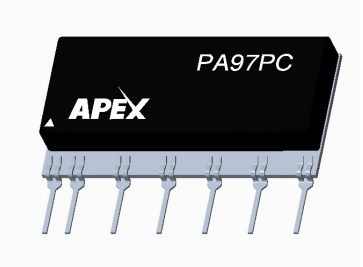
# PA97

## *Power Operational Amplifiers*

RoHS COMPLIANT

### FEATURES

- High Voltage — 900V (±450V)
- Low Quiescent Current — 600µA
- High Output Current — 10mA



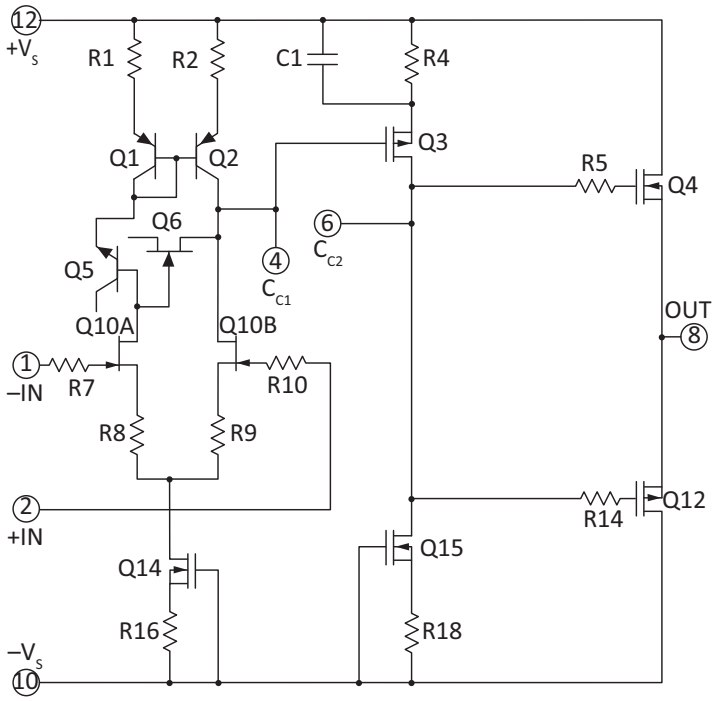

### APPLICATIONS

- Mass Spectrometers
- Scanning Coils
- High Voltage Instrumentation
- Programmable Power Supplies up to 880V
- Semiconductor Measurement Equipment

### DESCRIPTION

The PA97 is a high voltage MOSFET operational amplifier designed as a low cost solution for driving continuous output currents up to 10mA and pulse currents to 15mA into capacitive loads. The safe operating area (SOA) has no second breakdown limitations. The MOSFET output stage is biased class C for low quiescent current operation. External compensation provides flexibility in choosing bandwidth and slew rate for the application. Apex Microtechnology's 7-pin SIP package uses a minimum of board space allowing for high density circuit boards.

