PowerAmp Design

HIGH VOLTAGE OPERATIONAL AMPLIFIER **PAD196**

Preliminary Information ***Rev E***

KEY FEATURES

- **LOW COST**
- **SMALL SIZE – 50mm SQUARE**
- **HIGH VOLTAGE – 2050 VOLTS**
- **OUTPUT CURRENT– 50mA**
- **12 WATT DISSIPATION CAPABILITY**
- **5V/µS SLEW RATE**

APPLICATIONS

- **HIGH VOLTAGE INSTRUMENTATION**
- **PIEZO TRANSDUCER DRIVE**
- **ELECTRON BEAM FOCUSING**

DESCRIPTION

The PAD196 high voltage operational amplifier is constructed with surface mount components to provide a cost effective solution for many industrial applications such as high voltage instrumentation. With a footprint only 50mm square the PAD196 offers outstanding performance that rivals more expensive hybrid components. Integrated passive heat sink cooling is included. User selectable external compensation tailors the amplifier's response to the application requirements. A single resistor programs the current limit feature. The PAD196 is built on a thermally conductive but electrically insulating substrate. No BeO is used in the PAD196. For custom applications the PAD196-1 version of the amplifier is available without the integrated heat sink. The circuit is conformal coated for additional safety and reliability. See "CONFORMAL COATING" paragraph on page 5.

