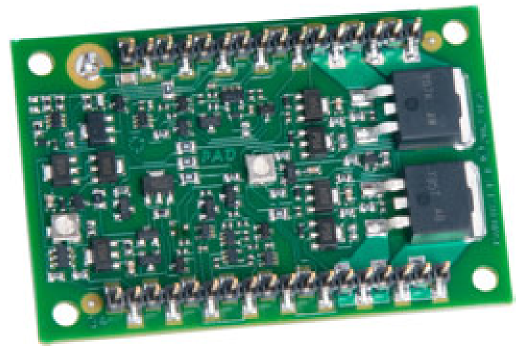
POWER OPERATIONAL AMPLIFIER

PAD148-1
Rev K

KEY FEATURES

- **LOW COST**
- **HIGH VOLTAGE – 200 VOLTS**
- **HIGH CURRENT – 10 AMPS**
- **125 WATT DISSIPATION CAPABILITY**
- **100kHz POWER BANDWIDTH**
- **SHORT CIRCUIT PROTECTION**
- **TEMPERATURE MONITORING**
- **RoHS COMPLIANT**
- **CONFORMALLY COATED**



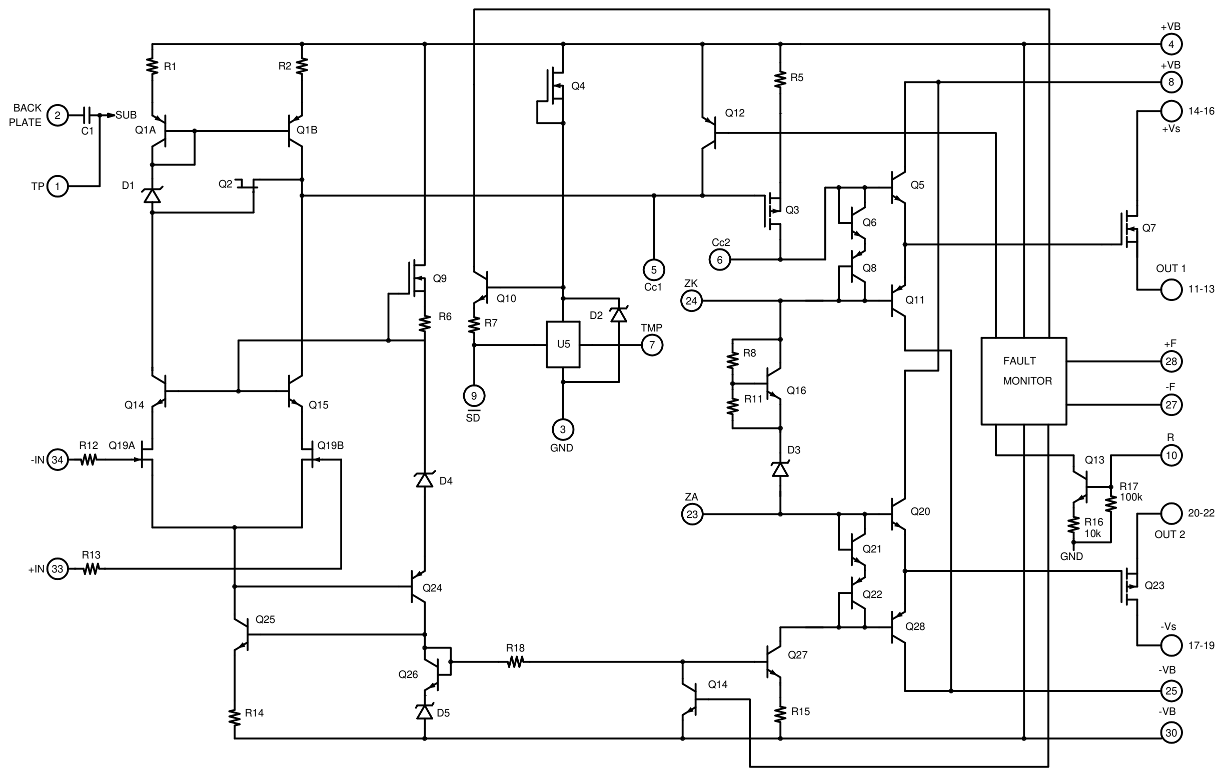
APPLICATIONS

- **INKJET PRINTER HEAD DRIVE**
- **PIEZO TRANSDUCER DRIVE**
- **INDUSTRIAL INSTRUMENTATION**
- **RELECTOMETERS**
- **ULTRA-SOUND TRANSDUCER DRIVE**

