

SBOS372E - OCTOBER 2008-REVISED JANUARY 2011

1.5A, 24V, 17MHz POWER OPERATIONAL AMPLIFIER

Check for Samples: OPA564

FEATURES

- **HIGH OUTPUT CURRENT: 1.5A**
- **WIDE POWER-SUPPLY RANGE:**
 - Single Supply: +7V to +24V
 - Dual Supply: ±3.5V to ±12V
- LARGE OUTPUT SWING: 20VPP at 1.5A
- **FULLY PROTECTED:**
 - THERMAL SHUTDOWN
 - ADJUSTABLE CURRENT LIMIT
- **DIAGNOSTIC FLAGS:**
 - OVER-CURRENT
 - THERMAL SHUTDOWN
- **OUTPUT ENABLE/SHUTDOWN CONTROL**
- **HIGH SPEED:**
 - GAIN-BANDWIDTH PRODUCT: 17MHz
 - FULL-POWER BANDWIDTH AT 10Vpp: 1.3MHz
 - SLEW RATE: 40V/μs
- DIODE FOR JUNCTION TEMPERATURE **MONITORING**
- **HSOP-20 PowerPAD™ PACKAGE** (Bottom- and Top-Side Thermal Pad Versions)

APPLICATIONS

- **POWERLINE COMMUNICATIONS**
- **VALVE, ACTUATOR DRIVER**
- **V_{COM} DRIVER**
- MOTOR DRIVER
- **AUDIO POWER AMPLIFIER**
- **POWER-SUPPLY OUTPUT AMPLIFIER**
- **TEST EQUIPMENT AMPLIFIER**
- TRANSDUCER EXCITATION
- LASER DIODE DRIVER
- **GENERAL-PURPOSE LINEAR POWER** BOOSTER

DESCRIPTION

The OPA564 is a low-cost, high-current operational amplifier that is ideal for driving up to 1.5A into reactive loads. The high slew rate provides 1.3MHz full-power bandwidth and excellent linearity. These monolithic integrated circuits provide high reliability in demanding powerline communications and motor control applications.

The OPA564 operates from a single supply of 7V to 24V, or dual power supplies of ±3.5V to ±12V. In single-supply operation, the input common-mode range extends to the negative supply. At maximum output current, a wide output swing provides a 20V_{PP} $(I_{OUT} = 1.5A)$ capability with a nominal 24V supply.

The OPA564 is internally protected against over-temperature conditions and current overloads. It is designed to provide an accurate, user-selected current limit. Two flag outputs are provided; one indicates current limit and the second shows a thermal over-temperature condition. It also has an Enable/Shutdown pin that can be forced low to shut down the output, effectively disconnecting the load.

The OPA564 is housed in a thermally-enhanced, surface-mount PowerPAD™ package (HSOP-20) with the choice of the thermal pad on either the top side or the bottom side of the package. Operation for both versions is specified over the industrial temperature range. -40°C to +85°C.

OPA564 RELATED PRODUCTS

FEATURES	DEVICE
Zerø-Drift PGA with 2-Channel Input Mux and SPI	PGA112
Zerø-Drift Operational Amplifier, 50MHz, RRI/O, Single-Supply	OPA365
Quad Operational Amplifier, JFET Input , Low Noise	TL074
Power Operational Amplifier, 1.2A, 15V, 17MHz, 50V/µs	OPA561

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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION(1)

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING
ODAF64	HSOP-20 (PowerPAD on bottom)	DWP	OPA564
OPA564	HSOP-20 (PowerPAD on top)	DWD	OPA564

⁽¹⁾ For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

Over operating free-air temperature range (unless otherwise noted).

		OPA564	UNIT	
Supply Voltage,	$V_S = (V+) - (V-)$	+26	V	
	Voltage ⁽²⁾	(V–)–0.4 to (V+)+0.4	V	
Signal Input Terminals	Current Through ESD Diodes (2)	±10	mA	
Terrimais	Maximum Differential Voltage Across Inputs (3)	0.5	V	
Signal Output	Voltage	(V-)-0.4 to (V+)+0.4	V	
Terminals	Current ⁽⁴⁾	±10	mA	
Output Short-Ci	rcuit ⁽⁵⁾	Continuous		
Operating Junct	ion Temperature, T _J	-40 to +125	°C	
Storage Tempe	rature, T _A	-55 to +150	°C	
Junction Tempe	rature, T _J	+150	°C	
	Human Body Model (HBM)	4000	V	
ESD Ratings	Charged Device Model (CDM)	1000	V	
	Machine Model (MM)	200	V	

⁽¹⁾ Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.

(5) Short-circuit to ground within SOA. See Power Dissipation and Safe Operating Area for more information.

⁽²⁾ Input terminals are diode-clamped to the power-supply rails. Signals that can swing more than 0.4V beyond the supply rails should be current limited to 10mA or less.

⁽³⁾ Refer to Figure 43 for information on input protection. See *Input Protection* section.

⁽⁴⁾ Output terminals are diode-clamped to the power-supply rails. Input signals forcing the output terminal more than 0.4V beyond the supply rails should be current limited to 10mA or less.

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ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range: $T_A = -40^{\circ}C$ to $+85^{\circ}C$. At $T_{CASE} = +25^{\circ}C$, $V_S = \pm 12V$, $R_{LOAD} = 20k\Omega$ to GND, $R_{SET} = 7.5k\Omega$, and E/\overline{S} pin enabled, unless otherwise noted.

PARAMETERS OFFSET VOLTAGE		CONDITIONS	MIN	UNIT		
Input Offset Voltage	Vos	V _{CM} = 0V		±2	±20	mV
vs Temperature	dV _{os} /dT			±10		μ ۷/ °C
vs Power Supply	PSRR	$V_{CM} = 0V, V_{S} = \pm 3.5V \text{ to } \pm 13V$		10	150	μV/V
INPUT BIAS CURRENT						
Input Bias Current ⁽¹⁾	I_{B}	V _{CM} = 0V		10	100	pA
vs Temperature			See Figure	10, Typical Cha	racteristics	
Input Offset Current ⁽¹⁾	Ios			10	100	pA
NOISE						
Input Voltage Noise Density	e _n	f = 1kHz		102.8		nV/√ Hz
		f = 10kHz		20		nV/√ Hz
		f = 100kHz		8		nV/√ Hz
Input Current Noise	In	f = 1kHz		4		fA/√Hz
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range:	V_{CM}	Linear Operation	(V-)		(V+)-3	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = (V-) \text{ to } (V+)-3V$	70	80		dB
vs Temperature			See Figure	9, Typical Cha	racteristics	
INPUT IMPEDANCE						
Differential				10 ¹² 16		Ω pF
Common-Mode				10 ¹² 9		Ω pF
OPEN-LOOP GAIN				10 110		
Open-Loop Voltage Gain	Aol	$V_{OUT} = 20V_{PP}, R_{LOAD} = 1k\Omega$	80	108		dB
	OL.	$V_{OUT} = 20V_{PP}, R_{LOAD} = 10\Omega$		93		dB
FREQUENCY RESPONSE		117 20/0				
Gain-Bandwidth Product ⁽¹⁾	GBW	$R_{LOAD} = 5\Omega$		17		MHz
Slew Rate	SR	G = 1, 10V Step		40		V/μs
Full Power Bandwidth		$G = +2, V_{OUT} = 10V_{PP}$		1.3		MHz
Settling Time ±0.1%		G = +1, 10V Step, C _{LOAD} = 100pF		0.6		μS
±0.01%		$G = +1$, 10V Step, $C_{LOAD} = 100pF$		0.8		μS
Total Harmonic Distortion + Noise	THD+N			0.003		%
OUTPUT		, LOAD - , - , 001 9 - F				
Voltage Output:	V_{OUT}					
Positive	001	I _{OUT} = 0.5A	(V+)-1	(V+)-0.4		V
Negative		$I_{OUT} = -0.5A$	(V-)+1	(V-)+0.3		V
Positive		I _{OUT} = 1.5A	(V+)-2	(V+)-1.5		V
Negative		I _{OUT} = -1.5A	(V-)+2	(V-)+1.1		V

⁽¹⁾ See Typical Characteristics.

Product Folder Link(s): OPA564



Boldface limits apply over the specified temperature range: $T_A = -40^{\circ}C$ to $+85^{\circ}C$. At $T_{CASE} = +25^{\circ}C$, $V_S = \pm 12V$, $R_{LOAD} = 20k\Omega$ to GND, $R_{SET} = 7.5k\Omega$, and E/\overline{S} pin enabled, unless otherwise noted.