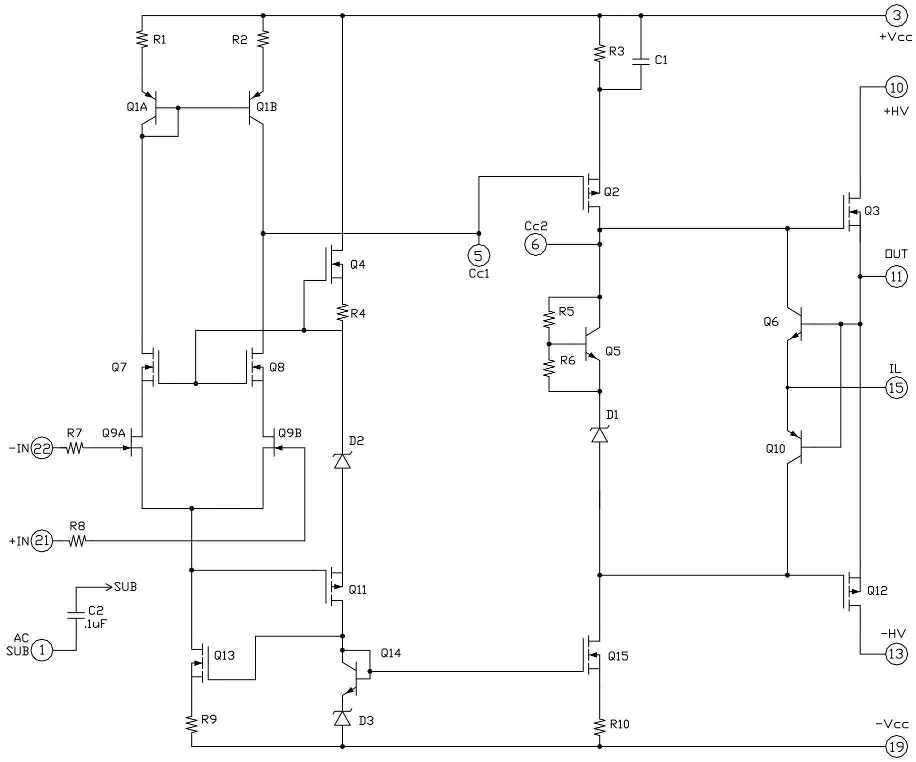
PAD196

PAD196-1

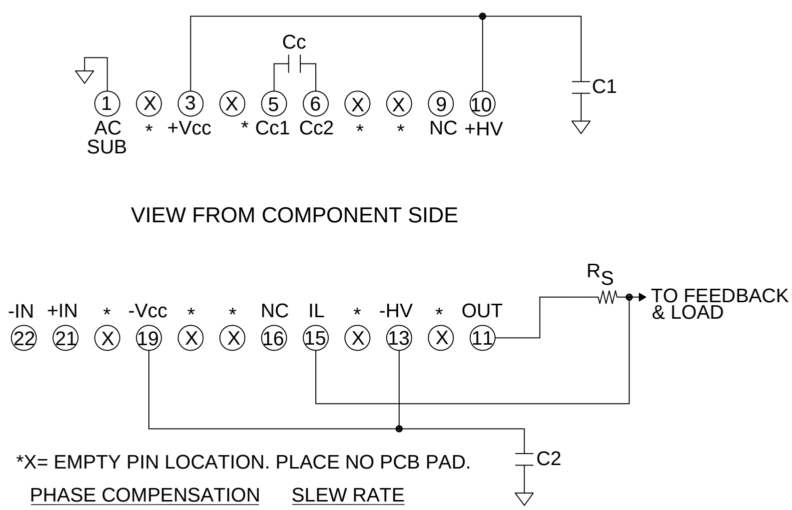
A NEW CONCEPT

A critical task in any power amplifier application is cooling the amplifier. Until now component amplifier manufacturers often treated this task as an after-thought, left for the user to figure out. At **Power Amp Design** the best heat sink is chosen at the start and becomes an integral part of the overall amplifier design. The result is the most compact and volumetric efficient design combination at the lowest cost. In addition, this integrated solution concept offers an achievable real-world power dissipation rating, not the ideal rating usually cited when the amplifier case is somehow kept at 25^{o}C. The user no longer needs to specify, procure or assemble separate components.

EQUIVALENT CIRCUIT



PINOUT & CONNECTIONS



*X= EMPTY PIN LOCATION. PLACE NO PCB PAD.

PHASE COMPENSATION GAIN	Cc	SLEW RATE
25	100pF	4V/uS
≥ 50	47pF	5V/uS
≥ 75	22pF	5V/uS
≥ 100	10pF	5V/uS

ABSOLUTE MAXIMUM RATINGS

SUPPLY VOLTAGE, +HV to −HV[4,10]	2050V	TEMPERATURE, pin solder,	10s, 300°C
SUPPLY VOLTAGE, +Vcc to −Vcc[4]	2050V	TEMPERATURE, junction[2]	150°C
INPUT VOLTAGE	+Vcc to −Vcc	TEMPERATURE RANGE, storage	−40 to 105°C
DIFFERENTIAL INPUT VOLTAGE	± 20V	TEMPERATURE RANGE, storage, PAD196- 1	−40 to 105°C
OUTPUT CURRENT, peak, within SOA	100mA	OPERATING TEMPERATURE, substrate	−40 to 85°C
POWER DISSIPATION, internal, DC	12W		

PARAMETER	TEST CONDITIONS[1]	MIN	TYP	MAX	PAD196-1[9]	UNITS
INPUT						
OFFSET VOLTAGE			.5	3		mV
OFFSET VOLTAGE vs. temperature	Full temperature range		4	15		µV/°C
OFFSET VOLTAGE vs. supply	Mother board must be clean			0.5		µV/V
BIAS CURRENT, initial[3]				100		pA
BIAS CURRENT vs. supply				0.1		pA/V
OFFSET CURRENT, initial				50		pA
INPUT RESISTANCE, DC			100			G Ω
INPUT CAPACITANCE			4			pF
COMMON MODE VOLTAGE RANGE				+Vcc−25		V
COMMON MODE VOLTAGE RANGE				−Vcc+25		V
COMMON MODE REJECTION, DC	Mother board must be clean	126	140			dB
NOISE	100kHz bandwidth, 1kΩ R_S		10			µV RMS
GAIN						
OPEN LOOP	R_L= 10kΩ, C_C=10pF	120				dB
GAIN BANDWIDTH PRODUCT @ 1MHz	C_C=10pF		0.7			MHz
PHASE MARGIN	Full temperature range	60				degree
OUTPUT						
VOLTAGE SWING	I_O = 10mA		+Vs−12	+Vs−20		V
VOLTAGE SWING	I_O = -10mA		−Vs+12	−Vs+20		V
CURRENT, continuous, DC				50		mA
CURRENT, pulse, ≤10mS, within SOA				100		mA
SLEW RATE, A_V = -200	C_C = 10pF		5			V/µS
SETTLING TIME, to 0.1%	2V Step, C_C = 10pF		10			µS
RESISTANCE	No load, DC		50			Ω
POWER SUPPLY						
VOLTAGE[10]		± 50	± 900	± 1025		V
CURRENT, quiescent			1	1.2		mA
THERMAL						
RESISTANCE, AC, junction to air or case[6]	Full temperature range, f ≥ 60Hz			8 to air	6.7 to case	°C/W
RESISTANCE, DC junction to air or case	Full temperature range			10.4 to air	8.4 to case	°C/W
TEMPERATURE RANGE, substrate		−40		85	85	°C
TEMPERATURE RANGE, ambient		−40		70	NA	°C

