

PowerAmp Design

HIGH POWER OPERATIONAL AMPLIFIER

PAD119

Rev D

KEY FEATURES

- LOW COST
- HIGH VOLTAGE – 200 VOLTS
- HIGH OUTPUT CURRENT – UP TO 30A
- 165 WATT DISSIPATION CAPABILITY
- 400 WATT OUTPUT CAPABILITY
- WIDE SUPPLY RANGE $\pm 10V$ – $\pm 100V$
- INTEGRATED HEAT SINK AND FAN
- TEMPERATURE REPORTING
- OVER-TEMPERATURE SHUTDOWN

APPLICATIONS

- LINEAR MOTOR DRIVE
- INDUSTRIAL AUDIO
- SEMICONDUCTOR TESTING
- VIBRATION CANCELLATION
- MAGNETIC BEARINGS

DESCRIPTION

The PAD119 high power operational amplifier is constructed with surface mount components to provide a cost effective solution for many industrial applications. With a footprint only 5.6 in² the PAD119 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 PAD119 also features a substrate temperature reporting output and over-temp shutdown. The amplifier circuitry is built on a thermally conductive but electrically insulating substrate mounted to an integral heat sink and fan assembly. The resulting module is a small, high performance turn-key solution for many industrial applications. The PAD119-1 model is available without the heat sink and fan assembly for custom heat sink applications.



