

# PA99 • PA99A

RoHS

COMPLIAN

# **Power Operational Amplifier**

FEATURES

- Up to 2400V<sub>P-P</sub> Output
- Wide Supply Range ±100V to ±1250V
- Programmable Current Limit
- 50mA Continuous Output
- Hermetically Sealed Package
- Temperature Sensor

## **APPLICATIONS**

- Semiconductor Testing
- Piezo Positioning
- High Voltage Instrumentation
- Electrostatic Deflection

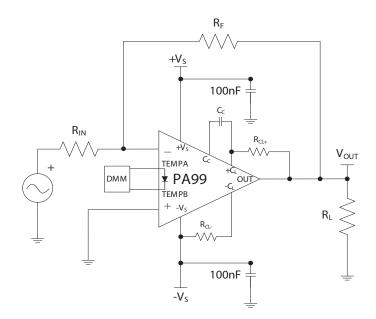
## DESCRIPTION

The PA99 is an ultra-high 2,500 V power operational amplifier designed for output currents up to 50mA to target high voltage applications including piezoelectric positioning, instrumentation, semiconductor production testing, and electrostatic deflection. Output voltages can swing up to 2,400  $V_{P-P}$ .

High accuracy for this MOSFET power amplifier is achieved with a cascode input circuit configuration. External compensation provides user flexibility by allowing customers to tailor slew rate and bandwidth performance. A resistor configurable current limit provides system level protection.

# TYPICAL CONNECTION

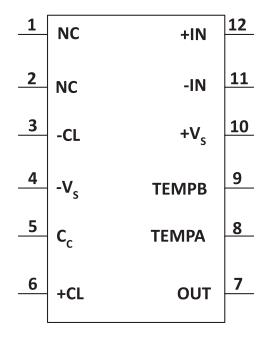
## Figure 1: Typical Connection





# **PINOUT AND DESCRIPTION TABLE**

## Figure 2: External Connections



Pin Number	Name	Description
1, 2	NC	No connection.
3	-CL	Connect a negative current limit resistor between this pin and -Vs pin.
4	-Vs	The negative supply rail.
5	СС	Connect a compensation capacitor between this pin and +CL pin. The compensation capacitor needs to be rated for at least the maximum supply voltage.
6	+CL	Connect a positive current limit resistor between this pin and the OUT pin. Output current flows out of this pin through R <sub>CL+</sub> .
7	OUT	The output. Connect this pin to load and to the feedback resistors.
8	TEMPA	The anode for the temperature sensing diode.
9	TEMPB	The cathode for the temperature sensing diode.
10	+Vs	The positive supply rail.
11	-IN	The inverting input.
12	+IN	The non-inverting input.



# SPECIFICATIONS

Unless noted otherwise, the test conditions are as follows:  $T_c = 25$ °C,  $\Delta V_s = 2000V$ ,  $R_L = 50 k\Omega$ ,  $A_V = 100$ ,  $R_F = 200 k\Omega$ ,  $C_c = 15$  pF. DC input specifications are value given. The power supply voltage is typical rating.

## ABSOLUTE MAXIMUM RATINGS

Parameter		PA99 & PA99A						
Palameter	Symbol	Min	Max	Unit				
Supply Voltage	+V <sub>s</sub> to -V <sub>s</sub>		2500	V				
Output Current, Peak, within SOA	Ι <sub>Ο</sub>		±70	mA				
Power Dissipation, internal, DC	PD		37	W				
Input Voltage, common mode	V <sub>cm</sub>		$-V_{S}+50$ to $+V_{S}-50$	V				
Input Voltage, differential	V <sub>IN (Diff)</sub>		±20	V				
Temperature, pin solder, 10s			+225	°C				
Temperature, junction <sup>1</sup>	Tj		+150	°C				
Temperature, storage		-40	+150	°C				
Operating Temperature Range, case	Τ <sub>C</sub>	-40	+85	°C				

1. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.

#### INPUT

Parameter	Test Conditions	PA99				Unit		
Parameter		Min	Тур	Max	Min	Тур	Max	Unit
Offset Voltage, initial			2.0	5.0			2.0	mV
Offset Voltage vs. temperature	Full temp range			75			50	μV/°C
Offset Voltage vs. supply			0.1			*		μV/V
Bias Current, Initial <sup>1</sup>			50			*		pА
Bias Current vs. supply			0.01			*		pA/V
Offset Current, Initial			5.0	50		*	*	pА
Input Resistance, DC			10 <sup>11</sup>			*		Ω
Input Capacitance			13			*		pF
Common Mode Voltage Range			-Vs + 50 +Vs - 50			*		V
Common Mode Rejection, DC			134			*		dB
Input Noise	20 kHz BW, R <sub>S</sub> =10 kΩ		2			*		μV RMS

