


KEY FEATURES

- **LOW COST**
- **POWER BANDWIDTH - 100kHz, 180Vp-p**
- **HIGH VOLTAGE – 200 VOLTS**
- **HIGH OUTPUT CURRENT - 20Apk**
- **140 WATT DC DISSIPATION CAPABILITY**
- **WIDE SUPPLY RANGE $\pm 20V - \pm 100V$**
- **INTEGRATED HEAT SINK AND FAN**
- **TEMPERATURE REPORTING**
- **SHORT CIRCUIT PROTECTION**
- **OVER-TEMPERATURE SHUTDOWN**
- **CONFORMALLY COATED**
-  **RoHS COMPLIANT**

APPLICATIONS

- **PRINT HEAD PIEZO DRIVE**
- **SEMICONDUCTOR TESTING**
- **VIBRATION CANCELLATION**

DESCRIPTION

The PAD146 high power operational amplifier is constructed with surface mount components to provide a cost-effective solution for many industrial applications but is aimed primarily for driving industrial ink jet print heads. With a footprint only 5.6 in² the PAD146 offers outstanding performance that rivals much more expensive hybrid components. User selectable external compensation tailors the amplifier's response to the application requirements. The PAD146 also features a substrate temperature reporting output and over-temp and over-current shutdown. The amplifier circuitry is built on a thermally conductive but electrically insulating substrate mounted to an integral heat sink and fan assembly. No BeO is used in the amplifier. The resulting module is a small, high-performance turn-key solution for many industrial applications. For custom applications the PAD146-1 can be ordered without the heat sink and fan.



PAD146



PAD146-1

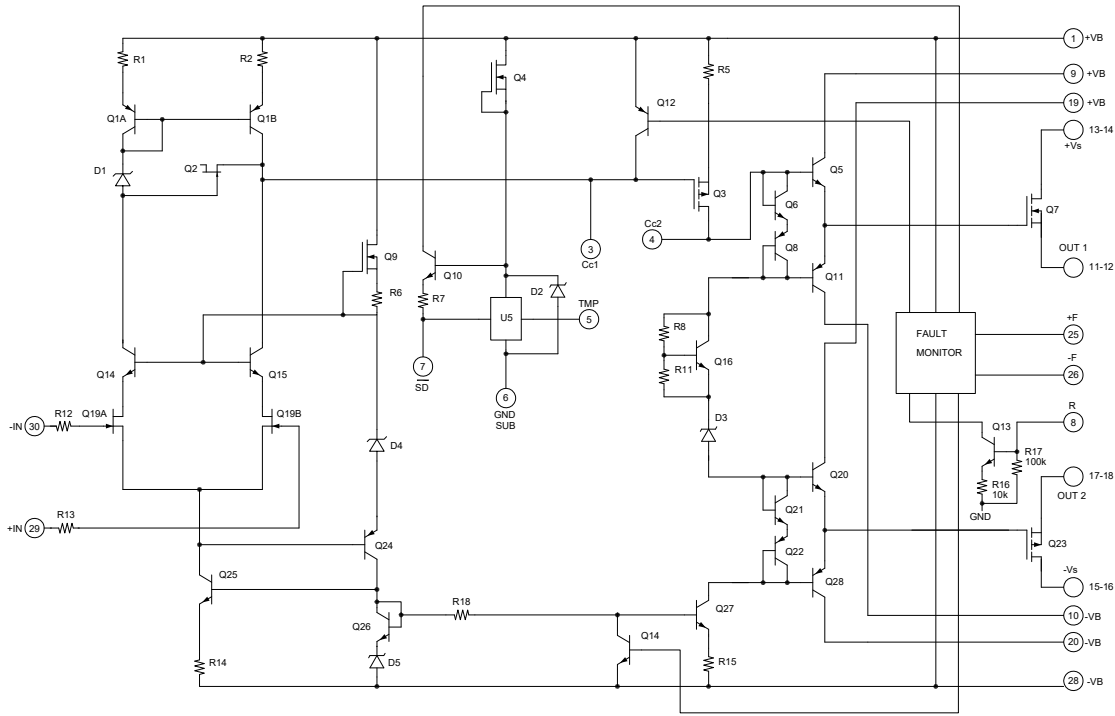


PAD146 mounted in EVAL146 evaluation kit

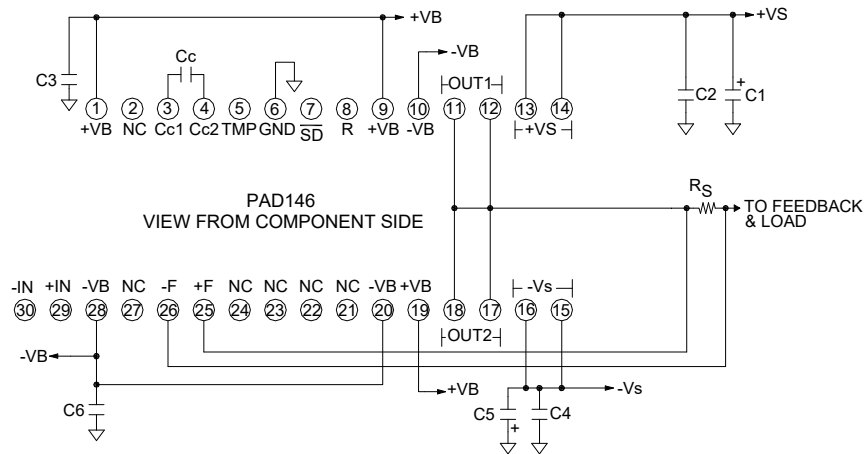
A NEW CONCEPT

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.