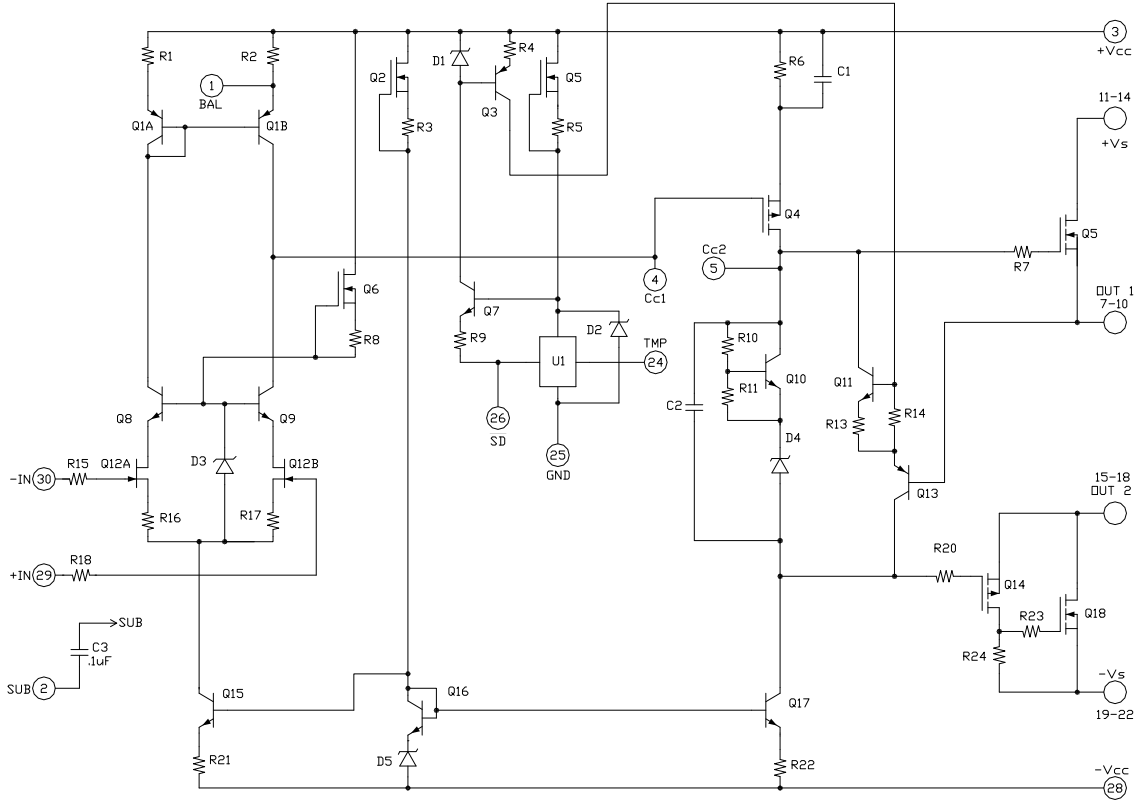
PAD119 MOUNTED IN EVALUATION KIT

A NEW CONCEPT

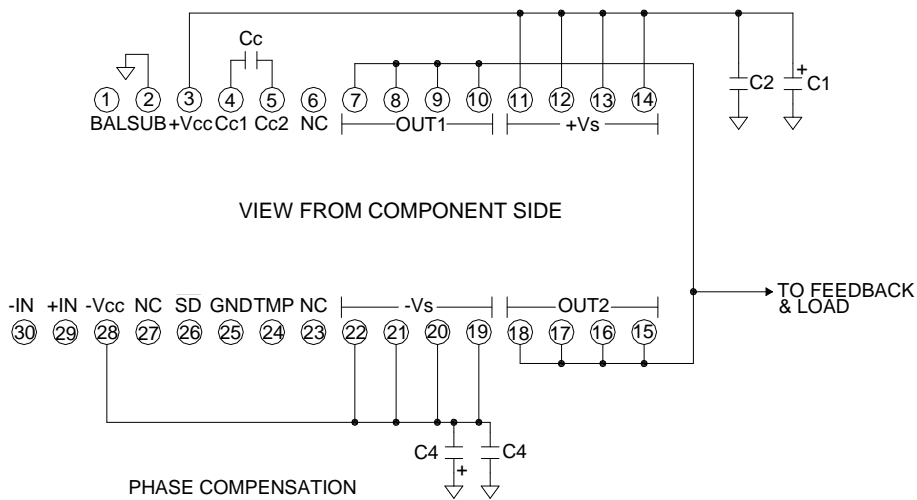
A critical task in any power amplifier application is cooling the amplifier. Until now component amplifier manufacturers often treated this task as an after-thought, left for the user to figure out. At **Power Amp Design** the best heat sink and fan combination is chosen at the start and becomes an integral part of the overall amplifier design. The result is the most compact and 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°C. The user no longer needs to specify, procure or assemble separate components.

PowerAmp Design ♦ PAD119 ♦ HIGH POWER OPERATIONAL AMPLIFIER

EQUIVALENT CIRCUIT



AMPLIFIER PINOUT & CONNECTIONS



PHASE COMPENSATION

| GAIN | Cc | SLEW V/uS |
|------|-------|-----------|
| 1 | 470pF | 3 |
| ≥10 | 100pF | 8 |

* SEE APPLICATION CIRCUITS FOR OTHER CONNECTIONS AND FUNCTIONS.

| ABSOLUTE MAXIMUM RATINGS | | | |
|---|--------------------------|------------------------------------|---------------------------|
| SUPPLY VOLTAGE, +Vs to -Vs ⁷ | 200V | INPUT VOLTAGE | +Vcc to -Vcc ⁷ |
| SUPPLY VOLTAGE +Vcc to -Vcc | 220V ⁷ | DIFFERENTIAL INPUT VOLTAGE | ± 20V |
| OUTPUT CURRENT, peak | 30A, within SOA | TEMPERATURE, pin solder, 10s | 300°C |
| POWER DISSIPATION, internal, DC | 165W | 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 | μV/°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 ∓ 10 | | | V |
| COMMON MODE REJECTION, DC | | 92 | | | dB |
| NOISE | 100kHz bandwidth, 1kΩ Rs | | 10 | | μV RMS |
| SHUTDOWN (SD) | Grounded | | | 1 | mA |
| GAIN | | | | | |
| OPEN LOOP | R _i = 100Ω, C _c =100pF | 108 | | | dB |
| GAIN BANDWIDTH PRODUCT @ 1MHz | C _c =100pF | | 1 | | MHz |
| PHASE MARGIN | Full temperature range | 60 | | | degree |
| OUTPUT | | | | | |
| VOLTAGE SWING | I _o = 20A | +Vs-6.1 | | | V |
| VOLTAGE SWING | I _o = -20A | -Vs+6.1 | | | V |
| CURRENT, continuous, DC | | 20 | | | A |
| CURRENT, peak within SOA | | | | 30 | A |
| SLEW RATE, A _v = -10 | C _c = 100pF | 7 | 8.5 | | V/μS |
| SETTLING TIME, to 0.1% | 2V Step | | 2 | | μS |
| RESISTANCE | No load, DC | | 3 | | Ω |
| POWER SUPPLY | | | | | |
| VOLTAGE ⁷ | | ± 15 | ± 75 | ± 100 | V |
| CURRENT, quiescent | | | 26 | 30 | mA |
| THERMAL | | | | | |
| RESISTANCE, AC, junction to air ⁴ | Full temperature range, f ≥ 60Hz | | | .46 | °C/W |
| RESISTANCE, DC, junction to air | Full temperature range | | | .76 | °C/W |
| TEMPERATURE RANGE, heat sink | | -40 | | 105 | °C |
| FAN, 60mm dc brushless, ball bearing | | | | | |
| OPERATING VOLTAGE | | | 12 | | V |
| OPERATING CURRENT | | | 150 | | mA |
| AIR FLOW | | | 25 | | CFM |
| RPM | | | 3800 | | RPM |
| NOISE | | | 30 | | dB |
| L10, life expectancy, 50°C ⁶ | | | 45 | | kHrs |
| L10, life expectancy, 25°C ⁶ | | | 60 | | kHrs |

NOTE

S:

1. Unless otherwise noted: T_c=25°C, compensation C_c=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°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°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.
7. +Vcc and -Vcc must not be more than 20V greater than +Vs and -Vs respectively

COOLING FAN

The PAD119 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. The cooling method used is impingement cooling, which means that cool air is pushed into the heat sink and warm air is exhausted through the spaces between the heat sink fins. To eliminate electrical noise created by the cooling fan we recommend a 47 μ F capacitor placed directly at the point where the fan wires connect to the PCB. See application note AN-24 for further details.