				OPA564		
PARAMETERS		CONDITIONS	MIN	UNIT		
OUTPUT, continued						
Maximum Continuous Current, dc	I _{OUT}			1.5 ⁽²⁾		Α
Output Impedance, closed loop	R_{O}	f = 100kHz		10		Ω
Output Impedance, open loop	Z _O	G = +2, $f = 100kHz$	See Figure	24, Typical Cha	aracteristics	
Output Current Limit Range (3)				±0.4 to ±2.0	II.	Α
Current Limit Equation	I _{LIM}		I _{LIM} ≅ 2000	$00 \times \left(\frac{1.2 \text{V}}{5000 + \text{R}} \right)$	SET (4) (5)	А
		Solved for R _{SET} (Current Limit)	R _{SE}	= (24k/I _{LIM}) - 5	5kΩ	Ω
Current Limit Accuracy		$I_{LIM} = 1.5A$		10		%
Current Limit Overshoot (6) (7)		$V_{IN} = 5V$ Pulse (200ns t_r), $G = +2$		50		%
Output Shut Down						
Output Impedance ⁽⁸⁾				6 120	Į.	GΩ pF
Capacitive Load Drive	C_{LOAD}		See Figure	6, Typical Cha	racteristics	
DIGITAL CONTROL						
Enable/Shutdown Mode INPUT		V_{DIG} = +3.3V to +5.5V referenced to V-				
V _{E/S̄} High (output enabled)		E/S Pin Open or Forced High	(V-)+2		(V-)+V _{DIG}	V
V _{E/S} Low (output shut down)		E/S Pin Forced Low	(V-)		(V-)+0.8	V
I _{E/S} High (output enabled)		E/S Pin Indicates High		10		μΑ
I _{E/S} Low (output shut down)		E/S Pin Indicates Low		1		μА
Output Shutdown Time				1		μS
Output Enable Time				3		μS
Current Limit Flag Output						
Normal Operation		Sinking 10μA		0	(V-)+0.8	V
Current-Limited		Sourcing 20μA	(V-)+2	V_{DIG}		V
Thermal Shutdown						
Normal Operation		Sinking 200μA		0	(V-)+0.8	V
Thermally Shutdown (9)		Sourcing 200μA	(V-)+2	V_{DIG}		V
Junction Temperature at Shutdown ⁽¹⁰⁾				+140 to +157		°C
Hysteresis ⁽¹⁰⁾				15 to 19		°C
T _{SENSE}						
Diode Ideality Factor	η			1.033		

- Under safe operating conditions. See Power Dissipation and Safe Operating Area for safe operating area (SOA) information.
- (3) Minimum current limit is 0.4A. See Adjustable Current Limit in the Applications section.
- Quiescent current increases when the current limit is increased (see Typical Characteristics).
- R_{SET} (current limit) can range from 55k Ω ($I_{OUT} = 400$ mA) to 10k Ω ($I_{OUT} = 1.6$ A typ). See *Adjustable Current Limit* in the *Applications* section.
- See Typical Characteristics.
- Transient load transition time must be ≥ 200ns.
- See Enable/Shutdown (E/S) Pin in the Applications section.
- (9) When sourcing, the V_{DIG} supply must be able to supply the current.
 (10) Characterized, but not production tested.



Boldface limits apply over the specified temperature range: $T_A = -40^{\circ}C$ to $+85^{\circ}C$. At $T_{CASE} = +25^{\circ}C$, $V_S = \pm 12V$, $R_{LOAD} = 20k\Omega$ to GND, $R_{SET} = 7.5k\Omega$, and E/\overline{S} pin enabled, unless otherwise noted.

				OPA564			
PARAMETERS		CONDITIONS	MIN	TYP	MAX	UNIT	
POWER SUPPLY ⁽¹¹⁾							
Specified Voltage Range	Vs			±12		V	
Operating Voltage Range			7		24	V	
Quiescent Current ⁽¹²⁾	IQ	$I_{OUT} = 0$		39	50	mA	
Over Temperature					50	mA	
Quiescent Current in Shutdown Mode	I _{QSD}				5	mA	
Specified Voltage for Digital	V_{DIG}		(V-) + 3.0		(V-) + 5.5	V	
Digital Quiescent Current	I _{DIG}	$V_{DIG} = 5V$		43	100	μΑ	
TEMPERATURE RANGE							
Specified Range			-40		+85	°C	
Operating Range			-40		+125 ⁽¹³⁾	°C	
Thermal Resistance							
HSOP-20 DWP PowerPAD (Pad Down)	θ_{JA}	High K Board		33		°C/W	
	θ_{JC}			50		°C/W	
	$\theta_{\sf JP}$			1.83		°C/W	
	θ_{JB}			22		°C/W	
HSOP-20 DWD PowerPAD (Pad Up) (14)	θ_{JA}	High K Board		45.5		°C/W	
	θ_{JC}			6.3		°C/W	
	$\theta_{\sf JB}$			22		°C/W	

⁽¹¹⁾ Power-supply sequencing requirements must be observed. See *Power Supplies* section for more information.

Product Folder Link(s): OPA564

⁽¹²⁾ Quiescent current increases when the current limit is increased (see Typical Characteristics).

 ⁽¹³⁾ The OPA564 typically goes into thermal shutdown at a junction temperature above +140°C.
 (14) Thermal modeling of the DWD-20 package was done based on a 1-inch AAVID Thermalloy heatsink (Thermalloy part no. 65810).



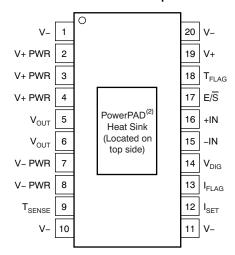
PIN CONFIGURATIONS

HSOP-20 PowerPAD on Bottom 20 V+ PWR 19 $\mathsf{T}_{\mathsf{FLAG}}$ 3 18 V+ PWR E/S V+ PWR 4 17 PowerPAD⁽¹⁾ +IN 5 16 $V_{\rm OUT}$ Heat Sink (Located on -IN 15 6 V_{OUT} bottom side) 14 V- PWR V_{DIG} V- PWR 13 I_{FLAG} 8 I_{SET} 9 12 T_{SENSE} 11 V-10

OPA564AIDWP

(1) PowerPAD is internally connected to V-, Soldering the PowerPAD to the PCB is always required, even with applications that have low power dissipation.

OPA564AIDWD HSOP-20 PowerPAD on Top



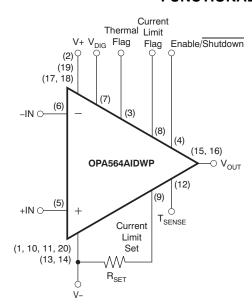
(2) PowerPAD is internally connected to V-.

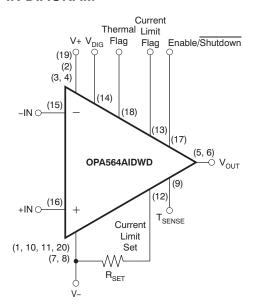
PIN DESCRIPTIONS

OPA564AIDWP (PAD DOWN) PIN NO.	OPA564AIDWD (PAD UP) PIN NO.	NAME	DESCRIPTION
1, 10, 11, 20	1, 10, 11, 20	V–	-Supply for Amplifier, PWR Out, and Metal PowerPAD
2	19	V+	+Supply for Signal Amplifier
3	18	T_{FLAG}	Thermal Over Temperature Flag; flag is high when alarmed and device has gone into thermal shutdown.
4	17	E/S	Enable/Shutdown Output Stage; take E/S low to shut down output
5	16	+IN	Noninverting Op Amp Input
6	15	-IN	Inverting Op Amp Input
7	14	V_{DIG}	+Supply for Digital Flag and E/\overline{S} (referenced to V–). Valid Range is (V–) + 3.0V \leq V _{DIG} \leq (V–) + 5.5V.
8	13	I _{FLAG}	Current Limit Flag; Active High
9	12	I _{SET}	Current Limit Set (see <i>Applications</i> Section)
12	9	T _{SENSE}	Temperature Sense Pin for use with TMP411
13, 14	7, 8	V– PWR	-Supply for Power Output Stage
15, 16	5, 6	V_{OUT}	Output Voltage; R _O is high impedance when shut down
17, 18, 19	3, 4, 2	V+ PWR	+Supply for Power Output Stage



FUNCTIONAL PIN DIAGRAM







TYPICAL CHARACTERISTICS

At T_{CASE} = +25°C, V_S = ±12V, R_{LOAD} = 20k Ω to GND, R_{SET} = 7.5k Ω , and E/ \overline{S} pin enabled, unless otherwise noted.

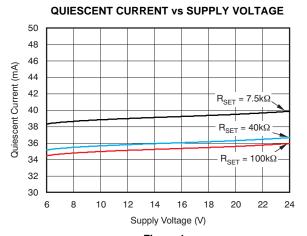


Figure 1.

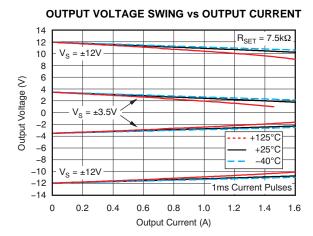


Figure 2.

LARGE-SIGNAL STEP RESPONSE, NO LOAD

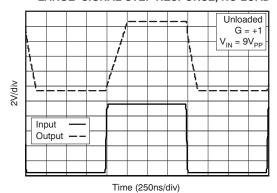


Figure 3.

LARGE-SIGNAL STEP RESPONSE

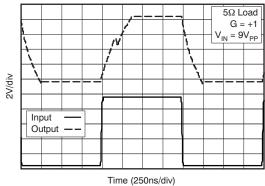


Figure 4.

SMALL-SIGNAL STEP RESPONSE

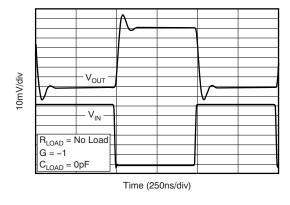


Figure 5.

SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE

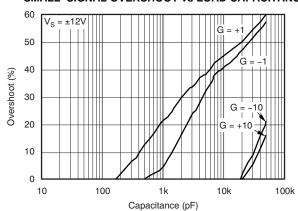
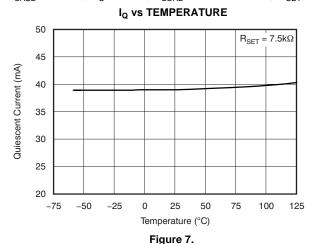


Figure 6.



At T_{CASE} = +25°C, V_{S} = ±12V, R_{LOAD} = 20k Ω to GND, R_{SET} = 7.5k Ω , and E/ \overline{S} pin enabled, unless otherwise noted.