EQUIVALENT CIRCUIT



AMPLIFIER PINOUT & CONNECTIONS



NOTES:

1. Cc IS NPO (COG) RATED FOR FULL SUPPLY VOLTAGE +Vs TO -Vs
2. PINS 13 & 14 MUST BE TIED TOGETHER, PINS 15 & 16 MUST BE TIED TOGETHER.
3. C1 AND C5 ELECTROLYTIC, 10uF PER AMP OUTPUT CURRENT
4. C2,3,4,6 HIGH QUALITY CERAMIC 0.1uF, RATED FOR FULL SUPPLY VOLTAGE
5. ALL OUTPUT PINS MUST BE TIED TOGETHER

ABSOLUTE MAXIMUM RATINGS			
SUPPLY VOLTAGE, +VS to -VS	200V	TEMPERATURE, pin solder, 10s	300C
BOOST VOLTAGE, ±VB	±VS ±20V	TEMPERATURE, junction ²	150°C
OUTPUT CURRENT, within SOA	20A PULSE, 9ADC	TEMPERATURE RANGE, storage	-40 to 105°C
POWER DISSIPATION, internal, DC	140W	OPERATING TEMPERATURE, heat sink	-40 to 85°C
INPUT VOLTAGE, differential	± 20V	INPUT VOLTAGE, common mode	±VB

PARAMETER	TEST CONDITIONS ¹	MIN	TYP	MAX	PAD146-1 ⁹	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				+VB-12		V
COMMON MODE VOLTAGE RANGE				-VB+7		V
COMMON MODE REJECTION, DC		98	106			dB
NOISE	100kHz bandwidth, 1kΩ R _s		10			μV RMS
FAULT SENSING INPUTS						
R (RESET), 10μS min pulse width	Relative to GND, >4.5V to insure reset	0		5.5		V
+F		-VB		+VB		V
-F		-VB		+VB		V
+F TO -F	Differential voltage, shutdown		± 0.15			V
\overline{SD}	<0.2V to insure shutdown	0		5.5		V
GAIN						
OPEN LOOP	R _L = 10kΩ, C _C =10pF	108				dB
GAIN BANDWIDTH PRODUCT @ 1MHz	C _C =10pF		10			MHz
PHASE MARGIN	Full temperature range	45	60			degree
OUTPUT						
VOLTAGE SWING	I _O = 9A	+Vs-10	+Vs-8.6			V
VOLTAGE SWING	I _O = -9A	-Vs+10	-Vs+7			V
VOLTAGE SWING	+V _B = +Vs+10V, I _O = 9A	+Vs-1.6	+Vs-1.2			V
VOLTAGE SWING	-V _B = -Vs-10V, I _O = -9A	-Vs+5.1	-Vs+4.1			V
CURRENT, continuous, DC				9		A
SLEW RATE, A _v = -10	C _C = 10pF	65	85			V/μS
SETTLING TIME, to 0.1%	2V Step, C _C = 10pF		1			μS
RESISTANCE	No load, DC		4			Ω
POWER BANDWIDTH, 180Vp-p	C _C = 10pF		100			kHz
POWER SUPPLY						
VOLTAGE		± 15	± 75	± 100		V
CURRENT, quiescent			27	33		mA

NOTES:

1. Unless otherwise noted: T_C = 25°C, compensation C_C = 100pF, 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. +VS and -VS denote the positive and negative supply voltages to the output stage. +VB and -VB denote the positive and negative supply voltages to the input stages.
5. Rating applies if the output current alternates between both output transistors at a rate faster than 60Hz.
7. Power supply voltages +VB and -VB must not be less than +VS and -VS respectively. Total voltage +VB to -VB 240V maximum.
8. The PAD146 is constructed with MOSFET transistors and ESD handling procedures must be observed.
9. Specifications for the PAD146-1 are the same as for the PAD146 except as shown in this column.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	PAD146-1	UNITS
THERMAL						
RESISTANCE, AC, junction to air ⁵	Full temperature range, $f \geq 60\text{Hz}$			0.78	0.4	°C/W
RESISTANCE, DC, junction to air	Full temperature range			0.89	13	°C/W
RESISTANCE, DC, junction to case					0.5	
TEMPERATURE RANGE, heat sink		-40		85	NA	°C
TEMPERATURE RANGE, substrate					105	
TEMPERATURE RANGE, ambient				85	NA	
FAN, 60mm dc brushless, ball bearing						
OPERATING VOLTAGE			12		NA	V
OPERATING CURRENT			150		NA	mA
AIR FLOW			25		NA	CFM
RPM			3800		NA	RPM
NOISE			30		NA	dB
L10, life expectancy, 50°C ⁹			45		NA	kHrs
L10, life expectancy, 25°C ⁹			60		NA	kHrs

NOTES:

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

9. L10 refers to the time it takes for 10% of a population of fans to fail.

SAFETY FIRST

The operating voltages of the PAD146 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.

PRINT HEAD APPLICATIONS

Although the PAD146 can be used for many applications it is primarily intended for ink jet print head driver applications. It can drive large pulse currents at high frequencies into the capacitive load of an ink jet print head. The various protection features of the PAD146 are ideal for such an application. The PAD146-1 version is available without the heat sink and fan for custom applications where the user supplies a custom heat sink. In addition, the PAD146 is conformally coated for operation in challenging environments. You can find suggested circuits (Figures 5 and 6) on page 12 and the resulting scope photos at the top of page 9.

OVER-CURRENT FAULT PROTECTION

The output stage of the PAD146 is shut down when an over-current fault is detected. The protection circuit monitors the voltage across an external sense resistor, RS. The fault condition set point is programmed by:

$$IF = 0.15V/RS$$

Where **IF** is the value of the fault current set point and **RS** is the value of the sense resistor.

Whenever the programmed current set point is exceeded for more than 10µS (typical) the drive to the output stage turns off (typically in less than 200µS), and remains off until the circuit is reset (pin 8, R) via a 5V momentary pulse $\geq 10\mu S$ (or power recycled). The internal sense voltage reference is a precision temperature compensated reference voltage of 0.15V. The accuracy of the current fault sensing is typically better than 2%, plus the tolerance of the external sense resistor. A Kelvin sense resistor is recommended for best accuracy, but a properly connected standard resistor usually suffices. For some loads a start-up current may exceed the normal programmed maximum value. This condition should be considered when setting the programmed fault value. See Figure 1, below, for a typical over-current fault connection diagram. Note that during 10µS it takes to initiate shutdown the current may still be increasing depending on the details of the application.