MOUNTING THE PAD119 AMPLIFIER

The amplifier is supplied with four 4-40 M/F hex spacers at the four corner of the amplifier. Since the male threaded ends of the spacers extend beyond the amplifier pins the spacers provide a convenient alignment tool to guide the insertion of the amplifier pins into the circuit board. 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.

MOUNTING THE PAD119-1 AMPLIFIER

Model PAD119-1 is supplied without the heat sink and fan assembly for custom applications. See “**PAD119-1 Dimensional Information**” for details. Spread a thin and even coat of heat sink grease across the back of the PAD119-1 and also the heat sink where the amplifier is to be mounted. Push the amplifier into the heat sink grease 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 and finish the mounting using 4-40 X 1/4” male/female hex spacers. Torque the hardware to 4.7 pound inch [0.53 N m] max. Do not rely on the hardware pressure to squeeze out any excess heat sink grease as this will likely only bend the substrate at the corners. The 1/4” hex spacers provide adequate spacing between the mother board and the components of the PAD119-1 and also provides some strain relief for the pins. It is recommended that the sockets similar to the PAD model CJS01 be used to mount the amplifier. The sockets provide additional strain relief on the pins and make it possible to remove the amplifier from the mother board. Without the sockets it may be next to impossible to remove the amplifier without damaging the mother board.

PHASE COMPENSATION

The PAD119 **must** be phase compensated to operate correctly. The compensation capacitor, C_C , is connected between pins 4 and 5. On page 6, Typical Performance Graphs, you will find plots for small signal response and phase response using compensation values of 100pF and 470pF. The compensation capacitor must be an NPO type capacitor rated for the full

supply voltage (200V). 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. A compensation capacitor less than 100pF is not recommended.

TEMPERATURE REPORTING

An analog output voltage is provided (pin 24, TMP) relative to ground 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. When monitoring TMP filter the voltage as shown in Figure 3. See **Applications Circuits**.

THERMAL SHUTDOWN

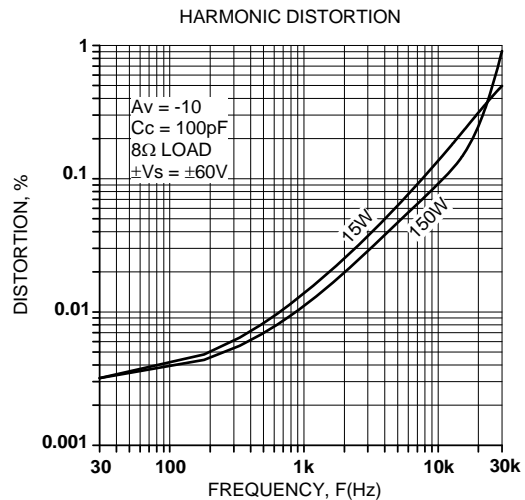
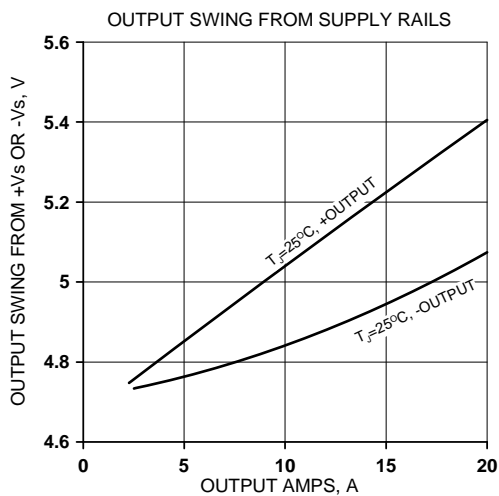
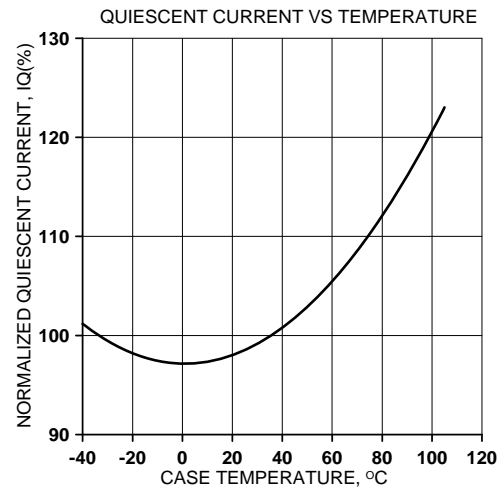
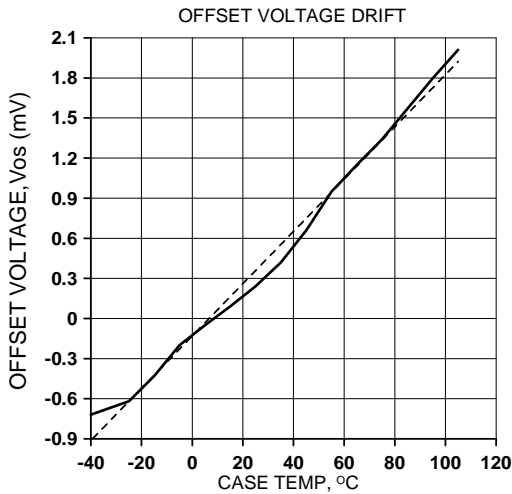
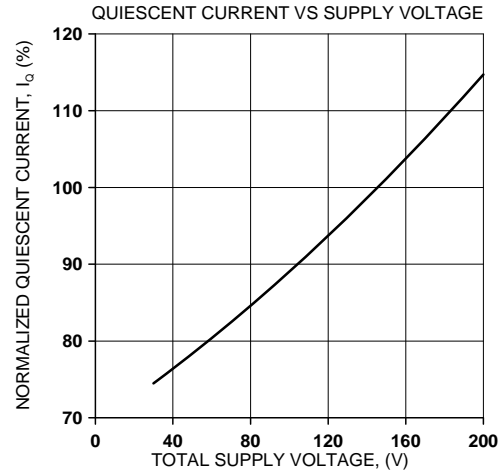
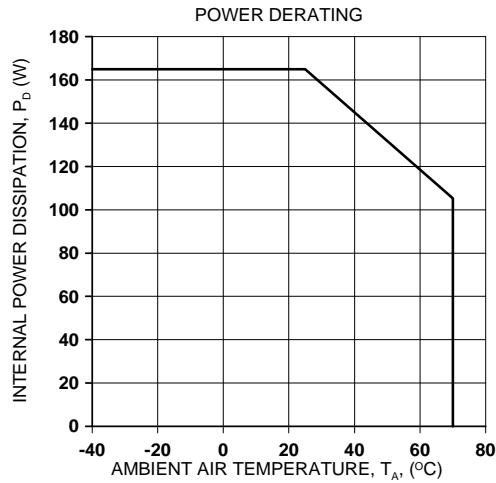
The temperature monitoring circuit automatically turns off the output transistors when the substrate temperature reaches 110°C. When the substrate cools down 10°C the output is enabled once again. The thermal shutdown feature is activated either by amplifier overloads or a failure of the fan circuit.