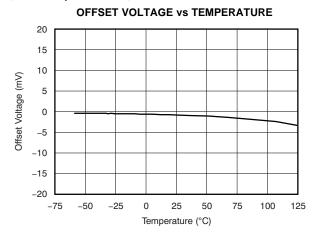


Figure 8.



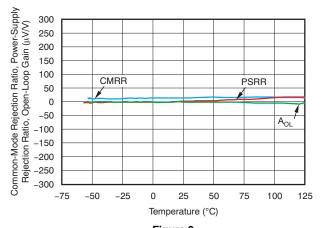


Figure 9.

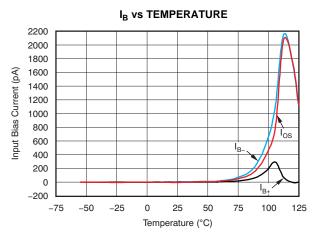


Figure 10.

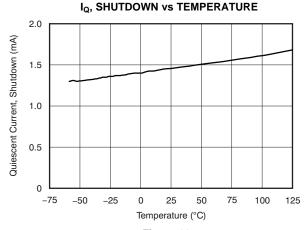


Figure 11.

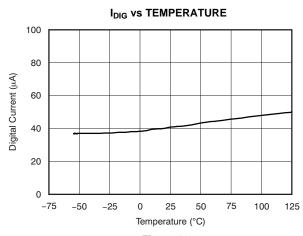


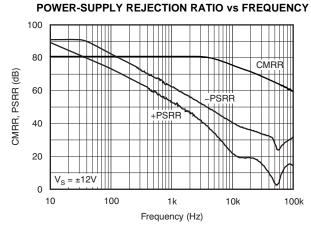
Figure 12.



At T_{CASE} = +25°C, V_S = ±12V, R_{LOAD} = 20k Ω to GND, R_{SET} = 7.5k Ω , and E/ \overline{S} pin enabled, unless otherwise noted.

GAIN AND PHASE vs FREQUENCY 120 100 -45 80 Gain (dB) 60 40 -135 20 0 -180 10 100 1k 10k 100k 1M 10M 40M Frequency (Hz)

Figure 13.



COMMON-MODE REJECTION RATIO AND

Figure 14.

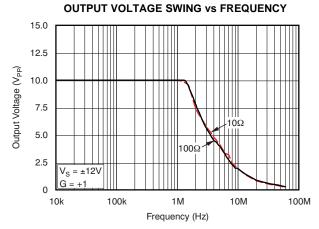
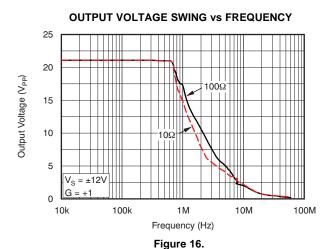
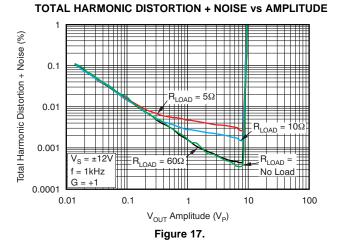
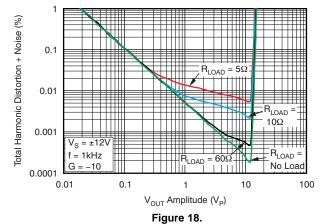


Figure 15.



TOTAL HARMONIC DISTORTION + NOISE vs AMPLITUDE





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At T_{CASE} = +25°C, V_S = ±12V, R_{LOAD} = 20k Ω to GND, R_{SET} = 7.5k Ω , and E/ \overline{S} pin enabled, unless otherwise noted.

TOTAL HARMONIC DISTORTION + NOISE vs AMPLITUDE

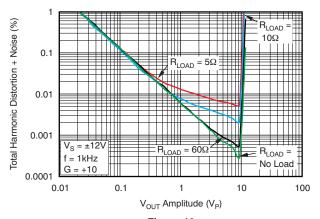


Figure 19.

TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY

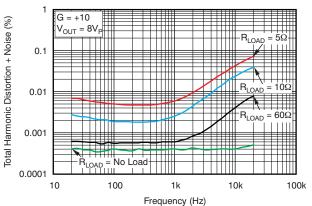


Figure 20.

TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY

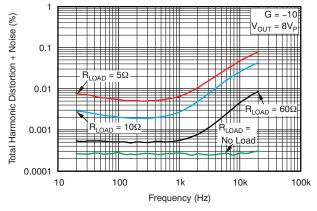


Figure 21.

TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY

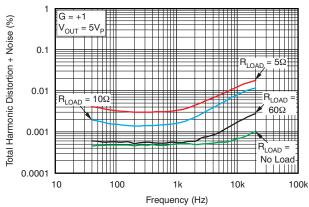


Figure 22.

INPUT VOLTAGE SPECTRAL NOISE AND CURRENT NOISE vs FREQUENCY

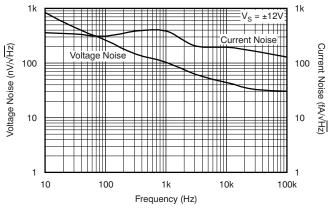


Figure 23.

OPEN-LOOP OUTPUT IMPEDANCE (No Load)

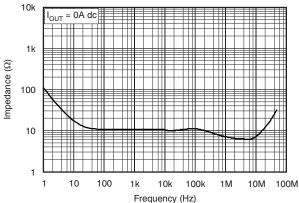


Figure 24.



At T_{CASE} = +25°C, V_S = ±12V, R_{LOAD} = 20k Ω to GND, R_{SET} = 7.5k Ω , and E/ \overline{S} pin enabled, unless otherwise noted.

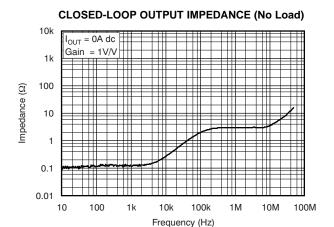


Figure 25.

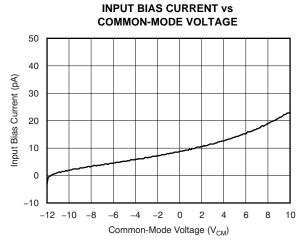


Figure 26.

ENABLE RESPONSE



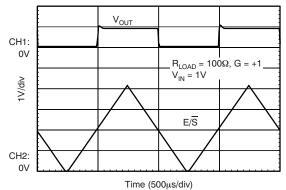


Figure 27.

SHUTDOWN TIME (INVERTING CONFIGURATION)

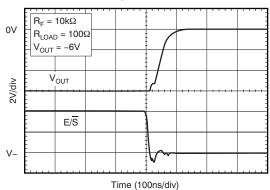


Figure 28.

ENABLE TIME (INVERTING CONFIGURATION)

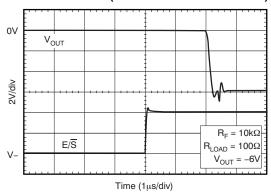


Figure 29.

CURRENT LIMIT PERCENT ERROR vs R_{SET}

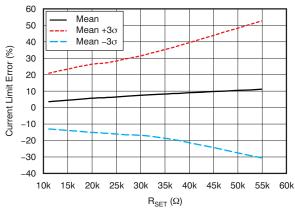


Figure 30.

5

4

2

0

5k

15k

25k

I_Q Increase (mA)



TYPICAL CHARACTERISTICS (continued)

At $T_{CASE} = +25^{\circ}C$, $V_{S} = \pm 12V$, $R_{LOAD} = 20k\Omega$ to GND, $R_{SET} = 7.5k\Omega$, and E/\overline{S} pin enabled, unless otherwise noted.

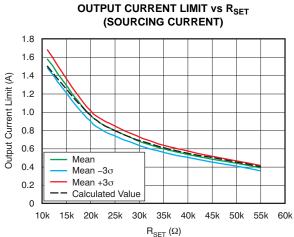


Figure 31.

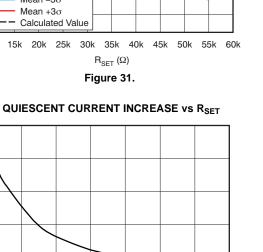


Figure 33.

 $R_{SET}(\Omega)$

45k

55k

65k

75k

35k

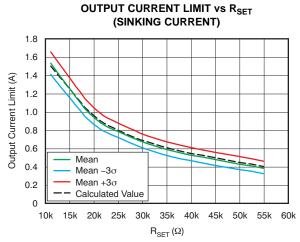


Figure 32.

OFFSET VOLTAGE PRODUCTION DISTRIBUTION

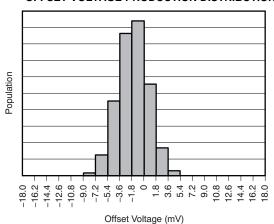


Figure 34.

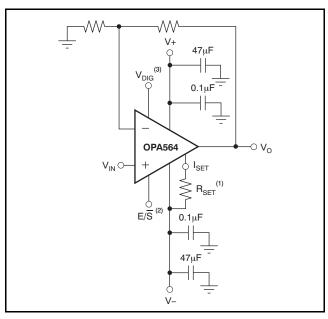


APPLICATION INFORMATION

BASIC CONFIGURATION

Figure 35 shows the OPA564 connected as a basic noninverting amplifier. However, the OPA564 can be used in virtually any op amp configuration.

Power-supply terminals should be bypassed with low series impedance capacitors. The technique of using ceramic and tantalum capacitors in parallel is recommended. Power-supply wiring should have low series impedance.



