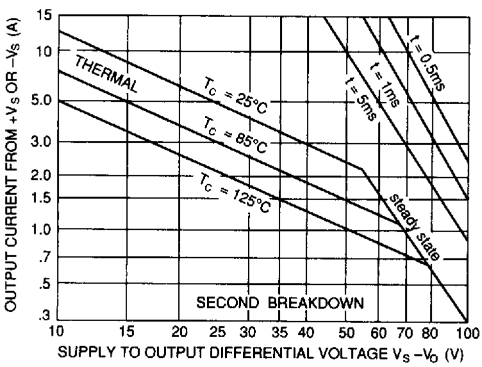
GENERAL

Please read the "General Operating Considerations" section, which covers stability, supplies, heatsinking, mounting, current limit, SOA interpretation, and specification interpretation. Additional information can be found in the application notes. For information on the package outline, heatsinks, and mounting hardware, consult the "Accessory and Package Mechanical Data" section of the handbook.

SAFE OPERATING AREA (SOA)

The output stage of most power amplifiers has three distinct limitations:

1. The current handling capability of the transistor geometry and the wire bonds.
2. The second breakdown effect which occurs whenever the simultaneous collector current and collector-emitter voltage exceeds specified limits.
3. The junction temperature of the output transistors.



The SOA curves combine the effect of all limits for this Power Op Amp. For a given application, the direction and magnitude of the output current should be calculated or measured and checked against the SOA curves. This is simple for resistive loads but more complex for reactive and EMF generating loads. However, the following guidelines may save extensive analytical efforts.

1. Capacitive and dynamic* inductive loads up to the following maximum are safe with the current limits set as specified.

	CAPACITIVE LOAD		INDUCTIVE LOAD	
$\pm V_S$	$I_{LIM} = 5A$	$I_{LIM} = 10A$	$I_{LIM} = 5A$	$I_{LIM} = 10A$
50V	200µF	125µF	5mH	2.0mH
40V	500µF	350µF	15mH	3.0mH
35V	2.0mF	850µF	50mH	5.0mH
30V	7.0mF	2.5mF	150mH	10mH
25V	25mF	10mF	500mH	20mH
20V	60mF	20mF	1,000mH	30mH
15V	150mF	60mF	2,500mH	50mH

*If the inductive load is driven near steady state conditions, allowing the output voltage to drop more than 8V below the supply rail with $I_{LIM} = 15A$ or 25V below the supply rail with $I_{LIM} = 5A$ while the amplifier is current limiting, the inductor must be capacitively coupled or the current limit must be lowered to meet SOA criteria.

2. The amplifier can handle any EMF generating or reactive load and short circuits to the supply rail or common if the current limits are set as follows at $T_C = 25°C$:

$\pm V_S$	SHORT TO $\pm V_S$ C, L, OR EMF LOAD	SHORT TO COMMON
50V	.30A	2.4A
40V	.58A	2.9A
35V	.87A	3.7A
30V	1.5A	4.1A
25V	2.4A	4.9A
20V	2.9A	6.3A
15V	4.2A	8.0A

These simplified limits may be exceeded with further analysis using the operating conditions for a specific application.

3. The output stage is protected against transient flyback. However, for protection against sustained, high energy flyback, external fast-recovery diodes should be used.

CURRENT LIMITING

To use standard current limiting, leave pin 7 open and proceed per "General Operating Considerations" section of the handbook, where initial setting and variation with temperature are described. Foldover action is described in detail in Application Note 9.

For certain applications, foldover protection allows for increased output current as the output of the Power Op Amp swings close to the supply rail. This function can be activated by connecting pin 7 directly or through a resistor to ground, and controlled by the following equation:

$$I_{LIM} = \frac{.65 + \dfrac{.28V_O}{20 + R_{FO}}}{R_{CL} + .007^{**}} \qquad (1)$$

Where:

I_{LIM} is the current limit, in Amps, at a given output voltage V_O.
R_{FO} is the current foldover resistor pin 7 to ground in KΩ.
R_{CL} is the current limit resistor in Ω.
V_O is the instantaneous output voltage in V.*

*The basic equation assumes V_O and the current carrying supply are of the same polarity. If these polarities differ, assign V_O a negative value.
**.007Ω = wire bond and pin resistance to R_{CL} connections.