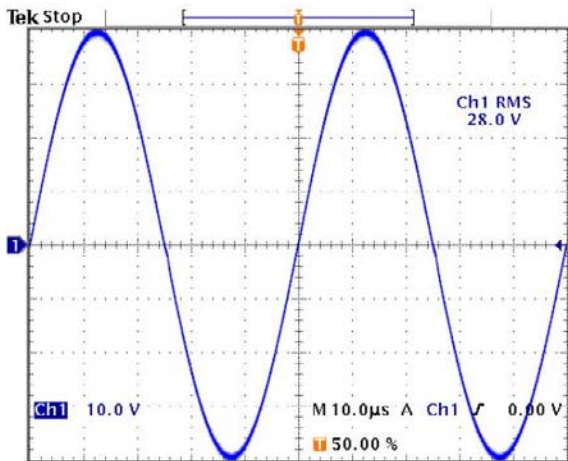
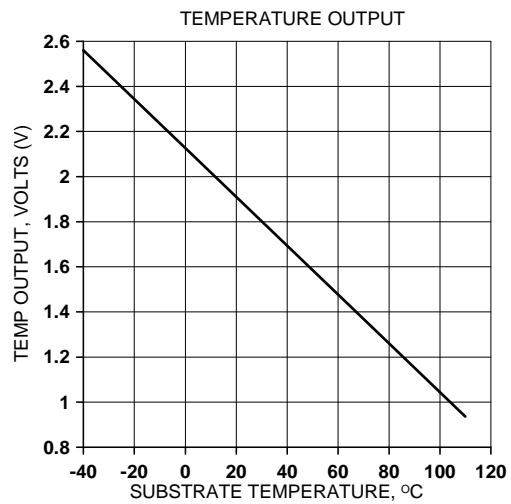
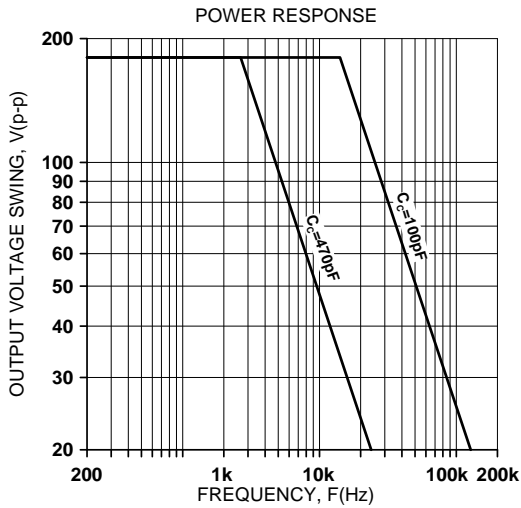
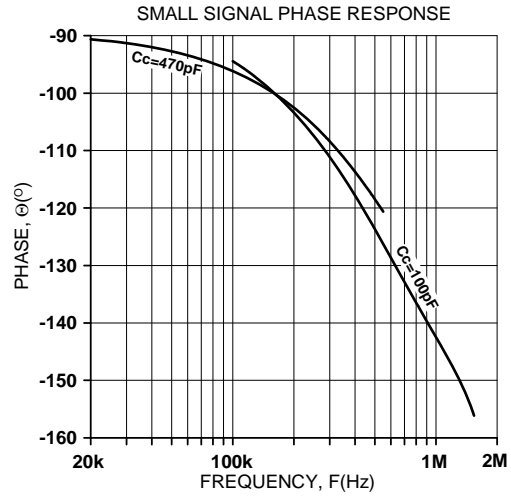
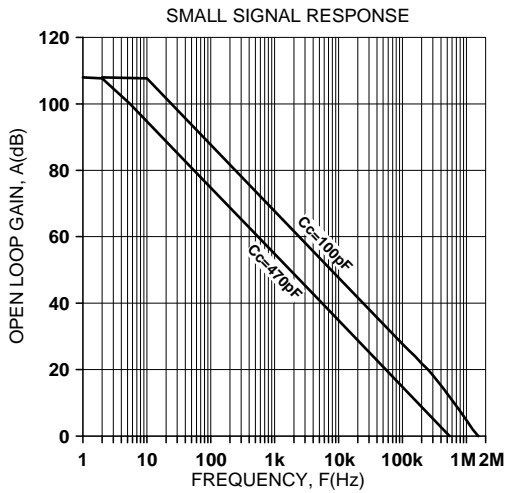
EXTERNAL SHUTDOWN