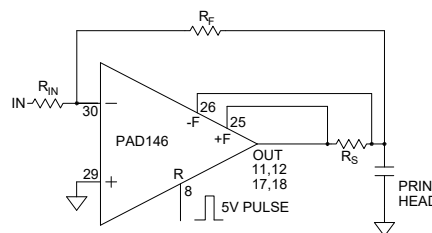


Figure 1

MOUNTING AMPLIFIER PAD146-1

In most applications the PAD146-1 must be attached to a heat sink. Spread a thin and even coat of heat sink grease across the back of the PAD146-1 and also the heat sink where the amplifier is to be mounted. 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 and finish the mounting using 4-40 X 3/16” X 7/16” hex male-female spacers. Mount the amplifier to the mother board with 4-40 X 1/4” screws.

PHASE COMPENSATION

The PAD146 **must** be phase compensated. The compensation capacitor, C_C, is connected between pins 3 and 4. The compensation capacitor must be an NPO type capacitor rated for the full supply voltage (200V). Consult also the small signal response and phase response plots for the selected compensation value in the Typical Performance Graphs section. Do not use a compensation capacitor less than 10pF. Recommended starting compensation capacitor, C_C, is 100pF.

BOOST OPERATION

The small signal stages of the PAD146 are connected to the ±VB power supply pins. When the ±VB voltages are greater than the ±VS power supply pins by 10V or more the small signal stages of the amplifier are biased so that the output MOSFETs can be driven very close to the ±VS rails. Close swings to the supply rails increase the efficiency of the amplifier and make better use the supply voltages. This technique is often used to operate the amplifier with only a single high current power supply, thus reducing the system size and cost. Also see the application article AN-22 *Single Supply Operation with Power Op Amps* for more detailed information and circuits. However, best fidelity of the output signal and highest frequency response is achieved when the output signal does not approach the power supply rails by less than 10V.

TEMPERATURE REPORTING

An analog output voltage is provided (pin 5, TMP) relative to ground (PIN 6) and proportional to the temperature in degrees C. The slope is approximately $-10.82\text{mV}/^\circ\text{C}$. The output voltage follows the equation:

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

or

$$V = 2.127 - (T/92.42)$$

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

SHUTDOWN FUNCTIONS

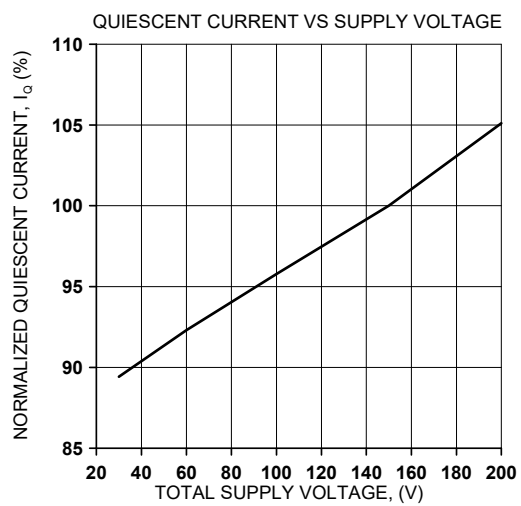
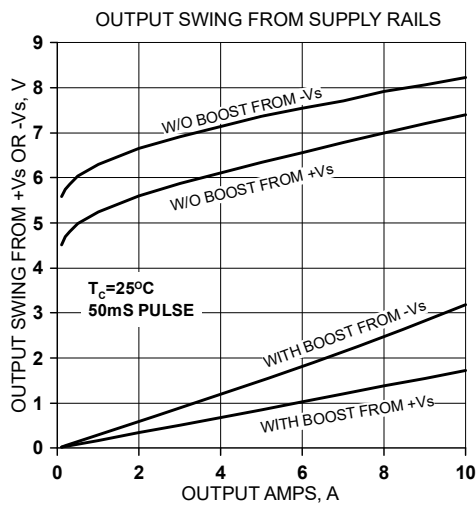
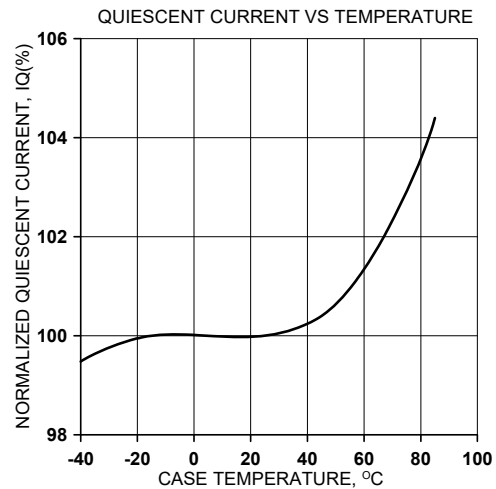
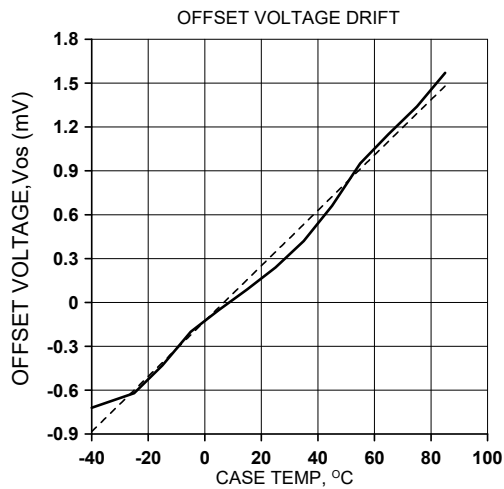
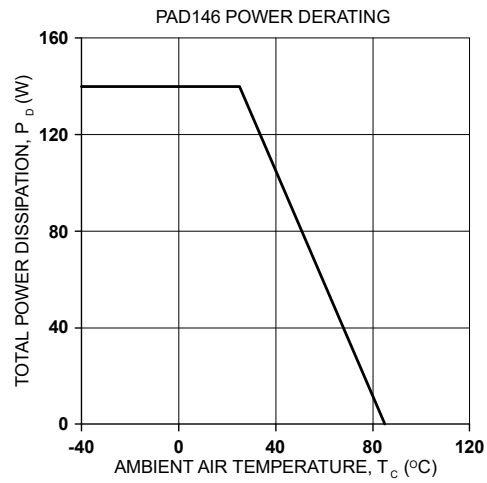
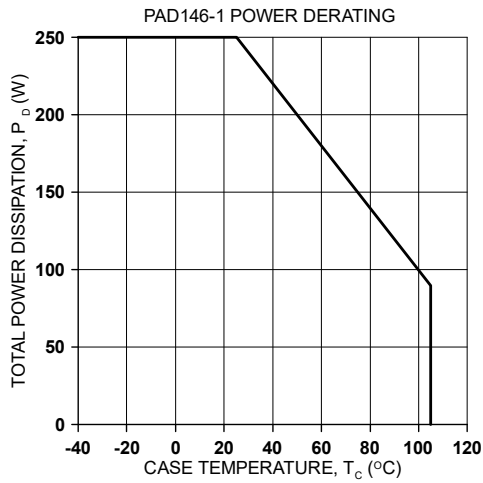
The temperature monitoring circuit automatically turns off the output MOSFETs when the substrate temperature reaches 110°C . The output remains disabled until the substrate temperature falls below 100°C and the circuit is reset (R, pin 8). The thermal shutdown feature is activated by amplifier thermal overload such as sustained high-power dissipation or inadequate heat sinking. The PAD146 may also be shut down using the $\overline{\text{SD}}$ function at pin 7. When pin 7 is driven low (to ground) the output of the amplifier shuts off (the output stage can supply no significant current but it is not a high impedance as some small current may still be available at the output pins and the output voltage during shutdown will be determined by the external circuit). Pin 7 may also serve as a monitor of the amplifier's status. When pin 7 is monitored with a high impedance circuit a "high" at pin 7 (about 5V) will indicate that the amplifier is functioning normally. A "low" (about ground voltage) will indicate that the amplifier is in its shutdown mode. When reset is applied the amplifier will resume normal operation unless the fault is still present. A continuous "high" at the reset pin will disable the fault circuits and consequently a reset signal should only be applied at a short pulse. See Figure 4 in Applications, page 11, for external shutdown circuits.

