KEY FEATURES

- **LOW COST**
- **HIGH VOLTAGE – 500 VOLTS**
- **HIGH OUTPUT CURRENT – 10A**
- **150 WATT DISSIPATION CAPABILITY**
- **450 WATT OUTPUT CAPABILITY**
- **WIDE SUPPLY RANGE ±20V – ±250V**
- **INTEGRATED HEAT SINK AND FAN**
- **TEMPERATURE REPORTING**
- **OVER-TEMPERATURE SHUTDOWN**

APPLICATIONS

- **LINEAR MOTOR DRIVE**
- **INDUSTRIAL AUDIO**
- **SEMICONDUCTOR TESTING**
- **VIBRATION CANCELLATION**
- **MAGNETIC BEARINGS**
- **LINE VOLTAGE SIMULATION**

DESCRIPTION

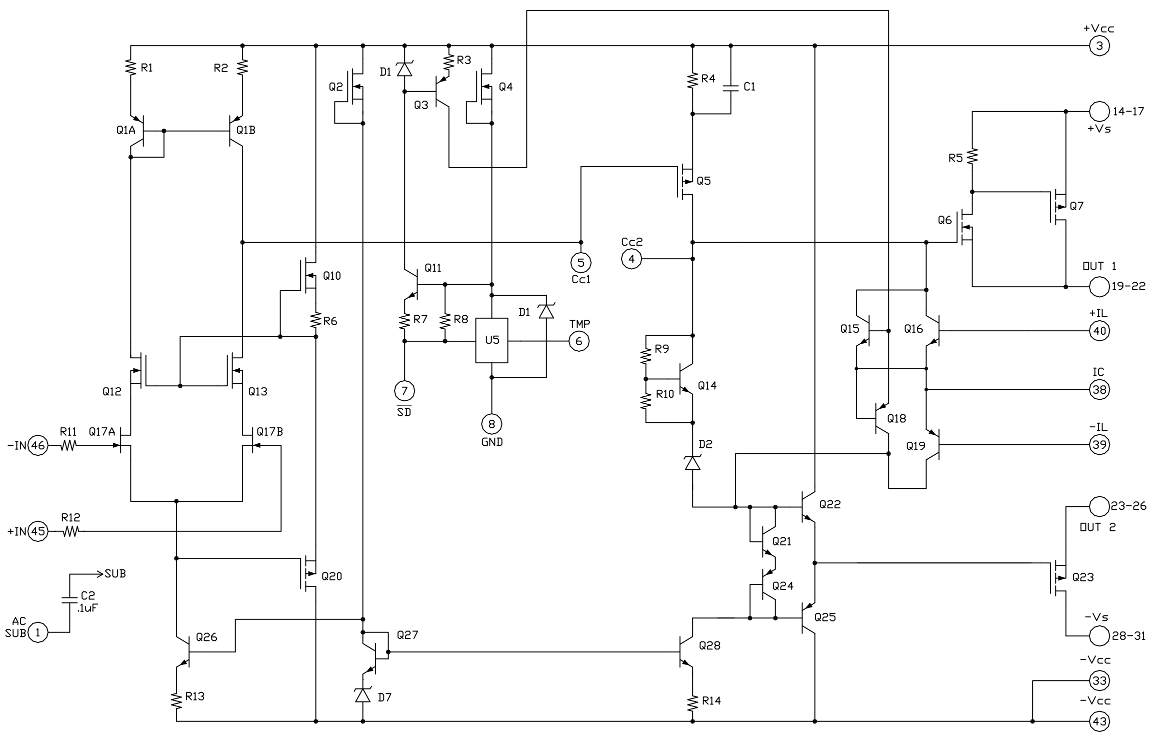
The PAD126 high voltage operational amplifier is constructed with surface mount components to provide a cost effective solution for many industrial applications. With a footprint only 80mm square the PAD126 offers outstanding performance that rivals much more expensive hybrid component amplifiers or rack-mount amplifiers. User selectable external compensation tailors the amplifier's response to the application requirements. The PAD126 also features a substrate temperature reporting output and over-temp shutdown and is also compatible with the PAD125 Current Limit Accessory Module. The amplifier circuitry is built on a thermally conductive but electrically insulating substrate mounted to an integrated heat sink and fan assembly. No BeO is used the amplifier. The resulting module is a small, high performance turn-key solution for many industrial applications.