**Figure 1: Equivalent Schematic**

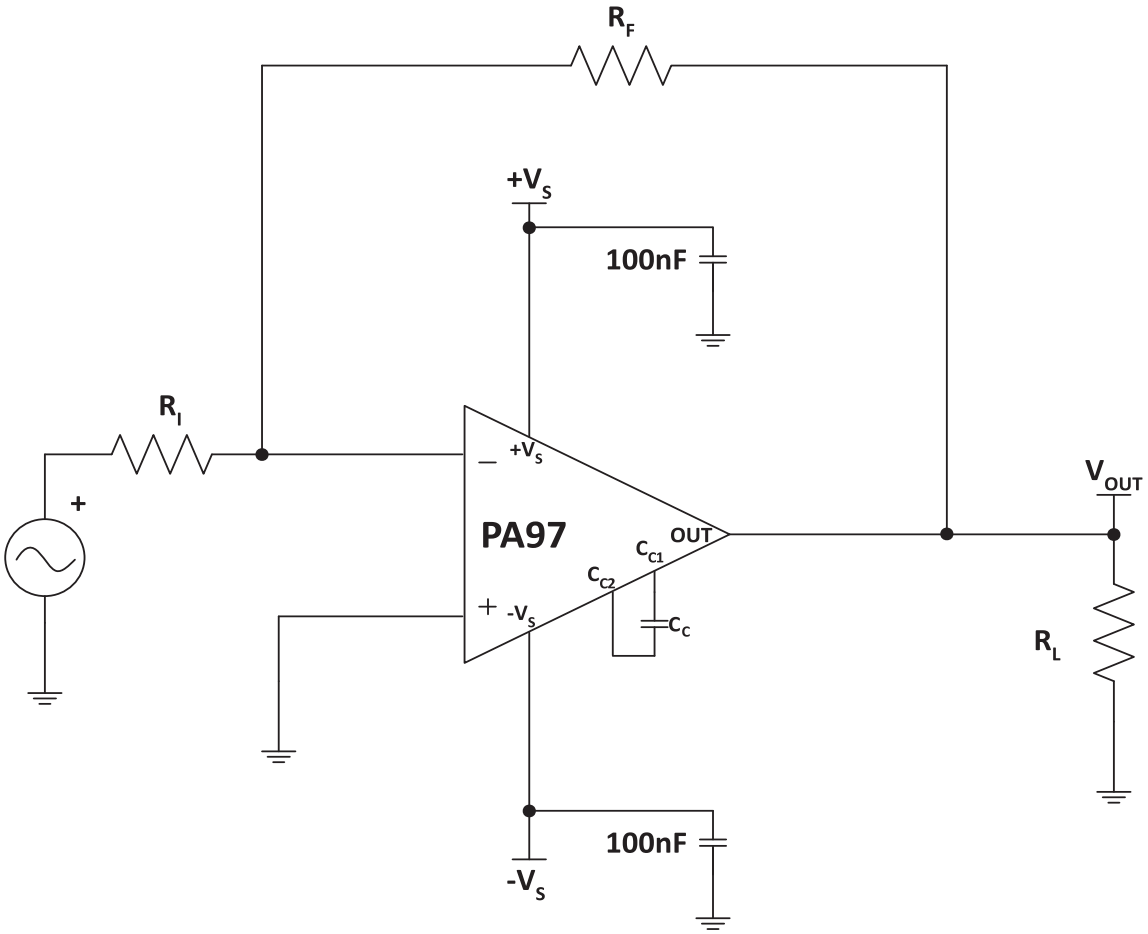




© Apex Microtechnology Inc.
All rights reserved

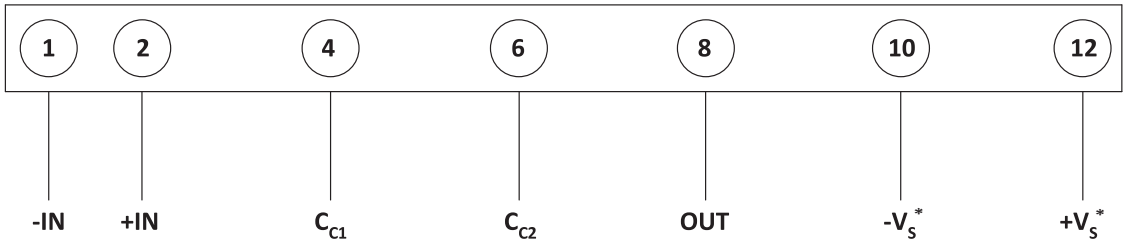
## TYPICAL CONNECTION

**Figure 2: Typical Connection**



## PINOUT AND DESCRIPTION TABLE

**Figure 3: External Connections**




* 0.01µF or greater ceramic power supply bypassing required. $C_C$ = 10pF minimum, 1kV NPO (COG).

| Pin Number | Name | Description |
|---|---|---|
| 1 | -IN | The inverting input. |
| 2 | +IN | The non-inverting input. |
| 4,6 | $C_C$ | Compensation capacitor connection. Select value based on Phase Compensation. See applicable section. |
| 8 | OUT | The output. Connect this pin to load and to the feedback resistors. |
| 10 | $-V_S$ | The negative supply rail. |
| 12 | $+V_S$ | The positive supply rail. |

## SPECIFICATIONS

Unless otherwise noted: $T_C$ = 25°C, DC input specifications are ± value given. Power supply voltage is typical rating. $C_C$ = 10pF.