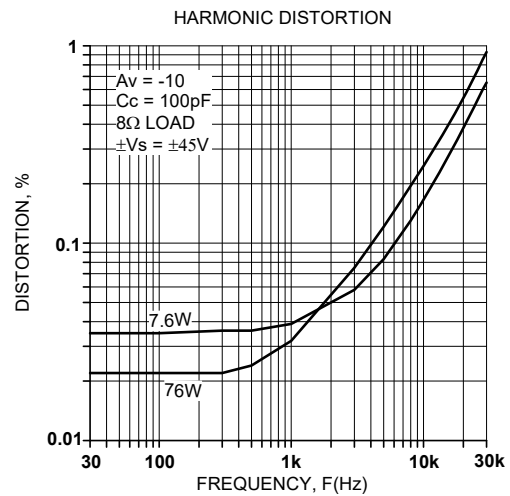
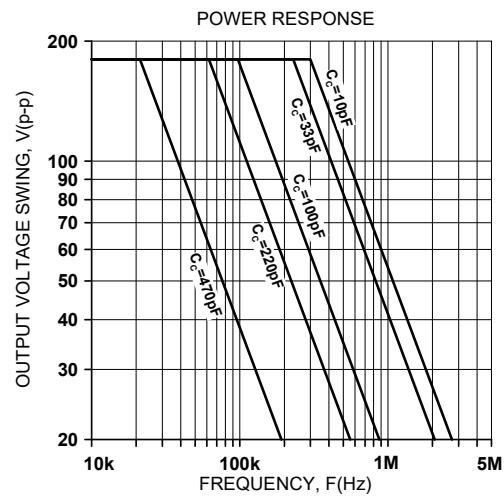
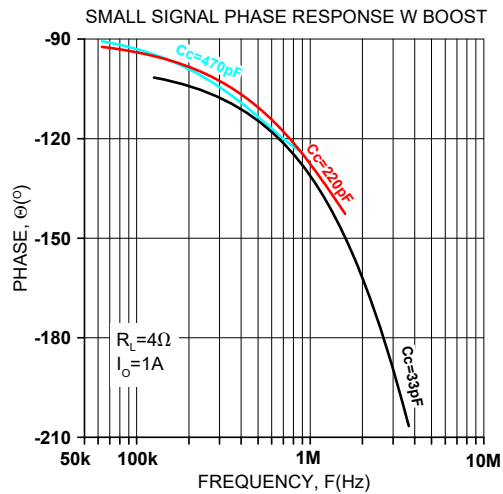
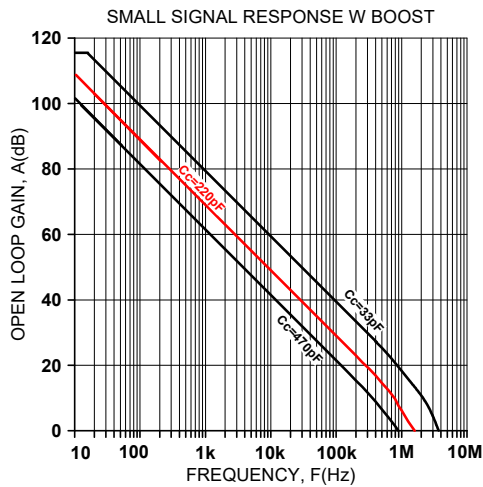
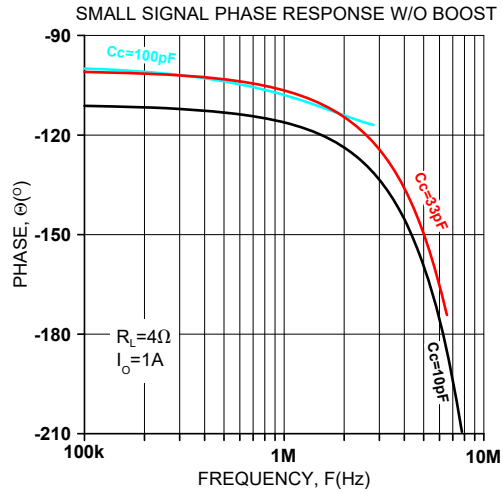
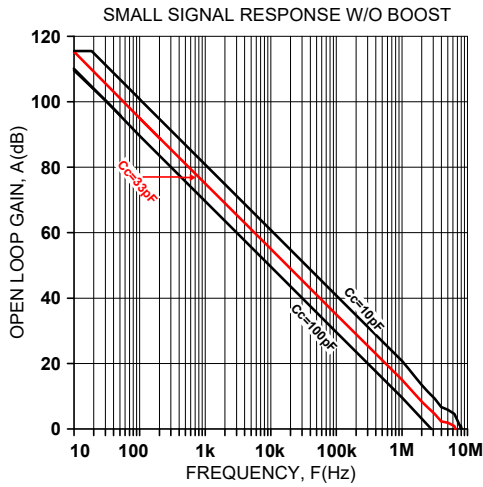
POWER-UP CONDITIONS

