

## High Voltage Power Operational Amplifiers



### FEATURES

- High Voltage — 450V ( $\pm 225V$ )
- High Slew Rate — 1000V/ $\mu s$
- High Output Current — 200mA
- 500 kHz Power Bandwidth



### APPLICATIONS

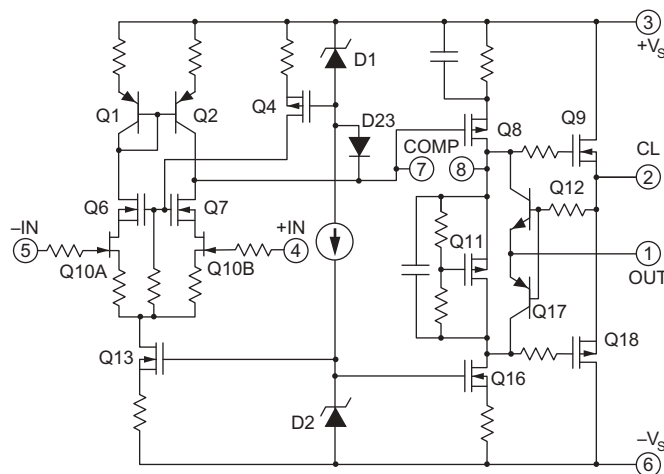
- High Voltage Instrumentation
- Piezo Transducer Excitation
- Programmable Power Supplies up to 430V
- Electrostatic Transducers & Deflection

### DESCRIPTION

The PA85 is a high voltage, high power bandwidth MOSFET operational amplifier designed for output currents up to 200mA. Output voltages can swing up to  $\pm 215V$  with a dual supply and up to +440V with a single supply. The safe operating area (SOA) has no second breakdown limitations and can be observed with all types of loads by choosing an appropriate current limiting resistor. High accuracy is achieved with a cascode input circuit configuration. All internal biasing is referenced to a bootstrapped zener-MOSFET current source. As a result, the PA85 features an unprecedented supply range and excellent supply rejection. The MOSFET output stage is biased on for linear operation. External compensation provides user flexibility.

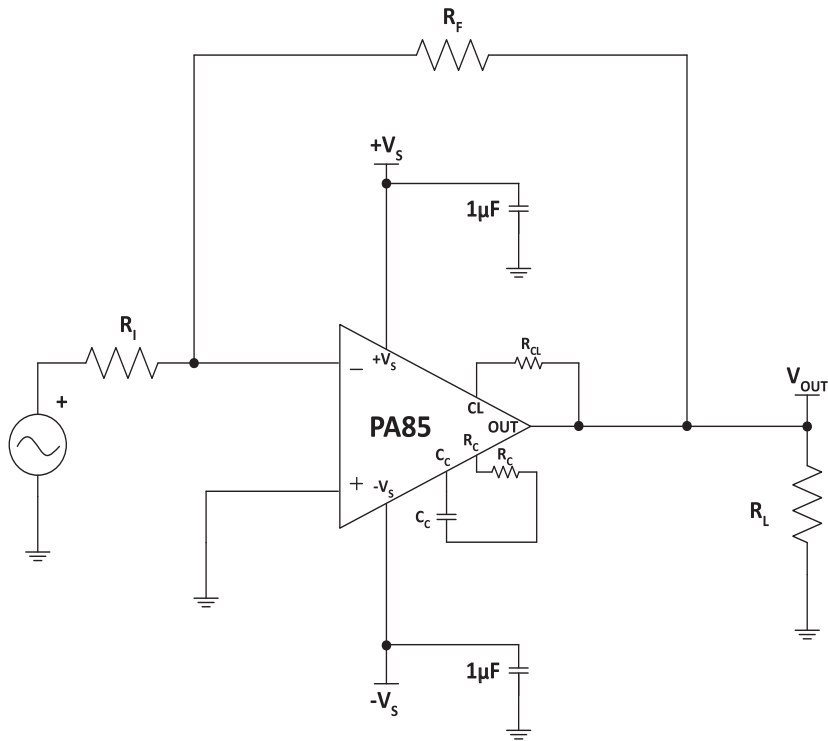
This hybrid circuit utilizes thick film (cermet) resistors, ceramic capacitors and silicon semiconductor chips to maximize reliability, minimize size and give top performance. Ultrasonically bonded aluminum wires provide reliable interconnections at all operating temperatures. The 8-pin TO-3 package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

