

# PowerAmp Design

COMPACT HIGH VOLTAGE OP AMP

PAD135

Rev G

## KEY FEATURES

- LOW COST
- SMALL SIZE 40mm SQUARE
- HIGH VOLTAGE – 200 VOLTS
- HIGH OUTPUT CURRENT – 10A PEAK
- 40 WATT DISSIPATION CAPABILITY
- 200V/ $\mu$ S SLEW RATE

## APPLICATIONS

- INDUSTRIAL INK JET PRINT HEADS
- HIGH VOLTAGE INSTRUMENTATION
- PIEZO TRANSDUCER DRIVE

## DESCRIPTION

The PAD135 compact high voltage op amp is constructed with surface mount components to provide a cost effective solution for many industrial applications such as an ink jet print head driver. With a footprint only 40mm square the PAD135 offers outstanding performance that rivals more expensive hybrid components. An integrated heat sink and fan cooling are included. User selectable external compensation tailors the amplifier's response to the application requirements. The PAD135 is capable of driving 150V pulses into 47nF at 50 kHz with a duty cycle of 40% and a slew rate of 200V/ $\mu$ S. The PAD135 is built on a thermally conductive but electrically insulating substrate. No BeO is used in the PAD135. For custom applications the PAD135-1 version of the amplifier is available without the integrated heat sink and fan



PAD135



PAD135-1



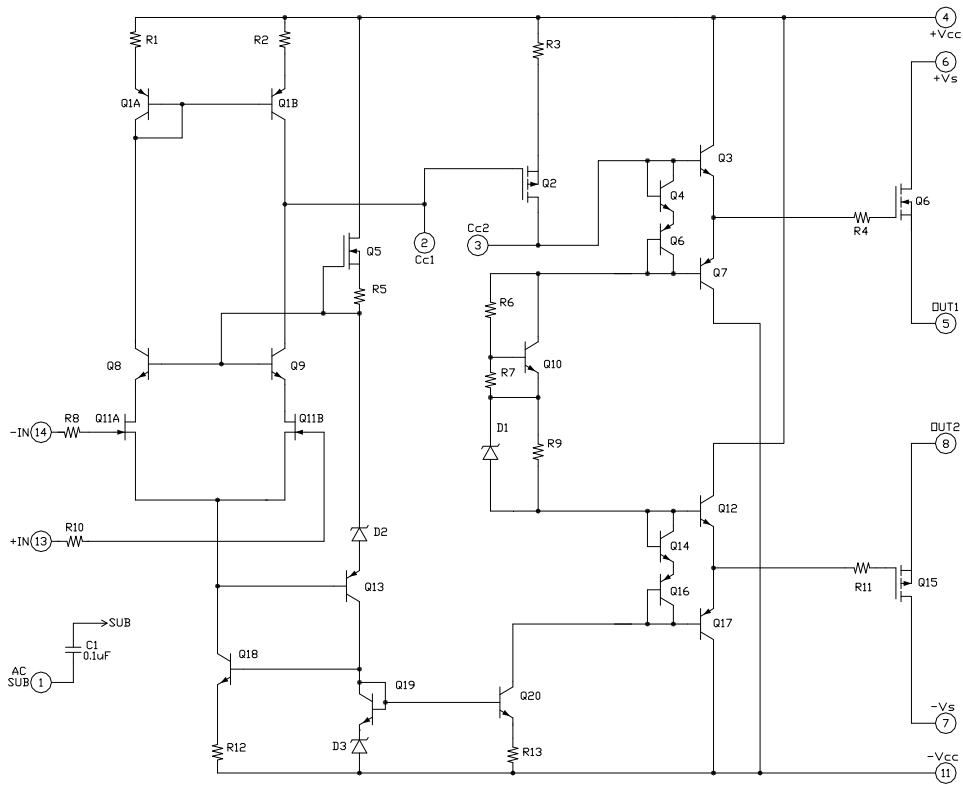
PAD135 MOUNTED IN EVAL135 EVALUATION KIT