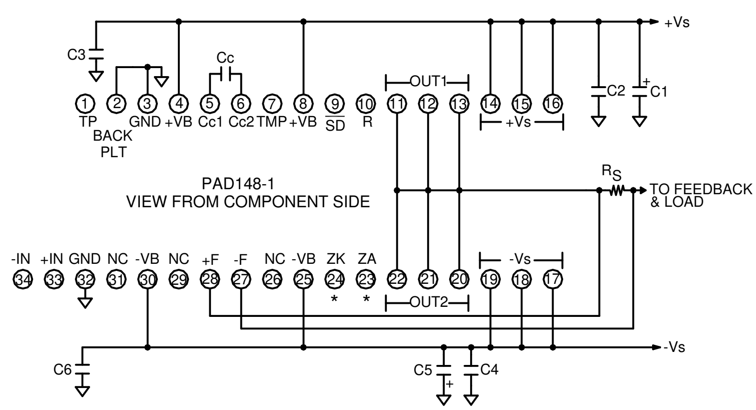
DESCRIPTION

The PAD148-1 is a high voltage operational amplifier constructed with surface mount components to provide a cost effective solution for many industrial applications With a footprint only 3.3in^2 the PAD148-1 offers outstanding performance that rivals more expensive hybrid component amplifiers. User selectable external compensation tailors the amplifier's response to the application requirements. An analog output voltage is provided that is proportional to the substrate temperature. The amplifier's output stage is shut down by pulling the shut down pin low or when the substrate temperature exceeds 110^{o}C. A short circuit or over-current condition also shuts down the output stage. The amplifier circuitry is built on a thermally conductive but electrically insulating substrate. No BeO is used in the PAD148-1. The resulting module is a small, high performance solution for many industrial applications. The PAD148-1 is a special version of the base product PAD148 where the fault sense voltage is 0.65V and the output stage is biased class C to lower quiescent current.

EQUIVALENT CIRCUIT



PINOUT & CONNECTIONS



NOTES:

1. Cc IS NPO (COG) RATED FOR FULL SUPPLY VOLTAGE +Vs TO -Vs
2. PINS 4 & 8 MUST BE TIED TOGETHER. PINS 25 & 30 MUST BE TIED TOGETHER.
3. C1 AND C5 ELECTROLYTIC, 10uF PER AMP OUTPUT CURRENT
4. C2,3,4,6 HIGH QUALITY CERAMIC 0.1uF
5, ALL OUTPUT PINS MUST BE TIED TOGETHER

* *MAKE NO CONNECTION FOR PAD148-1

ABSOLUTE MAXIMUM RATINGS

SUPPLY VOLTAGE, +Vs to −Vs	200V	TEMPERATURE, pin solder, 10s	237C
BOOST VOLTAGE,	$\pm V_B$ ±20V	TEMPERATURE, junction[2]	150°C
OUTPUT CURRENT, within SOA	12A	TEMPERATURE RANGE, storage	−40 to 105°C
POWER DISSIPATION, internal, DC	125W	OPERATING TEMPERATURE, case	−40 to 105°C
INPUT VOLTAGE, differential	± 20V		
INPUT VOLTAGE, common mode	$\pm V_B$		