**Figure 1: Equivalent Schematic**



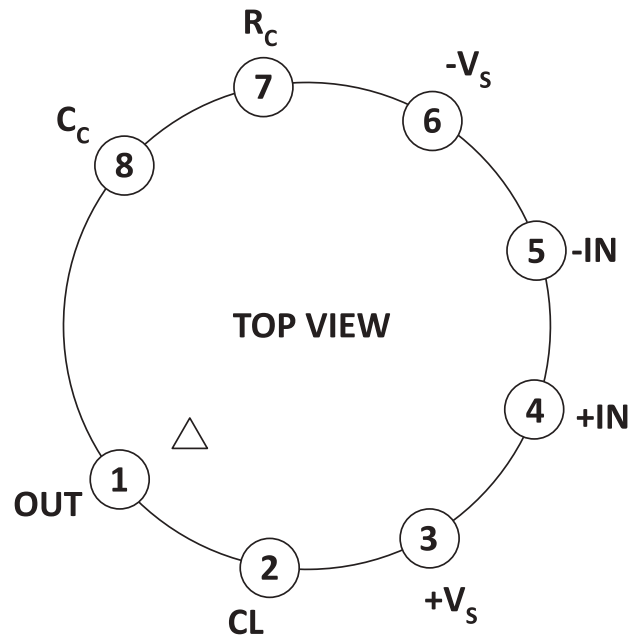
TYPICAL CONNECTION

Figure 2: Typical Connection



**PINOUT AND DESCRIPTION TABLE**

Figure 3: External Connections



Pin Number	Name	Description
1	OUT	The output. Connect this pin to load and to the feedback resistors.
2	CL	Connect to the current limit resistor, and then the OUT pin. Output current flows into/out of this pin through $R_{CL}$ .
3	+V <sub>S</sub>	The positive supply rail.
4	+IN	The non-inverting input.
5	-IN	The inverting input.
6	-V <sub>S</sub>	The negative supply rail.
7	R <sub>C</sub>	Compensation resistor connection. Select value based on Phase Compensation. See applicable section.
8	C <sub>C</sub>	Compensation capacitor connection. Select value based on Phase Compensation. See applicable section.

**SPECIFICATIONS**

Unless otherwise noted:  $T_c = 25^\circ\text{C}$ , compensation =  $C_c = 68\text{pF}$ ,  $R_c = 100 \Omega$ . DC input specifications are  $\pm$  value given. Power supply voltage is typical rating.

Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Units
Supply Voltage, total	$+V_s$ to $-V_s$		450	V
Output Current, continuous within SOA	$I_{OUT}$		200	mA
Power Dissipation, continuous @ $T_c = 25^\circ\text{C}$	$P_D$		30	W
Input Voltage, differential	$V_{IN(Diff)}$	-25	+25	V
Input Voltage, common mode	$V_{CM}$	$-V_s$	$+V_s$	V
Temperature, pin solder, 10s max.			350	$^\circ\text{C}$
Temperature, junction <sup>1</sup>	$T_J$		150	$^\circ\text{C}$
Temperature Range, storage		-65	+150	$^\circ\text{C}$
Operating Temperature Range, case	$T_c$	-55	+125	$^\circ\text{C}$

1. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF. Ratings apply only to output transistors. An additional 10W may be dissipated due to quiescent power.

The PA85 is constructed from MOSFET transistors. ESD handling procedures must be observed. 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  $850^\circ\text{C}$  to avoid generating toxic fumes.

**CAUTION**

**INPUT**

Parameter	Test Conditions	PA85			PA85A			Units
		Min	Typ	Max	Min	Typ	Max	
Offset Voltage, initial			0.5	2		0.25	0.5	mV
Offset Voltage vs. temperature	Full temp range		10	30		5	10	$\mu\text{V}/^\circ\text{C}$
Offset Voltage vs. supply			3	10		*	*	$\mu\text{V}/\text{V}$
Offset Voltage vs. time			75			*		$\mu\text{V}/\text{V}/\text{kh}$
Bias Current, initial <sup>1</sup>			5	50		3	10	$\mu\text{A}$
Bias Current vs. supply			0.01			*		$\mu\text{A}/\text{V}$
Offset Current, initial <sup>1</sup>			10	100		3	30	$\mu\text{A}$
Input Impedance, DC			$10^{11}$			*		$\Omega$
Input Capacitance			4			*		pF
Common Mode Voltage Range <sup>2</sup>		$\pm V_S - 15$			*			V
Common Mode Rejection, DC	$V_{CM} = \pm 90\text{V}$	90	110		*	*		dB
Noise	100 kHz BW, $R_S = 1\text{ k}\Omega$ , $C_C = 10\text{pF}$		1			*		$\mu\text{V}_{\text{rms}}$

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

2.  $+V_S$  and  $-V_S$  denote the positive and negative power supply rail respectively.