## A NEW CONCEPT

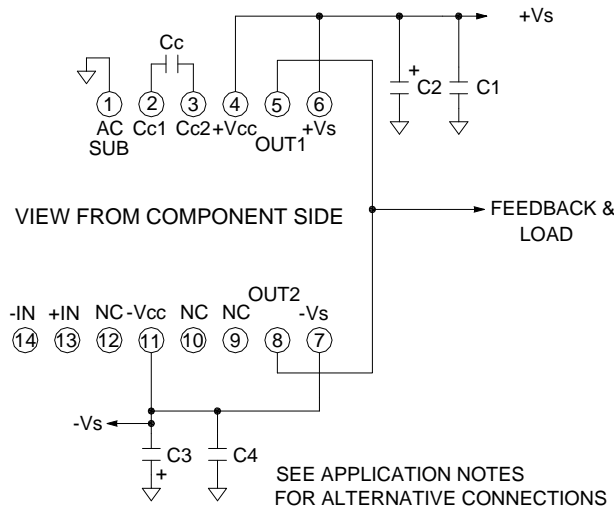
A critical task in any power amplifier application is cooling the amplifier. Until now component amplifier manufacturers often treated this task as an after-thought, left for the user to figure out. At **Power Amp Design** the best heat sink and fan is chosen at the start and becomes an integral part 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.

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EQUIVALENT CIRCUIT



PINOUT & CONNECTIONS



SEE APPLICATION NOTES FOR ALTERNATIVE CONNECTIONS

PHASE COMPENSATION	SLEW RATE
GAIN	$\frac{C_c}{C_c}$
$\geq 20$	10pF
$\geq 10$	22pF
$\geq 6$	47pF
$\geq 1$	150pF
	200V/uS
	150V/uS
	80V/uS
	25V/uS

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ABSOLUTE MAXIMUM RATINGS			
SUPPLY VOLTAGE, +Vs to -Vs <sup>4</sup>	200V	TEMPERATURE, pin solder,	10s, 300°C
SUPPLY VOLTAGE, +Vcc to -Vcc <sup>4</sup>	200V	TEMPERATURE, junction <sup>2</sup>	150°C
INPUT VOLTAGE +Vcc to -Vcc		TEMPERATURE RANGE, storage	-40 to 70°C <sup>5</sup>
DIFFERENTIAL INPUT VOLTAGE	± 20V	TEMPERATURE RANGE, storage, PAD135-1	105C
OUTPUT CURRENT, peak, within SOA	10A	OPERATING TEMPERATURE, substrate	-40 to 85°C
POWER DISSIPATION, internal, DC	40W		

PARAMETER	TEST CONDITIONS <sup>1</sup>	MIN	TYP	MAX	PAD135-1 <sup>9</sup>	UNITS
<b>INPUT</b>						
OFFSET VOLTAGE			1	5		mV
OFFSET VOLTAGE vs. temperature	Full temperature range		20	50		μV/°C
OFFSET VOLTAGE vs. supply				3		μV/V
BIAS CURRENT, initial <sup>3</sup>				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				+Vs-15		V
COMMON MODE VOLTAGE RANGE				-Vs+8		V
COMMON MODE REJECTION, DC		110	118			dB
NOISE	100kHz bandwidth, 1kΩ R <sub>s</sub>		10			μV RMS
<b>GAIN</b>						
OPEN LOOP	R <sub>L</sub> = 10kΩ, C <sub>C</sub> =10pF	108				dB
GAIN BANDWIDTH PRODUCT @ 1MHz	C <sub>C</sub> =10pF		4			MHz
PHASE MARGIN	Full temperature range	60				degree
<b>OUTPUT</b>						
VOLTAGE SWING	I <sub>O</sub> = 5A	+Vs-8	+Vs-6.5			V
VOLTAGE SWING	I <sub>O</sub> = -5A	-Vs+8	-Vs+6.5			V
CURRENT, continuous, DC				5		A
CURRENT, pulse, ≤10mS, within SOA				10		A
SLEW RATE, A <sub>v</sub> = +65	C <sub>C</sub> = 10pF		200			V/μS
SETTLING TIME, to 0.1%	2V Step, C <sub>C</sub> = 10pF		4			μS
RESISTANCE	No load, DC		8			Ω
<b>POWER SUPPLY</b>						
VOLTAGE		± 15	± 75	± 100		V
CURRENT, quiescent			29	32		mA
<b>THERMAL</b>						
RESISTANCE, AC, junction to air or case <sup>6</sup>	Full temperature range, f ≥ 60Hz			2.1 to air	1.7 to case	°C/W
RESISTANCE, DC junction to air or case	Full temperature range			3.1 to air	2.5 to case	°C/W
TEMPERATURE RANGE, substrate		-40		85	85	°C
TEMPERATURE RANGE, ambient <sup>5</sup>		-40		70	NA	°C
<b>FAN, 40mm dc brushless, ball bearing</b>						
OPERATING VOLTAGE			12		NA	V
OPERATING CURRENT			50		NA	mA
AIR FLOW			7.5		NA	CFM
RPM			7000		NA	RPM
NOISE			30		NA	dB
L10, life expectancy, 50°C <sup>8</sup>			45		NA	kHrs
L10, life expectancy, 25°C <sup>8</sup>			60		NA	kHrs