When pin 26 (\overline{SD}) is taken low (ground) the output stage is turned “off” and remains “off” as long as pin 26 is low. When pin 26 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 26 indicates the temperature is in the normal range. A “low” (ground) indicates a shutdown condition. See **Application Circuits** for details on how to implement an external shutdown circuit and how to monitor the shutdown status.

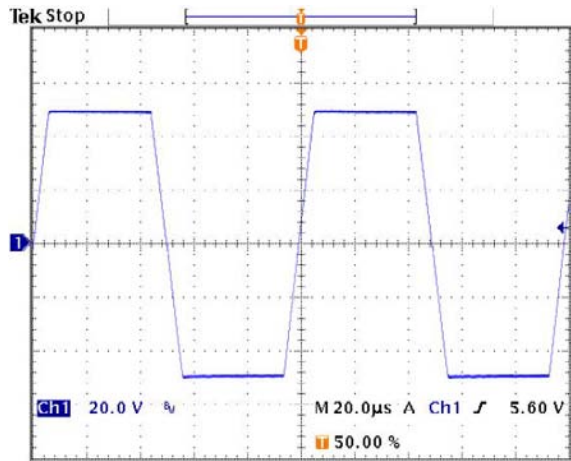
CURRENT LIMIT

The PAD119 does not have a current limiting circuit built in. However, a Current Limit Accessory Module, model PAD125, is available if the current limiting function is needed for the application. See the PAD125 data sheet and **Application Circuits** for a typical connection diagram.

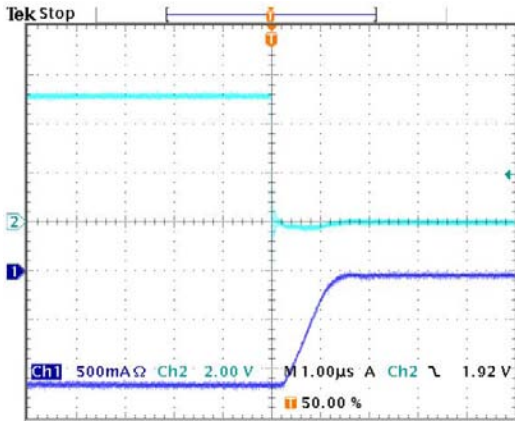




80V p-p 20kHz into 4 Ω load, G=-10, Cc=100pF



100Vp-p 10kHz Pulse into 8 Ω load, G=-10, Cc=100pF

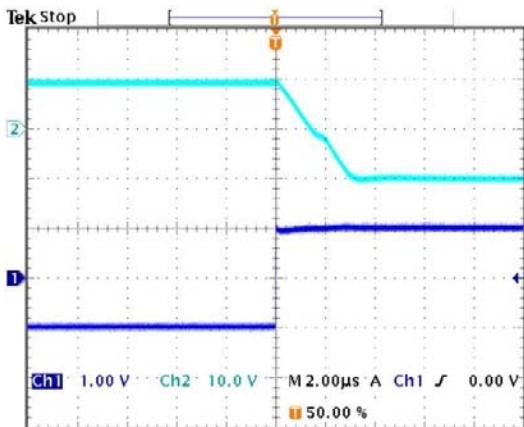
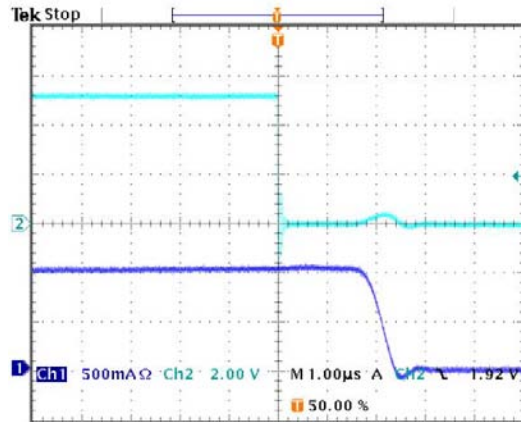