PROCEDURE

1. Select R_{CL} to provide a safe current limit at $V_O = 0$:

$$R_{CL}\,(\Omega) = (.65/I_{LIM}) - .007 \qquad (2)$$

2. Find the current limit for the maximum output voltage swing and pin 7 connected to ground/common:

$$I_{LIM} = \frac{.65 + \dfrac{.28V_O}{20}}{R_{CL} + .007} \qquad (3)$$

This is the highest current limit possible at maximum output. It may be decreased without affecting the short circuit current limit by putting a resistor in series with pin 7 to ground.

The following equation can be used to calculate R_{FO} (KΩ) using a lower current limit:

$$R_{FO} = \frac{.28V_O}{I_{LIM}\,(R_{CL} + .007) - .65} - 20 \qquad (4)$$

3. To calculate the current limit at any output voltage (V_O), use equation "one". If V_O is of opposite polarity to the current carrying supply, assign V_O a negative value and check the calculated current against the SOA graph.

PA12H

APEX MICROTECHNOLOGY CORPORATION • APPLICATIONS HOTLINE 800 546-APEX (800-546-2739)

FEATURES

- **LOW COST 200°C VERSION OF PA12**
- **OUTPUT CURRENT at 200°C — ±1A**
- **FULL SPECIFICATIONS — -25°C to +125°C**
- **WIDE SUPPLY RANGE — ±10 to ±45V**
- **CURRENT FOLDOVER PROTECTION**
- **EXCELLENT LINEARITY — Class A/B Output**

APPLICATIONS

- **MOTOR, VALVE AND ACTUATOR CONTROL**
- **POWER TRANSDUCERS UP TO 100kHz**
- **PROGRAMMABLE POWER SUPPLIES UP TO 80V**
- **TRANSMISSION LINE DRIVER**

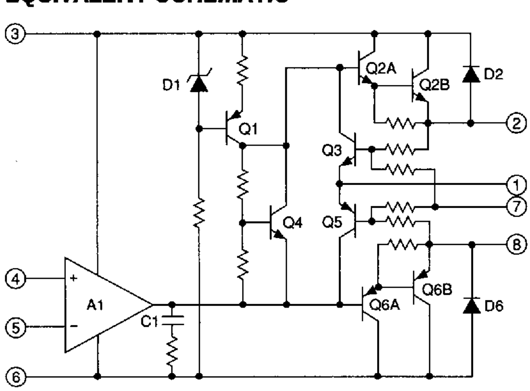
DESCRIPTION

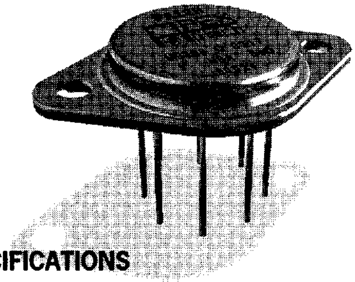
The PA12H is a low cost, high temperature Power Op Amp made especially for short term use in extreme environmental situations such as down hole instrumentation. The amplifier can power mechanical or electronic transducers and can drive the long transmission lines associated with these applications.

The PA12H, based on the standard PA12's very high power level, leaves a six watt capability after being derated for operation at a case temperature of 200°C. To meet the high temperature requirements for up to 200 hours, polyimid has replaced the standard epoxy for attaching the small signal devices. the melting point of the power transistor attach solder is 264°C.

These hybrid integrated circuits utilize thick film conductors, ceramic capacitors and silicon semiconductors to maximize reliability, minimize size and give top performance. Ultrasonically bonded aluminum wires provide reliable interconnections at all operating temperatures. The 8-pin TO-3 package (see Package Outlines) is hermetically sealed and isolated. The use of compressible thermal washers and/or improper mounting torque will void the product warranty. Please see "General Operating Considerations".