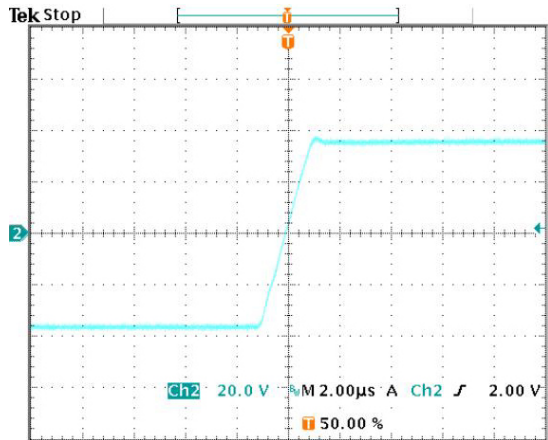
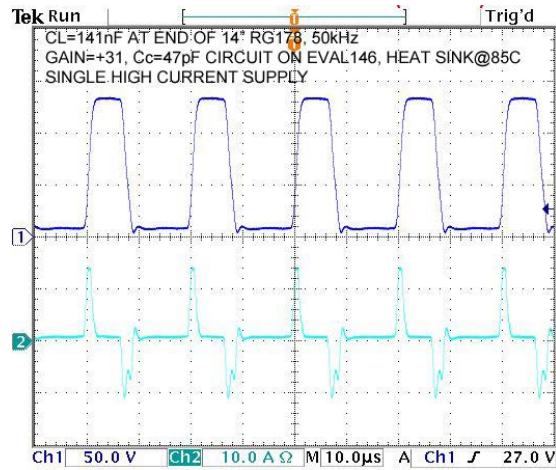
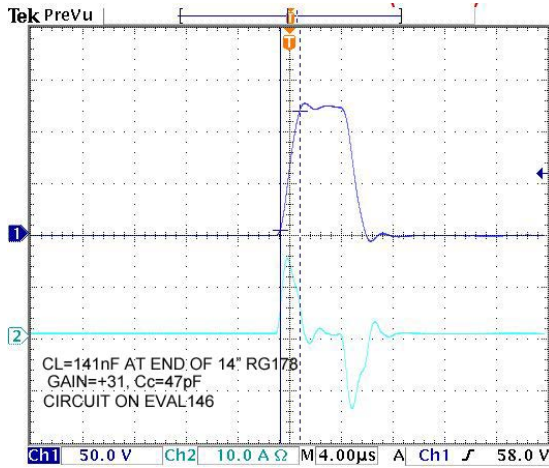
In most applications the PAD146 is powered by two power supplies. Under normal conditions both power supply voltages start to ramp up to their final values at the same time. However, if one power supply starts well before the other the over-current protection circuit may keep the output stage turned off. In this case it will be necessary to apply a momentary 5V reset pulse to pin 8 (Reset) to unlock the output stage of the amplifier. An auto-reset circuit can be connected to pin 8 to ensure that the amplifier's output is active upon power up, although this is not necessary if the power supplies are started at the same time. The form of this circuit is shown in Figure 3, Applications, page 11.

CONFORMAL COATING

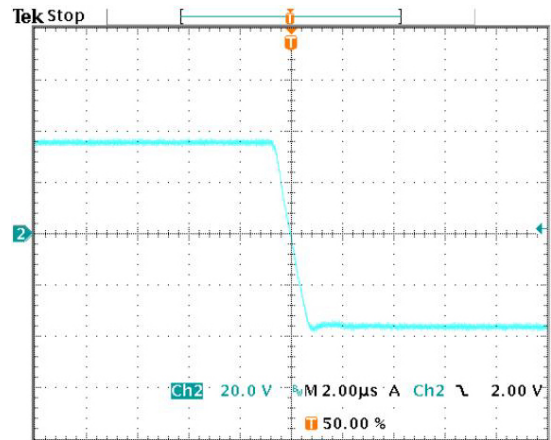
The PAD146 has a conformal coating to help protect against humidity and dirty environments. It is best that the circuit only be handled by the edges of the board to prevent disturbing the coating.