SHUTDOWN RESPONSE, NEGATIVE OUTPUT TO ZERO TRANSITION

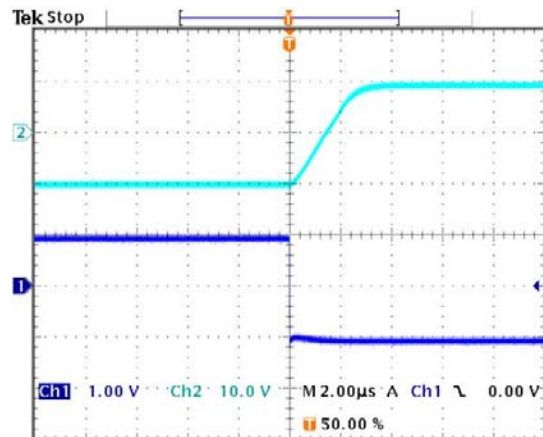
The oscilloscope display at the left shows an expanded view of a 1kHz 1.2A p-p amplifier output signal being interrupted near the negative peak by a shutdown signal on Ch2. The Ch1 display shows the output *current* going to zero about 1.5μS after the shutdown signal goes low.

SHUTDOWN RESPONSE, POSITIVE OUTPUT TO ZERO TRANSITION

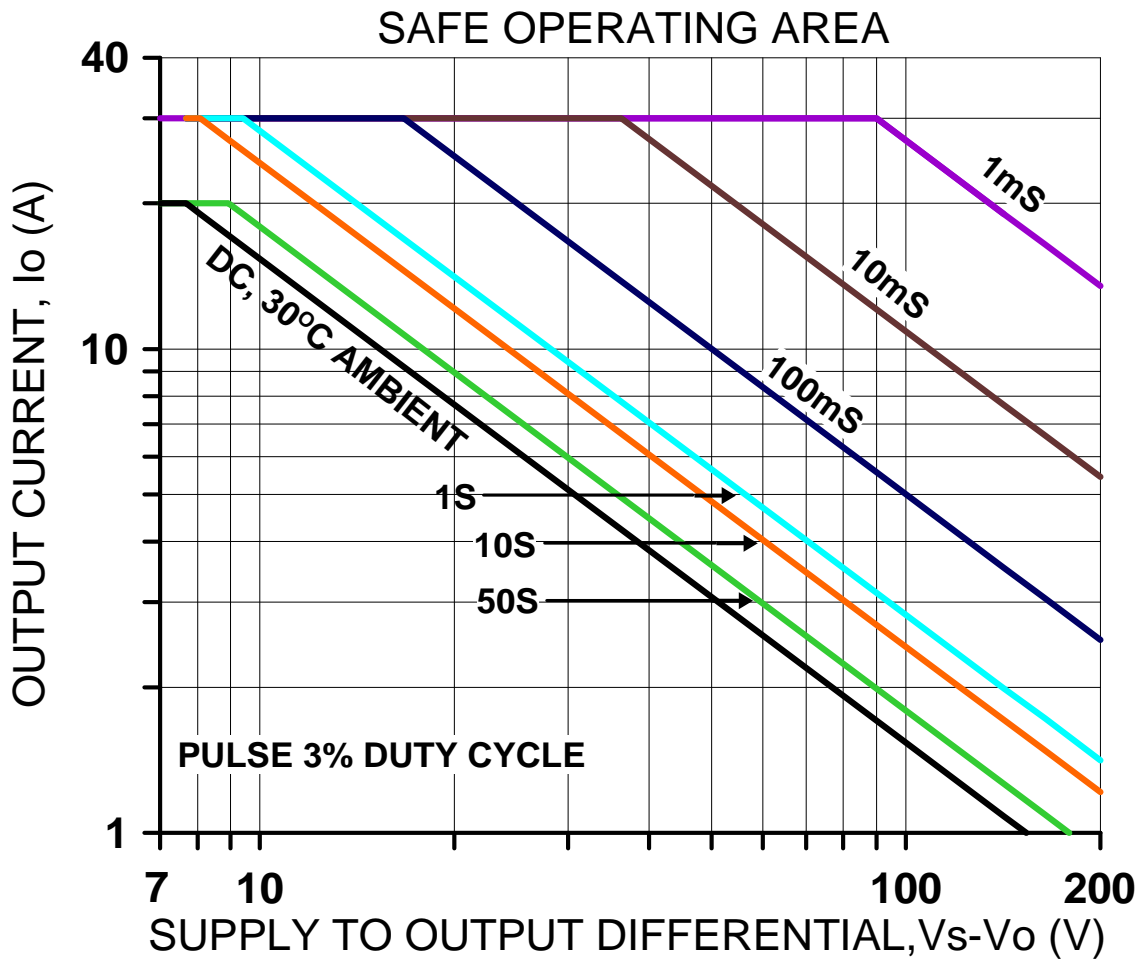
The oscilloscope display at the right shows an expanded view of a 1kHz 1.2A p-p amplifier output signal being interrupted near the positive peak by a shutdown signal on Ch2. The Ch1 display shows the output *current* going to zero about 2.5μS after the shutdown signal goes low.