**GAIN**

Parameter	Test Conditions	PA85			PA85A			Units
		Min	Typ	Max	Min	Typ	Max	
Open Loop, @ 15 Hz	$R_L = 2\text{ k}\Omega$ , $C_C = \text{Open}$	96	111		*	*		dB
Gain Bandwidth Product @ 1 MHz	$R_L = 2\text{ k}\Omega$ , $C_C = 3.3\text{pF}$		100			*		MHz
Power Bandwidth	$C_C = 10\text{pF}$		300			*		kHz
	$C_C = 3.3\text{pF}$		500			*		kHz
Phase Margin	Full temp range		60			*		°

**OUTPUT**

Parameter	Test Conditions	PA85			PA85A			Units
		Min	Typ	Max	Min	Typ	Max	
Voltage Swing <sup>1</sup>	I <sub>OUT</sub> = ±200mA	±V <sub>S</sub> -10	±V <sub>S</sub> -6.5		*	*		V
Voltage Swing <sup>1</sup>	I <sub>OUT</sub> = ±75mA	±V <sub>S</sub> -8.5	±V <sub>S</sub> -6.0		*	*		V
Voltage Swing <sup>1</sup>	I <sub>OUT</sub> = ±20mA	±V <sub>S</sub> -8.0	±V <sub>S</sub> -5.5		*	*		V
Current, continuous	T <sub>C</sub> = 85°C	±200			*			mA
Slew Rate, A <sub>V</sub> = 20	C <sub>C</sub> = 10pF		400			*		V/μs
Slew Rate, A <sub>V</sub> = 100	C <sub>C</sub> = open		1000		700	*		V/μs
Capacitive Load, A <sub>V</sub> = +1	Full temp range	470			*			pf
Settling Time to 0.1%	C <sub>C</sub> =10pF, 2V step		1			*		μs
Resistance, no load	R <sub>CL</sub> = 0		50			*		Ω

1. +V<sub>S</sub> and -V<sub>S</sub> denote the positive and negative power supply rail respectively.

**POWER SUPPLY**

Parameter	Test Conditions	PA85			PA85A			Units
		Min	Typ	Max	Min	Typ	Max	
Voltage <sup>1</sup>	Full temp range	±15	±150	±225	*	*	*	V
Current, quiescent			21	25		*	*	mA

1. Derate max supply rating 0.625 V/°C below 25°C case. No derating needed above 25°C case.

**THERMAL**

Parameter	Test Conditions	PA85			PA85A			Units
		Min	Typ	Max	Min	Typ	Max	
Resistance, AC, junction to case <sup>1</sup>	Full temp range, F > 60 Hz			2.5			*	°C/W
Resistance, DC, junction to case	Full temp range, F < 60 Hz			4.2			*	°C/W
Resistance, junction to air	Full temp range		30			*		°C/W
Temperature Range, case	Meets full range specifications	-25		+85	*		*	°C