NOTES:
1. Unless otherwise noted: T_C = 25°C, compensation Cc = 150pF, DC input specifications are ± value given, power supply voltage is typical rating.
2. Derate internal power dissipation to achieve high MTBF.
3. Doubles for every 10°C of case temperature increase.
4. +HV and −HV denote the positive and negative supply voltages to the output stage. +Vcc and –Vcc denote the positive and negative supply voltages to the small signal stages. +Vcc and –Vcc may not be more than + and – 20V greater than +Vs and –Vs respectively.
6. Rating applies if the output current alternates between both output sets of transistors at a rate faster than 60Hz.
7. Power supply voltages +Vcc and −Vcc must not be less than +HV and −HV respectively. Total voltage +Vcc to −Vcc 2050V maximum.
9. Specifications for the PAD196-1 are the same as for the PAD196 except as shown in this column.
10. See "POWER SUPPLY CONSIDERATIONS" on pg. 5 for cautionary note.

SAFETY FIRST

The operating voltages of the PAD196 are potentially deadly. When developing an application circuit it is wise to begin with power supply voltages as low as possible while checking for circuit functionality. Increase supply voltages slowly as confidence in the application circuit increases. Always use a "hands-off" method whereby test equipment probes are attached only when power is off. Be sure test equipment and probes can withstand 2000V.

MOUNTING THE PAD196 AMPLIFIER

The amplifier is supplied with four 4-40 M/F hex spacers at the four corners of the amplifier. The hex spacer near pin 1 is metal and the other three hex spacers are nylon for extra safety and arc resistance. Once the amplifier is seated, secure the module with the provided 4-40 nuts and torque the metal nut to 4.7 in lb [53 N cm] max. Tighten the nylon nuts snug only. See "**Dimensional Information**" for a detailed drawing. It is recommended that the heat sink be grounded to the system ground. This can easily be done by providing a grounded circuit board pad around the hole near pin 1 for the metal mounting stud. The other 3 mounting spacers are nylon and do not conduct.

MOUNTING THE PAD196-1 AMPLIFIER

In many applications the amplifier must be attached to a heat sink. Spread a thin and even coat of heat sink grease across the back of the PAD196-1 and also the heat sink where the amplifier is to be mounted. While holding on to the lead frames push the amplifier into the heat sink grease on the heat sink while slightly twisting the amplifier back and forth a few times to bed the amplifier into the heat sink grease. On the final twist align the mounting holes of the amplifier with the mounting holes in the heat sink. Be careful not to disturb the soft silicone overcoat on the amplifier's components. Finish the mounting using a metal 1/4", 4-40 hex male-female spacers at the location near pin 1 and torque to 4.7 in oz [3.8 N cm] max. At the other three locations use 1/4" nylon hex male-female spacers and nylon hex nuts. See Dimensional Information for additional recommendations.

PHASE COMPENSATION

The PAD196 **must** be phase compensated. The compensation capacitor, C_C, is connected between pins 5 and 6. The compensation capacitor must be an NPO type capacitor rated for 500-1000V. On page 2, under Amplifier Pinout and Connections, you will find a table that gives recommended compensation capacitance value for various circuit gains and the resulting slew rate for each capacitor value. Consult also the small signal response and phase response plots for the selected compensation value in the Typical Performance Graphs section. A compensation capacitor less than 10pF is not recommended.

EXTERNAL CIRCUIT COMPONENTS

The output of the PAD196 can swing up to +/- 1000V (or 2000V unipolar) and this may stress or destroy external components that are often not seriously considered when developing circuits with small signal op amps. For example, it is often overlooked that the usual voltage rating for metal film resistors is only 200V and that application circuits using the PAD196 may place up to 2000V across the feedback resistor. High voltage rated resistors may be purchased for the feedback circuit or, alternately, several ordinary resistors may be placed in series to obtain the proper voltage rating. We recommend at least 10 resistors in series for the feedback resistor. The compensation capacitor C_C is a NPO type and is rated for 500-1000V. The voltage rating of the connecting wire and PCB spacing between pads and connecting traces needs to be considered as well. See application note AN-16 for details.

CURRENT LIMIT

Current limit can be programmed by attaching a suitable value resistor as shown in Figure 1. The value of the limited current can be approximately calculated by:

$$I_L = .65/R_S$$

Where I_L is the value of the limited current and R_S is the value of the current sense resistor. It is important that the type of resistor chosen for R_S be non-inductive. A wire-wound resistor is not a good choice even if it rated as "non-inductive" since it will exhibit significant inductance at some frequency. A better choice is a type of resistor that is more inherently non-inductive such as a metal film resistor or a thick film resistor. The power dissipation rating of the sense resistor should not to be forgotten. The current limit circuitry works by diverting the stage currents of the amplifier into the output circuit (about 5mA) and this introduces an error term compared to the approximate equation given above. As the current limit value is reduced the proportion of the error term increases. The practical range of current limit is from 50mA to 2mA. The current limit decreases 2.2mV/^{O}C with increasing temperature since the sense voltage for calculating the current limit is the emitter-base circuit of a bipolar transistor.