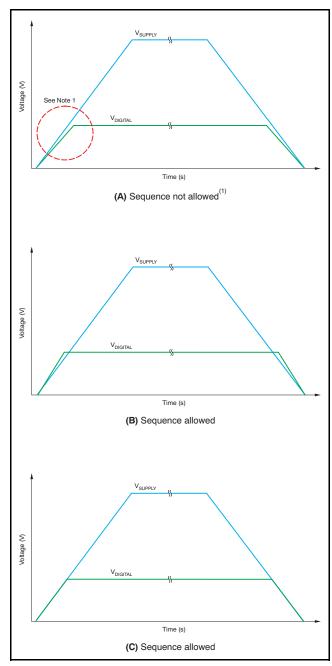
- (1) R_{SFT} sets the current limit value from 0.4A to 1.5A.
- (2) E/\overline{S} pin forced low shuts down the output.
- (3) $\rm V_{DIG}$ must not exceed (V–) + 5.5V; see Figure 56 for examples of generating a signal for $\rm V_{DIG}.$

Figure 35. Basic Noninverting Amplifier

POWER SUPPLIES

The OPA564 operates with excellent performance from single (+7V to +24V) or dual (±3.5V to ±12V) analog supplies and a digital supply of +3.3V to +5.5V (referenced to the V- pin). Note that the analog power-supply voltages do not need to be symmetrical, as long as the total voltage remains below 24V. For example, the positive supply could be set to 14V with the negative supply at -10V. Most behaviors remain constant across the operating voltage range. Parameters that vary significantly with operating voltage are shown in the Typical Characteristics.

Sequencing of power supplies must assure that the digital supply voltage (V_{DIG}) be applied before the supply voltage to prevent damage to the OPA564. Figure 36 shows acceptable versus unacceptable power-supply sequencing.



(1) The power-supply sequence illustrated in (A) is not allowed. This power-supply sequence causes damage to the device.

Figure 36. Power-Supply Sequencing

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ADJUSTABLE CURRENT LIMIT

The OPA564 provides over-current protection to the load through its accurate, user-adjustable current limit (I_{SET} pin). The current limit value, I_{LIM} , can be set from 0.4A to 1.5A by controlling the current through the I_{SET} pin. Setting the current limit does not require special power resistors. The output current does not flow through the I_{SET} pin.

A simple resistor to the negative rail is sufficient for a general, coarse limit of the output current. Figure 30 exhibits the percent of error in the transfer function between I_{SET} and I_{OUT} versus the current limit set resistor, R_{SET} ; Figure 31 and Figure 32 show how this error translates to variation in I_{OUT} versus R_{SET} . The dotted line represents the ideal output current setting which is determined by the following equation:

$$I_{LIM} \approx 20000 \times \left[\frac{1.2V}{5000 + R_{SET}} \right]$$
 (1)

The mismatch errors between the current limit set mirror and the output stage are primarily a result of variations in the ~1.2V bandgap reference, an internal $5k\Omega$ resistor, the mismatch between the current limit and the output stage mirror, and the tolerance and temperature coefficient of the R_{SET} resistor referenced to the negative rail. Additionally, an increase in junction temperature can induce added mismatch in accuracy between the I_{SET} and I_{OUT} mirror. See Figure 53 for a method that can be used to dynamically change the current limit setting using a simple, zero drift current source. This approach simplifies the current limit equation to the following:

$$I_{\text{LIM}} \cong 20,000 \times I_{\text{SET}} \tag{2}$$

The current into the I_{SET} pin is determined by the NPN current source. Therefore, the errors contributed by the internal 1.2V bandgap reference and the $5k\Omega$ resistor mismatch are eliminated, thus improving the overall accuracy of the transfer function. In this case, the primary source of error in I_{SET} is the R_{SET} resistor tolerance and the beta of the NPN transistor.

It is important to note that the primary intent of the current limit on the OPA564 is coarse protection of the output stage; therefore, the user should exercise caution when attempting to control the output current by dynamically toggling the current limit setting. Predictable performance is better achieved by controlling the output voltage through the feedback loop of the OPA564.

Setting the Current Limit

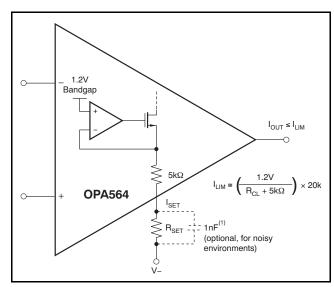
Leaving the I_{SET} pin unconnected damages the device. Connecting I_{SET} directly to V- is not recommended because it programs the current limit far beyond the 1.5A capability of the device and causes excess power dissipation. The minimum recommended value for R_{SET} is 7.5k Ω , which programs the maximum current limit to approximately 1.9A. The maximum value for R_{SET} is 55k Ω , which programs the minimum current limit to approximately 0.4A. The simplest method for adjusting the current limit (I_{LIM}) uses a resistor or potentiometer connected between the I_{SET} pin and V-, according to Equation 1.

If I_{LIM} has been defined, R_{SET} can be solved by rearranging Equation 1 into Equation 3:

$$R_{SET} \cong \left(\frac{24k\Omega}{I_{LIM}}\right) - 5k\Omega \tag{3}$$

 R_{SET} in combination with a $5k\Omega$ internal resistor determines the magnitude of a small current that sets the desired output current limit.

Figure 37 shows a simplified schematic of the OPA564 current limit architecture.



(1) At power-on, this capacitor is not charged. Therefore, the OPA564 is programmed for maximum output current. Capacitor values > 1nF are not recommended.

Figure 37. Adjustable Current Limit



ENABLE/SHUTDOWN (E/S) PIN

The output of the OPA564 shuts down when the E/\overline{S} pin is forced low. For normal operation (output enabled), the E/\overline{S} pin must be pulled high (at least 2V above V-). To enable the OPA564 permanently, the E/\overline{S} pin can be left unconnected. The E/\overline{S} pin has an internal $100k\Omega$ pull-up resistor. When the output is shut down, the output impedance of the OPA564 is $6G\Omega \parallel 120pF$. The output shutdown output voltage versus output current is shown in Figure 42. Although the output is high-impedance when shut down, there is still a path through the feedback network into the input stage to ground; see Figure 43. To prevent damage to the OPA564, ensure that the voltage across the input terminals +IN and -IN does not exceed 0.5V, and that the current flowing through the input terminals does not exceed 10mA when operated beyond the supply rails, V- and V+. Refer to the *Input Protection* section.

Input Protection

Electrostatic discharge (ESD) protection followed by back-to-back diodes and input resistors (see Figure 43) are used for input protection on the OPA564. Exceeding the turn-on threshold of these diodes, as in a pulse condition, can cause current to flow through the input protection diodes because of the finite slew rate of the amplifier. If the input current is not limited, the back-to-back diodes and the input devices can be destroyed. Sources of high input current can also cause subtle damage to the amplifier. Although the unit may still be functional, important parameters such as input offset voltage, drift, and noise may shift.

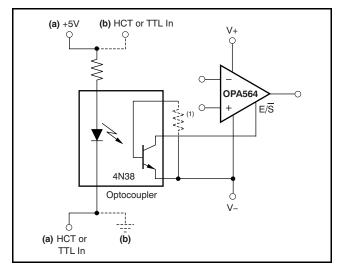
When using the OPA564 as a unity-gain buffer (follower), as an inverting amplifier, or in shutdown mode, the input voltage between the input terminals (+IN and -IN) must be limited so that the voltage does not exceed 0.5V. This condition must be maintained across the entire common-mode range from V- to V+. If the inputs are taken above either supply rail, the current must be limited to 10mA through the ESD protection diodes. During excursions past the rails, it is still necessary to limit the voltage across the input terminals. If necessary, external back-to-back diodes should be added between +IN and -IN to maintain the 0.5V requirement between these connections.

Output Shutdown

The shutdown pin (E/\overline{S}) is referenced to the negative supply (V-). Therefore, shutdown operation is slightly different in single-supply and dual-supply applications. In single-supply operation, V- typically equals common ground. Therefore, the shutdown

logic signal and the OPA564 shutdown pin are referenced to the same potential. In this configuration, the logic pin and the OPA564 enable can simply be connected together. Shutdown occurs for voltage levels of less than 0.8V. The OPA564 is enabled at logic levels greater than 2V. In dual-supply operation, the logic pin remains referenced to a logic ground. However, the shutdown pin of the OPA564 continues to be referenced to V—.

Thus, in a dual-supply system, to shut down the OPA564 the voltage level of the logic signal must be level-shifted by some means. One way to shift the logic signal voltage level is by using an optocoupler, as Figure 38 shows.



(1) Optional; may be required to limit leakage current of optocoupler at high temperatures.

Figure 38. Shutdown Configuration for Dual Supplies (Using Optocoupler)

To shut down the output, the E/\overline{S} pin is pulled low, no greater than 0.8V above V–. This function can be used to conserve power during idle periods. To return the output to an enabled state, the E/\overline{S} pin should be pulled to at least 2.0V above V–. Figure 27 shows the typical enable and shutdown response times. It should be noted that the E/\overline{S} pin does not affect the internal thermal shutdown.

When the OPA564 will be used in applications where the device shuts down, special care should be taken with respect to input protection. Consider the following two examples.



Figure 39 shows the amplifier in a follower configuration. The load is connected midway between the supplies, V+ and V-.

When the device shuts down in this situation, the load pulls V_{OUT} to ground. Little or no current then flows through the input of the OPA564.