PARAMETER	TEST CONDITIONS[1]	MIN	TYP	MAX	UNITS
INPUT					
OFFSET VOLTAGE			1	3	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				$+V_B-12$	V
COMMON MODE VOLTAGE RANGE				$-V_B+7$	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		-Vs		+Vs	V
-F		-Vs		+Vs	V
+F TO -F	Differential voltage , shutdown		±0.65		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 = 10A	±Vs−10	+Vs−8.6		V
VOLTAGE SWING	I_O = −10A	−Vs+10	−Vs+7		V
VOLTAGE SWING	$+V_B$=+Vs+10V, I_O = 10A	+Vs−1.6	+Vs−1.2		
VOLTAGE SWING	$-V_B$=-Vs-10V, I_O = -10A	-Vs−5.1	+Vs+4.1		
CURRENT, continuous, DC		10			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		150		kHz
POWER SUPPLY					
VOLTAGE		±15	±75	±100	V
CURRENT, quiescent			21	25	mA
THERMAL					
RESISTANCE, AC, junction to case[5]	Full temperature range, f ≥ 60Hz			0.8	°C/W
RESISTANCE, DC junction to case	Full temperature range			1.0	°C/W
RESISTANCE, DC junction to air	Full temperature range			13	°C/W
TEMPERATURE RANGE, case		−40		105	°C

NOTES:
1. Unless otherwise noted: T_C = 25°C, compensation Cc = 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. $+V_B$ and $-V_B$ 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 $+V_B$ and $-V_B$ must not be less than +Vs and −Vs respectively. Total voltage $+V_B$ to $-V_B$ 240V maximum.
8. The PAD148-1 is constructed with MOSFET transistors and ESD handling procedures must be observed.

SAFETY FIRST

The operating voltages of the PAD148-1 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.

OVER-CURRENT FAULT PROTECTION

The output stage of the PAD148-1 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:

$$I_F = \frac{0.65V}{R_s}$$

Where I_F is the value of the fault current set point and R_S is the value of the sense resistor.

Whenever the programmed current set point is exceeded for more than 10 µS (typical) the drive to the output stage turns off completely (typically in less than 400µS), and remains off until the circuit is reset (pin 10, R) via a 5V momentary pulse ≥ 10µS (or power recycled). The internal sense voltage is a precision temperature compensated reference voltage of 0.65V. 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. 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.

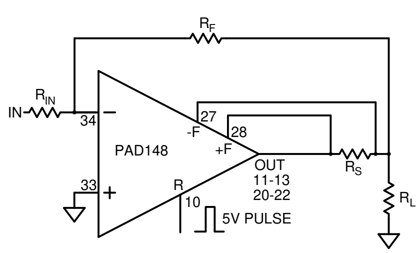


Figure 1

MOUNTING THE 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 PAD148-1 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. Mount the amplifier to the mother board with 4-40 X 1/4" screws.

PHASE COMPENSATION

The PAD148-1 **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 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. Do not use a compensation capacitor less than 10pF.

BOOST OPERATION

The small signal stages of the PAD148-1 are connected to the $\pm V_B$ power supply pins. When the $\pm V_B$ voltages are greater than the ±Vs power supply pins the small signal stages of the amplifier are biased so that the output transistors 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.

TEMPERATURE REPORTING

An analog output voltage is provided (pin 7, TMP) relative to ground (PIN 3) and proportional to the temperature in degrees C. The slope is approximately -10.82mV/°C. The output voltage follows the equation:

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

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

THERMAL SHUTDOWN

The temperature monitoring circuit automatically turns off the output transistors 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 10). The thermal shutdown feature is activated by amplifier thermal overload such as sustained high power dissipation or inadequate heat sinking.