1. Doubles for every 10°C of case temperature increase.

# PA99 • PA99A



#### GAIN

Parameter	Test Conditions	PA99			PA99A			Unit
Falameter	Test conditions	Min	Тур	Max	Min	Тур	Мах	Unit
Open Loop, @ 15 Hz			117			*		dB
Gain Bandwidth Product	AV=100, 280 kHz		28			*		MHz
Power Bandwidth	V <sub>O</sub> = 2000V, V <sub>S</sub> = 2200V	1.6	5		*	*		kHz
Phase Margin			60			*		o
Harmonic Distortion, HD2	1 kHz		61			*		dB
Harmonic Distortion, HD3	1 kHz		56			*		dB

## OUTPUT

Parameter	Test Conditions	PA99			PA99A			Unit
Falameter	lest conditions	Min	Тур	Max	Min	Тур	Max	Onit
Voltage Swing, negative rail	l <sub>0</sub> = 20mA		-Vs+20			*		V
Voltage Swing, positive rail	l <sub>0</sub> = 20mA		+Vs-20			*		V
Current, continuous	Within SOA			±50			*	mA
Slew Rate, rising		10	30		*	*		V/µs
Slew Rate, falling		10	30		*	*		V/µs
Resistive Load		1000			*			Ω

## **POWER SUPPLY**

Parameter	Test Conditions	PA99				Unit		
ratameter	lest conditions	Min	Тур	Max	Min	Тур	Max	Onic
Voltage		±100		±1250	*		*	V
Current, quiescent			4.0			*		mA

#### THERMAL

Parameter	Test Conditions	PA99				Unit		
Falameter	lest conditions	Min	Тур	Max	Min	Тур	Max	Onit
Resistance, DC, junction to case	Full temp range, F < 60 Hz		3.3			*		°C/W
Resistance, junction to air	Full temp range		15.4			*		°C/W

**Note:** An asterisk (\*) in a specification column of PA99A indicates that the value is identical to the specification for the PA99 in the applicable column to the left



# **TYPICAL PERFORMANCE GRAPHS**

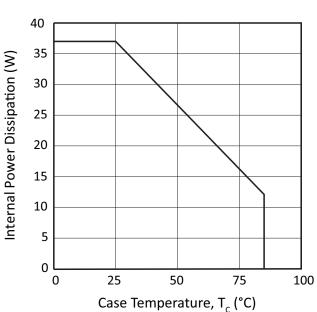


Figure 3: Power Derating

# Figure 5: Small Signal Pulse Response

Figure 4: Large Signal Pulse Response

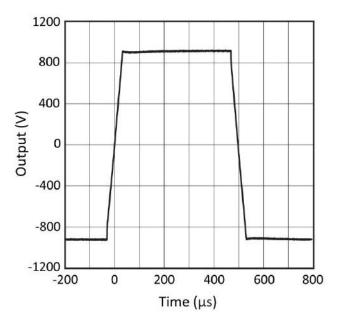
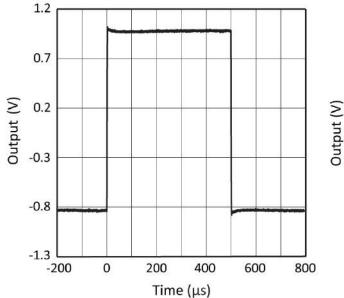
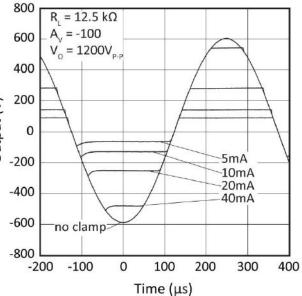


Figure 6: Large Signal Response with Current Limit





160

140

120

100

80

60

40

20

0

1

10

CMR (dB)



10k 100k 1M 10M 100M

Figure 7: Open Loop Gain vs. Frequency

**Figure 8: Phase Response** 

Cc=15pF

0

-20

-40

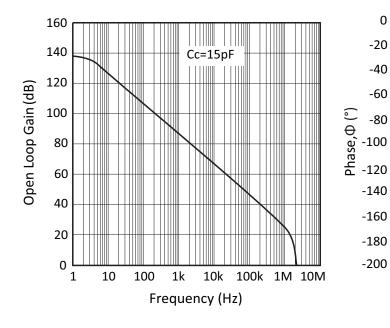
-60

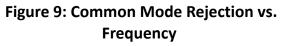
-140

-160

-180 -200

1





1k

Frequency (Hz)