1. Rating applies if the output current alternates between both output transistors at a rate faster than 60 Hz.

**Note:** \* The specification of PA85A is identical to the specification for PA85 in applicable column to the left.

TYPICAL PERFORMANCE GRAPHS

Figure 4: Power Derating

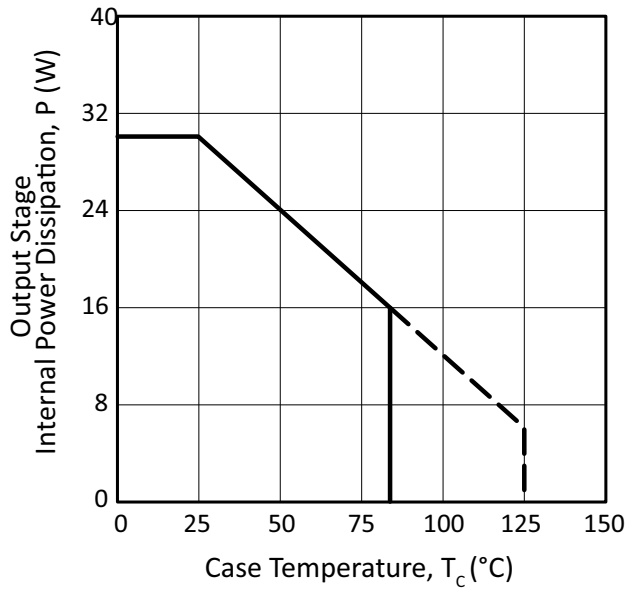


Figure 5: Quiescent Current