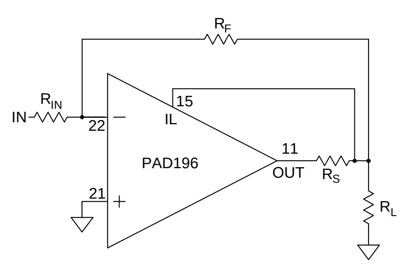


Figure 1
Current Limit

INPUT PROTECTION

In applications where the input differential voltage may be exceeded (dc or transient) it is important to add differential input voltage protection. See Figure 2.

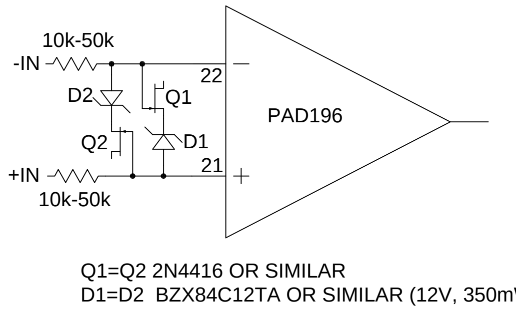


Figure 2
Input differential voltage protection

POWER SUPPLY CONSIDERATIONS

The high voltage rating of the PAD196 relies on several transistors stacked in series to increase the voltage rating of the amplifier. The several transistors must be biased correctly for the power supply voltages to be equally distribute across the several transistors. The internal biasing network cannot function properly if either power supply voltage is insufficient or open. **Therefore it is required that both power supplies be energized at the same time.** Once each power supply reaches about 20V the biasing network functions properly. Add the power supply clamps shown below to help protect the PAD196.

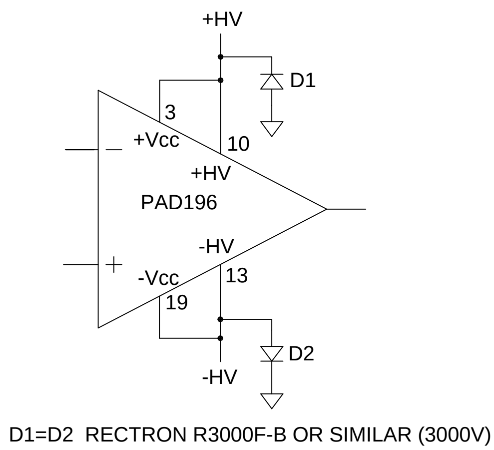
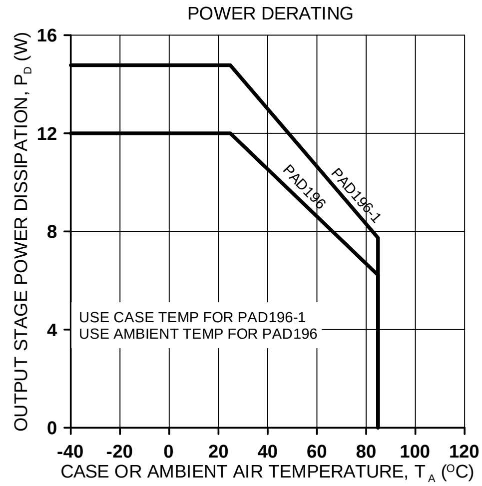
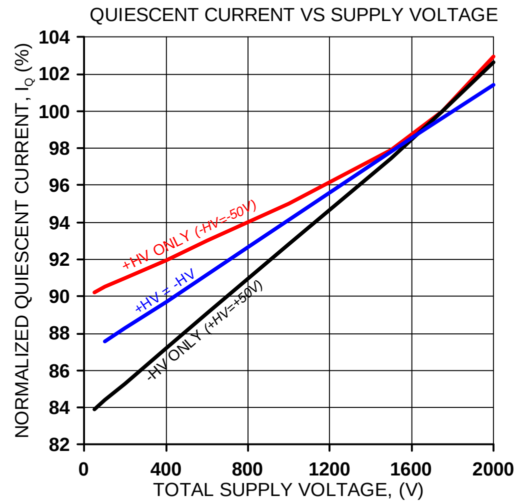