**NOTES:**

1. Unless otherwise noted: T<sub>C</sub> = 25°C, compensation C<sub>C</sub> = 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. +Vs and -Vs 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.

5. Limited by fan characteristics. During operation, even though the heat sink may be at 85°C the fan will be at a lower temperature.

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

7. Power supply voltages +Vcc and -Vcc must not be less than +Vs and -Vs respectively. Total voltage +Vcc to -Vcc 200V maximum.

8. L10 refers to the time it takes for 10% of a population of fans to fail. Lower ambient temperature increases fan life.

9. Specifications for the PAD135-1 are the same as for the PAD135 except as shown in this column.

### SAFETY FIRST

The operating voltages of the PAD135 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.

### COOLING FAN

The PAD135 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 $\mu$ 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 PAD135 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 oz [3.8 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.

### MOUNTING THE PAD135-1 AMPLIFIER

In most 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 PAD135-1 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 hex male-female spacers and torque to 4.7 in oz [3.8 N cm] max. Mount the amplifier to the mother board with 4-40 X 1/4” screws. See Dimensional Information for additional recommendations.

### PHASE COMPENSATION

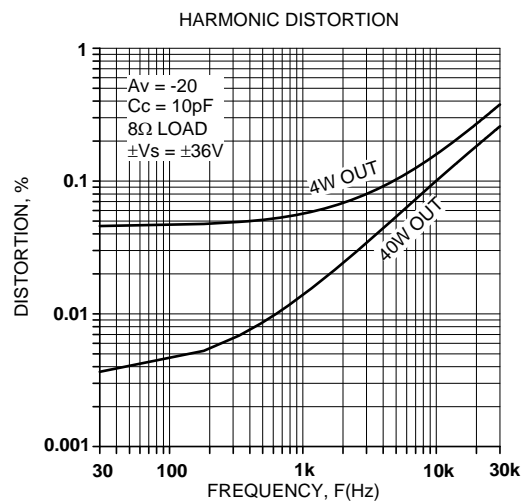
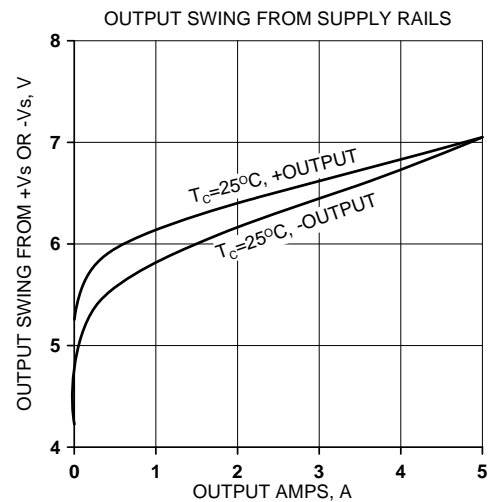
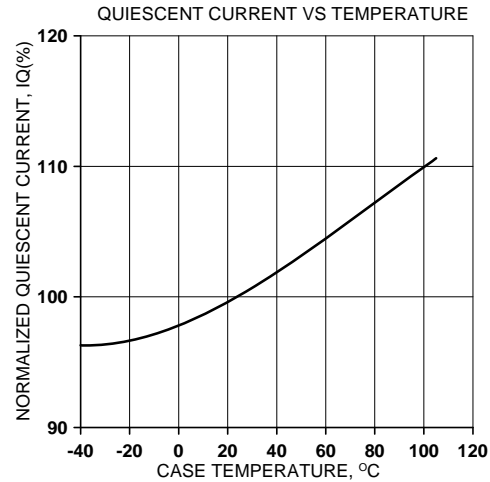
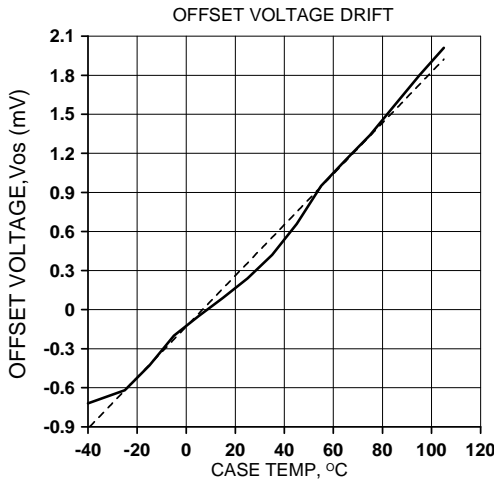
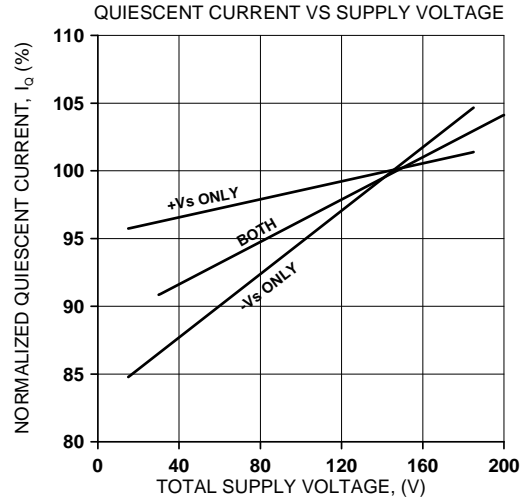
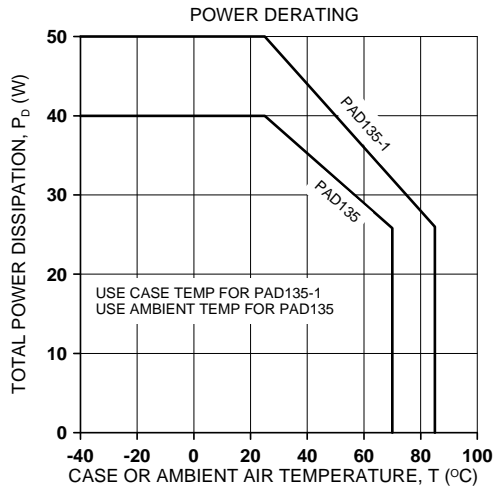
The PAD135 **must** be phase compensated. The compensation capacitor,  $C_C$ , is connected between pins 2 and 3. The compensation capacitor must be an NPO type capacitor rated for the full supply voltage (200V). On page 2, under Amplifier Pinout and Connections, you will find a table that gives recommended compensation capacitance value for various circuit gains and the resulting slew rate for each capacitor

value. 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.