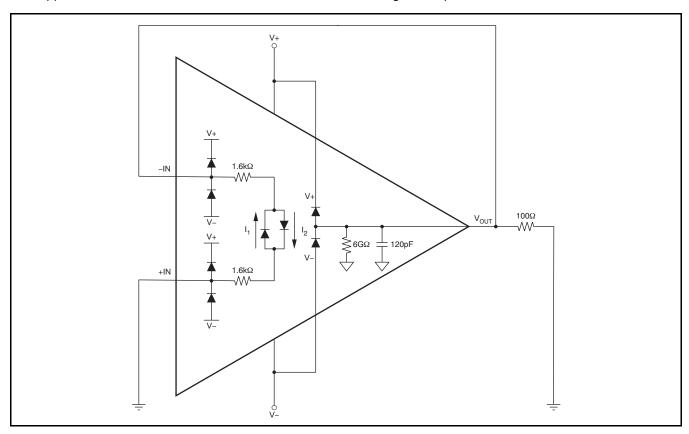


Figure 39. Shutdown Equivalent Circuit with Load Connected Midway Between Supplies

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Now consider Figure 40. Here, the load is connected to V–. When the device shuts down, current flows from the positive input +IN through the first $1.6k\Omega$ resistor through an input protection diode, then through the second $1.6k\Omega$ resistor, and finally through the 100Ω resistor to V–.

This current flow produces a voltage across the inputs which is much greater than 0.5V, which damages the OPA564. A similar problem would occur if the load is connected to the positive supply.

CAUTION

This configuration damages the device.

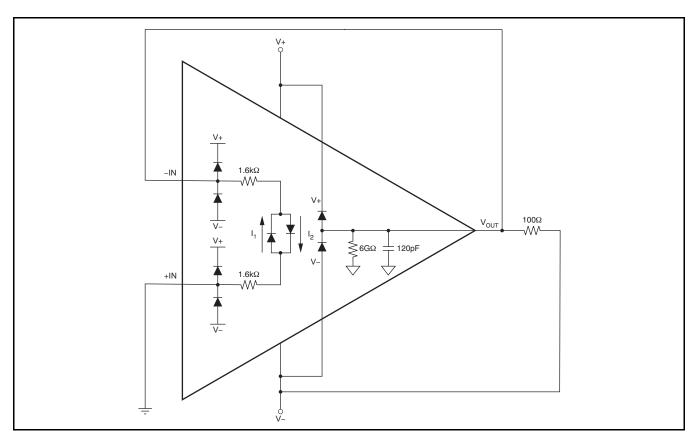


Figure 40. Shutdown Equivalent Circuit with Load Connected to V-: Voltage Across Inputs During DIsable Exceeds Input Requirements

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The solution is to place external protection diodes across the OPA564 input. Figure 41 illustrates this configuration.

NOTE

This configuration protects the input during shutdown.

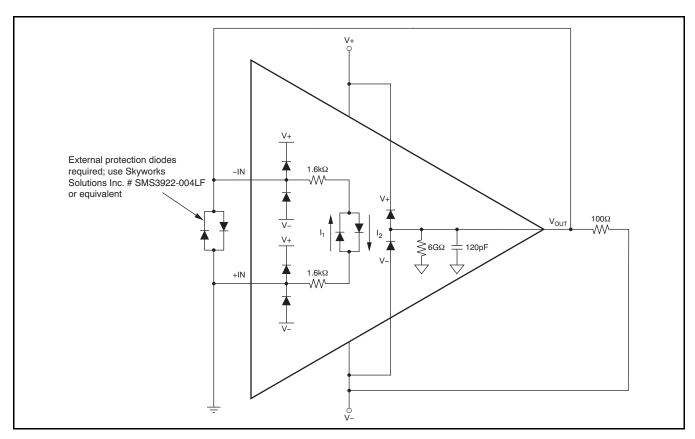


Figure 41. Shutdown Equivalent Circuit with Load Connected to V-: Protected Input Configuration

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Ensuring Microcontroller Compatibility

Not all microcontrollers output the same logic state after power-up or reset. 8051-type microcontrollers, for example, output logic high levels while other models power up with logic low levels after reset. In the configuration of Figure 38(a), the shutdown signal is applied on the cathode side of the photodiode

within the optocoupler. A high logic level causes the OPA564 to be enabled, and a low logic level shuts the OPA564 down. In the configuration of Figure 38(b), with the logic signal applied on the anode side, a high level causes the OPA564 to shut down, and a low level enables the op amp.

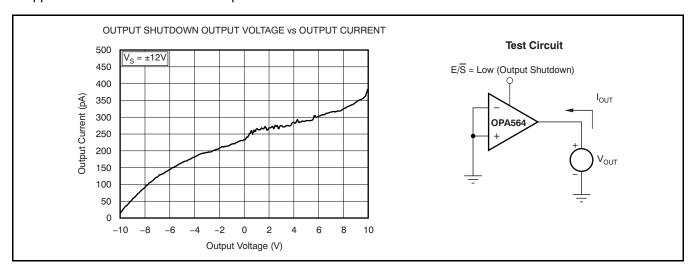


Figure 42. Output Shutdown Output Impedance

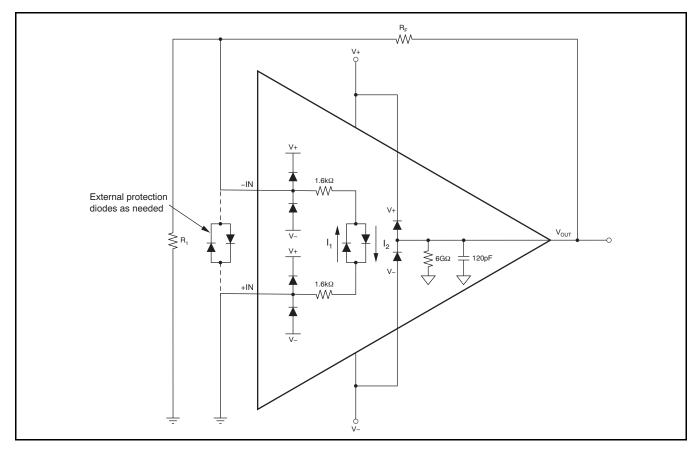


Figure 43. OPA564: Output Shutdown Equivalent Circuit (with External Feedback)

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CURRENT LIMIT FLAG

The OPA564 features a current limit flag (I_{FLAG}) that can be monitored to determine if the load current is operating within or exceeding the current limit set by the user. The output signal of I_{FLAG} is compatible with standard CMOS logic and is referenced to the negative supply pin (V–). A voltage level of + 0.8V or less with respect to V– indicates that the amplifier is operating within the limits set by the user. A voltage level of +2.0V or greater with respect to V– indicates that the OPA564 is operating above (exceeds) the current limit set by the user. See Setting the Current Limit for proper current limit operation.

OUTPUT STAGE COMPENSATION

The complex load impedances common in power op amp applications can cause output stage instability. For normal operation, output compensation circuitry is typically not required. However, if the OPA564 is intended to be driven into current limit, an R/C network (snubber) may be required. A snubber circuit such as the one shown in Figure 54 may also enhance stability when driving large capacitive loads (greater than 1000pF) or inductive loads (for example, motors or loads separated from the amplifier by long cables). Typically, 3Ω to 10Ω in series with $0.01\mu F$ to $0.1\mu F$ is adequate. Some variations in circuit value may be required with certain loads.

OUTPUT PROTECTION

The output structure of the OPA564 includes ESD diodes (see Figure 43). Voltage at the OPA564 output must not be allowed to go more than 0.4V beyond either supply rail to avoid damaging the device. Reactive and electromagnetic field (EMF)-generation loads can return load current to the amplifier, causing the output voltage to exceed the power-supply voltage. This damaging condition can be avoided with clamping diodes from the output terminal to the power supplies, as Figure 54 and Figure 55 illustrate. Schottky rectifier diodes with a 3A or greater continuous rating are recommended.

THERMAL PROTECTION

The OPA564 has thermal sensing circuitry that helps protect the amplifier from exceeding temperature limits. Power dissipated in the OPA564 causes the junction temperature to rise. Internal thermal shutdown circuitry disables the output when the die temperature reaches the thermal shutdown temperature limit. The OPA564 output remains shut down until the die has cooled sufficiently; see the Electrical Characteristics, Thermal Shutdown section.

Depending on load and signal conditions, the thermal protection circuit may cycle on and off. This cycling limits the amplifier dissipation, but may have undesirable effects on the load. Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heatsink. For reliable, long-term, continuous operation, with I_{OUT} at the maximum output of 1.5A, the junction temperature should be limited to +85°C maximum. Figure 44 shows the maximum output current versus junction temperature for dc and RMS signal outputs. To estimate the margin of safety in a complete design (including heatsink), increase the ambient temperature until the thermal protection Use worst-case loading and signal triggers. conditions. For good, long-term reliability, thermal protection should trigger more than 35°C above the maximum expected ambient condition of the application.

The internal protection circuitry of the OPA564 was designed to protect against overload conditions; it was not intended to replace proper heatsinking. Continuously running the OPA564 into thermal shutdown degrades reliability.

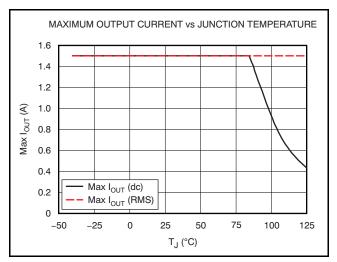


Figure 44. Maximum Output Current vs Junction Temperature

USING T_{SENSE} FOR MEASURING JUNCTION TEMPERATURE

The OPA564 includes an internal diode for junction temperature monitoring. The $\eta\text{-factor}$ of this diode is 1.033. Measuring the OPA564 junction temperature can be accomplished by connecting the T_{SENSE} pin to a remote-junction temperature sensor, such as the TMP411 (see Figure 57).