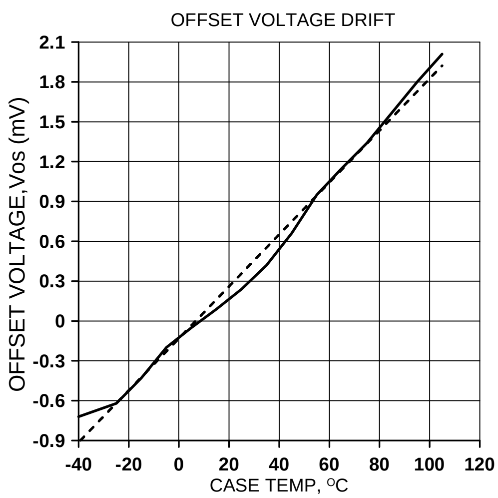
Figure 3
Power supply clamps

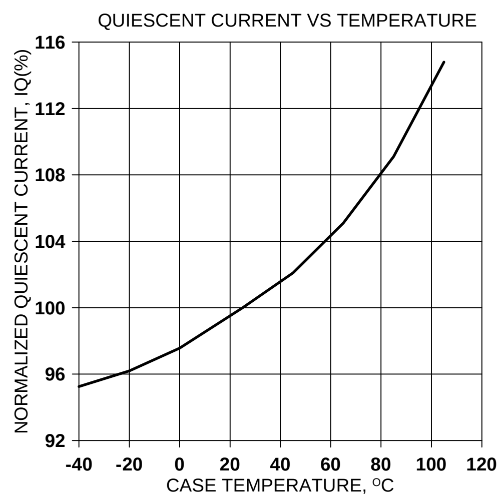
CONFORMAL COATING

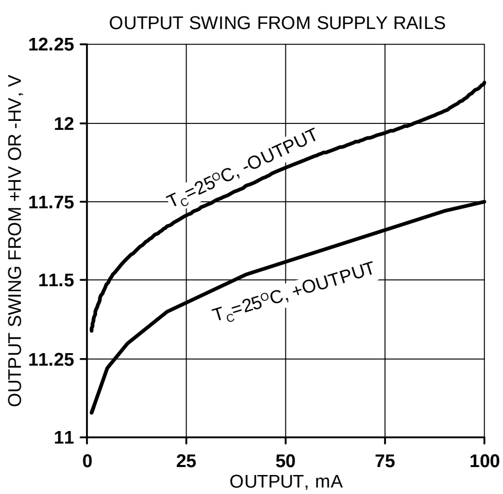
The circuit of the PAD196 is covered by a silicone conformal coating for extra protection against internal arcing and environmental considerations such as humidity. The conformal coating is soft and may be damaged by rough handling. It is therefore recommended that the circuit be handled only by the edges of the substrate to avoid disturbing the coating. The PAD196 is only rated for normal environmental conditions of atmospheric pressure, humidity and temperature usually found in a laboratory or production floor. The user must appropriate steps to insure the reliability of the application circuit beyond those conditions.

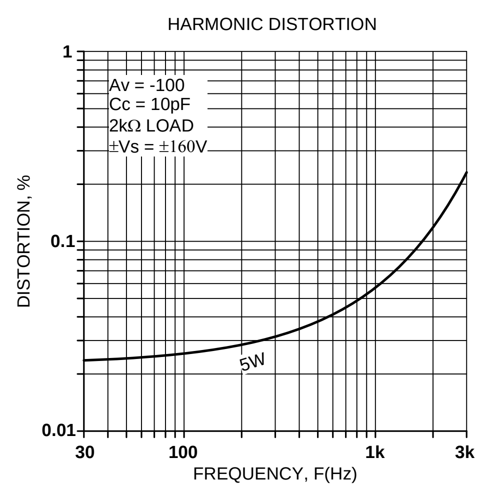

POWER DERATING
OUTPUT STAGE POWER DISSIPATION, P_D (W)
16
12
8
4
0
PAD196
PAD196-1
USE CASE TEMP FOR PAD196-1
USE AMBIENT TEMP FOR PAD196
-40 -20 0 20 40 60 80 100 120
CASE OR AMBIENT AIR TEMPERATURE, T_A (°C)

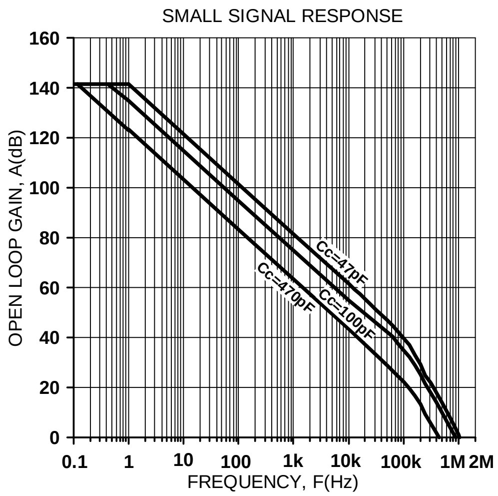

QUIESCENT CURRENT VS SUPPLY VOLTAGE
NORMALIZED QUIESCENT CURRENT, I_Q (%)
104
102
100
98
96
94
92
90
88
86
84
82
+HV ONLY (-HV=-50V)
+HV = -HV
-HV ONLY (+HV=+50V)
0 400 800 1200 1600 2000
TOTAL SUPPLY VOLTAGE, (V)