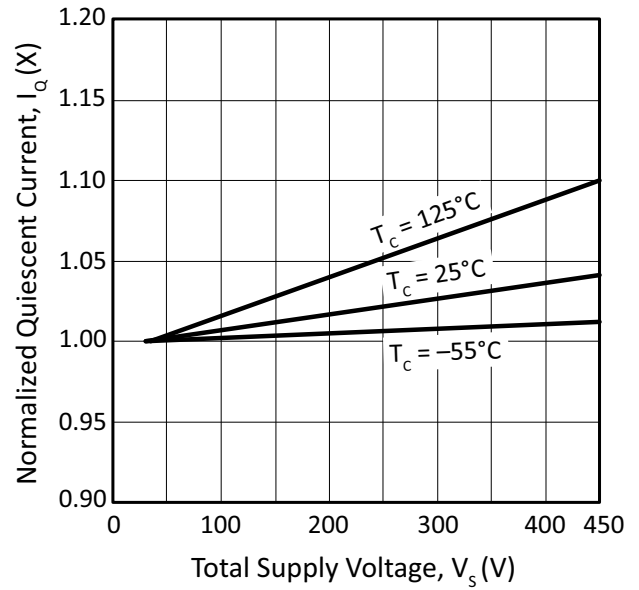


Figure 6: Small Signal Response

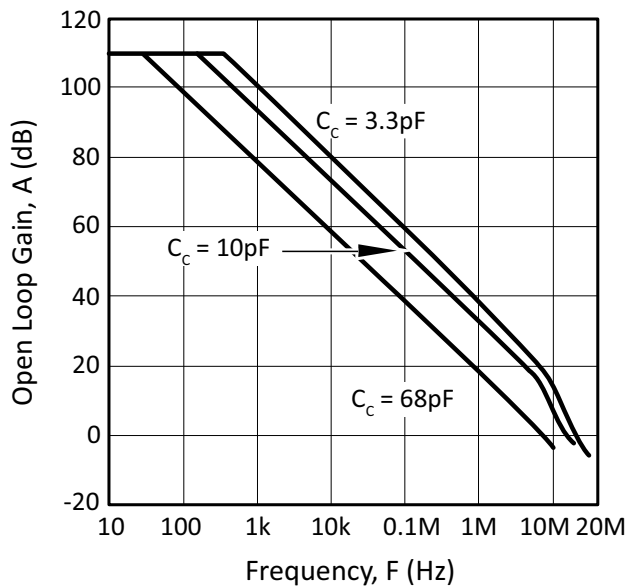


Figure 7: Phase Response

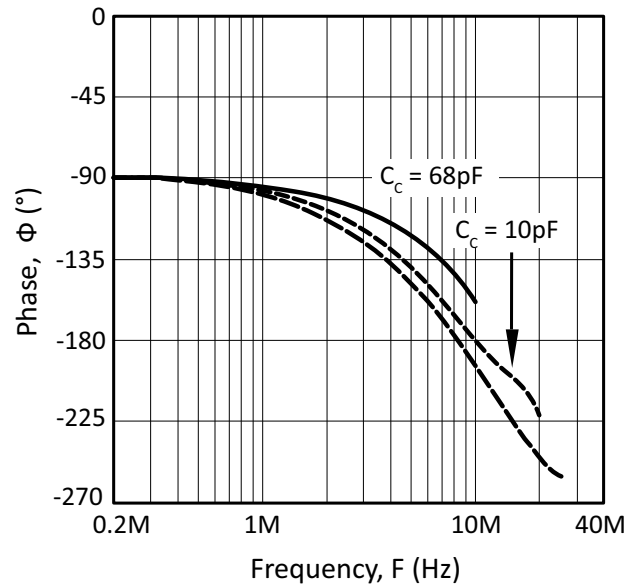


Figure 8: Output Voltage Swing

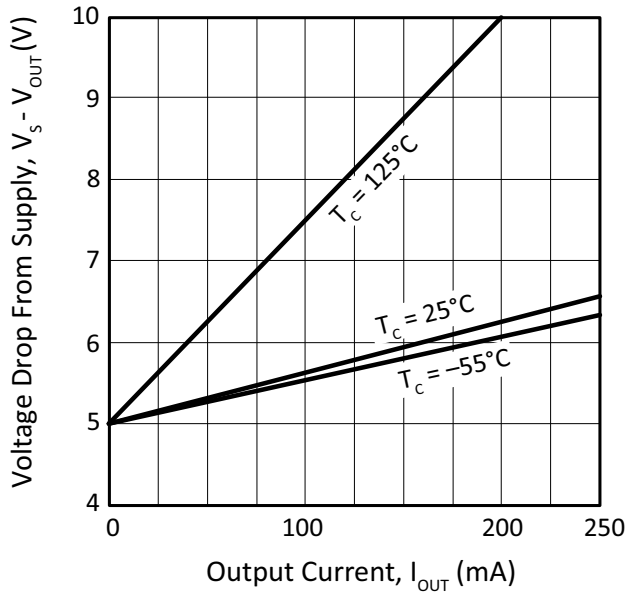


Figure 9: Power Response

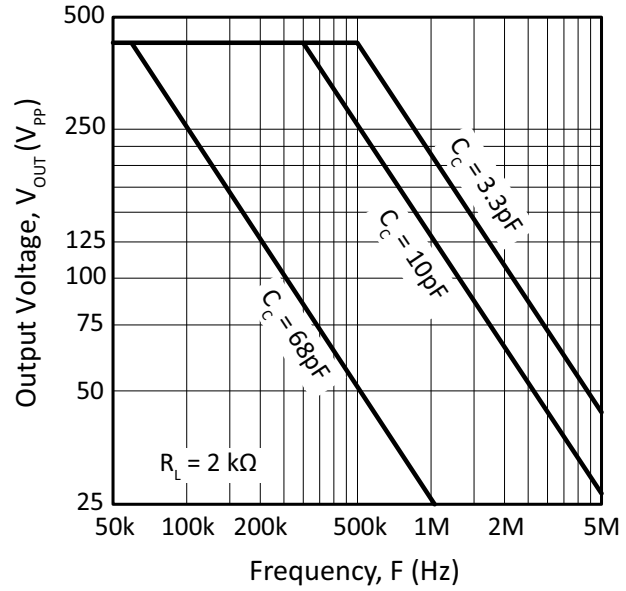


Figure 10: Slew Rate

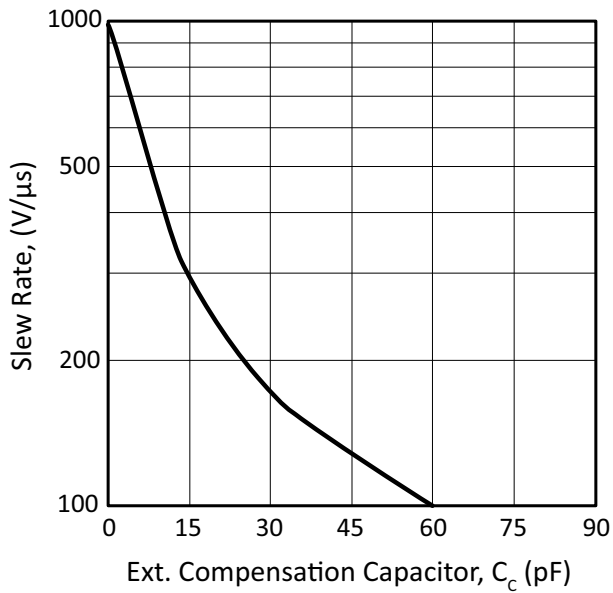


