PA94

FEATURES

- **HIGH VOLTAGE — 900V (±450V)**
- **HIGH SLEW RATE — 500V/μS**
- **HIGH OUTPUT CURRENT — 100mA**
- **PROGRAMMABLE CURRENT LIMIT**

APPLICATIONS

- **HIGH VOLTAGE INSTRUMENTATION**
- **PROGRAMMABLE POWER SUPPLIES UP TO ±430V**
- **MASS SPECTROMETERS**
- **SEMICONDUCTOR MEASUREMENT EQUIPMENT**

DESCRIPTION

The PA94 is a high voltage, MOSFET operational amplifier designed as a low cost solution for driving continuous output currents up to 100mA and pulse currents up to 200mA into capacitive loads. The safe operating area (SOA) has no second breakdown limitations and can be observed for all load types by choosing an appropriate current limiting resistor. The MOSFET output stage is biased AB for linear operation. External compensation provides flexibility in choosing bandwidth and slew rate for the application. APEX's Power SIP04 package uses a minimum of board space allowing for high density circuit boards.. The Power SIP package is electrically isolated.
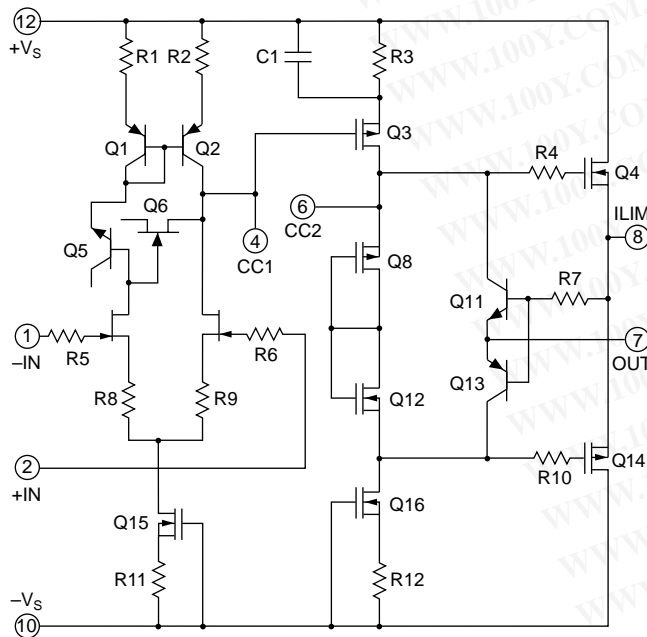
PATENT PENDING

**8-pin SIP**
PACKAGE STYLE DQ

TYPICAL APPLICATION

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 PA94 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 package.

EQUIVALENT SCHEMATIC

EXTERNAL CONNECTIONS

PACKAGE SIP04
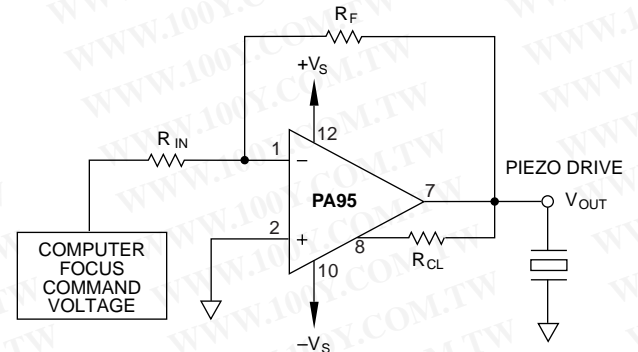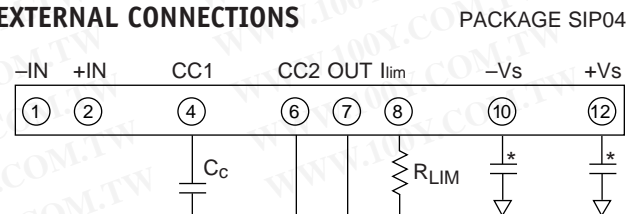
*   .01μF or greater ceramic power supply bypassing required.