PAD126 MOUNTED IN EVALUATION KIT WITH OPTIONAL ACCESSORY MODULES PAD125 & PAD131

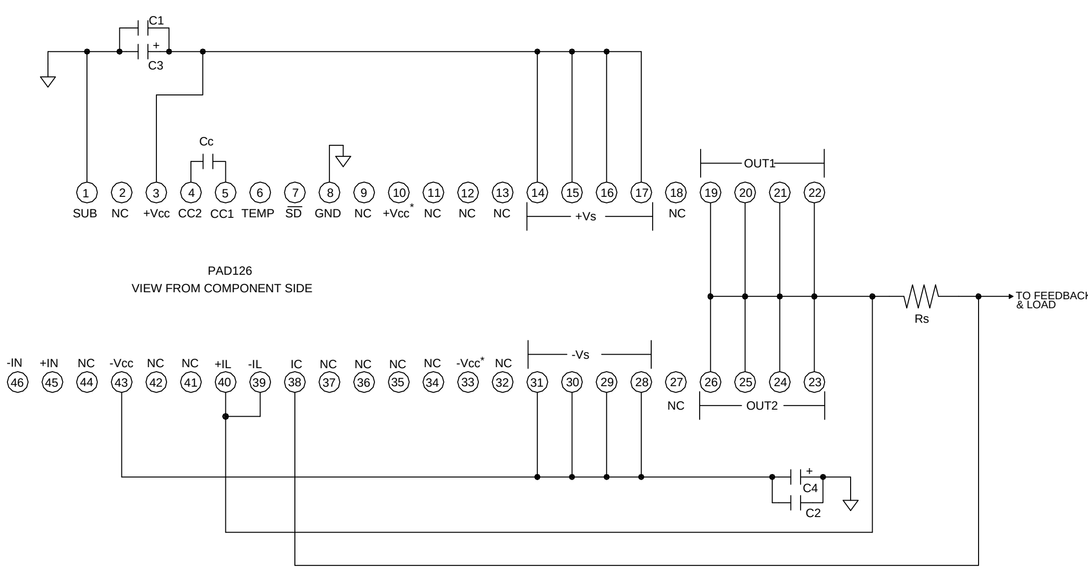
A NEW CONCEPT

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 and fan combination is chosen at the start and becomes an integral part of the overall amplifier design. The result is the most compact and volumetrically 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°C. The user no longer needs to specify, procure or assemble separate components.

EQUIVALENT CIRCUIT



AMPLIFIER PINOUT & CONNECTIONS



PHASE COMPENSATION

GAIN	Cc	SLEW V/uS
1	470pF	5
>15	33pF	50

SEE APPLICATION CIRCUITS FOR OTHER CONNECTIONS AND FUNCTIONS.

* INTERNALLY CONNECTED

ABSOLUTE MAXIMUM RATINGS

SUPPLY VOLTAGE, +Vs to −Vs	500V	INPUT VOLTAGE	+Vcc to −Vcc
SUPPLY VOLTAGE +Vcc to −Vcc	500V	DIFFERENTIAL INPUT VOLTAGE	± 20V
OUTPUT CURRENT, peak	12A, within SOA	TEMPERATURE, pin solder, 10s	300°C
POWER DISSIPATION, internal, DC	150W	TEMPERATURE, junction[2]	150°C
TEMPERATURE RANGE, storage	−40 to 70°C[5]	OPERATING TEMPERATURE, heat sink	−40 to 105°C

PARAMETER	TEST CONDITIONS[1]	MIN	TYP	MAX	UNITS
INPUT					
OFFSET VOLTAGE			1	5	mV
OFFSET VOLTAGE vs. temperature	Full temperature range		20	50	$\mu V/^{O}C$
OFFSET VOLTAGE vs. supply				20	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 ∓ 15			V
COMMON MODE REJECTION, DC		92			dB
NOISE	100kHz bandwidth, 1kΩ R_S		10		μV RMS
GAIN					
OPEN LOOP	R_L= 100Ω, C_C=47pF	108			dB
GAIN BANDWIDTH PRODUCT @ 1MHz	C_C=47pF		1		MHz
PHASE MARGIN	Full temperature range	60			degree
OUTPUT					
VOLTAGE SWING	I_O = 10A	+Vs−14			V
VOLTAGE SWING	I_O = −10A	−Vs+14			V
CURRENT, continuous, DC		10			A
CURRENT, peak within SOA				12	A
SLEW RATE, A_V = −100	C_C = 10pF	40	50		V/μS
SETTLING TIME, to 0.1%	2V Step		2		μS
RESISTANCE	No load, DC		3		Ω
POWER SUPPLY					
VOLTAGE[7]		±20	±200	±250	V
CURRENT, quiescent			16	20	mA
THERMAL					
RESISTANCE, AC, junction to air[4]	Full temperature range, f ≥ 60Hz			.46	$^{O}C/W$
RESISTANCE, DC, junction to air	Full temperature range			0.75	$^{O}C/W$
TEMPERATURE RANGE, heat sink		−40		105	^{O}C
FAN, 80mm dc brushless, ball bearing					
OPERATING VOLTAGE			12		V
OPERATING CURRENT			150		mA
AIR FLOW			40		CFM
RPM			3800		RPM
NOISE			30		dB
L10, life expectancy, $50^{O}C$[6]			45		kHrs
L10, life expectancy, $25^{O}C$[6]			60		kHrs

NOTES:
1. Unless otherwise noted: T_C=$25^{O}C$, compensation Cc=470pF, 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 $10^{O}C$ of case temperature increase.
4. Rating applies if the output current alternates between both output transistors at a rate faster than 60Hz.
5. Limited by fan storage characteristics. During operation, even though the case may be at $85^{O}C$ the fan will be at a lower temperature.
6. L10 refers to the time it takes for 10% of a population of fans to fail. MTBF (Mean Time Before Failure), on the other hand, refers to a 50% failure rate. The MTBF of fans used by Power Amp Design is 210 kHrs at 50C.

SAFETY FIRST

The operating voltages of the PAD126 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. **See application note AN-16 for PCB layout guidelines.**

EXTERNAL CIRCUIT COMPONENTS

The output of the PAD126 can swing up to +/- 240V and this may stress or destroy external components that are often not seriously considered when developing circuits with small signal op amps. 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. The compensation capacitor C_C is a NPO type and is rated for 500V. **See AN-16 for PCB layout guidelines.**

COOLING FAN

The PAD126 relies on its fan for proper cooling of the amplifier. Make sure that air flow to the fan and away from the heat sink remains unobstructed. To eliminate electrical noise created by the cooling fan we recommend a 47µF capacitor placed directly at the point where the fan wires connect to the PCB. See application note AN-24 for further details.