Pulse Response, Positive to Negative, 4Ω Load
G=-10, Cc=100pF

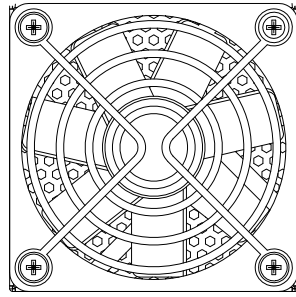


Pulse Response, Negative to Positive, 4Ω Load
G=-10, Cc=100pF



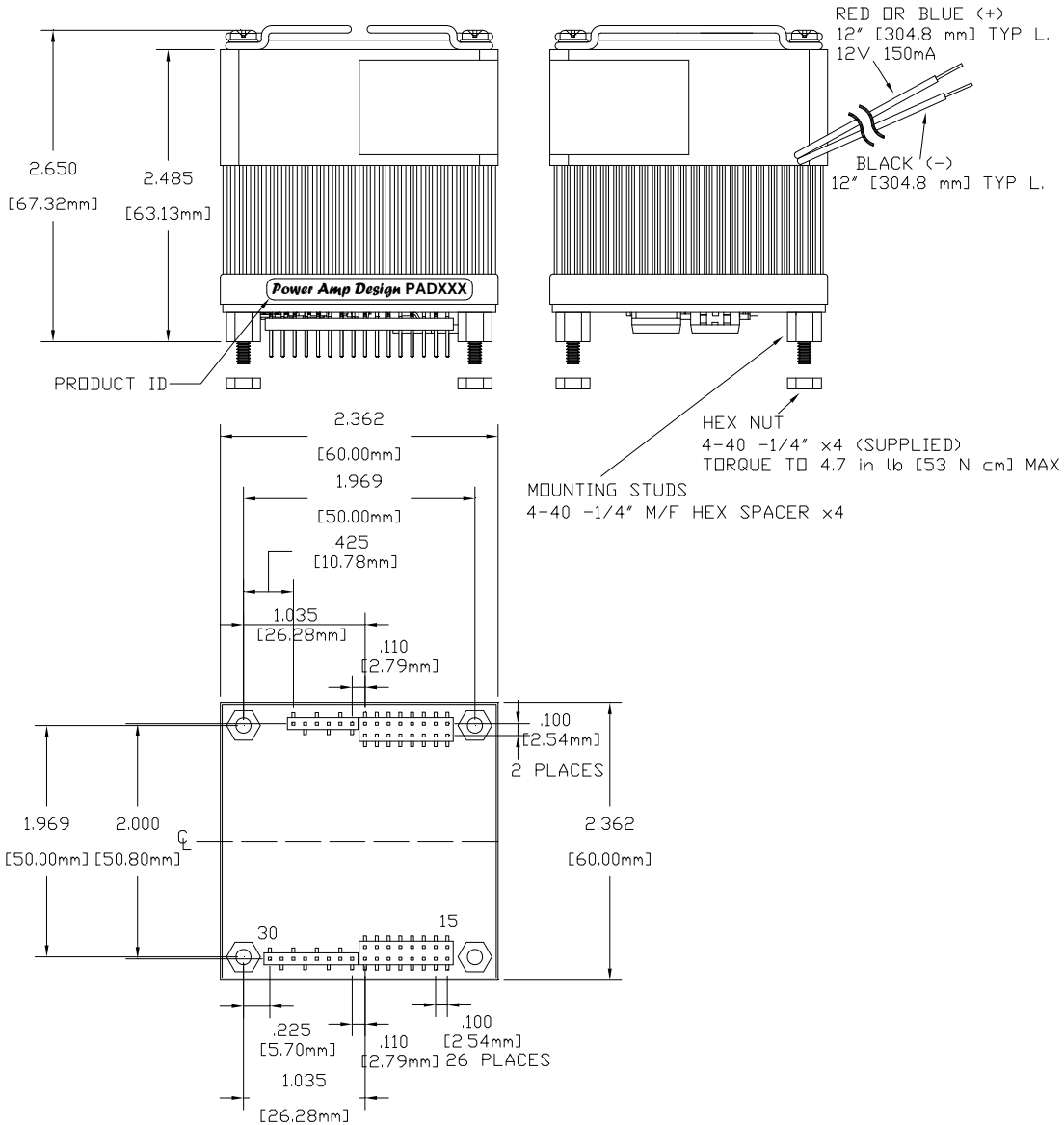
SAFE OPERATING AREA

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 PAD119 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 under the *Design Spreadsheet tab*. While the graph above adequately shows DC SOA and some pulse information it does not take into account ambient temperatures higher than 30°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.