EQUIVALENT SCHEMATIC





SPECIFICATIONS

Specifications of the standard PA12 apply to the PA12H with the exception of the temperature range extensions

1. The operating and storage temperature ranges extend to +200°C.
2. Static and dynamic tests are performed at +125°C as shown in SG 2 and SG 5 of the military PA12M data sheet.
3. Additional tests at T_C = 200°C:
   A. Quiescent current = 100mA max at $\pm V_S$ = 45.
   B. Voltage swing = $\pm V_S$ –4 (I_O = 1A, $\pm V_S$ = 15)

GENERAL CONSIDERATIONS

The primary aim of the PA12H is to provide a reasonable level of power output at a minimum cost. To achieve this end, full dynamic tests are performed up to 125°C, with only minimal 100% testing at 200°C. This approach saves nearly an order of magnitude over the cost of a fully tested long life product, but does require recognition of two limitations.

First, input parameters such as voltage offset and bias current are not tested above 125°C. This could lead to accuracy problems if the PA12H is used as a precision computational element. Solutions to this limitation include contacting the factory regarding additional testing at higher temperatures or using high temperature small signal amplifiers for computational tasks.

The second limitation of life span requires the PA12H to be used in short term applications. This requirement is mandated by the low cost design concept. At 200°C component degradation is nearly as severe during storage as during actual operation. This must be taken into account when scheduling actual implementation of the finished package.

Please consult the PA12 data sheet for basic information on this amplifier; the PA12M data sheet for details on +125°C tests, and Power Operational Amplifier handbook section "General Operating Considerations," for recommendations on supplies, stability, heatsinks and bypassing.

EXTERNAL CONNECTIONS

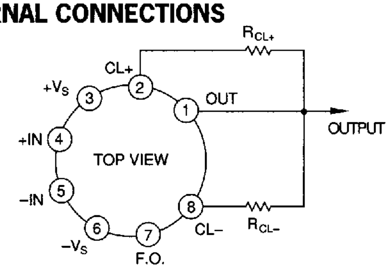


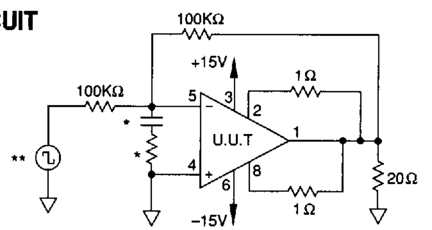
TABLE 4 GROUP A INSPECTION

PA12M/SMD 5962-9065901HXX

APEX MICROTECHNOLOGY CORPORATION • APPLICATIONS HOTLINE 800.546-APEX (800-546-2739)