CURRENT LIMIT

The current limiting function of the PAD126 is a versatile circuit that can be used to implement a four-wire current limit configuration or, in combination with some external components can be configured to implement a fold-over current limit circuit. The four-wire current limit configuration insures that parasitic resistance in the output line, Rp, does not affect the programmed current limit setting. See Figure 1. The sense voltage for current limit is 0.65V. Thus approximately:

$$I_L = \frac{0.65V}{R_S}$$

Where I_L is the value of the limited current and R_S is the value of the current limit sense resistor.

In addition, the sense voltage has a temperature coefficient approximately equal to −2.2mV/°C. The fold-over function reduces the available current as the voltage across the output transistors increases to help insure that the SOA of the output transistors is not exceeded. Refer to **Application Circuits** for details on how to connect the current limit circuitry to implement either a four-wire current limit or current limit with a fold-over function (Figures 1 and 5).

MOUNTING THE AMPLIFIER

The amplifier is supplied with four 4-40 M/F hex spacers at the four corners of the amplifier. Once the amplifier is seated, secure the module with the provided 4-40 nuts and torque to 4.7 in lb [53 N cm] max. 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 any of the holes for the mounting studs.

TEMPERATURE REPORTING

An analog output voltage is provided (pin 6, TMP) relative to ground (pin 8, GND) and proportional to the temperature in degrees C. The slope is approximately -10.82mV/°C. The output voltage follows the equation:

$$T = (2.127 - V)\,(92.42)$$

Where V is the TMP output voltage and T is the substrate temperature in degrees C.

This high impedance output circuit is susceptible to capacitive loading and pickup from the output of the amplifier. TMP is internally filtered, but when monitoring TMP the filter as shown in Figure 3 may be useful. See **Applications Circuits.**

THERMAL SHUTDOWN

The temperature monitoring circuit turns off the amplifier when the substrate temperature reaches 110°C. When the substrate cools down 10°C the amplifier is enabled once again. The thermal shutdown feature is activated either by amplifier overloads or a failure of the fan circuit.

EXTERNAL SHUTDOWN

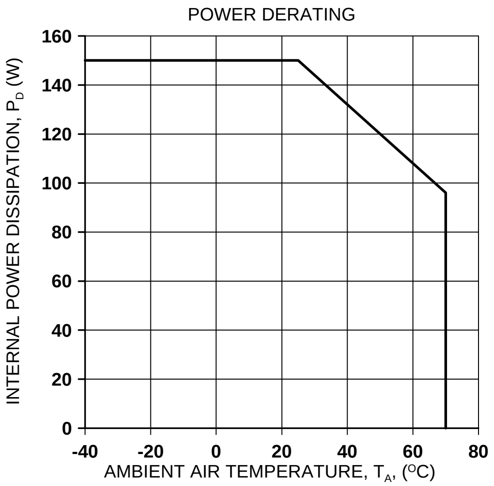
When pin 7 ($\overline{SD}$) goes low (ground) or is forced low the amplifier is turned “off” and remains “off” as long as pin 7 is low. When pin 7 is monitored with a high impedance circuit it also functions as a flag, reporting when the amplifier is shut down. A “high” (+5V) on pin 7 indicates the temperature is in the normal range. A “low” (ground) indicates a shutdown condition. See **Application Circuits (**Figure 2**)** for details. To avoid loading the internal circuit any external circuit must be an open collector or open drain connection.

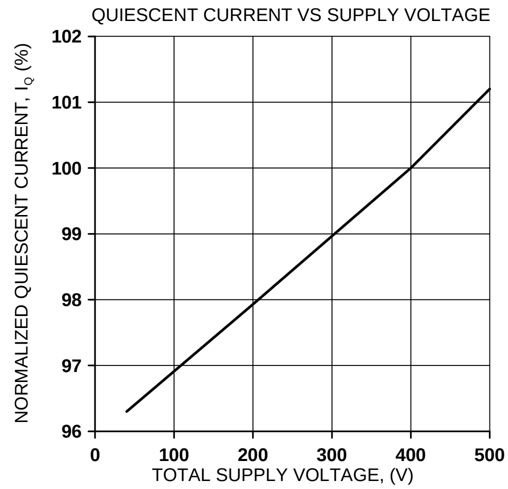
PHASE COMPENSATION

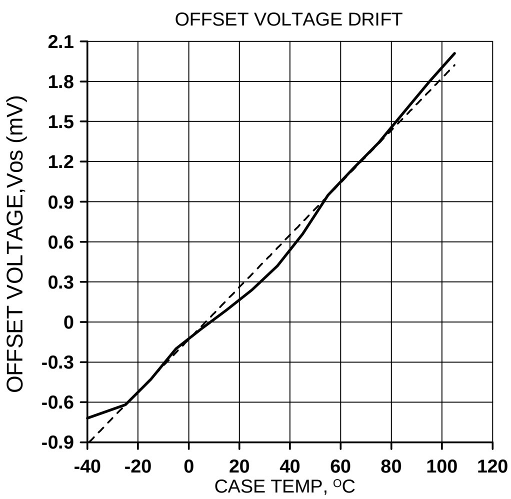
The PAD126 **must** be phase compensated. The compensation capacitor, C_C, is connected between pins 4 and 5. The compensation capacitor must be an NPO type capacitor rated for the full supply voltage (500V). On page 2, under Amplifier Pinout and Connections, you will find a table that gives recommended 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.