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EXTERNAL SHUTDOWN

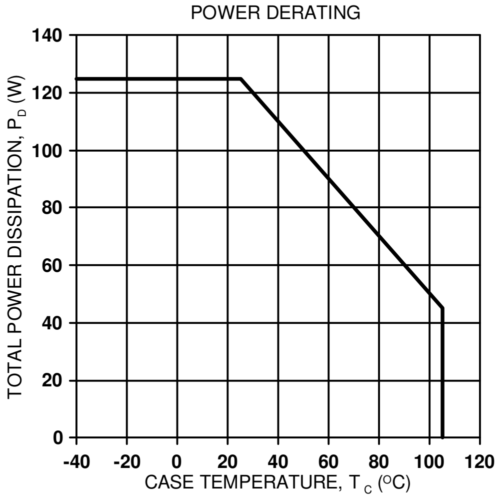
When pin 9 ($\overline{SD}$) is taken low (GND) the output stage is turned off and remains off until reset at pin 10 (R) with a 5V pulse or power to the amplifier is restarted. If the $\overline{SD}$ pin is monitored with a high impedance circuit (>100k input impedance) it also gives an indication of the temperature status of the amplifier. A "high" (+5V) indicates normal temperature operation and a "low" (zero volts, approximately) indicates that the amplifier is shut down due to the occurrence of an over-temp condition. See Figure 4 in Applications, page 10, for external shutdown circuits.

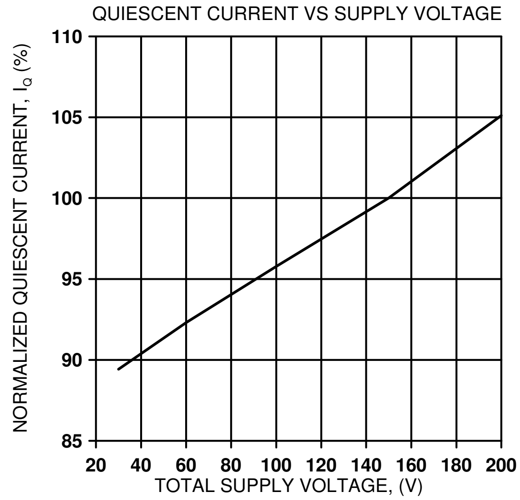
POWER-UP CONDITIONS

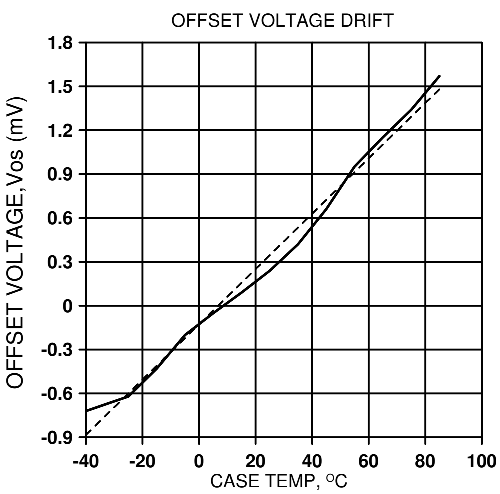
In most applications the PAD148-1 is powered by two power supplies. Under normal conditions both power supply voltages start to ramp up to their final values at the same time. However, if one power supply starts well before the other the over-current protection circuit may keep the output stage turned off. In this case it will be necessary to apply a momentary 5V reset pulse to pin 10 (Reset) to unlock the output stage of the amplifier. A auto-reset circuit can be connected to pin 10 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 10.