NOTES:

1. PINS .0025" SQUARE X30
2. RECOMMENDED HOLE FOR MOUNTING 0.129" X4
3. RECOMMENDED HOLE FOR PINS 0.052" D.
4. TOTAL ASSEMBLY WEIGHT APPROX 8.1 oz [230 g]
5. HEAT SINK WEIGHT APPROX 4.55 oz [129 g]



PowerAmp Design ♦ PAD119 ♦ HIGH POWER OPERATIONAL AMPLIFIER

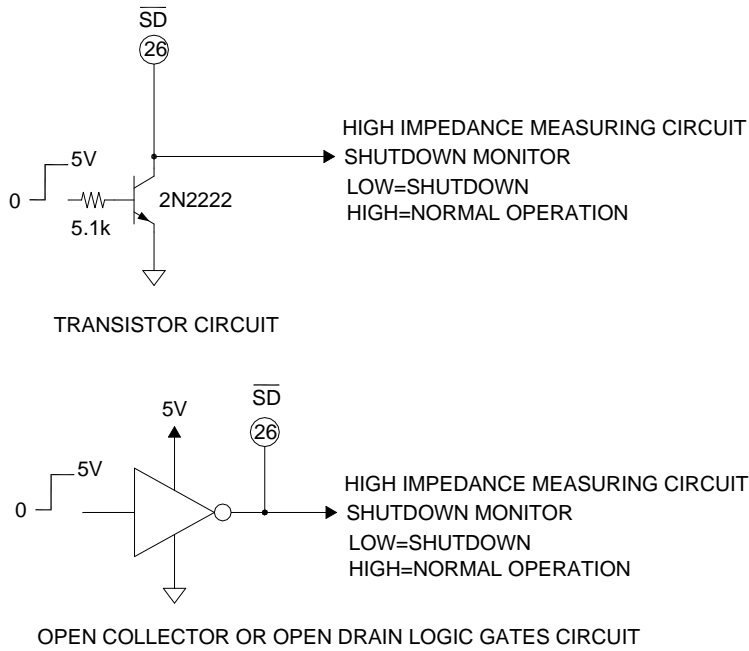


FIGURE 1.
EXTERNAL SHUTDOWN WITH MONITOR

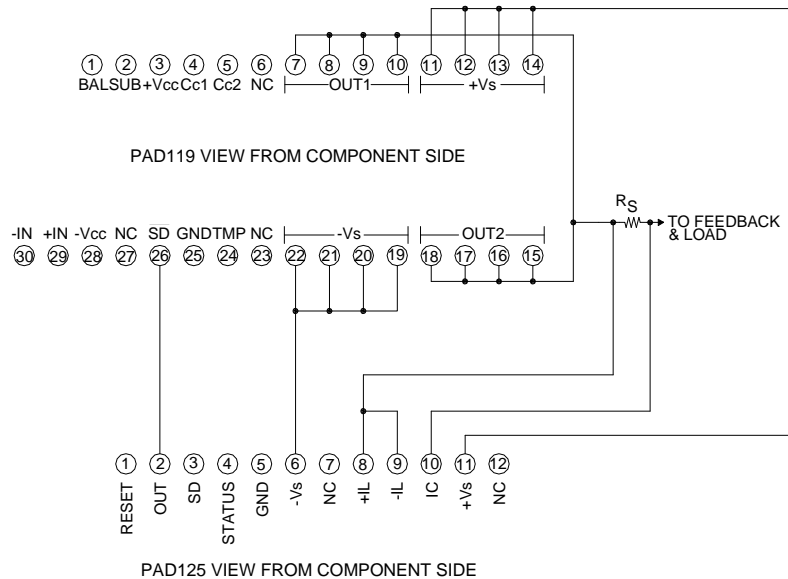


FIGURE 2.
TYPICAL PAD119 CONNECTIONS TO PAD125 ACCESSORY MODULE

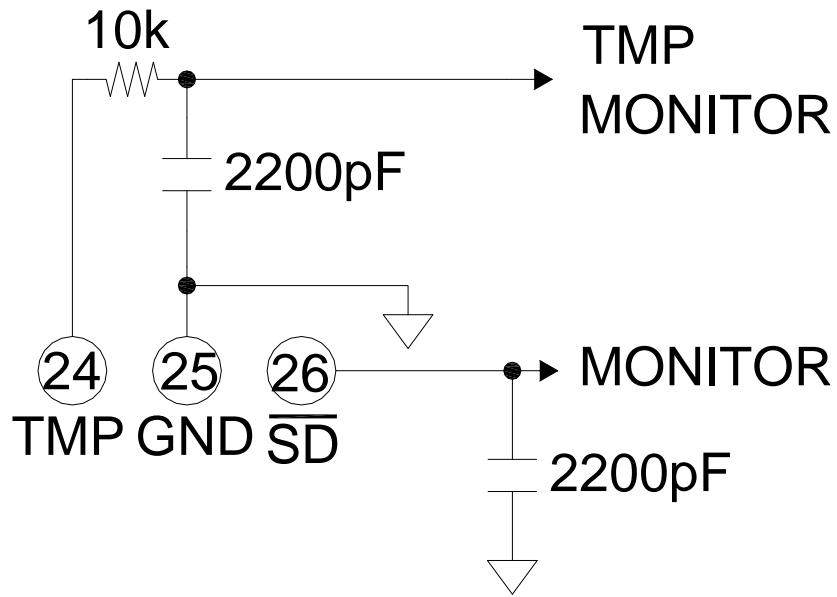


FIGURE 3.
MONITORING TMP AND \overline{SD} OUTPUTS