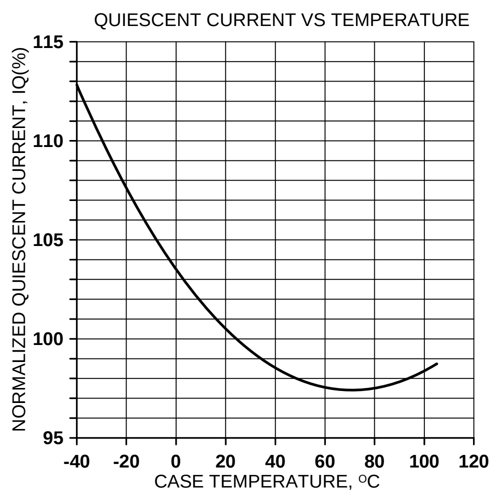
PAD125 ACCESSORY MODULE

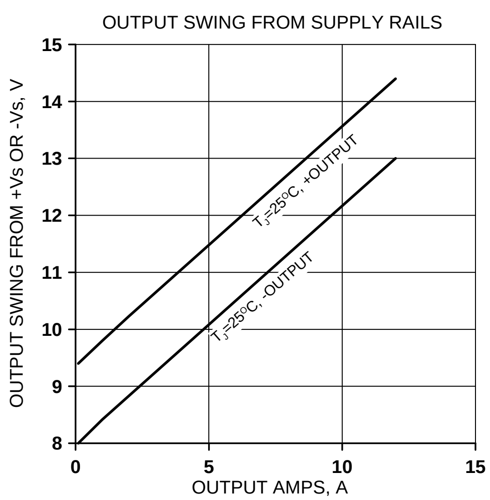
Precision current limiting can be achieved connecting the optional PAD125 Current Limit Accessory Module (See Figure 3) that provides a precision 150mV temperature compensated set point for the current limit as well as other programmable features. Please refer to the PAD125 datasheet for details on the operation of the module.

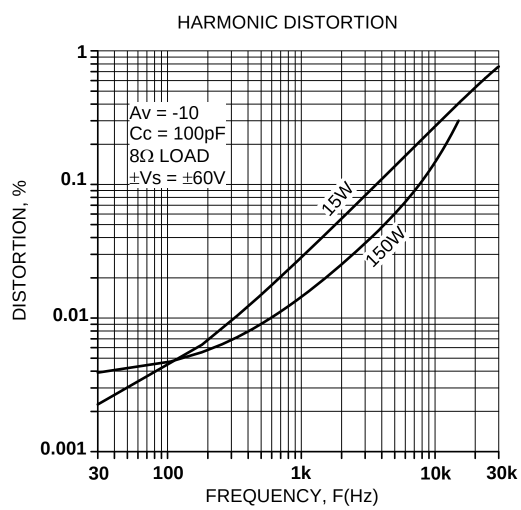

POWER DERATING
INTERNAL POWER DISSIPATION, P_D (W)
AMBIENT AIR TEMPERATURE, T_A, (°C)

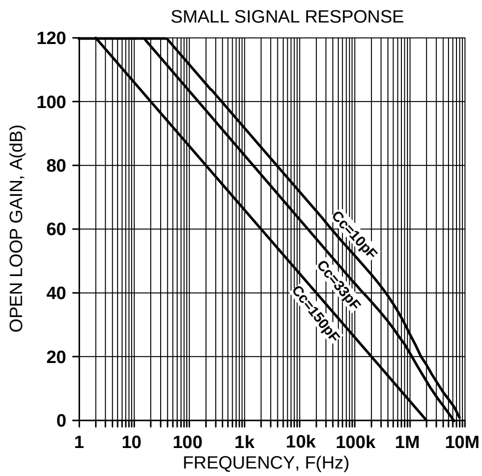

QUIESCENT CURRENT VS SUPPLY VOLTAGE
NORMALIZED QUIESCENT CURRENT, I_Q (%)
TOTAL SUPPLY VOLTAGE, (V)