100

10k

100k

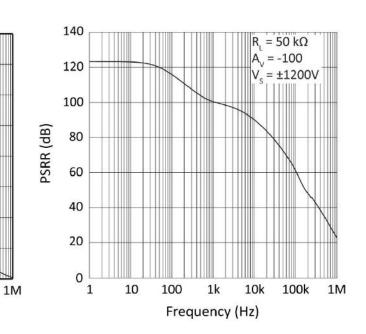


Frequency (Hz)

1k

100

10





4.2

4.1

4.0

3.9

3.8

3.7

3.6

3.5

3.4

0

500

Quiescent Current, I<sub>a</sub> (mA)

## Figure 11: Quiescent Current



60

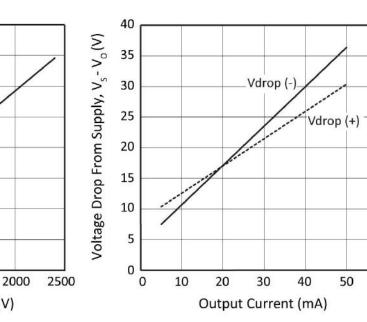


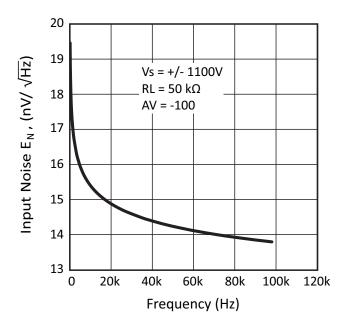
Figure 12: Output Voltage Swing

**Figure 13: Input Noise vs. Frequency** 

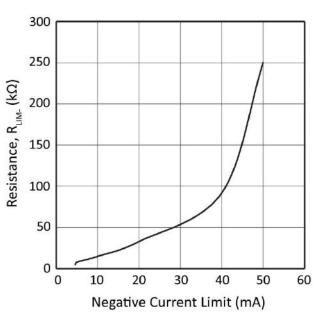
Total Supply Voltage (V)

1000

1500



**Figure 14: Negative Current Limit Resistor** 





500 Vp-p

100 Vp-p

**3RD HARMONIC** 

2ND HARMONIC

70  $R_1 = 50 k\Omega$ 60 A\_ = -100 50 Slew Rate (V/µs) 40 30 20 10 0 0 10 20 30 40 50 60 70 Compensation (pF)

Figure 15: Slew Rate vs. Compensation

Figure 17: Temperature Diode (1mA Bias)

0.8 0.75 0.7 0.65 0.6 0.65 0.6 0.55 0.5 0.5 0.4 -60 -40 -20 0 20 40 60 80 100 120 140 Temperature (°C)

Figure 18: Temperature Diode (500µA Bias)

2ND HARMONIC

3

Frequency (kHz)

4

5

500 Vp-p

2

**Figure 16: Harmonic Distortion** 

 $R_{1} = 12 \text{ k}, V_{0} = 100 \text{ V}_{P-P}$ 

R = 50 k, V = 500 V<sub>P-P</sub>

-40

-45

-50

-55

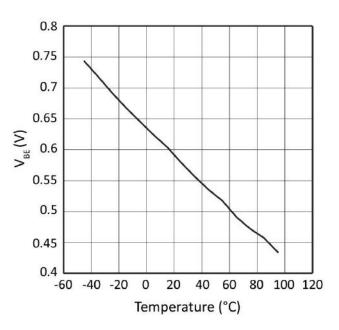
-60

-65

0

1

Distortion (dBc)



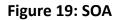
100 Vp-p 3RD HARMONIC

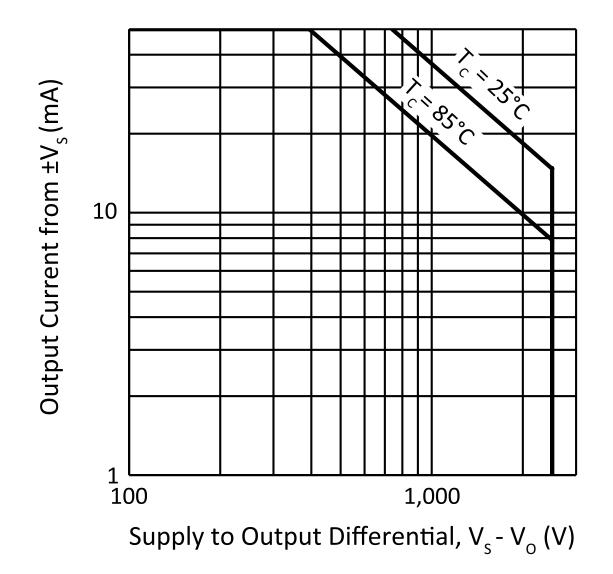
6

7



SAFE OPERATING AREA (SOA)







## GENERAL

Please read Application Note 1 "General Operating Considerations" which covers stability, supplies, heat sinking, mounting, current limit, SOA interpretation, and specification interpretation. Visit www.apexanalog.com for Apex Microtechnology's complete Application Notes library, Technical Seminar Workbook, and Evaluation Kits.