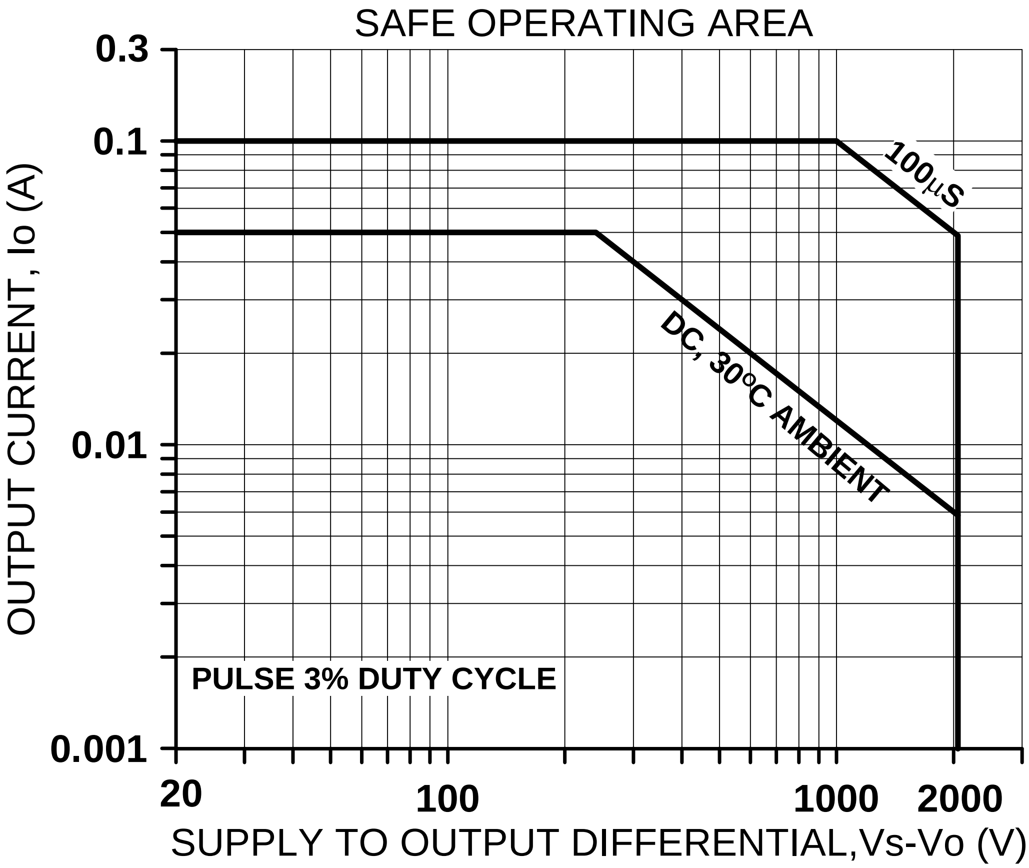

OFFSET VOLTAGE DRIFT
OFFSET VOLTAGE, Vos (mV)
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9
-40 -20 0 20 40 60 80 100 120
CASE TEMP, °C


QUIESCENT CURRENT VS TEMPERATURE
NORMALIZED QUIESCENT CURRENT, IQ(%)
116
112
108
104
100
96
92
-40 -20 0 20 40 60 80 100 120
CASE TEMPERATURE, °C