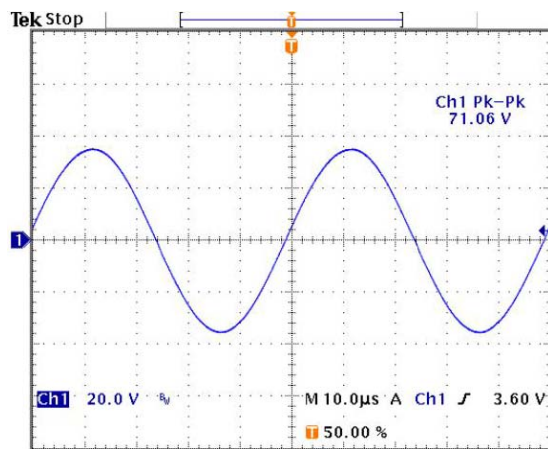




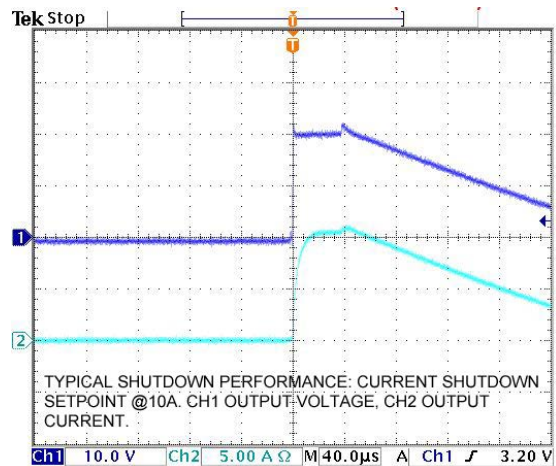
Pos. Pulse response, $G=-10$, $C_C=100\text{pF}$, 47nF load