POWER DISSIPATION AND SAFE OPERATING AREA

Power dissipation depends on power supply, signal, and load conditions. For dc signals, power dissipation is equal to the product of output current (I_{OUT}) and the voltage across the conducting output transistor [(V+) – V_{OUT} when sourcing; V_{OUT} – (V–) when sinking]. Dissipation with ac signals is lower. Application Bulletin AB-039, *Power Amplifier Stress and Power Handling Limitations* (SBOA022, available for download from www.ti.com) explains how to calculate or measure power dissipation with unusual signals and loads.

Figure 45 shows the safe operating area at room temperature with various heatsinking efforts. Note that the safe output current decreases as $(V+)-V_{OUT}$ or $V_{OUT}-(V-)$ increases. Figure 46 shows the safe operating area at various temperatures with the PowerPAD being soldered to a 2oz copper pad.

The power that can be safely dissipated in the package is related to the ambient temperature and the heatsink design. The PowerPAD package was specifically designed to provide excellent power dissipation, but board layout greatly influences the heat dissipation of the package. Refer to the *Thermally-Enhanced PowerPAD Package* section for further details.

The relationship between thermal resistance and power dissipation can be expressed as:

$$T_J = T_A + T_{JA}$$

$$T_{JA} = P_D \times \theta_{JA}$$

Combining these equations produces:

$$T_J = T_A + P_D \times \theta_{JA}$$

where:

 $T_J = Junction temperature (°C)$

 T_A = Ambient temperature (°C)

 θ_{JA} = Junction-to-ambient thermal resistance (°C/W)

P_D = Power dissipation (W)

To determine the required heatsink area, required power dissipation should be calculated and the relationship between power dissipation and thermal resistance should be considered to minimize shutdown conditions and allow for proper long-term operation (junction temperature of +85°C or less).

Once the heatsink area has been selected, worst-case load conditions should be tested to ensure proper thermal protection.

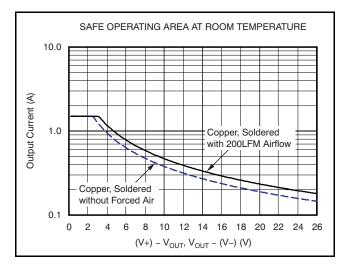
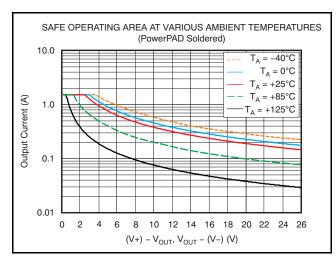


Figure 45. Safe Operating Area at Room Temperature



PowerPAD soldered to a 2oz copper pad.

Figure 46. Safe Operating Area at Various Ambient Temperatures



For applications with limited board size, refer to Figure 47 for the approximate thermal resistance relative to heatsink area. Increasing heatsink area beyond 2in² provides little improvement in thermal resistance. To achieve the 33°C/W shown in the Electrical Characteristics, a 2oz copper plane size of 9in² was used. The PowerPAD package is well-suited for continuous power levels from 2W to 4W, depending on ambient temperature and heatsink area. The addition of airflow also influences maximum power dissipation, as Figure 48 illustrates. Higher power levels may be achieved in applications with a low on/off duty cycle, such as remote meter reading.

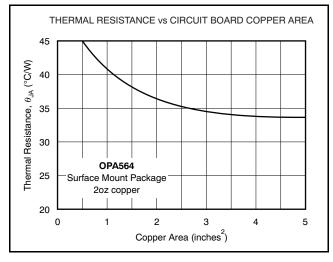


Figure 47. Thermal Resistance vs Circuit Board Copper Area

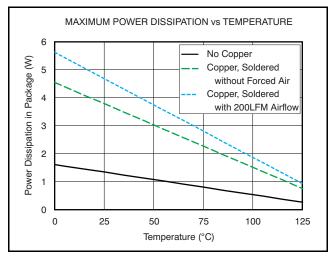


Figure 48. Maximum Power Dissipation vs
Temperature

THERMALLY-ENHANCED PowerPAD PACKAGE

The OPA564 uses the HSOP-20 PowerPAD DWP and DWD packages, which are thermally-enhanced, standard size IC packages. These packages enhance power dissipation capability significantly and can be easily mounted using standard printed circuit board (PCB) assembly techniques, and can be removed and replaced using standard repair procedures.

The DWP PowerPAD package is designed so that the leadframe die pad (or thermal pad) is exposed on the bottom of the IC, as shown in Figure 49 \mathbf{a} ; the DWD PowerPAD package has the exposed pad on the top side of the package, as shown in Figure 49 \mathbf{b} . The thermal pad provides an extremely low thermal resistance (θ_{JC}) path between the die and the exterior of the package.

PowerPAD packages with exposed pad down are designed to be soldered directly to the PCB, using the PCB as a heatsink. Texas Instruments does not recommend the use of the of a PowerPAD package without soldering it to the PCB because of the risk of lower thermal performance and mechanical integrity. In addition, through the use of thermal vias, the bottom-side thermal pad can be directly connected to a power plane or special heatsink structure designed into the PCB. The PowerPAD should be at the same voltage potential as V—. Soldering the bottom-side PowerPAD to the PCB is always required, even with applications that have low power dissipation. It provides the necessary thermal and mechanical connection between the leadframe die and the PCB.

Pad-up PowerPAD packages should have appropriately designed heatsinks attached. Because of the variation and flexible nature of this type of heat sink, additional details should come from the specific manufacturer of the heatsink.



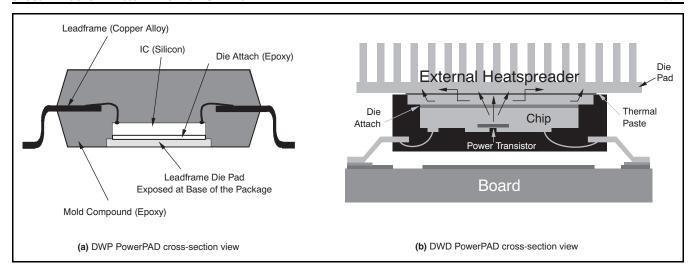


Figure 49. Cross-Section Views

Bottom-Side PowerPAD Assembly Process

- 1. The PowerPAD must be connected to the most negative supply of the device, V-.
- 2. Prepare the PCB with a top side etch pattern, as shown in the attached thermal land pattern mechanical drawing. There should be etch for the leads as well as etch for the thermal land.
- 3. Place the recommended number of holes (or thermal vias) in the area of the thermal pad, as seen in the attached thermal land pattern mechanical drawing. These holes should be 13mils (.013in, or 330.2μm) in diameter. They are kept small so that solder wicking through the holes is not a problem during reflow.
- 4. It is recommended, but not required, to place a small number of the holes under the package and outside the thermal pad area. These holes provide an additional heat path between the copper land and ground plane and are 25mils (.025in, or 635μm) in diameter. They may be larger because they are not in the area to be soldered, so wicking is not a problem. This configuration is illustrated in the attached thermal land pattern mechanical drawing.
- Connect all holes, including those within the thermal pad area and outside the pad area, to the internal plane that is at the same voltage potential as V-.
- 6. When connecting these holes to the internal plane, do not use the typical web or spoke via connection methodology (as Figure 50 shows). Web connections have a high thermal resistance connection that is useful for slowing the heat transfer during soldering operations. This configuration makes the soldering of vias that have plane connections easier. However, in this application, low thermal resistance is desired for the most efficient heat transfer. Therefore, the

- holes under the PowerPAD package should be connected to the internal plane with a complete connection around the entire circumference of the plated through-hole.
- 7. The top-side solder mask should leave exposed the terminals of the package and the thermal pad area. The thermal pad area should leave the 13mil holes exposed. The larger 25mil holes outside the thermal pad area should be covered with solder mask.
- 8. Apply solder paste to the exposed thermal pad area and all of the package terminals.
- 9. With these preparatory steps completed, the PowerPAD IC is simply placed in position and run through the solder reflow operation as any standard surface-mount component. This processing results in a part that is properly installed.

For detailed information on the PowerPAD package including thermal modeling considerations and repair procedures, see Technical Brief SLMA002, PowerPAD Thermally Enhanced Package, available at www.ti.com.

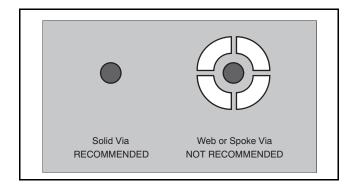
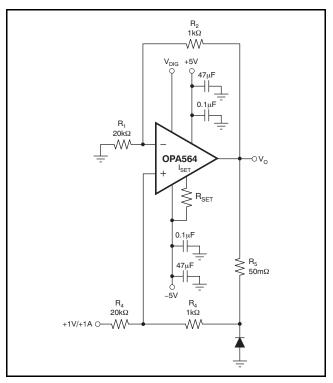


Figure 50. Via Connection Methods

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(1) See Figure 35 for an example of a basic noninverting amplifier with $\rm V_{DIG}$ not exceeding 5.5V.