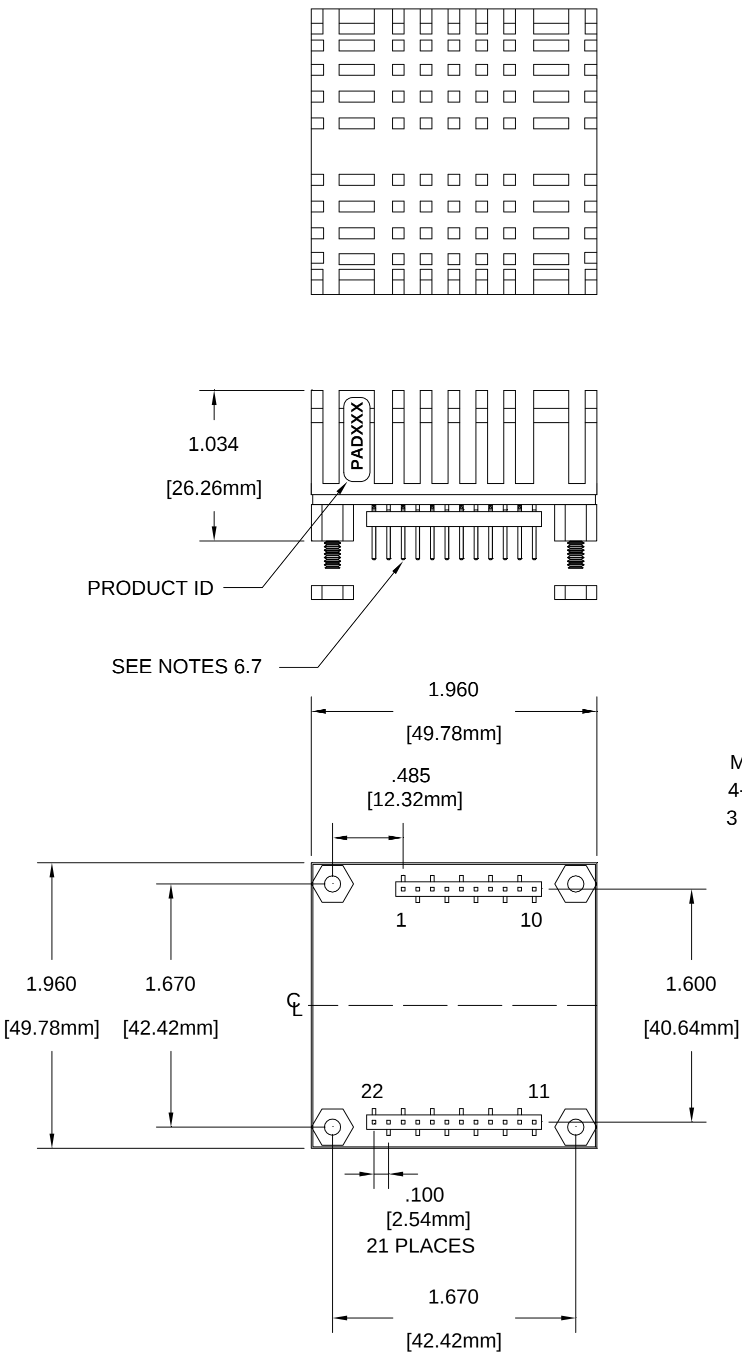

OUTPUT SWING FROM SUPPLY RAILS
OUTPUT SWING FROM +HV OR -HV, V
12.25
12
11.75
11.5
11.25
11
T_C=25°C, -OUTPUT
T_C=25°C, +OUTPUT
0 25 50 75 100
OUTPUT, mA

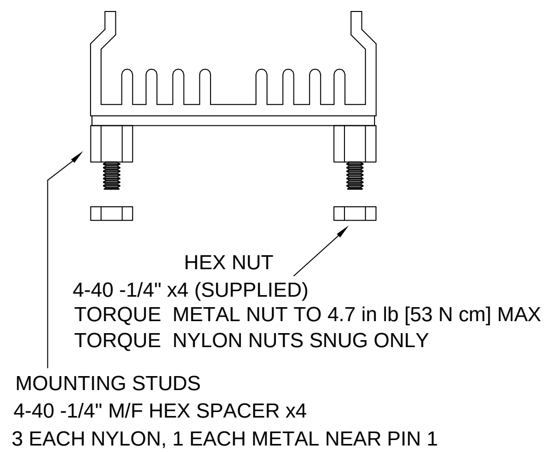

HARMONIC DISTORTION
DISTORTION, %
1
0.1
0.01
Av = -100
Cc = 10pF
2kΩ LOAD
±Vs = ±160V
5W
30 100 1k 3k
FREQUENCY, F(Hz)


SMALL SIGNAL RESPONSE
OPEN LOOP GAIN, A(dB)
160
140
120
100
80
60
40
20
0
0.1
1
10
100
1k
10k
100k
1M
2M
FREQUENCY, F(Hz)
Cc=47pF
Cc=100pF
Cc=470pF