### *ABSOLUTE MAXIMUM RATINGS*

| Parameter | Symbol | Min | Max | Units |
|---|---|---|---|---|
| Supply Voltage, $+V_S$ To $-V_S$ | $+V_S$ to $-V_S$ | | 900 | V |
| Output Current, source, sink, peak, within SOA | $I_{OUT}$ | | 15 | mA |
| Power Dissipation, continuous @ $T_c$ = 25°C | $P_D$ | | 5 | W |
| Input Voltage, differential [1] | $V_{IN\ (Diff)}$ | -20 | 20 | V |
| Input Voltage, common mode (See Text) | $V_{CM}$ | $-V_S$ | $V_S$ | V |
| Temperature, pin solder, 10s max. | | | 220 | °C |
| Temperature, junction [2] | $T_J$ | | 150 | °C |
| Temperature Range, storage | | -65 | 150 | °C |
| Operating Temperature, case | $T_C$ | -55 | 125 | °C |

1. Although supply voltages can range up to ± 450V the input pins cannot swing over this range. The input pins must be at least 30V from either supply rail but not more than 500V from either supply rail. See text for a more complete description of the common mode voltage range.
2. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.

**CAUTION** The PA97 is constructed from MOSFET devices. ESD handling procedures must be observed.

### *INPUT*

| Parameter | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Offset Voltage, initial | | | 0.5 | 5 | mV |
| Offset Voltage vs. Temperature | Full temp range | | 10 | 50 | µV/°C |
| Offset Voltage vs. Supply | | | 10 | 25 | µV/V |
| Offset Voltage vs. Time | | | 75 | | µV/kh |
| Bias Current, initial | | | 200 | 2000 | pA |
| Bias Current vs. Supply | | | 4 | | pA/V |
| Offset Current, initial | | | 50 | 500 | pA |
| Input Impedance, DC | | | $10^{11}$ | | Ω |
| Input Capacitance | | | 4 | | pF |
| Common Mode Voltage Range [1] | $V_S$= ±250V | ±$V_S$ ∓ 30 | | | V |
| Common Mode Rejection, DC | $V_{CM}$ = ±90V | 80 | 98 | | dB |
| Noise | 100 kHz BW, $R_S$ = 1 kΩ, $C_C$ = 10pF | | 2 | | µVRMS |

1. Although supply voltages can range up to ± 450V the input pins cannot swing over this range. The input pins must be at least 30V from either supply rail but not more than 500V from either supply rail. See text for a more complete description of the common mode voltage range.

### *GAIN*

| Parameter | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Open Loop @ 15 Hz | $R_L$ = 5 kΩ, $C_C$ = 10pF | 94 | 111 | | dB |
| Gain Bandwidth Product @ 1 MHz | $R_L$ = 5 kΩ, $C_C$ = 10pF | | 1 | | MHz |
| Power Bandwidth | $R_L$ = 5 kΩ, $C_C$ = 10pF | | 2 | | kHz |
| Phase Margin, $A_V$ = 100 | Full temp range | | 60 | | ° |

### *OUTPUT*

| Parameter | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Voltage Swing | $I_{OUT}$ = 10mA | ±$V_S$ ∓ 24 | ±$V_S$ ∓ 20 | | V |
| Current, continuous | | 10 | | | mA |
| Slew Rate, $A_V$ = 100 | $C_C$ = 10pF | | 8 | | V/µs |
| Settling Time, to 0.1% | $C_C$ = 10pF, 2V step | | 2 | | µs |
| Resistance | 10mA Load | | 100 | | Ω |

### *POWER SUPPLY*

| Parameter | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Voltage [1] | | ±50 | ±300 | ±450 | V |
| Current, quiescent, amplifier only | | | 0.6 | 1 | 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 | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| Resistance, AC, junction to case [1] | Full temp range, F > 60 Hz | | | 20 | °C/W |
| Resistance, DC, junction to case | Full temp range, F < 60 Hz | | | 25 | °C/W |
| Resistance, junction to air | Full temp range | | 40 | | °C/W |
| Temperature Range, case | | -25 | | +85 | °C |