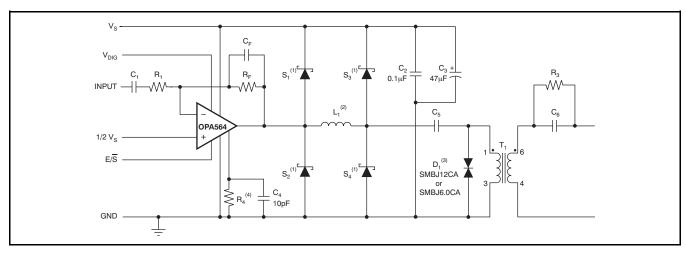
Figure 51. Improved Howland Current Pump

APPLICATIONS CIRCUITS

The high output current and low supply of the OPA564 make it a good candidate for driving laser diodes and thermoelectric coolers. Figure 51 shows an improved Howland current pump circuit.

POWERLINE COMMUNICATION

Powerline communication (PLC) applications require some form of signal transmission over an existing ac power line. A common technique used to couple these modulated signals to the line is through a signal transformer. A power amplifier is often needed to provide adequate levels of current and voltage to drive the varying loads that exist on today's powerlines. One such application is shown in Figure 52. The OPA564 is used to drive signals used in frequency modulation schemes such as FSK (Frequency-Shift Keying) or OFDM (Orthogonal Frequency-Division Multiplexing) to transmit digital information over the powerline. The power output capabilities of the OPA564 are needed to drive the current requirements of the transformer that is shown in the figure, coupled to the ac power line via a coupling capacitor. Circuit protection is often needed or required to prevent excessive line voltages or current surges from damaging the active circuitry in the power amplifier and application circuitry.



- (1) S₁, S₂, S₃, and S₄ are Schottky diodes. S₁ and S₂ are B350 or equivalent. S₃ and S₄ are BAV99T or equivalent.
- (2) L₁ should be small enough so that it does not interfere with the bandwidth of interest but large enough to suppress transients that could damage the OPA564.
- (3) D₁ is a transient suppression diode. For 24V supplies, use SMBJ12CA. For 12V supplies, use SMBJ6.0CA. Voltage rating of transient voltage suppressor should be half the supply rating or less.
- (4) The minimum recommended value for R_4 is $7.5k\Omega$.

Figure 52. Powerline Communication Line Coupling



PROGRAMMABLE POWER SUPPLY

Figure 53 shows the OPA333 used to control I_{SET} in order to adjust the current limit of the OPA564.

Figure 54 shows a basic motor speed driver but does not include any control over the motor speed. For applications where good control of the speed of the motor is desired, but the precision of a tachometer control is not required, the circuit in Figure 55 provides control by using feedback of the current consumption to adjust the motor drive.

For more information on this circuit, see the Application Bulletin *DC Motor Speed Controller:* Control a *DC Motor without Tachometer Feedback* (SBOA043), available for download at the TI web site.

Figure 56 shows two examples of generating the signal for V_{DIG} . Figure 56**a** uses an 1N4732A zener to bias the V_{DIG} to precisely 4.7V above V—. Figure 56**b** uses a high-voltage subregulator to derive the V_{DIG} voltage. Figure 58 illustrates a detailed powerline communication circuit.

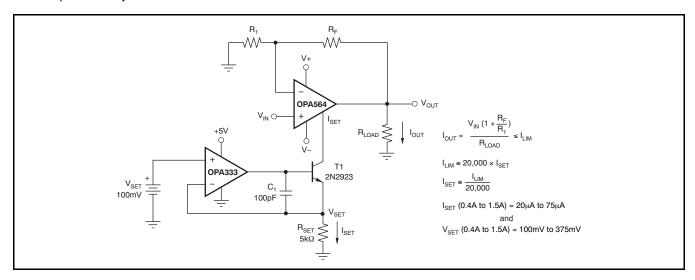
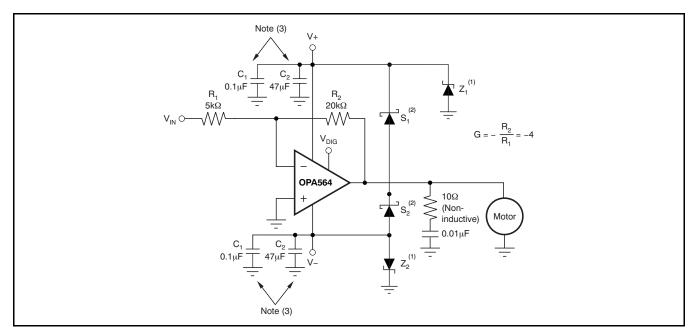


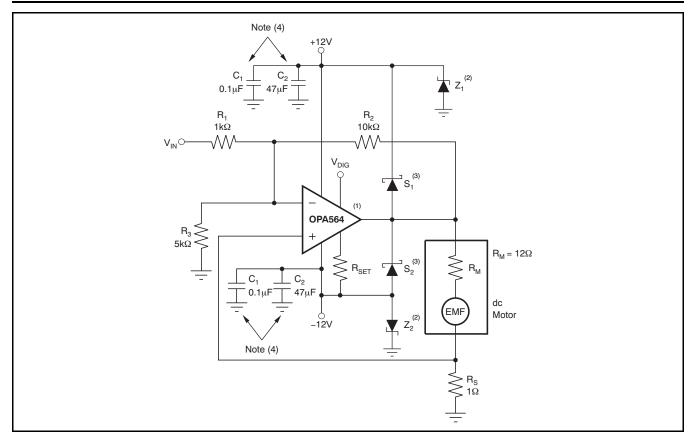
Figure 53. Programmable Current Limit Option



- (1) Z_1 , Z_2 = zener diodes (IN5246 or equivalent). Select Z_1 and Z_2 diodes that are capable of the maximum anticipated surge current.
- (2) S_1 , S_2 = Schottky diodes (STPS1L40 or equivalent).
- (3) C_1 = high-frequency bypass capacitors; C_2 = low-frequency bypass capacitors (minimum of $10\mu F$ for every 1A peak current)

Figure 54. Motor Drive Circuit





- (1) I_{FLAG} and T_{FLAG} connections are not shown.
- (2) Z_1 , Z_2 = zener diodes (IN5246 or equivalent). Select Z_1 and Z_2 diodes that are capable of the maximum anticipated surge current.
- (3) S_1 , S_2 = Schottky diodes (STPS1L40 or equivalent).
- (4) C_1 = high-frequency bypass capacitors; C_2 = low-frequency bypass capacitors (minimum of $10\mu F$ for every 1A peak current).

Figure 55. DC Motor Speed Controller (without Tachometer)

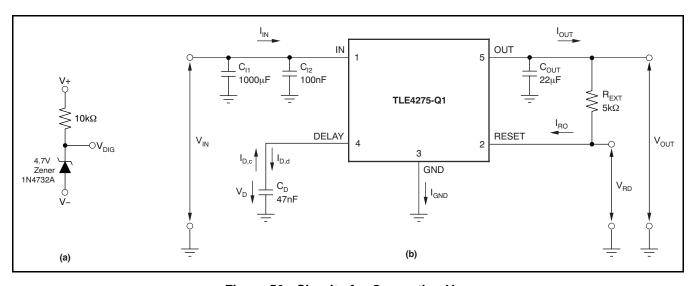


Figure 56. Circuits for Generating V_{DIG}



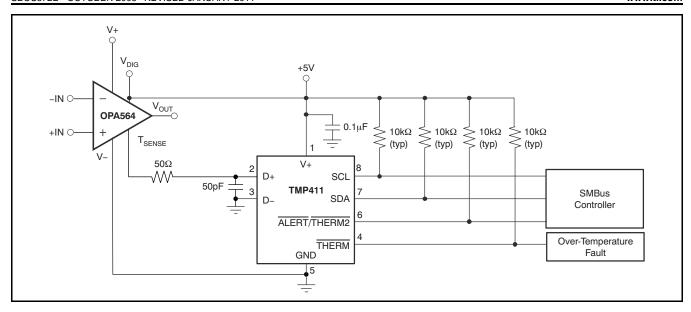


Figure 57. Temperature Measurement Using T_{SENSE} and TMP411

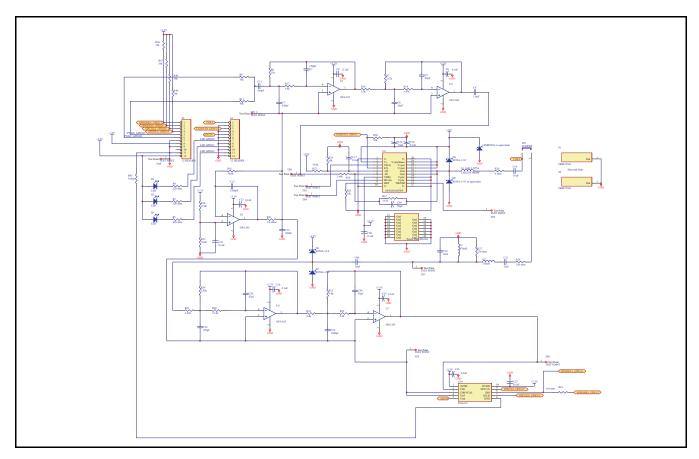


Figure 58. Detailed Powerline Communication Circuit



REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Cł	nanges from Revision D (November, 2010) to Revision E	Page
	Changed R _{CL} to R _{SET} throughout document	1
•	Updated Absolute Maximum Ratings table, signal input terminals specifications; added new footnote	
•	Deleted current through back-to-back input protection diodes specification; added maximum differential voltage across inputs specification	
•	Changed footnote (4) in Absolute Maximum Ratings table	<u>2</u>
•	Revised conditions for Electrical Characteristics table	3
•	Revised conditions for Electrical Characteristics table	4
•	Updated current limit equation	4
•	Changed ideality factor value for T _{SENSE} parameter	4
•	Changed footnote (5) in Electrical Characteristics table	
•	Revised conditions for Electrical Characteristics table	5
•	Deleted condition statement for I _Q and I _{QSD} parameters in Electrical Characteristics table	5
•	Updated minimum value for V _{DIG} parameter in Electrical Characteristics table	
•	Changed description of V _{DIG} pin operation	6
•	Updated condition statement for Typical Characteristics	
•	Corrected y-axis values in Figure 1	
•	Revised Setting the Current Limit section to update maximum value for R _{SET}	
•	Revised ENABLE/SHUTDOWN Pin section	16
•	Added Input Protection section	16
•	Added Figure 39	17
•	Added Figure 41	19
•	Changed Figure 43	20
•	Changed ideality factor value	21
•	Changed Figure 52	25
•	Corrected signal indicators shown in Figure 53	26
•	Updated footnote (1) to Figure 54	26
•	Changed footnote (2) to Figure 54	26
•	Changed footnote (2) to Figure 55	
•	Updated footnote (3) to Figure 55	27
•	Revised Figure 58	28
Cł	nanges from Revision C (November, 2009) to Revision D	Page
•	Deleted references to HTSSOP-20 (PWP) package throughout document; this package version will not be manufactured	1
•	Removed HTSSOP-20 (PWP) package option and footnote (2) from Package/Ordering Information table	<u>2</u>
•	Deleted HTSSOP-20 PWP package thermal resistance information in Electrical Characteristics table	5