Figure 11: Harmonic Distortion

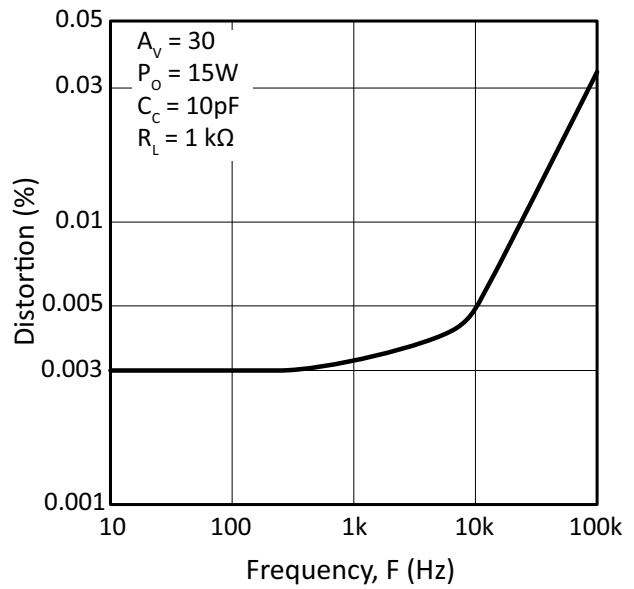




Figure 12: Input Noise Voltage

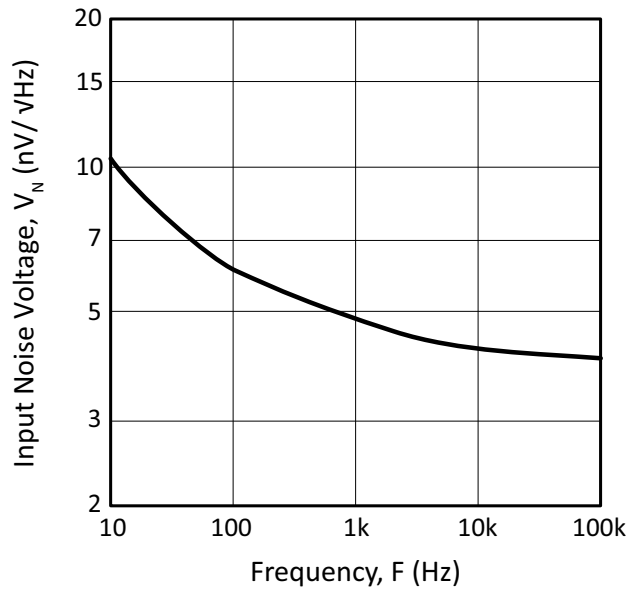


Figure 13: Common Mode Rejection

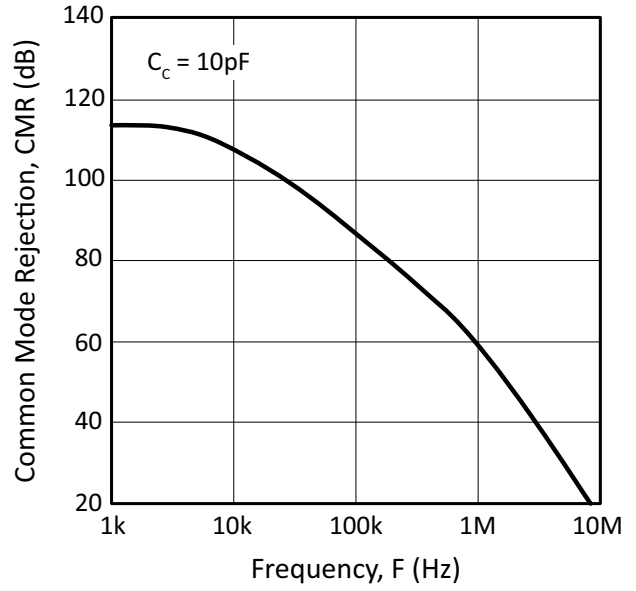


Figure 14: Power Supply Rejection

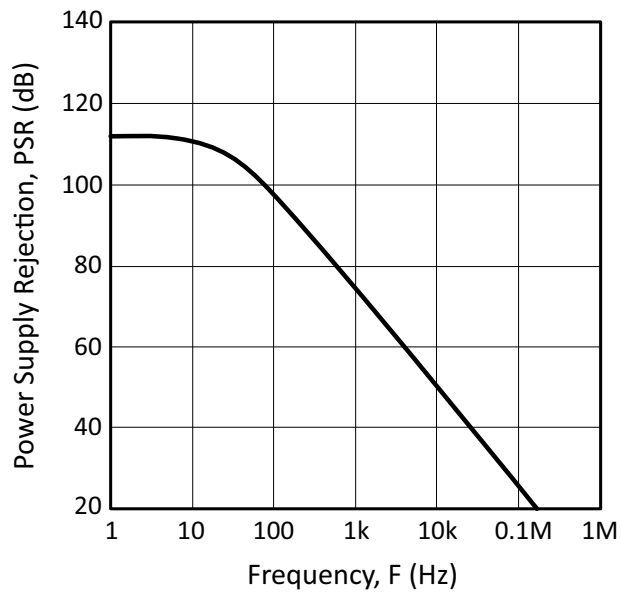
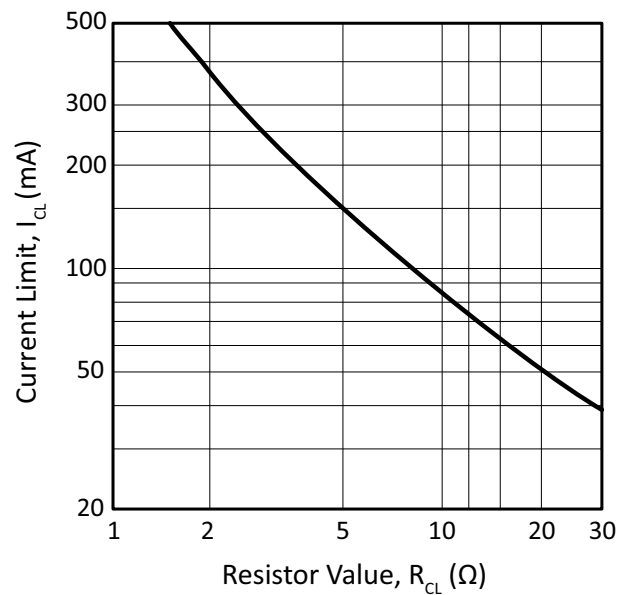