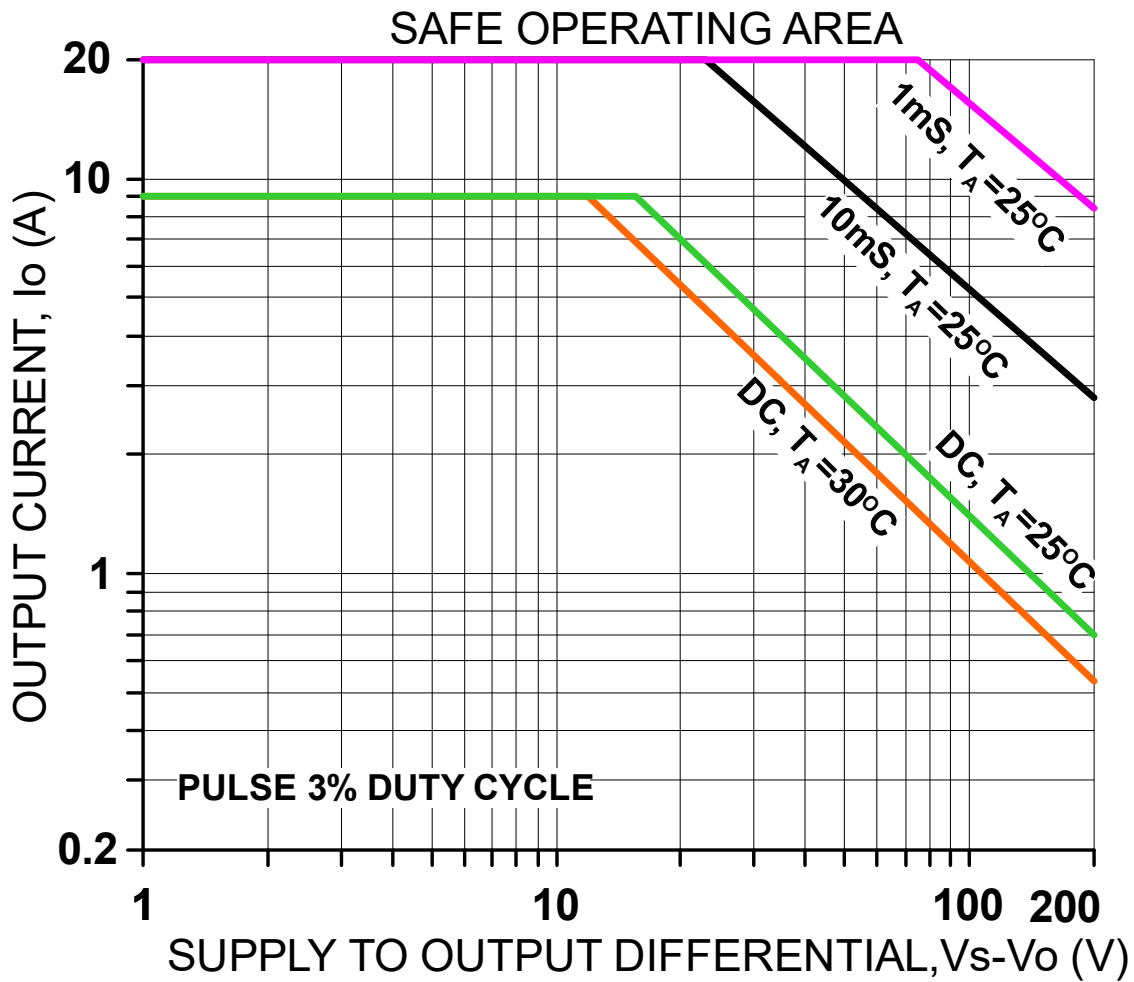


Neg. Pulse response, $G=-10$, $C_C=100\text{pF}$, 47nF load



20kHz sine into 8Ω load, $G=-10$, $C_C=100\text{pF}$





SAFE OPERATING AREA

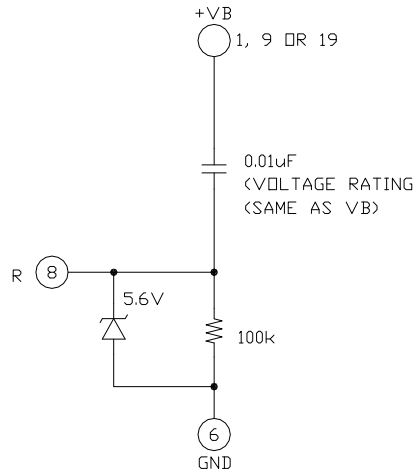


Figure 3
Power-up Reset

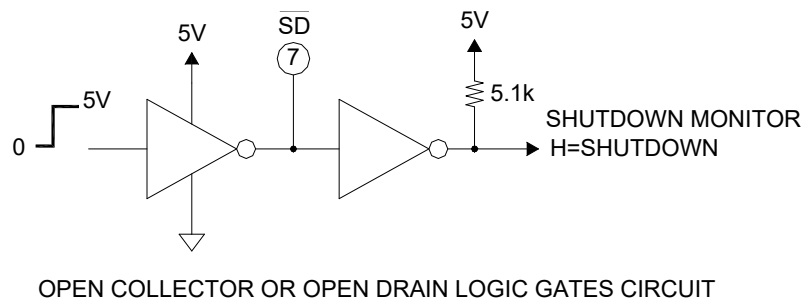
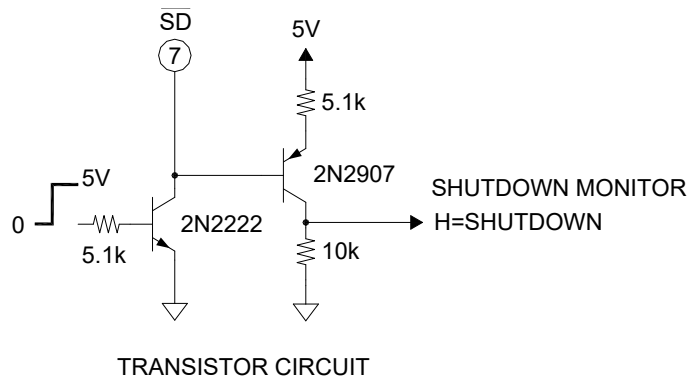


Figure 4
External Shutdown Circuits

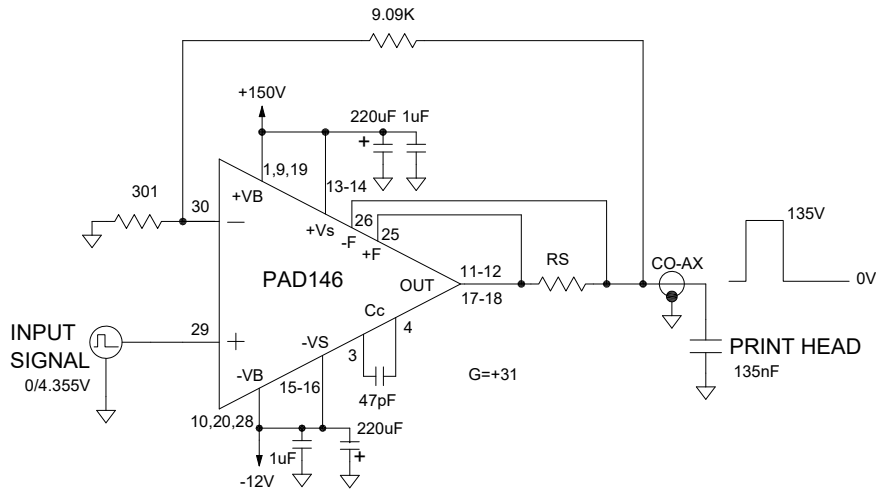


Figure 5
 Print Head Driver Circuit w/Two Power Supplies

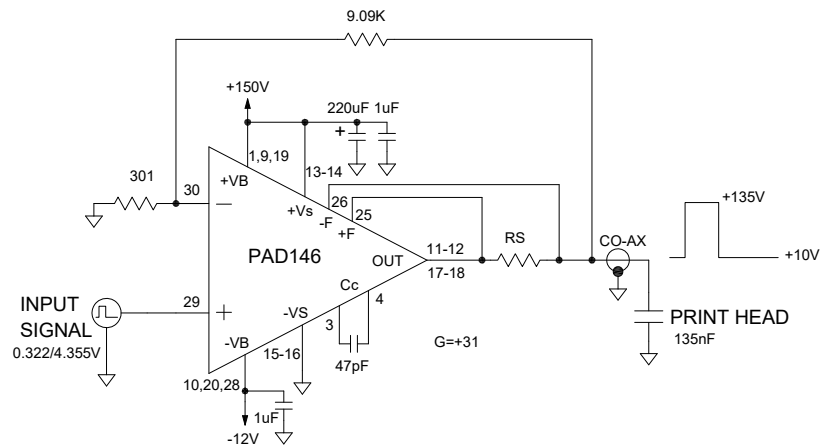
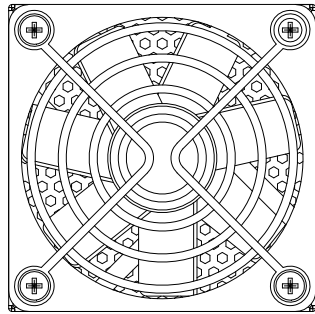
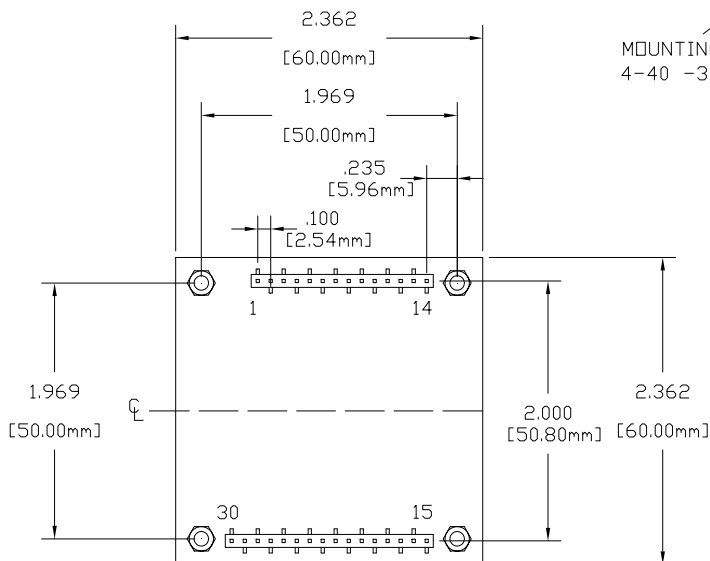
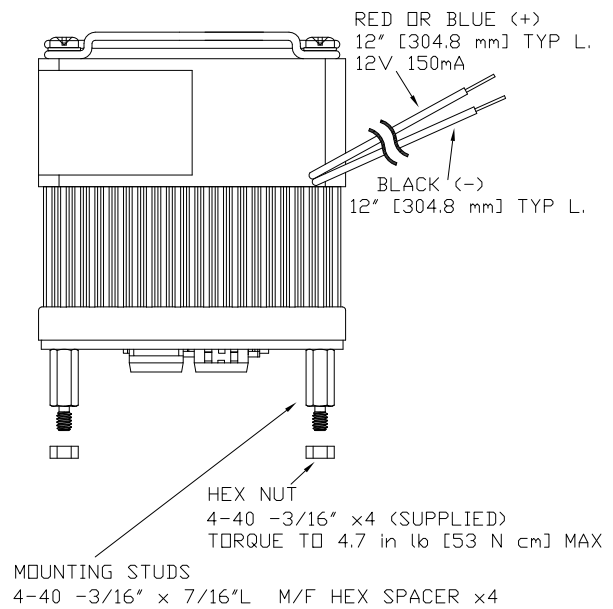
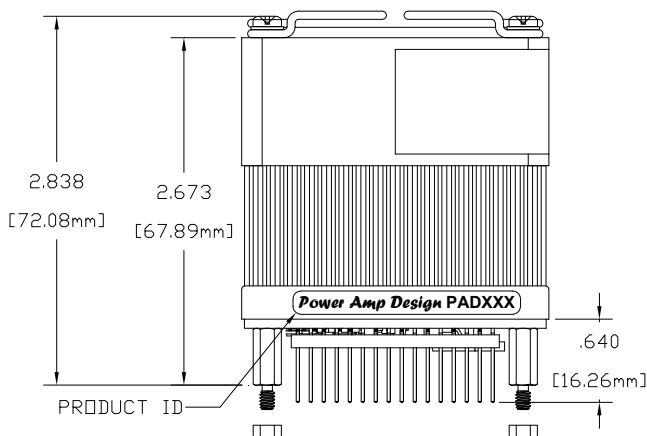