SG	PARAMETER	SYMBOL	TEMP.	POWER	TEST CONDITIONS	MIN	MAX	UNITS
1	Quiescent current	I_Q	25°C	±40V	$V_{IN} = 0$, $A_V = 100$, $R_{CL} = .1\Omega$		50	mA
1	Input offset voltage	V_{OS}	25°C	±40V	$V_{IN} = 0$, $A_V = 100$		±6	mV
1	Input offset voltage	V_{OS}	25°C	±10V	$V_{IN} = 0$, $A_V = 100$		±12	mV
1	Input offset voltage	V_{OS}	25°C	±45V	$V_{IN} = 0$, $A_V = 100$		±7	mV
1	Input bias current, +IN	$+I_B$	25°C	±40V	$V_{IN} = 0$		±30	nA
1	Inout bias current,–IN	$-I_B$	25°C	±40V	$V_{IN} = 0$		±30	nA
1	Input offset current	I_{OS}	25°C	±40V	$V_{IN} = 0$		±30	nA
3	Quiescent current	I_Q	–55°C	±40V	$V_{IN} = 0$, $A_V = 100$, $R_{CL} = .1\Omega$		100	mA
3	Input offset voltage	V_{OS}	–55°C	±40V	$V_{IN} = 0$, $A_V = 100$		±11.2	mV
3	Input offset voltage	V_{OS}	–55°C	±10V	$V_{IN} = 0$, $A_V = 100$		±17.2	mV
3	Input offset voltage	V_{OS}	–55°C	±45V	$V_{IN} = 0$, $A_V = 100$		±12.2	mV
3	Input bias current, +IN	$+I_B$	–55°C	±40V	$V_{IN} = 0$		±115	nA
3	Input bias current,–IN	$-I_B$	–55°C	±40V	$V_{IN} = 0$		±115	nA
3	Input offset current	I_{OS}	–55°C	±40V	$V_{IN} = 0$		±115	nA
2	Quiescent current	I_Q	125°C	±40V	$V_{IN} = 0$, $A_V = 100$, $R_{CL} = .1\Omega$		50	mA
2	Input offset voltage	V_{OS}	125°C	±40V	$V_{IN} = 0$, $A_V = 100$		±12.5	mV
2	Input offset voltage	V_{OS}	125°C	±10V	$V_{IN} = 0$, $A_V = 100$		±18.5	mV
2	Input offset voltage	V_{OS}	125°C	±45V	$V_{IN} = 0$, $A_V = 100$		±13.5	mV
2	Input bias current, +IN	$+I_B$	125°C	±40V	$V_{IN} = 0$		±70	nA
2	Input bias current, –IN	$-I_B$	125°C	±40V	$V_{IN} = 0$		±70	nA
2	Input offset current	I_{OS}	125°C	±40V	$V_{IN} = 0$		±70	nA
4	Output voltage, $I_O = 10A$	V_O	25°C	±16V	$R_L = 1\Omega$	10		V
4	Output voltage, $I_O = 80mA$	V_O	25°C	±45V	$R_L = 500\Omega$	40		V
4	Output voltage, $I_O = 5A$	V_O	25°C	±35V	$R_L = 6\Omega$	30		V
4	Current limits	I_{CL}	25°C	±14V	$R_L = 1\Omega$, $R_{CL} = .1\Omega$	5	7.9	A
4	Stability/noise	E_N	25°C	±40V	$R_L = 500\Omega$, $A_V = 1$, $C_L = 1.5nF$		1	mV
4	Slew rate	SR	25°C	±40V	$R_L = 500\Omega$	2.5	10	V/µs
4	Open loop gain	A_{OL}	25°C	±40V	$R_L = 500\Omega$, F = 10Hz	96		dB
4	Common mode rejection	CMR	25°C	±15V	$R_L = 500\Omega$, F = DC, $V_{CM} = \pm 9V$	74		dB
6	Output voltage, $I_O = 8A$	V_O	–55°C	±14V	$R_L = 1\Omega$	8		V
6	Output voltage, $I_O = 80mA$	V_O	–55°C	±45V	$R_L = 500\Omega$	40		V
6	Stability/noise	E_N	–55°C	±40V	$R_L = 500\Omega$, $A_V = 1$, $C_L = 1.5nF$		1	mV
6	Slew rate	SR	–55°C	±40V	$R_L = 500\Omega$	2.5	10	V/µs
6	Open loop gain	A_{OL}	–55°C	±40V	$R_L = 500\Omega$, F = 10Hz	96		dB
6	Common mode rejection	CMR	–55°C	±15V	$R_L = 500\Omega$, F = DC, $V_{CM} = \pm 9V$	74		dB
5	Output voltage, $I_O = 8A$	V_O	125°C	±14V	$R_L = 1\Omega$	8		V
5	Output voltage, $I_O = 80mA$	V_O	125°C	±45V	$R_L = 500\Omega$	40		V
5	Stability/noise	E_N	125°C	±40V	$R_L = 500\Omega$, $A_V = 1$, $C_L = 1.5nF$		1	mV
5	Slew rate	SR	125°C	±40V	$R_L = 500\Omega$	2.5	10	V/µs
5	Open loop gain	A_{OL}	125°C	±40V	$R_L = 500\Omega$, F = 10Hz	96		dB
5	Common mode rejection	CMR	125°C	±15V	$R_L = 500\Omega$, F = DC, $V_{CM} = \pm 9V$	74		dB

BURN IN CIRCUIT



* These components are used to stabilize device due to poor high frequency characteristics of burn in board.

** Input signals are calculated to result in internal power dissipation of approximately 2.1W at case temperature = 125°C.