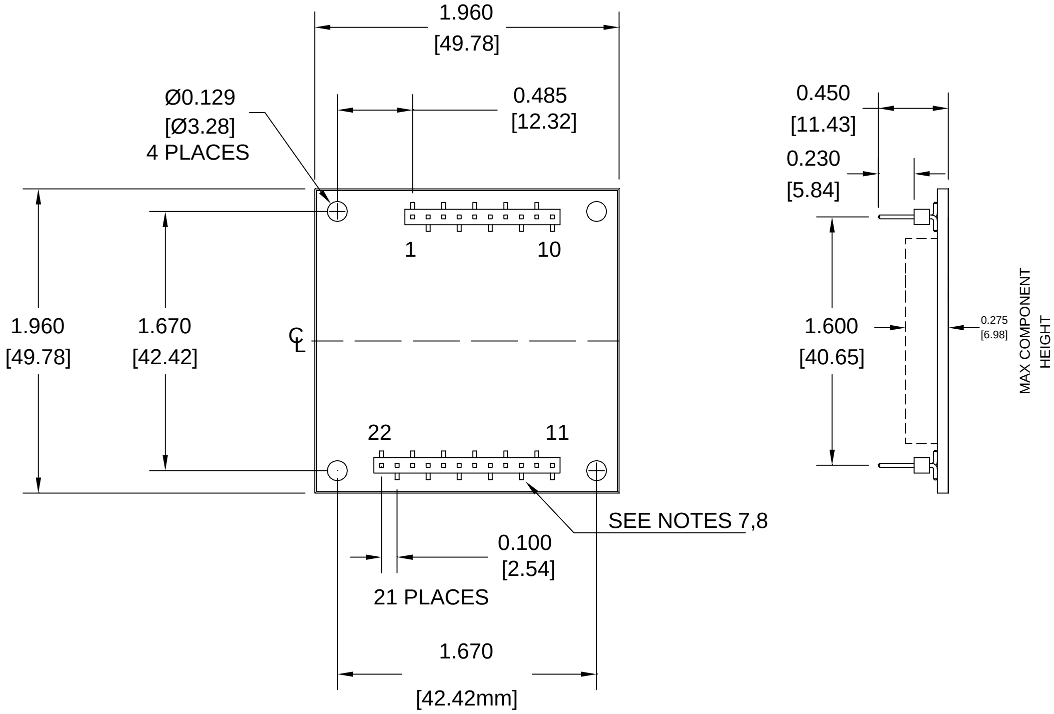
SAFE OPERATING AREA





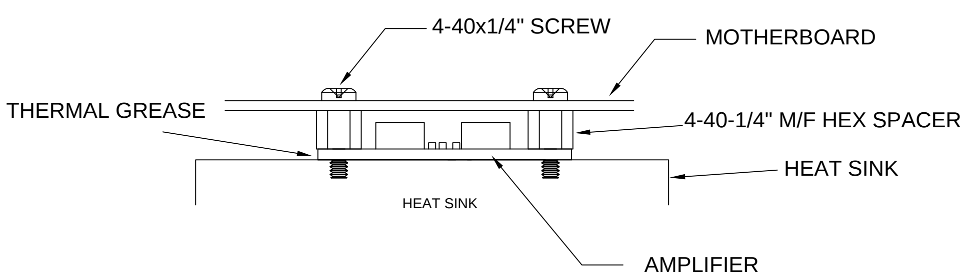
NOTES:

1. PINS .0.025" SQUARE X22
2. RECOMMENDED HOLE
   FOR MOUNTING 0.129" X4
3. RECOMMENDED HOLE
   FOR PINS 0.052" D.
4. TOTAL ASSEMBLY WEIGHT
   APPROX 2.6 oz [73.7 g]
5. HEAT SINK WEIGHT
   APPROX 0.91 oz [25.8 g]
6. PIN LOCATIONS 2,4,7,8,12,14,17,18,20 ARE EMPTY
7. PLACE NO PCB PADS AT EMPTY PIN LOCATIONS



NOTES:

1: DIMENSIONS ARE INCHES, [mm]
2: PINS 0.025" SQUARE [0.635mm], GOLD PLATED
3: RECOMMENDED HOLE FOR MOUNTING 0.129" D. x2 [3.277mm]
4: RECOMMENDED HOLE FOR PINS 0.052" D. [1.321mm]
5: HIGHLY RECOMMENDED THAT AMPLIFIER IS MOUNTED INTO CAGE JACKS USING PAD PART NUMBER CJS01. USE 0.062" [1.575mm] HOLE FOR CAGE JACKS.
6: HIGHLY RECOMMENDED THAT AMPLIFIER IS MOUNTED INTO HEAT SINK WITH 4-40 M/F SPACERS TO PROVIDE STRAIN RELIEF FOR PINS. SEE DRAWING BELOW.
7: PIN LOCATIONS 2.4.7.8.12.14.17.18,20 ARE EMPTY
8: PLACE NO PCB PADS AT EMPTY LOCATIONS



PAD196-1