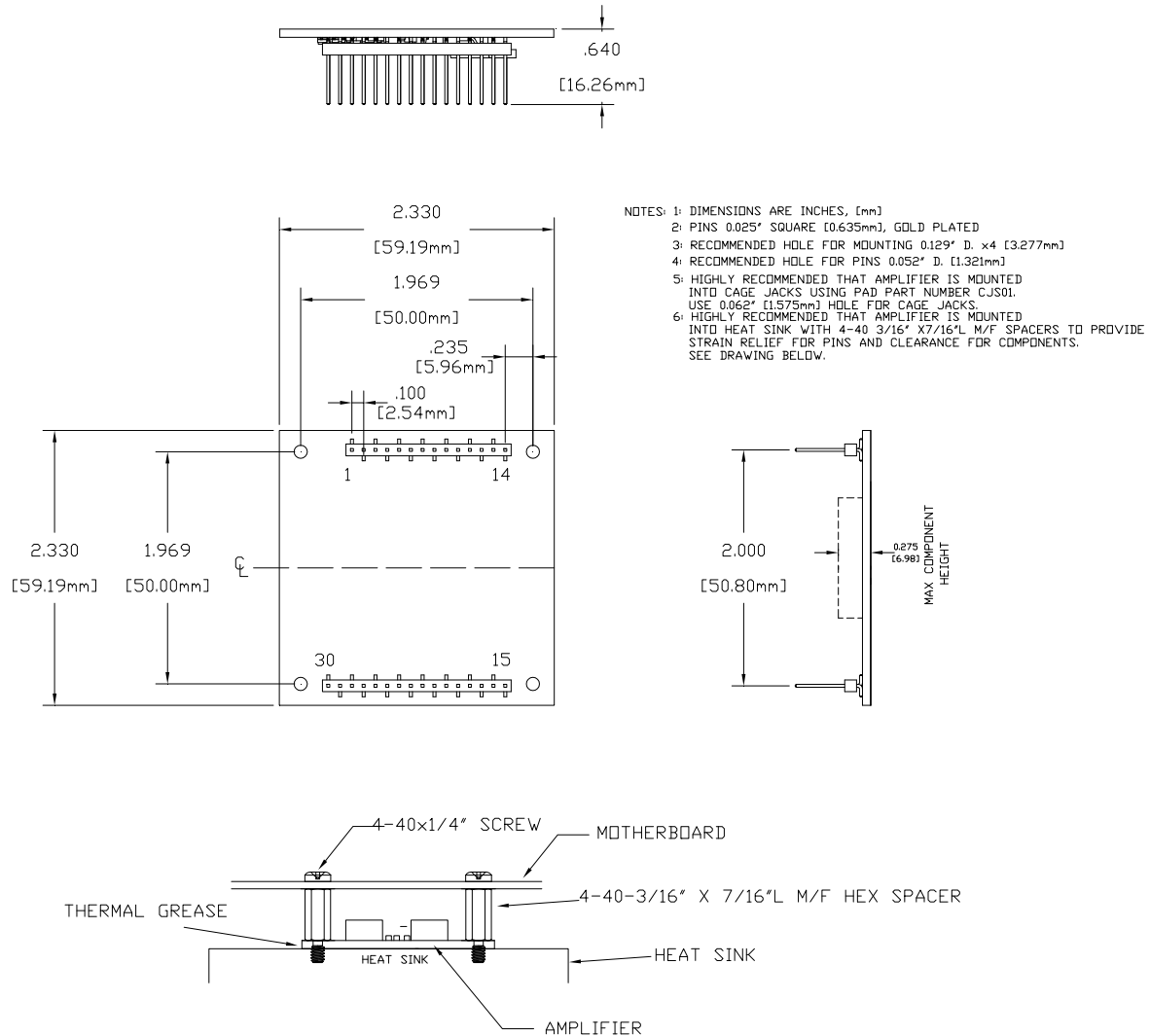
Figure 6
 Print Head Driver Circuit w/Single High Current Supply



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]
6. BOTTOM VIEW DIMENSIONS SUITABLE FOR PAD146-1





PAD146-1 DIMENSIONS