PHASE COMPENSATION

GAIN	C_C
≥100	2.2pF
≥50	4.7pF
≥10	22pF

$$R_{LIM} = \frac{.7}{I_{LIM}}$$

ABSOLUTE MAXIMUM RATINGS

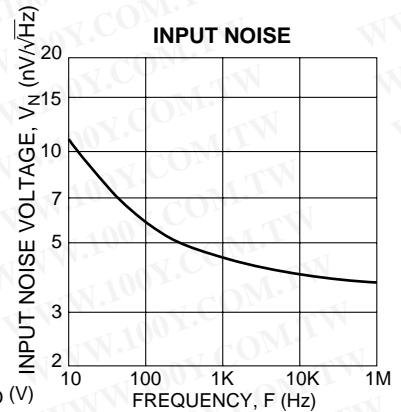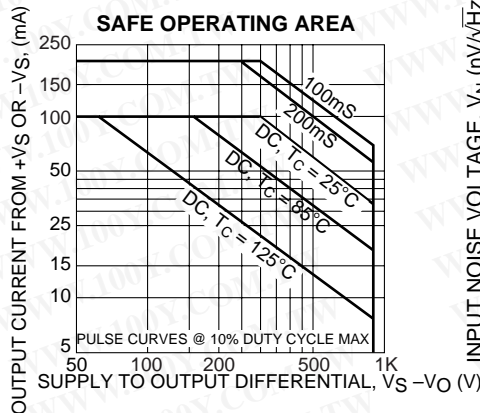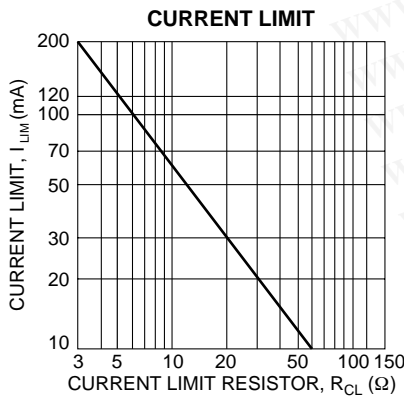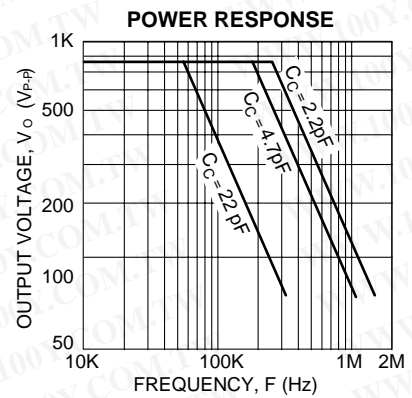|	
SUPPLY VOLTAGE, $+V_S$ to $-V_S$	900V
OUTPUT CURRENT, source, sink	200mA, within SOA
POWER DISSIPATION, continuous @ $T_C = 25°C$	30W
INPUT VOLTAGE, differential	±20V
INPUT VOLTAGE, common mode[3]	$±V_S$
TEMPERATURE, pin solder - 10s max.	260°C
TEMPERATURE, junction[2]	150°C
TEMPERATURE RANGE, storage	−40 to +85°C
OPERATING TEMPERATURE RANGE, case	−25 to +85°C

SPECIFICATIONS

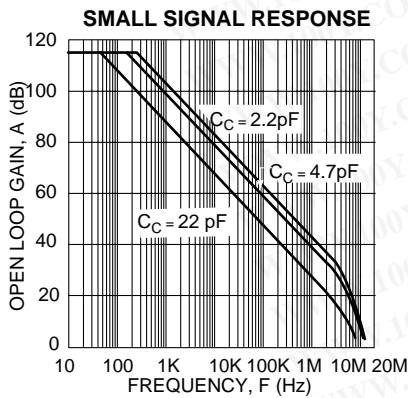| PARAMETER	TEST CONDITIONS [1]	MIN	TYP	MAX	UNITS
INPUT					
OFFSET VOLTAGE, initial			.5	5	mV
OFFSET VOLTAGE, vs. temperature	Full temperature range		15	50	μV/°C
OFFSET VOLTAGE, vs. supply			10	25	μV/V
OFFSET VOLTAGE, vs. time			75		μV/√kh
BIAS CURRENT, initial			200	2000	pA
BIAS CURRENT, vs. supply			4		pA/V
OFFSET CURRENT, initial			50	500	pA
INPUT IMPEDANCE, DC			10^{11}		Ω
INPUT CAPACITANCE			4		pF
COMMON MODE VOLTAGE RANGE[3]	Vs=±250V SEE NOTE 3	$±V_S \mp 30$			V
COMMON MODE REJECTION, DC	$V_{CM} = ±90V$	80	98		dB
NOISE	10KHz BW, $R_S = 1KΩ$		2		μVrms
GAIN					
OPEN LOOP, @ 15Hz	$R_L = 5KΩ$	94	115		dB
GAIN BANDWIDTH PRODUCT at 1MHz	$R_L = 5KΩ$		140		MHz
POWER BANDWIDTH	$R_L = 5KΩ$		300		kHz
PHASE MARGIN, Av=100	Full temperature range		60		°
OUTPUT					
VOLTAGE SWING	$I_O = 100mA$	$±V_S \mp 24$	$±V_S \mp 20$		V
CURRENT, continuous		100			mA
SLEW RATE, $A_V = 100$	$C_C = 2.2pF$	500	700		V/μs
SETTLING TIME to .1%	2V step		1		μs
RESISTANCE	no load		100		Ω
POWER SUPPLY					
VOLTAGE[5]	See note 5	±50	±300	±450	V
CURRENT, quiescent total			17	24	mA
CURRENT, quiescent output stage only				120	μA
THERMAL					
RESISTANCE, AC, junction to case[4]	Full temperature range, F > 60Hz			2.5	°C/W
RESISTANCE, DC, junction to case	Full temperature range, F < 60Hz			4.2	°C/W
RESISTANCE, junction to air	Full temperature range		30		°C/W
TEMPERATURE RANGE, case	Meets full range specifications	−25		+85	°C