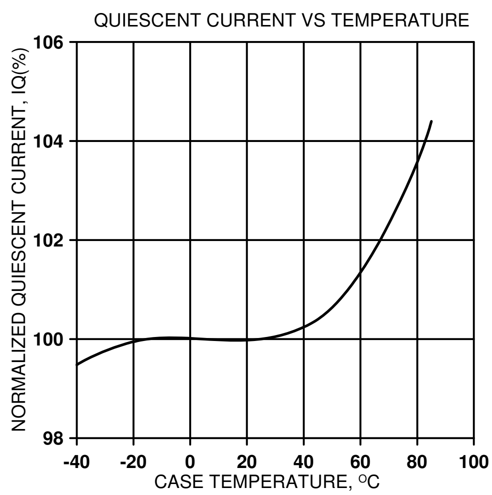
CONFORMAL COATING

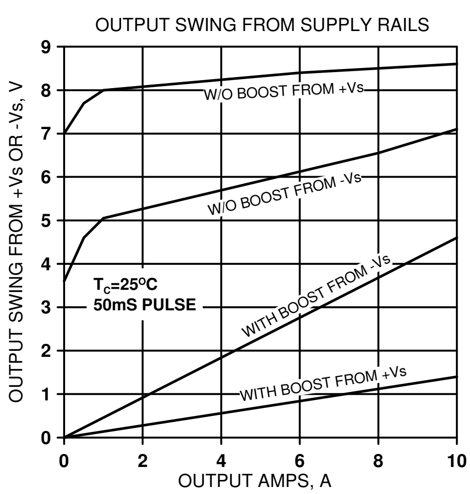
The PAD148-1 has a conformal coating to help protect against humidity and dirty environments. It is best that the circuit only be handled by the edges of the board to prevent disturbing the coating. The silicone conformal coat is Dow Corning 1-2577 and is applied in a thickness from 0.1 to 0.2 mm.











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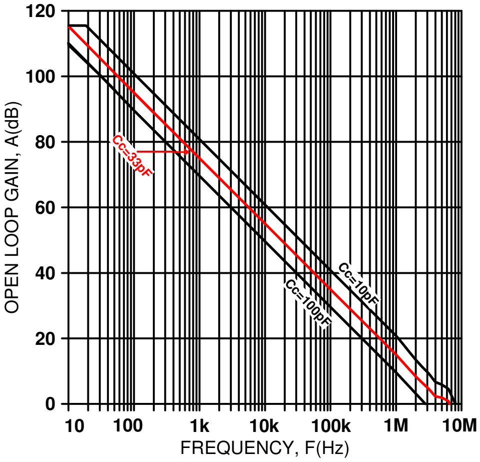
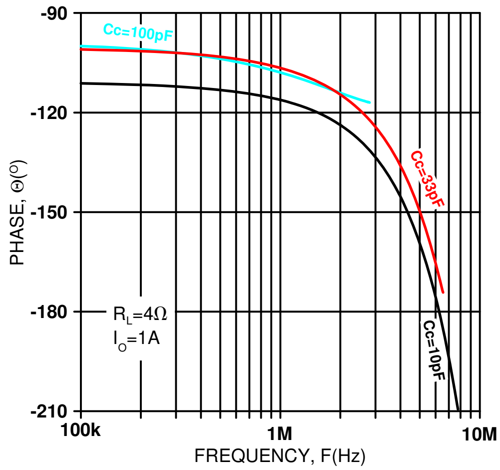
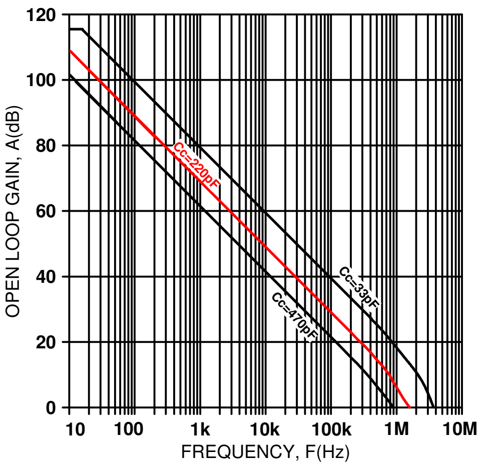
SMALL SIGNAL RESPONSE W/O BOOST