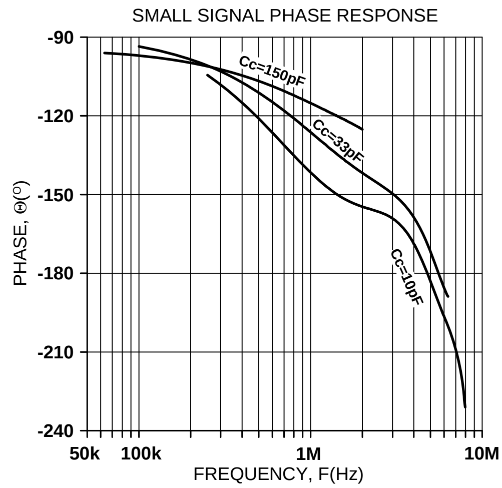

OFFSET VOLTAGE DRIFT
OFFSET VOLTAGE,Vos (mV)
CASE TEMP, °C

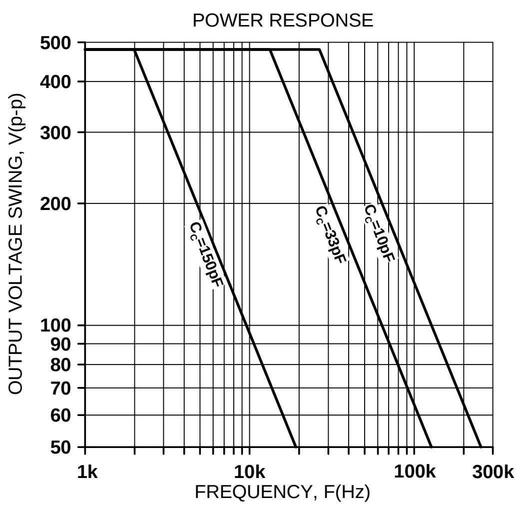

QUIESCENT CURRENT VS TEMPERATURE
NORMALIZED QUIESCENT CURRENT, IQ(%)
CASE TEMPERATURE, °C

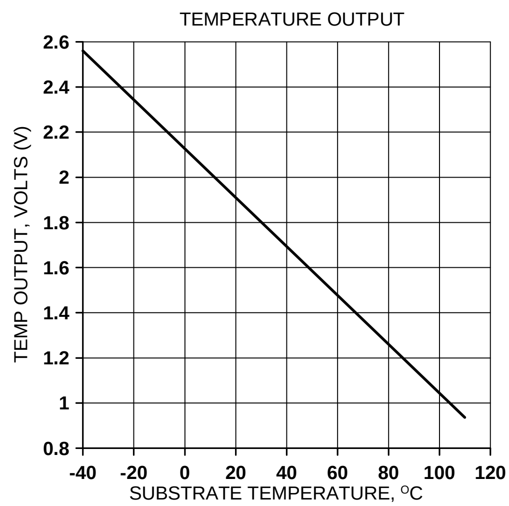

OUTPUT SWING FROM SUPPLY RAILS
OUTPUT SWING FROM +Vs OR -Vs, V
OUTPUT AMPS, A
T_J=25°C, +OUTPUT
T_J=25°C, -OUTPUT

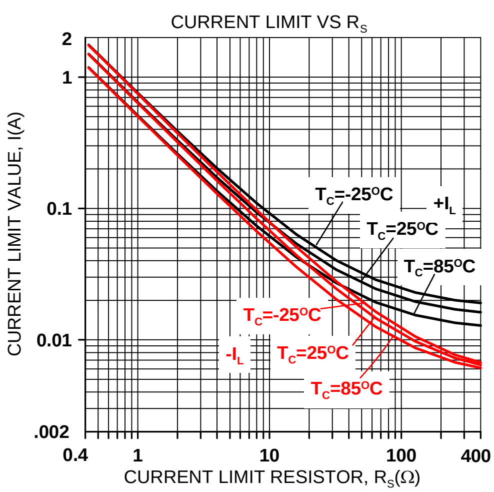

HARMONIC DISTORTION
Av = -10
Cc = 100pF
8Ω LOAD
±Vs = ±60V
15W
150W
DISTORTION, %
FREQUENCY, F(Hz)

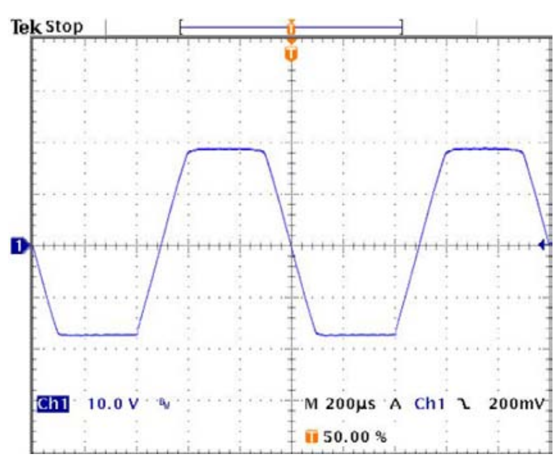




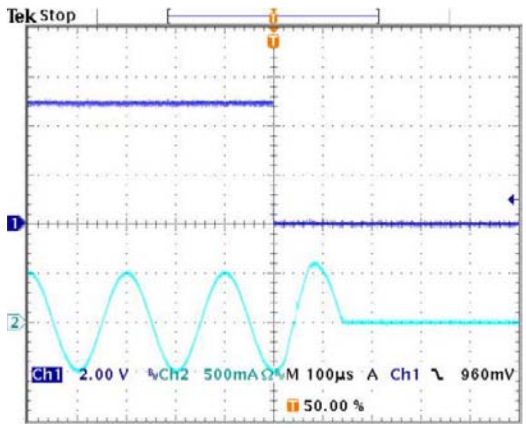








1kHz sine clipped by current limit into 250Ω load

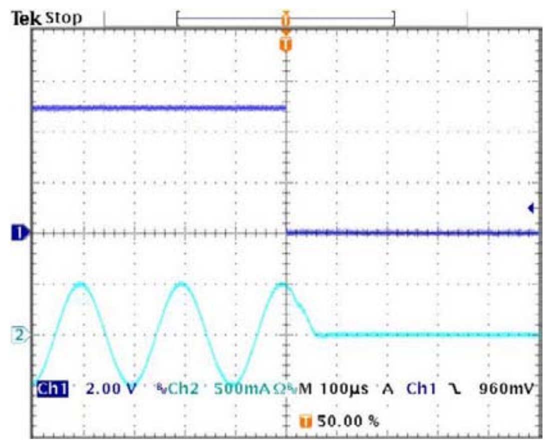


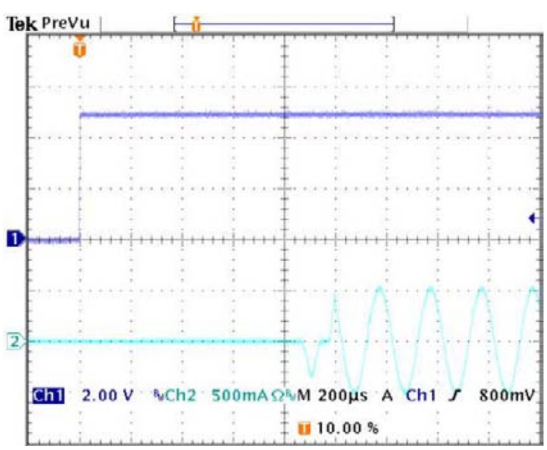
SHUTDOWN RESPONSE, NEGATIVE OUTPUT TO ZERO TRANSITION

The oscilloscope display at the left shows a view of a 5kHz, 1A p-p amplifier output signal being interrupted near the negative peak by a shutdown signal on Ch1. The Ch2 display shows the output *current* going to zero about 150µS after the shutdown signal goes low.