NOTES:
1. Unless otherwise noted: $T_C = 25°C$, DC input specifications are ± value given. Power supply voltage is typical rating. $C_c = 4.7pF$.
2. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.
3. 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.
4. Rating applies if the output current alternates between both output transistors at a rate faster than 60Hz.
5. Derate max supply rating .625 V/°C below 25°C case. No derating needed above 25°C case.

CAUTION The PA94 is constructed from MOSFET transistors. ESD handling procedures must be observed.
The exposed substrate contains beryllia (BeO). Do not crush, machine, or subject to temperatures in excess of 850°C to avoid toxic fumes.

POWER DERATING

PHASE RESPONSE

QUIESCENT CURRENT

SMALL SIGNAL RESPONSE

OUTPUT VOLTAGE SWING

POWER RESPONSE

CURRENT LIMIT

SAFE OPERATING AREA

INPUT NOISE
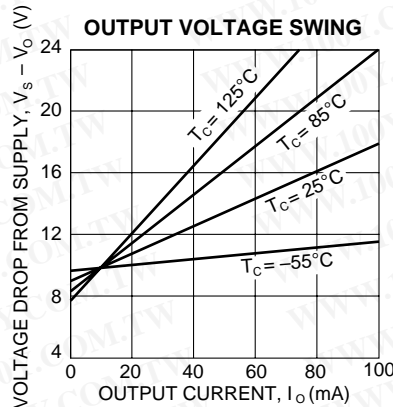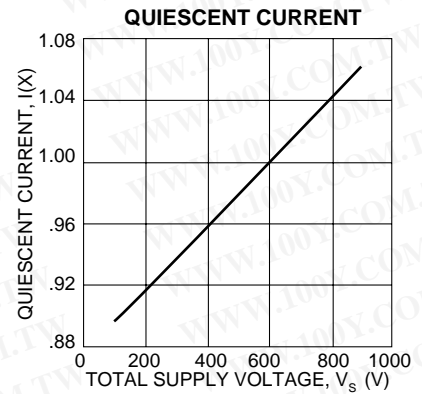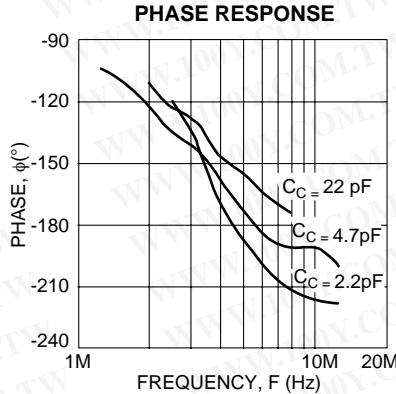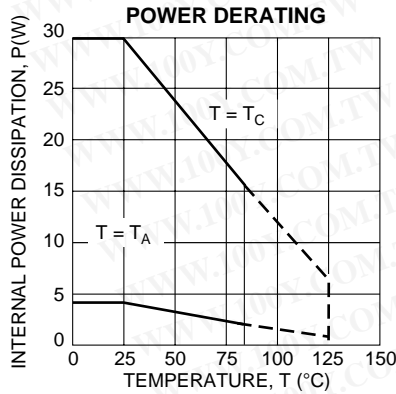
INTERNAL POWER DISSIPATION AND HEATSINK SELECTION

With the unique combination of high voltage and speed of the PA94, traditional formulas for heatsink selection will falsely lower the apparent power handling capability of this amplifier. To more accurately predict operating temperatures use Power Design[1] revision 10 or higher, or use the following procedure:

Find internal dissipation (PD) resulting from driving the load. Use Power Design or refer to Apex Applications Note 1, General Operating Considertaions, paragraph 7. Find total quiescent power (PD_Q) by multiplying 0.024A by V_{SS} (total supply voltage). Find output stage quiescent power (PD_{QOUT}) by multiplying 0.00012 by V_{SS}.