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

## TYPICAL PERFORMANCE GRAPHS

**Figure 4: Power Derating**

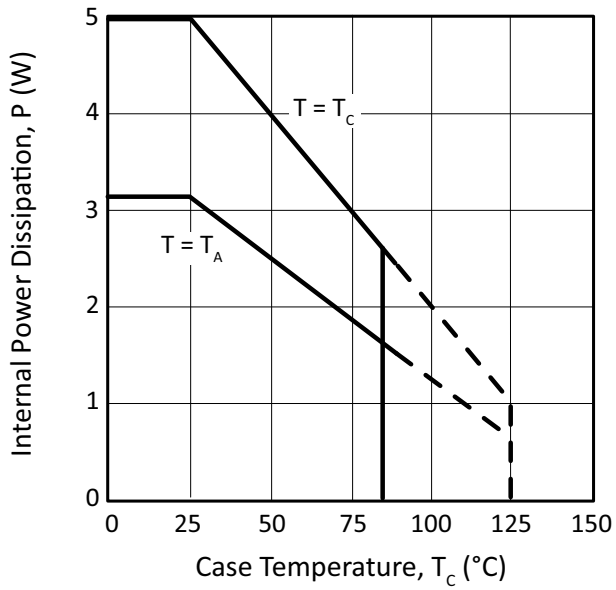



**Figure 5: Phase Response**

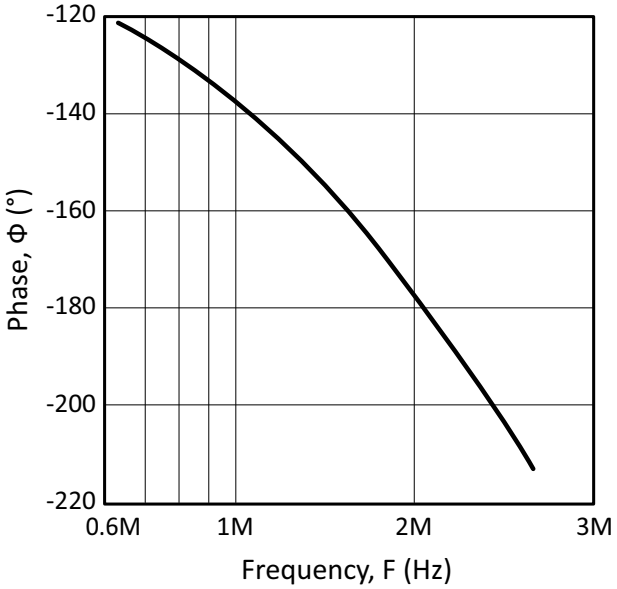