Figure 15: Current Limit



**SAFE OPERATING AREA (SOA)**

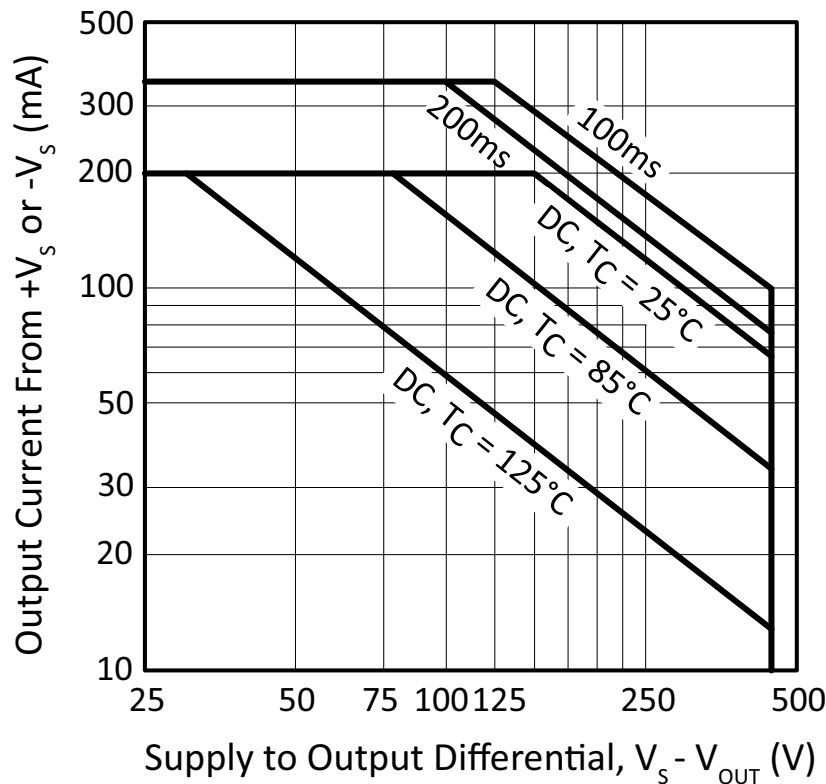
The safe operating area curves define the maximum additional internal power dissipation the amplifier can tolerate when it produces the necessary output to drive an external load. This is not the same as the absolute maximum internal power dissipation listed elsewhere in the specification since the quiescent power dissipation is significant compared to the total.

The MOSFET output stage of this power operational amplifier has two distinct limitations:

1. The current handling capability of the MOSFET geometry and the wire bonds.
2. The junction temperature of the output MOSFETs.

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

Figure 16: SOA



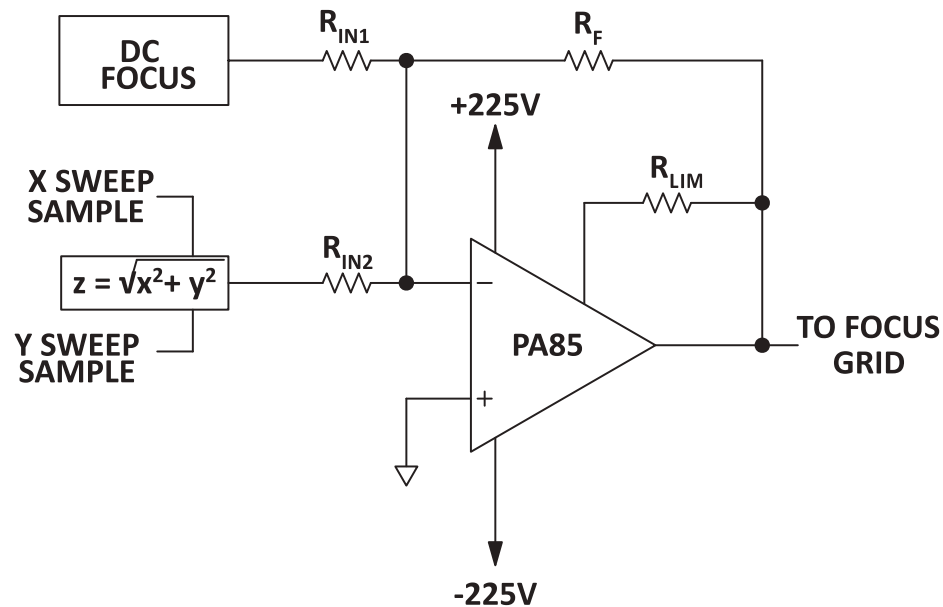
## GENERAL

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](http://www.apexanalog.com) for Apex Microtechnology’s complete Application Notes library, Technical Seminar Workbook, and Evaluation Kits.

## TYPICAL APPLICATION

Dynamic focusing is the active correction of focusing voltage as a beam traverses the face of a CRT. This is necessary in high resolution flat face monitors since the distance between cathode and screen varies as the beam moves from the center of the screen to the edges. PA85 lends itself well to this function since it can be connected as a summing amplifier with inputs from the nominal focus potential and the dynamic correction. The nominal might be derived from a potentiometer, or perhaps automatic focusing circuitry might be used to generate this potential. The dynamic correction is generated from the sweep voltages by calculating the distance of the beam from the center of the display.

Figure 17: Typical Application



## PHASE COMPENSATION

Gain	C <sub>C</sub> *	R <sub>C</sub>
1	68pF	100 Ω
20	10pF	330 Ω
100	3.3pF	0 Ω

\*C<sub>C</sub> rated for full supply voltage.