Calculate a heatsink rating which will maintain the case at 85°C or lower.

$$R_{\varnothing SA} = \frac{Tc - Ta}{PD + PD_Q} - 0.1°C/W$$

Where: T_C = maximum case temperature allowed
T_A = maximum ambient temperature encountered

Calculate a heatsink rating which will maintain output transistor junctions at 150°C or lower.

$$R_{\varnothing SA} = \frac{T_J - Ta - (PD + PD_{QOUT}) *R_{\varnothing JC}}{PD + PD_Q} - 0.1°C/W$$

Where: T_J = maximum junction temperature allowed.
$R_{\Delta JC}$ = AC or DC thermal resistance from the specification table.
Use the larger heatsink of these two calculations.

Power Design is an Excel spreadsheet available free from

GENERAL

Please read Application Note 1 "General Operating Consid-erations" which covers stability, supplies, heat sinking, mount-ing, current limit, SOA interpretation, and specification inter-pretation. Visit www.apexmicrotech.com for design tools that help automate tasks such as calculations for stability, internal power dissipation, current limit; heat sink selection; Apex's complete Application Notes library; Technical Seminar Work-book; and Evaluation Kits.

CURRENT LIMIT

For proper operation, the current limit resistor (R_{LIM}) must be connected as shown in the external connection diagram. The minimum value is 3.5 ohm, 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.

$$R_{LIM} = \frac{.7}{I_{LIM}}$$

COMMON MODE INPUT RANGE

Operational amplifiers are usually designed to have a com-mon 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 PA94 is re-stricted. The input pins must always be a least 30V from either supply voltage but never more than 500V. This means that the PA94 cannot be used in applications where the supply volt-ages 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 PA94 can withstand differential input voltages up to ±20V, additional external protection is recommended. In most applications 1N4148 or 1N914 signal diodes are suffi-cient (D1, D2 in Figure 1a). In more demanding applications where low leakage or low capacitance are of concern 2N4416 or 2N5457-2N5459 JFETs connected as diodes will be re-quired (Q1, Q2 in Figure 1b). 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.

POWER SUPPLY PROTECTION

Unidirectional zener diode transient suppressors are recom-mended 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 rever-sals 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.

STABILITY

The PA94 is stable at gains of 100 or more with a NPO (COG) compensation capacitor of 2.2pF. The compensation capacitor, Cc, 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 capaci-tor less than 2.2pF is not recommended.

EXTERNAL COMPONENTS

The compensation capacitor Cc must be rated for the total supply voltage. An NPO (COG) capacitor rated a 1kV is recommended.

Of equal importance are the voltage rating and voltage coefficient of the gain setting feedback resistor. Typical volt-age ratings of low wattage resistors are 150 to 250V. Up to 500 V can appear across the feedback resistor. High voltage rated resistors can be obtained. However a 1 megohm feedback resistor composed of five 200k resistors in series will produce the proper voltage rating.

CAUTIONS

The operating voltages of the PA94 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.
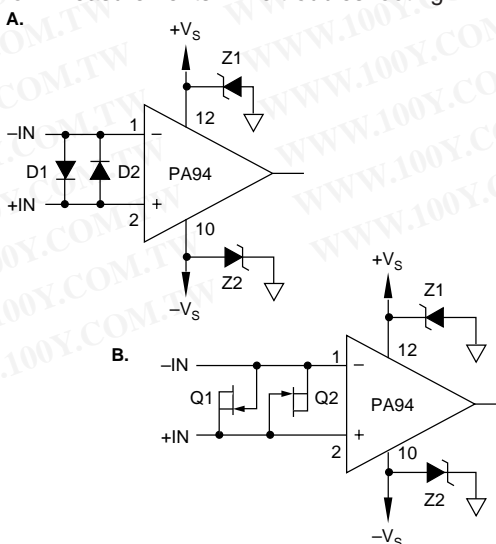

FIGURE 1. OVERVOLTAGE PROTECTION