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
OPA564AIDWD	Active	Production	HSOP (DWD) 20	25 TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWD.A	Active	Production	HSOP (DWD) 20	25 TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWDR	Active	Production	HSOP (DWD) 20	2000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWDR.A	Active	Production	HSOP (DWD) 20	2000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWP	Active	Production	SO PowerPAD (DWP) 20	25 TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWP.A	Active	Production	SO PowerPAD (DWP) 20	25 TUBE	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWPR	Active	Production	SO PowerPAD (DWP) 20	2000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWPR.A	Active	Production	SO PowerPAD (DWP) 20	2000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWPRG4	Active	Production	SO PowerPAD (DWP) 20	2000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564
OPA564AIDWPRG4.A	Active	Production	SO PowerPAD (DWP) 20	2000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA564

⁽¹⁾ Status: For more details on status, see our product life cycle.

⁽²⁾ Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ RoHS values: Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

⁽⁴⁾ Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

⁽⁵⁾ MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

⁽⁶⁾ Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

PACKAGE OPTION ADDENDUM

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Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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OTHER QUALIFIED VERSIONS OF OPA564:

Automotive : OPA564-Q1

NOTE: Qualified Version Definitions:

Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

PACKAGE MATERIALS INFORMATION

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TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
В0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
OPA564AIDWDR	HSOP	DWD	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1
OPA564AIDWPR	SO PowerPAD	DWP	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1
OPA564AIDWPRG4	SO PowerPAD	DWP	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1

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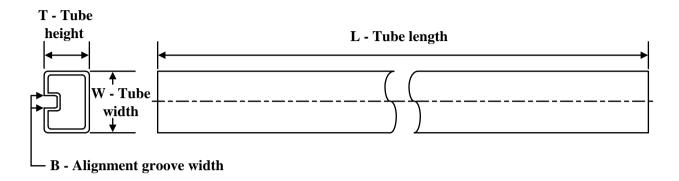
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA564AIDWDR	HSOP	DWD	20	2000	350.0	350.0	43.0
OPA564AIDWPR	SO PowerPAD	DWP	20	2000	350.0	350.0	43.0
OPA564AIDWPRG4	SO PowerPAD	DWP	20	2000	350.0	350.0	43.0

PACKAGE MATERIALS INFORMATION

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TUBE



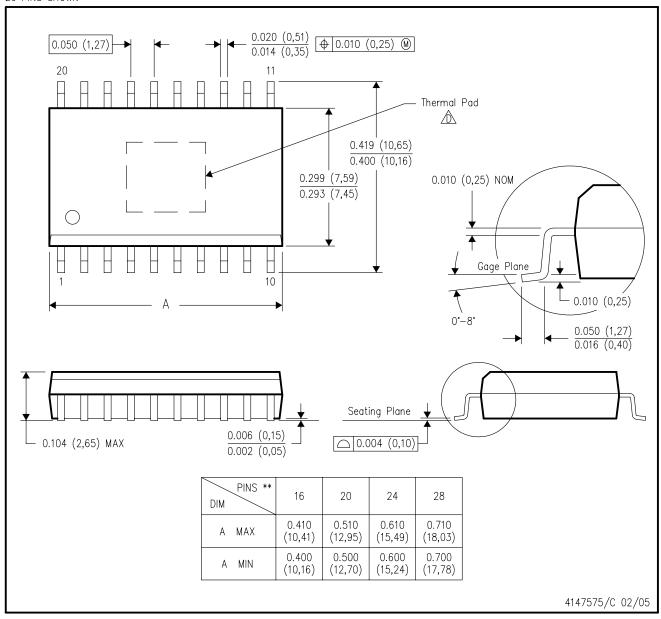
*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
OPA564AIDWD	DWD	HSOIC	20	25	506.98	12.7	4826	6.6
OPA564AIDWD.A	DWD	HSOIC	20	25	506.98	12.7	4826	6.6
OPA564AIDWP	DWP	HSOIC	20	25	506.98	12.7	4826	6.6
OPA564AIDWP.A	DWP	HSOIC	20	25	506.98	12.7	4826	6.6

DWP (R-PDSO-G**)

PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE

20 PINS SHOWN



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com http://www.ti.com. See the product data sheet for details regarding the exposed thermal pad dimensions.

PowerPAD is a trademark of Texas Instruments.



DWP (R-PDSO-G20)

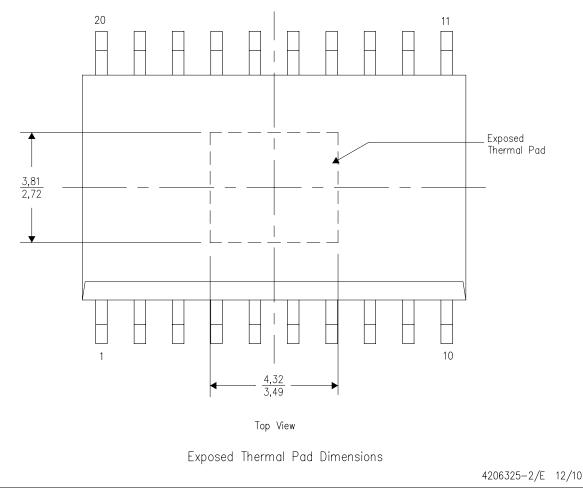
PowerPAD™ PLASTIC SMALL OUTLINE

THERMAL INFORMATION

This PowerPAD $^{\mathsf{M}}$ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

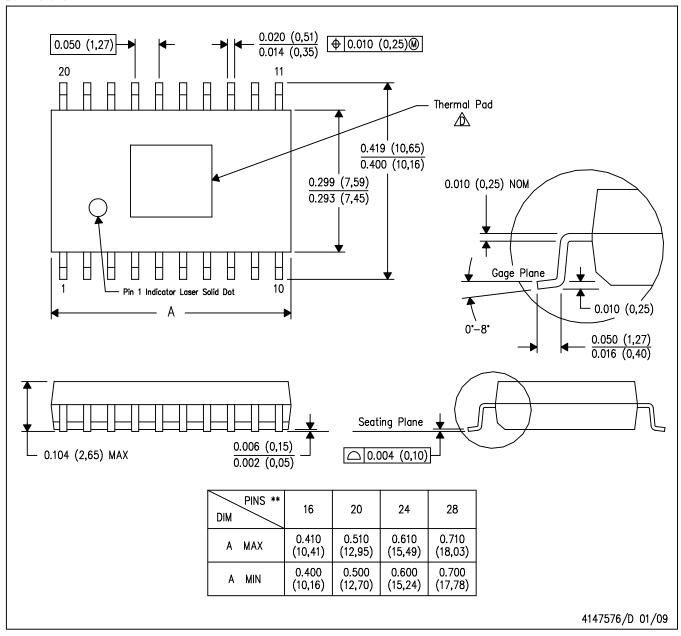
For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



NOTE: A. All linear dimensions are in millimeters

DWD (R-PDSO-G**) PowerPAD™ PLASTIC SMALL-OUTLINE (DIE DOWN)
20 PINS SHOWN



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
- This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com www.ti.com. See the product data sheet for details regarding the exposed thermal pad dimensions.

PowerPAD is a trademark of Texas instruments.

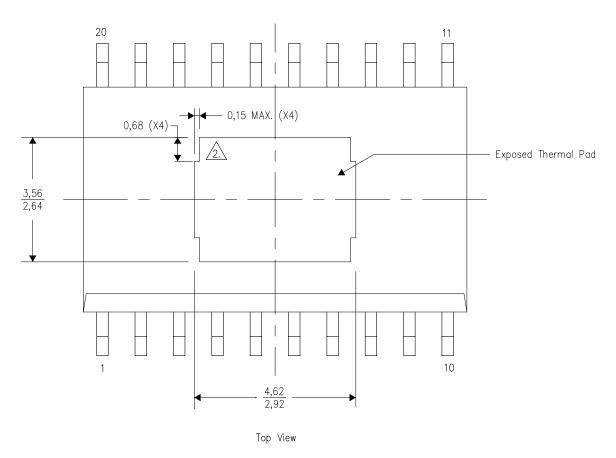


THERMAL INFORMATION

This PowerPADTM package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Exposed Thermal Pad Dimensions

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