### CURRENT LIMIT

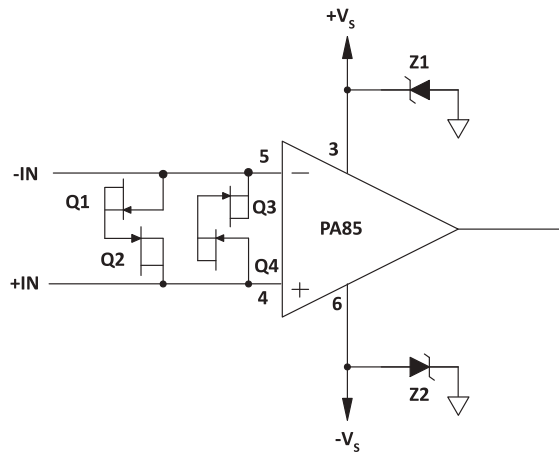
For proper operation, the current limit resistor ( $R_{CL}$ ) must be connected as shown in the typical connection diagram. The minimum value is 1.4  $\Omega$ , however for optimum reliability the resistor value should be set as high as possible. The value is calculated as follows; with the maximum practical value of 30 ohms.

$$R_{CL}(\Omega) = \frac{0.7V}{I_{CL} - 0.016(A)}$$

### INPUT PROTECTION

Although the PA85 can withstand differential voltages up to  $\pm 25V$ , additional external protection is recommended. Since the PA85 is a high speed amplifier, low leakage, low capacitance JFETs connected as diodes are recommended (e.g. 2N4416, Q1-Q4 in Figure 17). The differential input voltage will be clamped to  $\pm 1.4V$ . This is sufficient overdrive to produce maximum power bandwidth.

Figure 18: Overvoltage Protection



### POWER SUPPLY PROTECTION

Unidirectional transient voltage suppressors diodes are recommended as protection on the supply pins. The diodes clamp transients to voltages within the power supply rating and also clamp power supply reversals to ground. Whether the diodes are used or not, the system power supply should be evaluated for transient performance including power-on overshoot and power-off polarity reversals as well as line regulation.

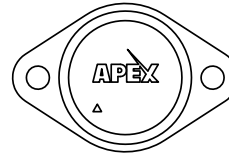
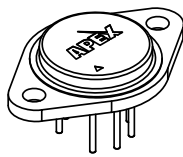
Conditions which can cause open circuits or polarity reversals on either power supply rail should be avoided or protected against. Reversals or opens on the negative supply rail are known to induce input stage failure. Unidirectional TVS diodes prevent this, and it is desirable that they be both electrically and physically as close to the amplifier as possible.

### STABILITY

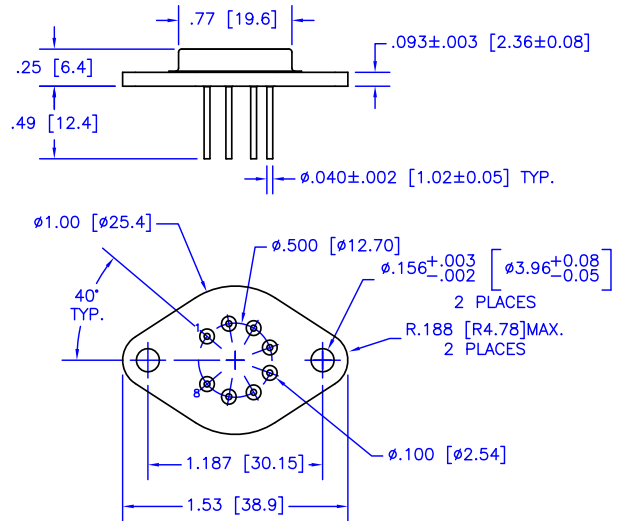
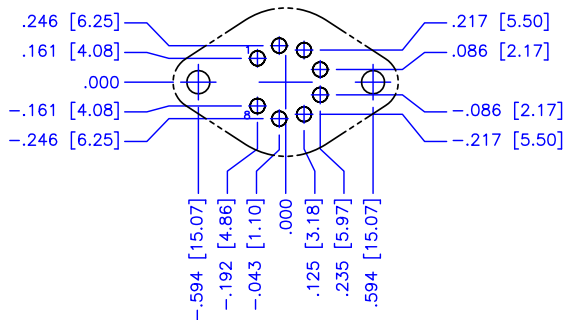
The PA85 is externally compensated and performance can be tailored to the application. Use the graphs of small signal response and power response as a guide. The compensation capacitor  $C_C$  must be rated at 500V working voltage. An NPO capacitor is recommended. The compensation network  $C_C R_C$  must be mounted closely to the amplifier pins 7 and 8 to avoid spurious oscillation.

**PACKAGE OPTIONS**

**PACKAGE STYLE CE**



**Ordinate dimensions for CAD layout**



**NOTES:**

1. Dimensions are inches & [mm].
2. Triangle printed on lid denotes pin 1.
3. Header flatness within pin circle is .0005" TIR, max.
4. Header flatness between mounting holes is .0015" TIR, max.
5. Standard pin material: Solderable nickel-plated Alloy 52.
6. Header material: Nickel-plated cold-rolled steel.
7. Welded hermetic package seal
8. Isolation: 500 VDC any pin to case.
9. Package weight: .53 oz [15 g]

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