SHUTDOWN RESPONSE, POSITIVE OUTPUT TO ZERO TRANSITION

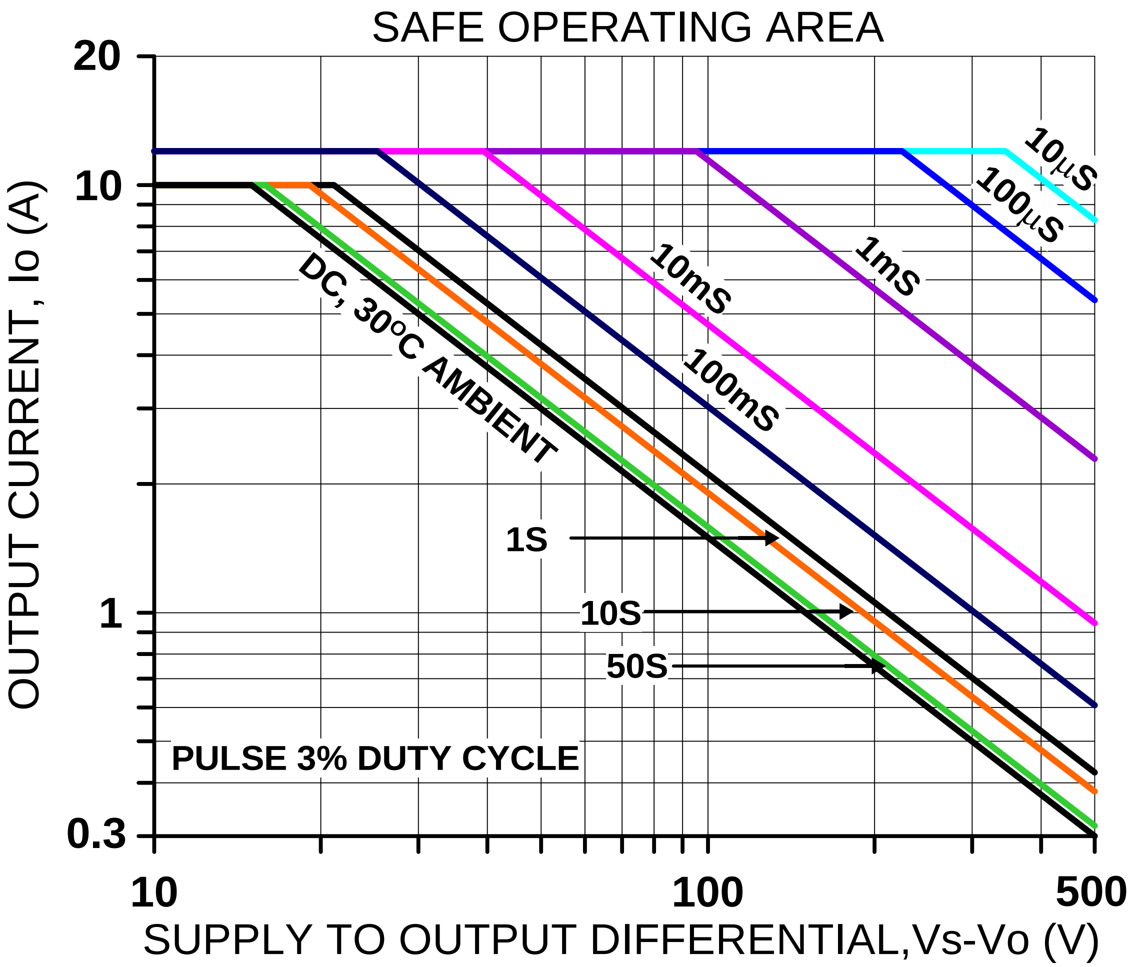
The oscilloscope display at the right shows a view of a 5kHz, 1A p-p amplifier output signal being interrupted near the positive peak by a shutdown signal on Ch1. The Ch2 display shows the output *current* going to zero about 50µS after the shutdown signal goes low.