## **TYPICAL APPLICATION**



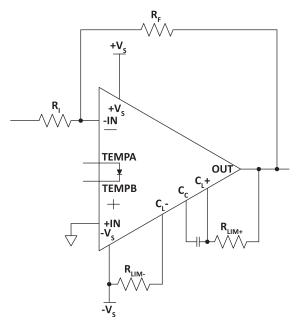


Figure 20 shows PA99 in a typical inverting amplifier circuit. The resistors  $R_{LIM+}$  and  $R_{LIM-}$  are used to limit the current output. If no current limit is desired, a direct connection between  $C_L+$  and OUT is required for proper operation, and  $C_L-$  must be connected to  $-V_S$  with a resistor larger or equal 200 k $\Omega$  in that case.

# **OUTPUT CURRENT AND DEVICE COOLING**

PA99 can handle output currents of  $\pm$ 50mA, but careful considerations need to be done about proper cooling of the device to avoid damage due to overheating. When calculating the power loss inside the device, the output current and the quiescent currents need to be considered.

For example, if the device uses a supply voltage of 1000V, the output voltage to a resistive load is 500V and the output current is 50mA, the power loss inside the device is calculated as follows:

$$P_{DEVICE} = (1000V - 500V) \cdot (50 + 4)mA = 27W$$

In the above example, the device will dissipate 27W of heat. If we supply 1500V instead of 1000V, the power dissipation of the device doubles, resulting in a loss of 54W.

As alternative to extensive device cooling, it should be considered to alter the supply voltage of the device. If the PA99 is used in a test environment where is needs to drive 50mA at 500V but 5mA at 2000V, consider supplying two voltages, i.e. 1000V and 2500V, and provide for sufficient cooling for the approximate 30W of power dissipation of the device.



# **OVERVOLTAGE PROTECTION**

Although the PA99 can withstand differential input voltages up to  $\pm 20V$ , additional external protection is recommended. In most applications 1N4148 signal diodes connected anti-parallel across the input pins are sufficient. In more demanding applications where bias current is important diode connected JFETs such as 2N4416 will be required. In either case the differential input voltage will be clamped to  $\pm 0.7V$ . This is usually sufficient overdrive to produce the maximum power bandwidth.

# **CURRENT LIMIT**

PA99 allows independent setting of a positive and negative current limit.

## **POSITIVE CURRENT LIMIT**

The resistor value  $R_{IIM+}$  for positive current limit is calculated as follows:

 $R_{LIM}(\Omega) = \frac{0.65V}{I_{LIM}(A)}$ 

## **NEGATIVE CURRENT LIMIT**

The current limit resistor for the negative current limit can be approximated as:

$$R_{LIM}(\Omega) = 5324 \times e^{76.4 \times I_{LIM}}(A)$$

Negative Current Limit	Measured Resistor Value (R <sub>LIM-</sub> )
5mA	8 kΩ
10mA	15 kΩ
20mA	33 kΩ
40mA	92 kΩ

## TEMPERATURE SENSING

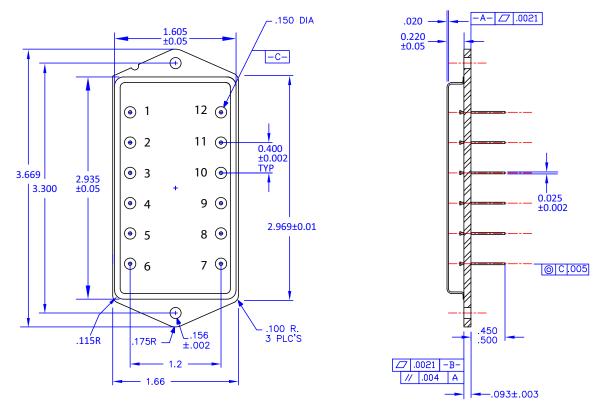
The temperature sensing pins of the PA99 are connected to a 1N4448 type of diode that can be used to sense the temperature inside the device. A typical application will use a current source as the best means for the excitation of the diode.



# **PACKAGE OPTIONS**

Part Number	Apex Package Style	Description
PA99	CW	12-pin Power DIP, High Voltage
PA99A	CW	12-pin Power DIP, High Voltage

#### PACKAGE STYLE CW



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