**Figure 6: Quiescent Current**

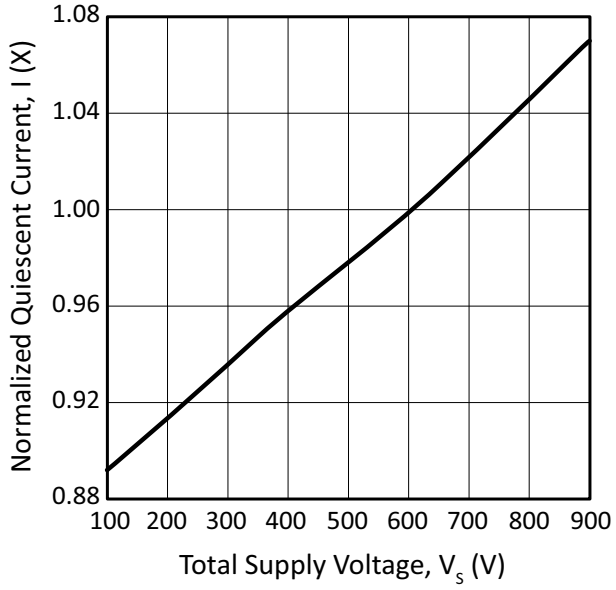



**Figure 7: Small Signal Response**

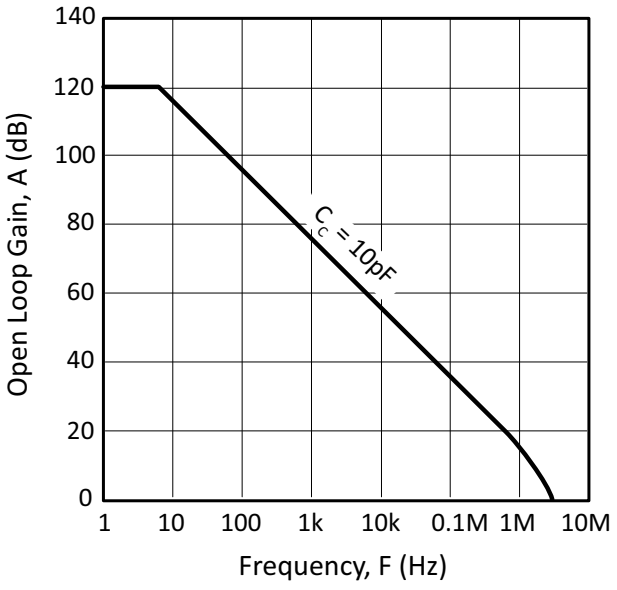