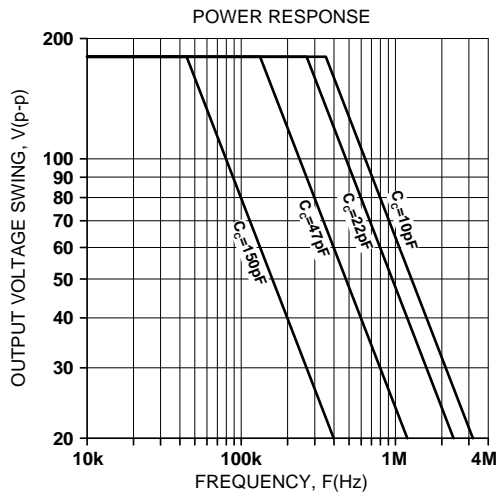
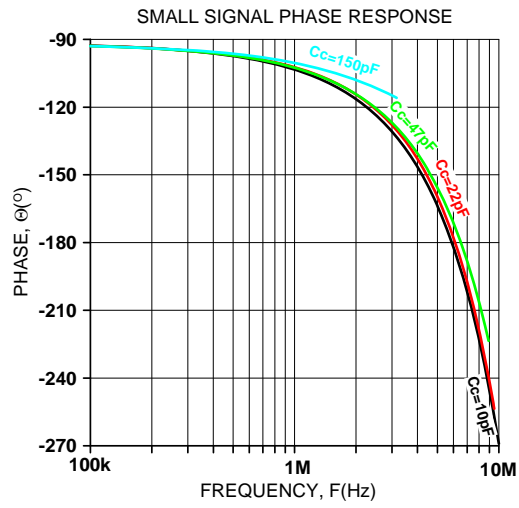
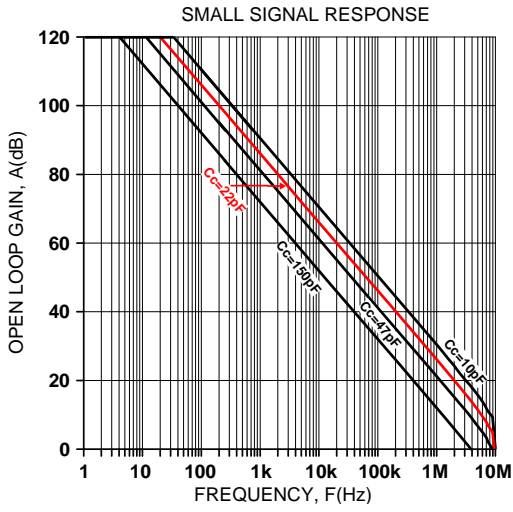
### SINGLE HIGH-CURRENT SUPPLY OPERATION