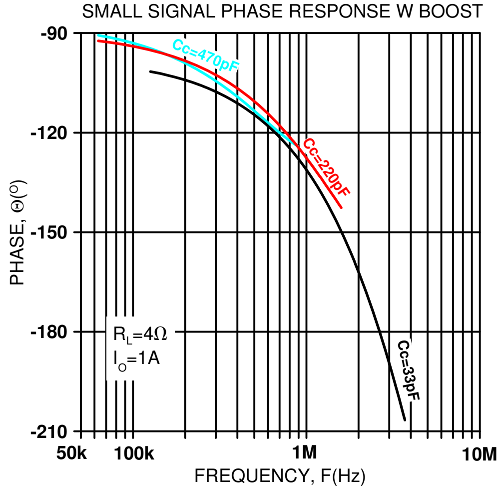
SMALL SIGNAL PHASE RESPONSE W/O BOOST



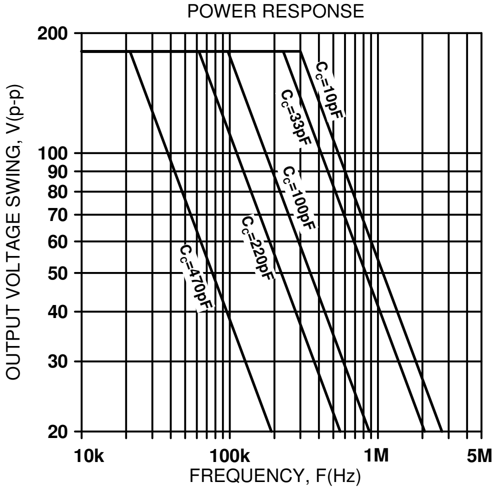
SMALL SIGNAL RESPONSE W BOOST



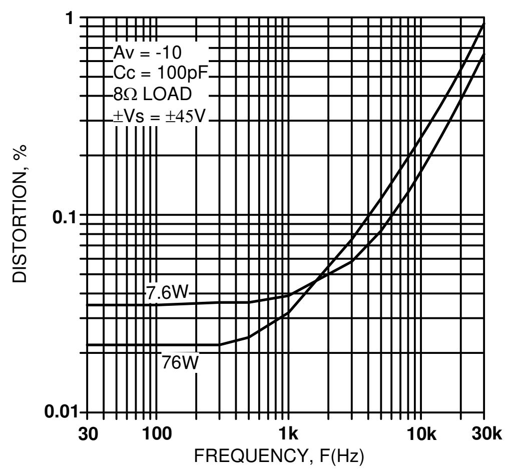
SMALL SIGNAL PHASE RESPONSE W BOOST