**Figure 8: Output Voltage Swing**

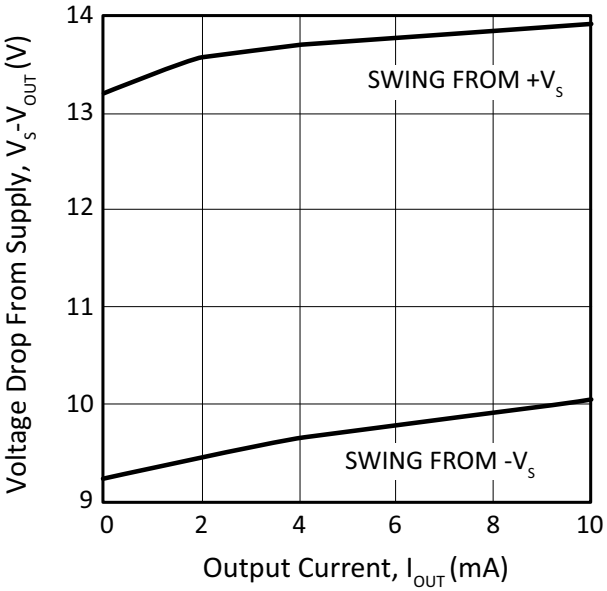



**Figure 9: Power Response**

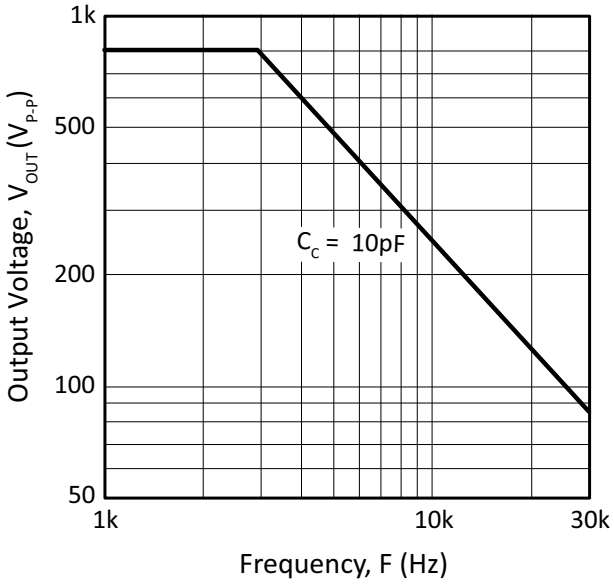
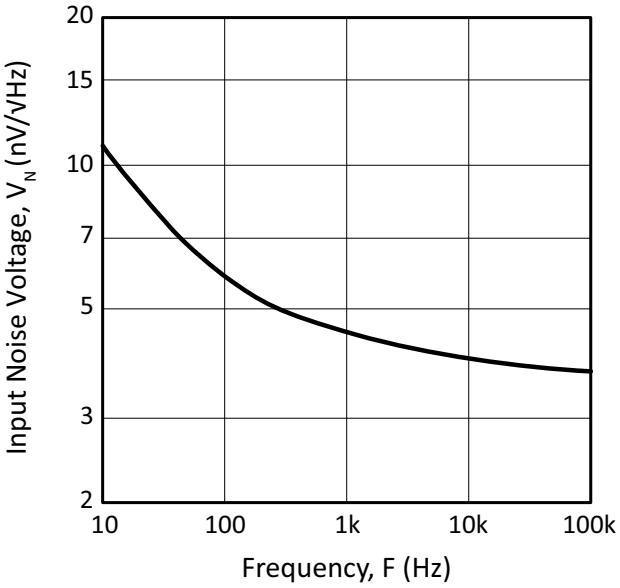
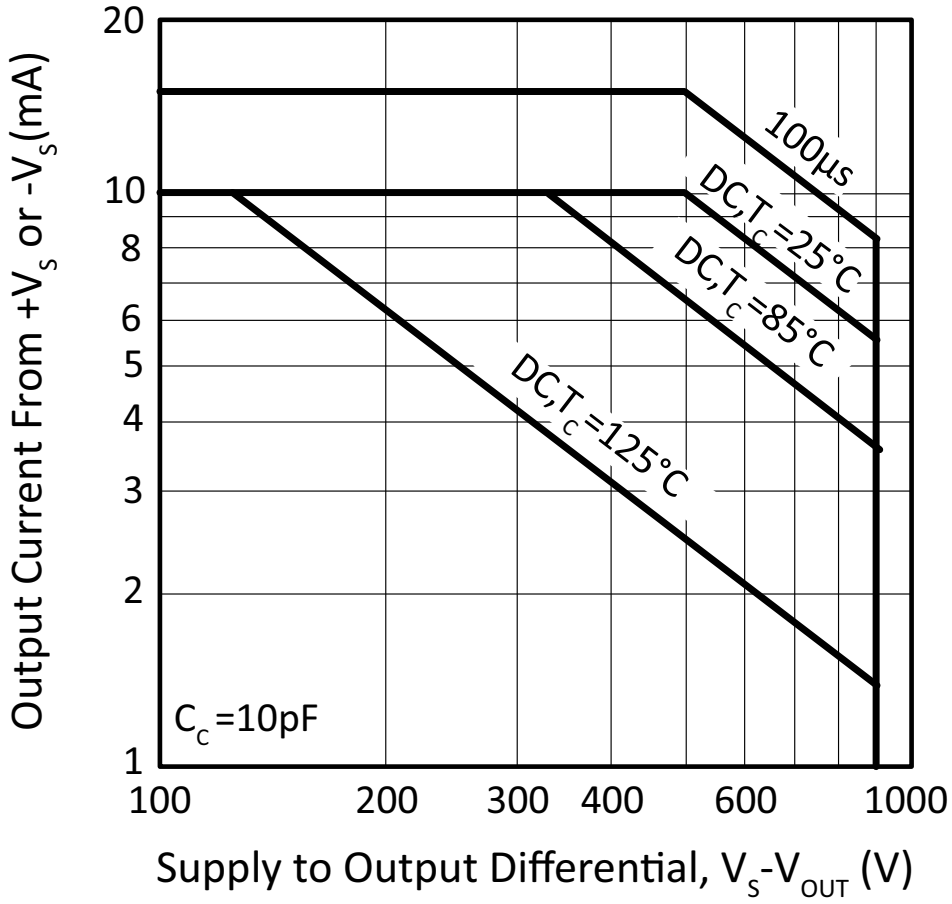