SHUTDOWN RECOVERY

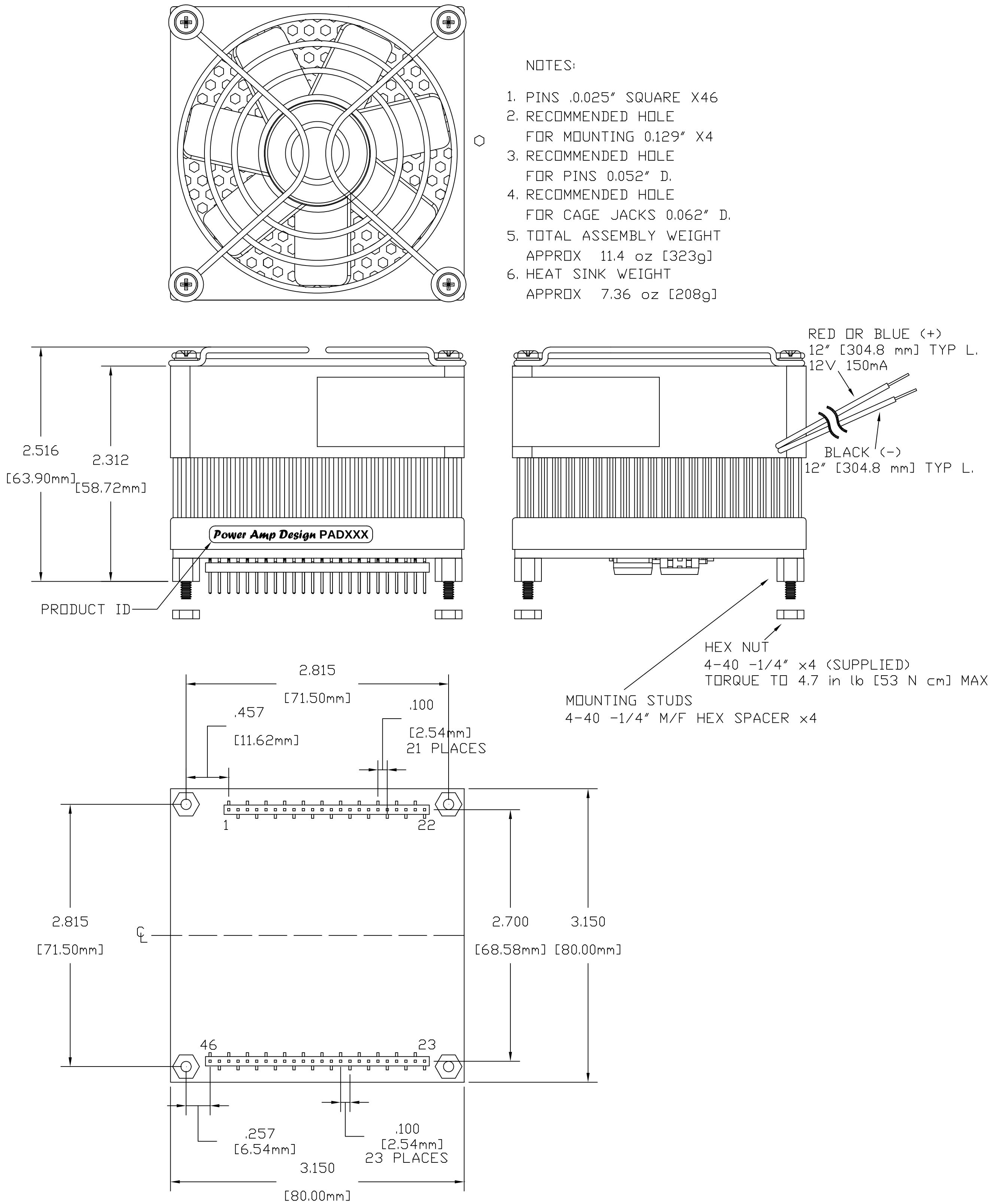
The oscilloscope display at the left shows a view of a 5kHz, 1A p-p amplifier output signal on Ch2 resuming normal operation after a shutdown signal on Ch1 go high (not shutdown). The output signal resumes normal operation after a delay of about 1mS.



SAFE OPERATING AREA

The safe operating area (SOA) of a power amplifier is its single most important specification. The SOA graph presented above serves as a first approximation to help you decide if the PAD126 will meet the demands of your application. But a more accurate determination can be reached by making use of the ***PAD Power***™ spreadsheet which can be found in the ***Power Amp Design*** website. While the graph above adequately shows DC SOA and some pulse information it does not take into account ambient temperatures higher than 30^{O}C, AC sine, phase or non-symmetric conditions that often appear in real-world applications. The ***PAD Power***™ spreadsheet takes all of these effects into account.