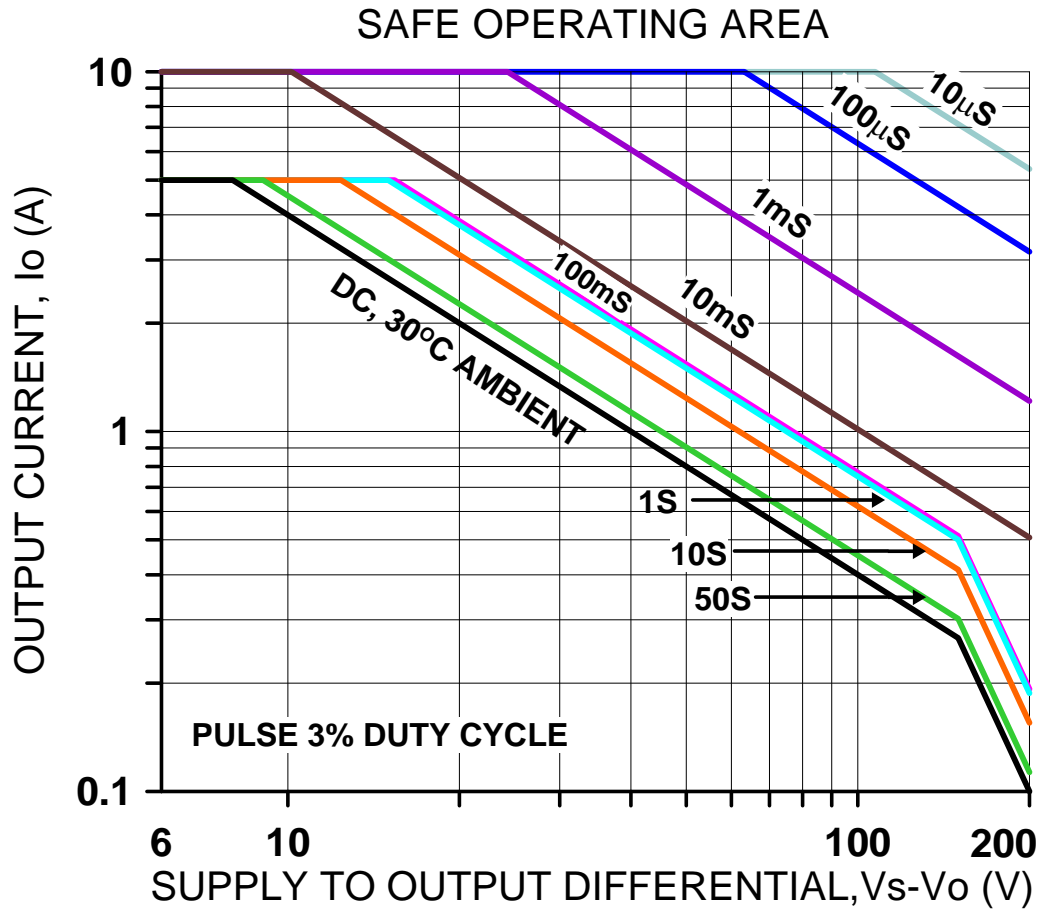
It is often desirable to operate the PAD135 with a single high-current power supply as this reduces system cost. Figure 2 in the application circuits section shows one way to do this. However, in this case the input signal should be offset slightly to prevent the output from being driven to ground. When the output swings closer to ground than 10V the output transistor connected to the negative supply must recover from being over-driven. This causes a delay in the output going to a high condition. If the input signal is offset slightly so that the output is not driven to less than 10V this delay is avoided. The resulting output signal will then vary from 10V to 150V. For a circuit gain of +65 the required input signal then becomes 0.156V to 2.344V.

For custom applications the PAD135 or PAD135-1 can be ordered with its offset voltage set to produce the same effect. This option is desirable in applications where adjusting the input signal is difficult.



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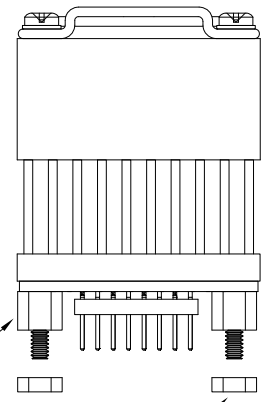
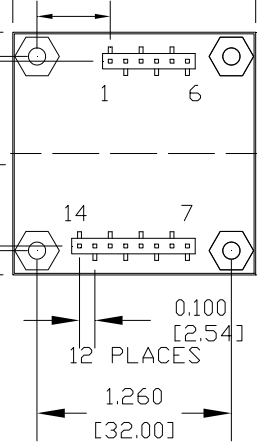
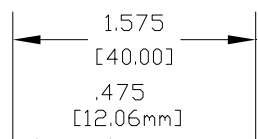
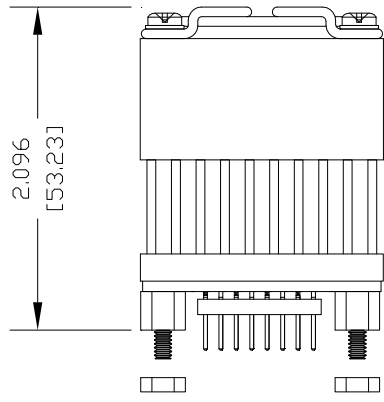
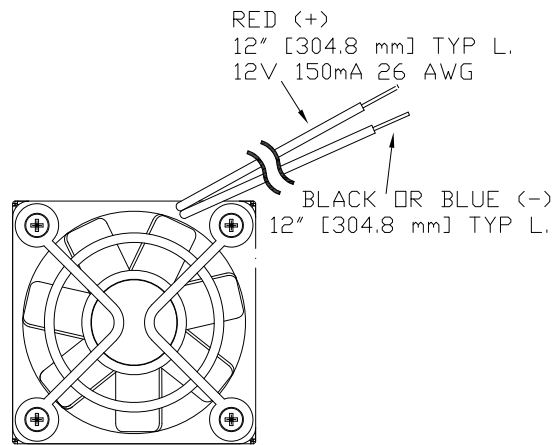