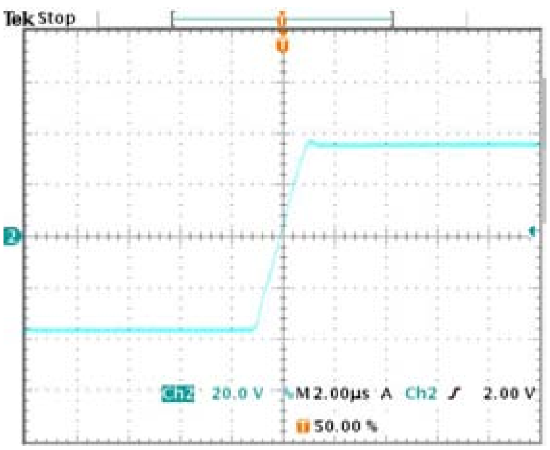


POWER RESPONSE

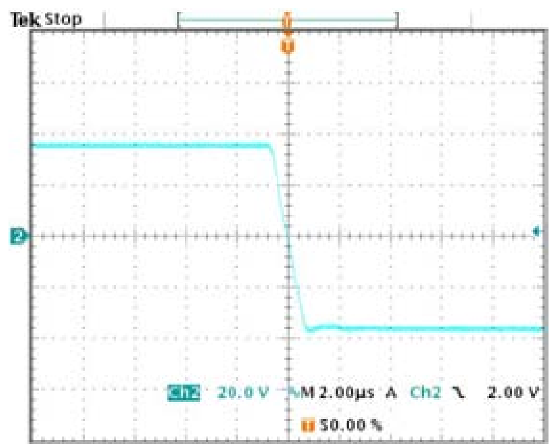


HARMONIC DISTORTION

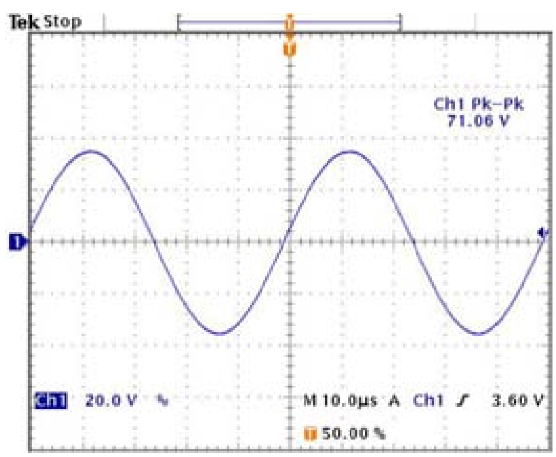




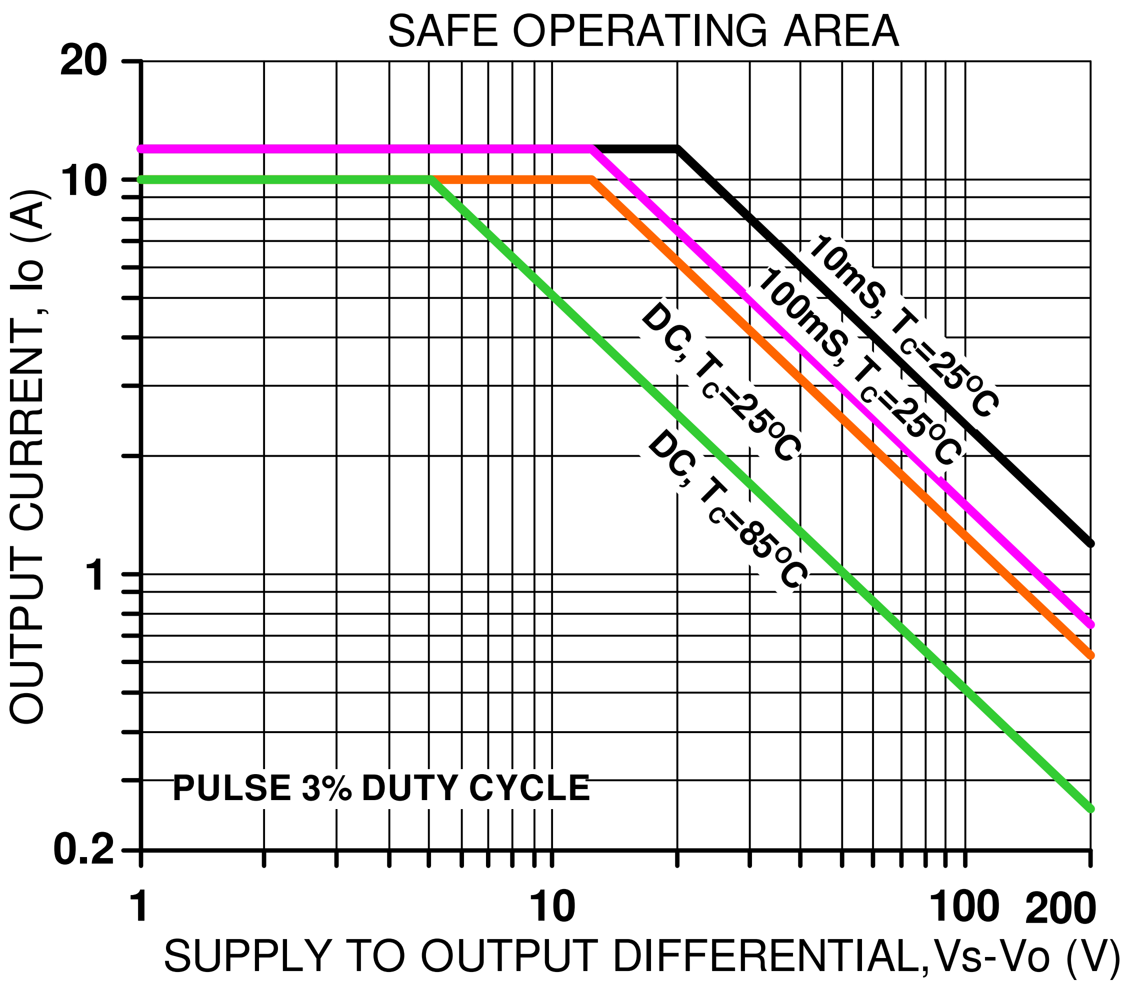
Pos. Pulse response, G=-10, C_C=100pF, 47nF load