**Figure 10: Input Noise**



## SAFE OPERATING AREA (SOA)

**Figure 11: SOA**



## GENERAL

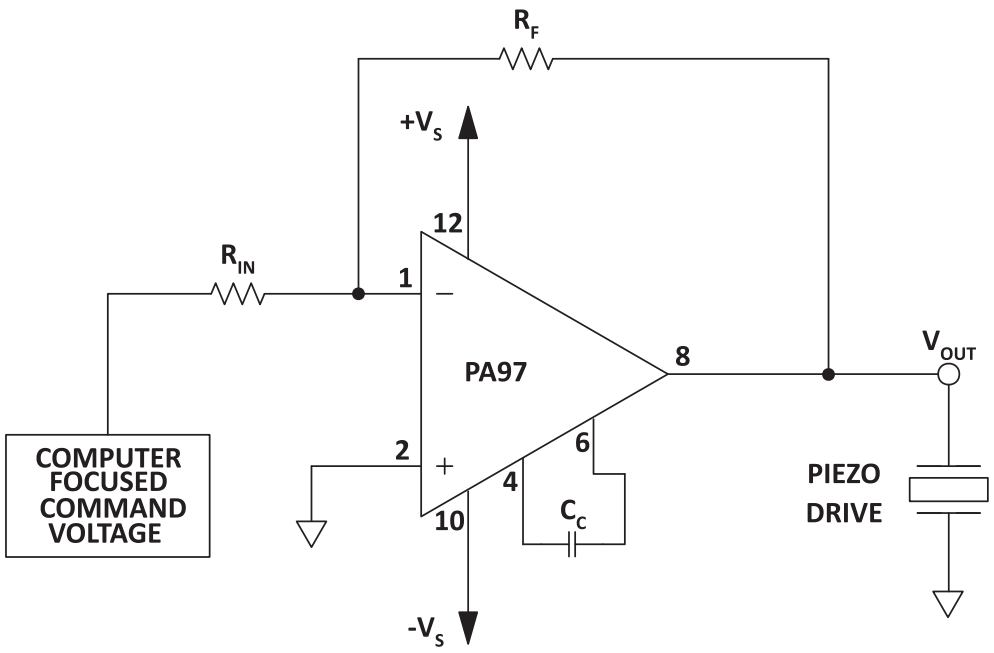
Please read Application Note 1 “General Operating Considerations” which covers stability, supplies, heat sinking, mounting, current limit, SOA interpretation, and specification interpretation. Visit www.apexanalog.com for Apex Microtechnology’s complete Application Notes library, Technical Seminar Workbook,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

## TYPICAL APPLICATION

### *LOW POWER, PIEZOELECTRIC POSITIONING*

Piezo positioning may be applied to the focusing of segmented mirror systems. The composite mirror may be composed of hundreds of elements, each requiring focusing under computer control. In such complex systems the PA97 reduces the costs of power supplies and cooling with its advantages of low cost and low quiescent power consumption while increasing circuit density with the SIP.

**Figure 12: Typical Application**




## PHASE COMPENSATION

| Gain | $C_C$ |
|---|---|
| ≥10 | 10pF |

## CURRENT LIMIT

The PA97 has no provision for current limiting the output.