**SAFE OPERATING AREA**

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 PAD135 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 website. 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.

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HEX NUT  
4-40 -1/4" x4 (SUPPLIED)  
TORQUE TO 4.3 in oz [3 N cm] MAX

MOUNTING STUDS  
4-40 -1/4" M/F HEX SPACER x4

- NOTES:
1. PINS .0025" 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]



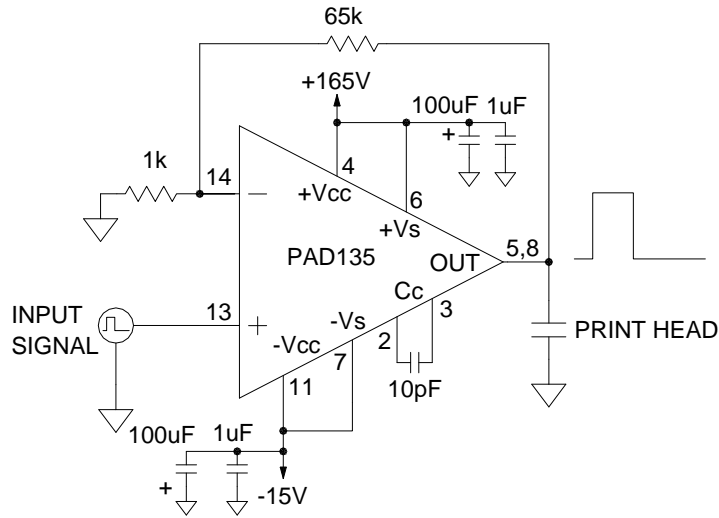


FIGURE 1.  
TYPICAL DUAL SUPPLY PRINT HEAD DRIVE CIRCUIT

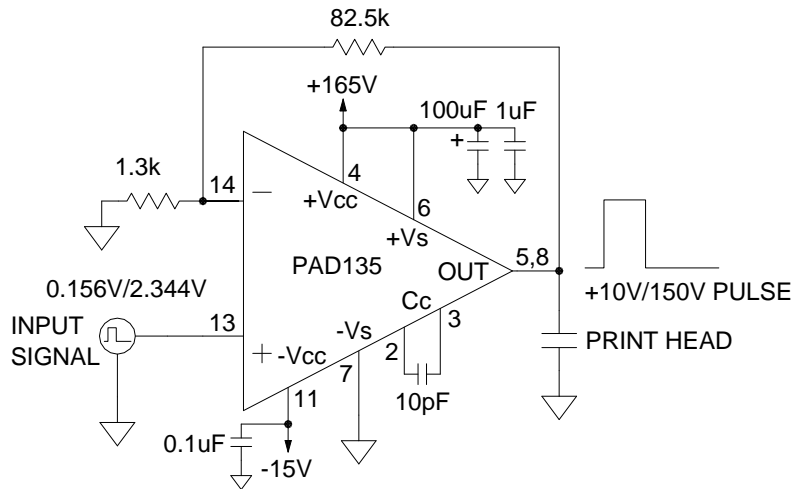


FIGURE 2.  
SINGLE HIGH-CURRENT POWER SUPPLY PRINT HEAD DRIVE CIRCUIT