Neg. Pulse response, G=-10, C_C=100pF, 47nF load



20kHz sine into 8Ω load, G=-10,C_C=100pF



SAFE OPERATING AREA

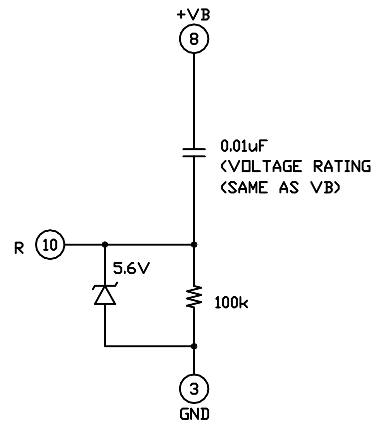


Figure 3
Power-up Reset

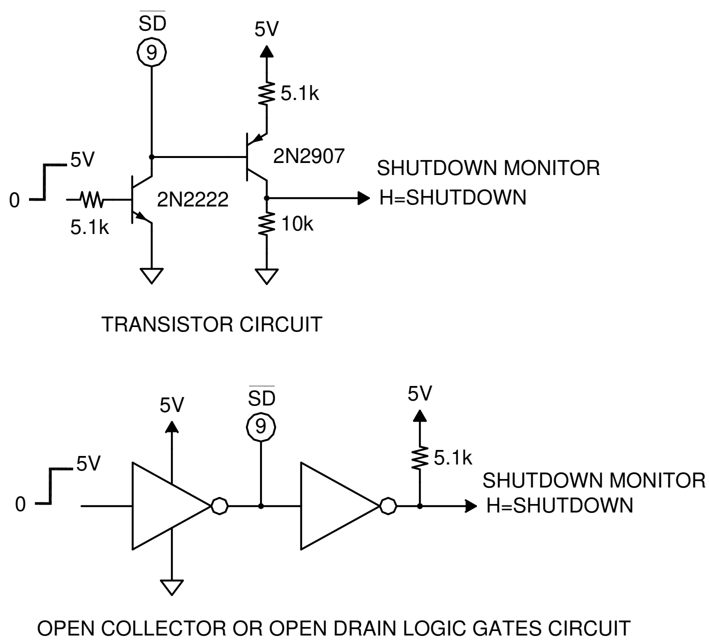
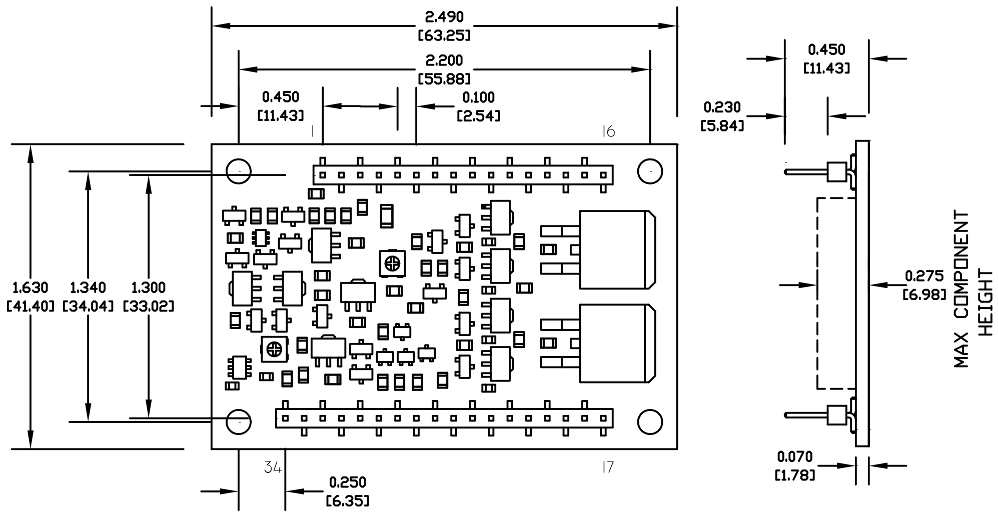


Figure 4
External Shutdown Circuits



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.