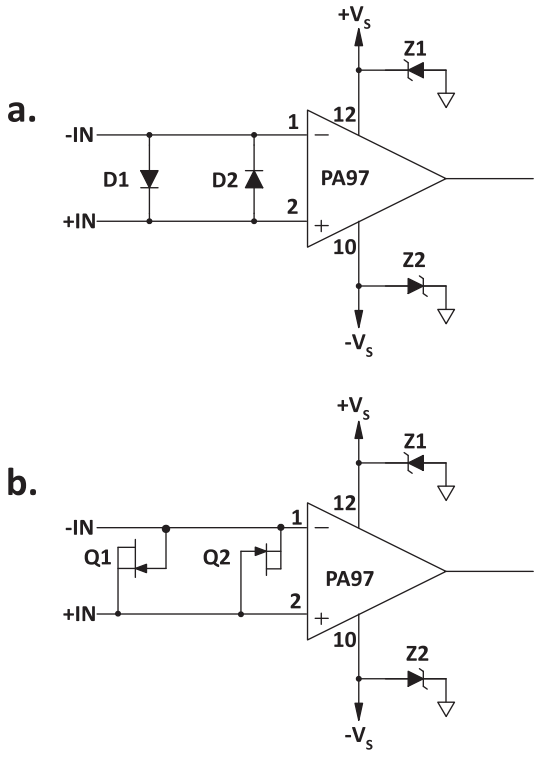
## COMMON MODE INPUT RANGE

Operational amplifiers are usually designed to have a common mode input voltage range that approximates the power supply voltage range. However, to keep the cost as low as possible and still meet the requirements of most applications the common mode input voltage range of the PA97 is restricted. The input pins must always be at least 30V from either supply voltage but never more than 500V. This means that the PA97 cannot be used in applications where the supply voltages are extremely unbalanced. For example, supply voltages of +800V and –100V would not be allowed in an application where the non-inverting pin is grounded because in normal operation both input pins would be at 0V and the difference voltage between the positive supply and the input pins would be 800V. In this kind of application, however, supply voltages +500V and -100V does meet the input common mode voltage range requirements since the maximum difference voltage between the inputs pins and the supply voltage is 500V (the maximum allowed). The output has no such restrictions on its voltage swing. The output can swing within 24V of either supply voltage regardless of value so long as the total supply voltage does not exceed 900V.

## INPUT PROTECTION

Although the PA97 can withstand differential input voltages up to ±20V, additional external protection is recommended. In most applications 1N4148 or 1N914 signal diodes are sufficient (D1, D2 in Figure 13a). In more demanding applications where low leakage or low capacitance are of concern 2N4416 or 2N5457-2N5459 JFETs connected as diodes will be required (Q1, Q2 in Figure 13b). In either case the input differential voltage will be clamped to ±.7V. This is sufficient overdrive to produce maximum power bandwidth. Note that this protection does not automatically protect the amplifier from excessive common mode input voltages.

**Figure 13: Input Protection**



## POWER SUPPLY PROTECTION

Unidirectional zener diode transient suppressors are recommended as protection on the supply pins. The zeners clamp transients to voltages within the power supply rating and also clamp power supply reversals to ground. Whether the zeners are used or not, the system power supply should be evaluated for transient performance including power-on overshoot and power-off polarity reversal 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 is known to induce input stage failure. Unidirectional transzorbs prevent this, and it is desirable that they be both electrically and physically as close to the amplifier as possible.

## EXTERNAL COMPONENTS

The compensation capacitor $C_C$ must be rated for the total supply voltage. 10pF NPO (COG) capacitor rated at 1kV is recommended.

Of equal importance is the voltage rating and voltage coefficient of the gain setting feedback resistor. Typical voltage ratings of low wattage resistors are 150 to 250V. Up to 900V can appear across the feedback resistor. High voltage rated resistors can be obtained. However a 1 MΩ feedback resistor composed of five 200 kΩ resistors in series will produce the proper voltage rating.

## CAUTIONS

The operating voltages of the PA97 are potentially lethal. During circuit design develop a functioning circuit at the lowest possible voltages. Clip test leads should be used for “hands off” measurements while troubleshooting. With no internal current limit, proper choice of load impedance and supply voltage is required to meet SOA limitations. An output short circuit will destroy the amplifier within milliseconds.

## STABILITY

The PA97 is stable at gains of 10 or more with a NPO (COG) compensation capacitor of 10pF. The compensation capacitor, $C_C$, in the external connections diagram must be rated at 1000V working voltage and mounted closely to pins 4 and 6 to prevent spurious oscillation. A compensation capacitor less than 10pF is not recommended.

## PACKAGE OPTIONS

| Part Number | Apex Package Style | Description |
|---|---|---|
| PA97PC | PC | 7-Pin SIP |
| PA97DR | DR | Not recommended for new design |

### *PACKAGE STYLE PC*

NOTES:
1. Dimensions are inches & [mm].
2. Triangle printed on lid denotes pin 1.
3. Pins: Alloy 510 phosphor bronze plated with matte tin (150 - 300µ") over nickel (50 µ" max.) underplate.
4. Package Material: Alumina substrate with plastic lid.
5. Package weight: 2.4 grams.
6. Epoxy sealed, non-hermetic package.
7. Drawing scale is 2X.