DIMENSIONAL INFORMATION



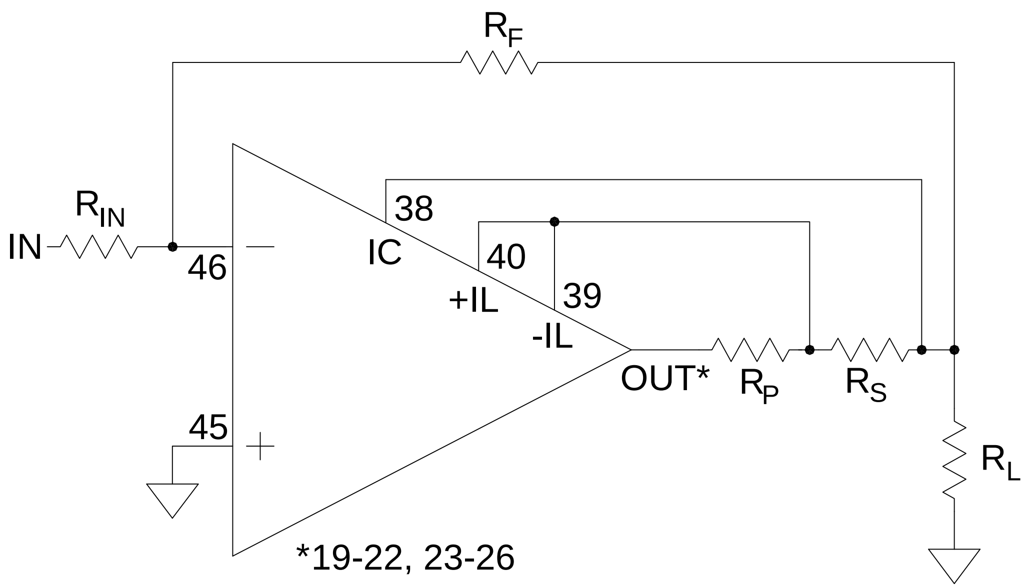


FIGURE 1.
4-WIRE CURRENT LIMIT CONNECTIONS

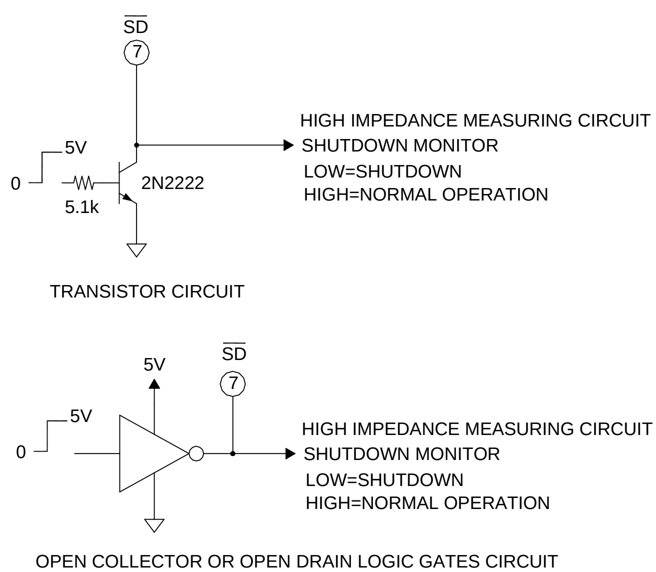


FIGURE 2.
EXTERNAL SHUTDOWN

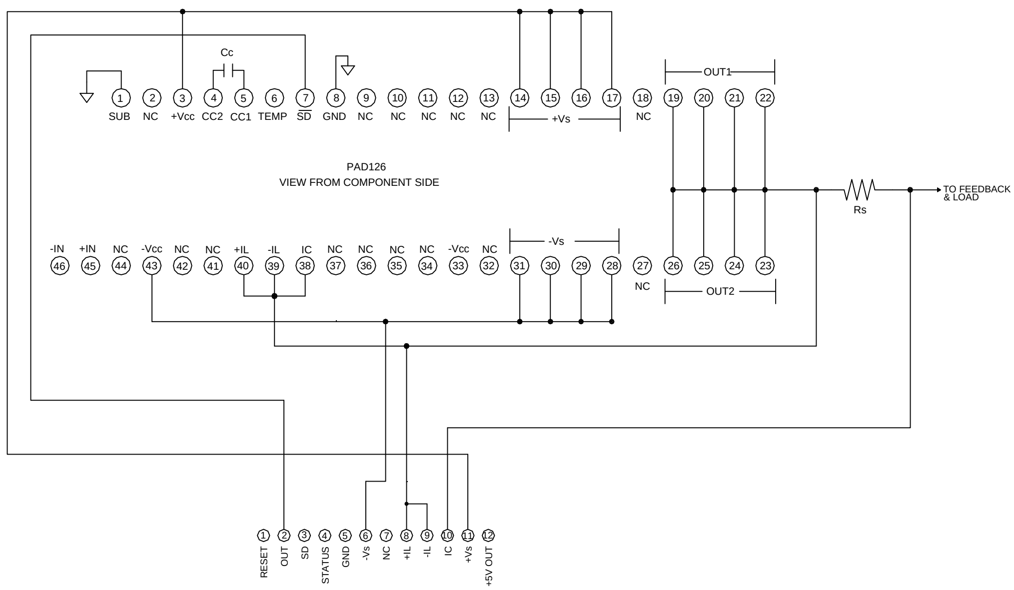


FIGURE 3.
TYPICAL CONNECTIONS PAD126 TO PAD125

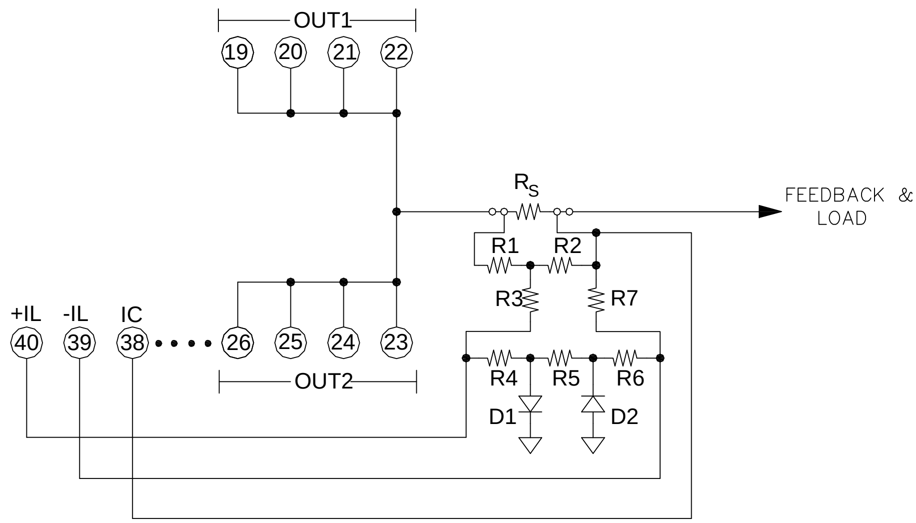


FIGURE 5
DUAL SLOPE (FOLD-OVER) CURRENT LIMIT

With the three current limit function pins (pins 38-40) dual slope current limiting can be implemented that more closely approximates the SOA curve of the amplifier than can be achieved with standard current limiting techniques. Values for resistors R1-R7 and R_S can be calculated using the ***PAD Power***™ spreadsheet that can be downloaded from the Power Amp Design web site.