

## 2-Channel Power Amplifier Print Head Driver

### FEATURES

- Optimized Solution to Drive Dynamic Capacitive Loads
- Peak Output Current: 21A
- Slew Rate: 100V/ $\mu$ s (at 180nF load)
- Maximum Pulse Voltage: up to  $\pm 60$ V (with boost supplies)
- Temperature Sensor
- 30-pin Open Frame Package

### APPLICATION

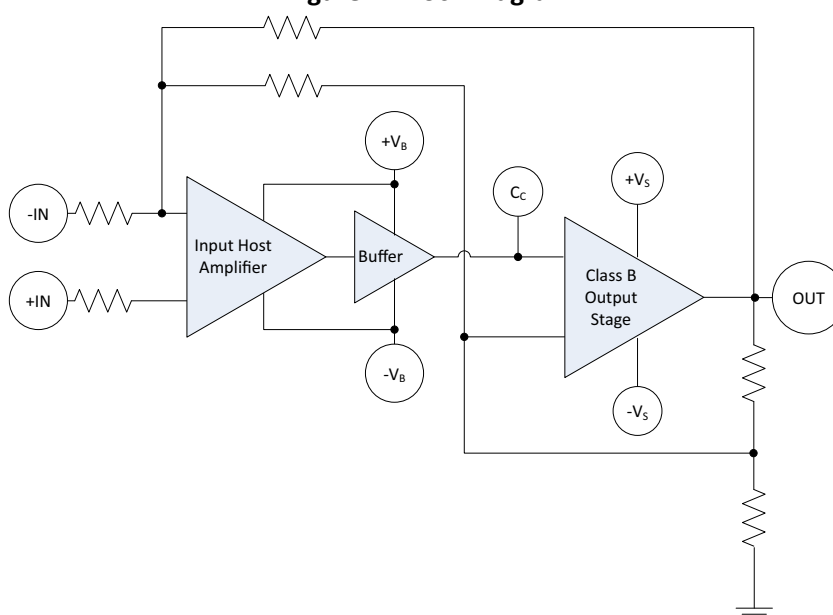
- Piezoelectric Actuation for Inkjet Printheads
  - Fujifilm Dimatix Samba G3L
  - Fujifilm Dimatix GMA series

### DESCRIPTION

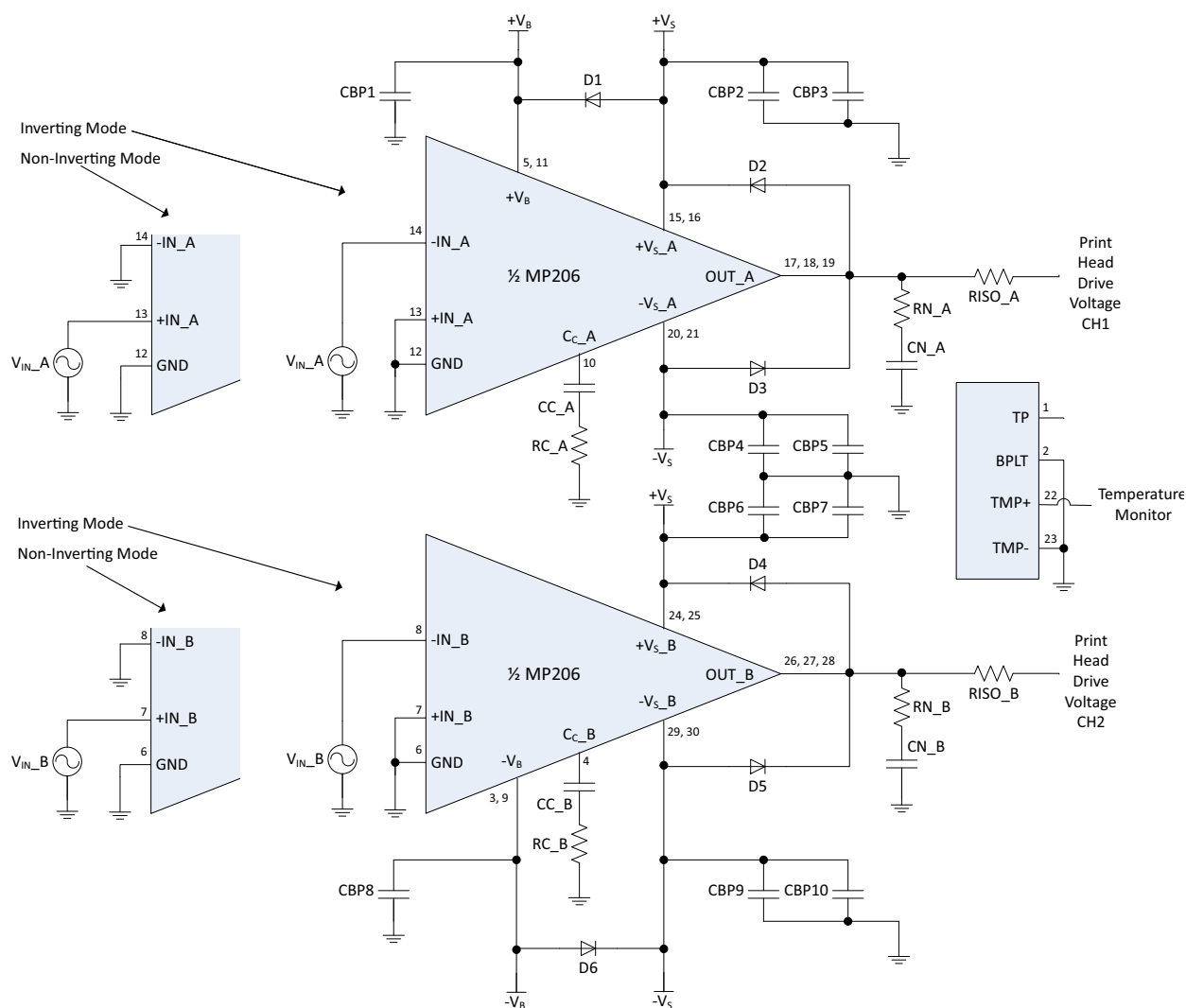
The MP206 is a 2-channel high output power amplifier for driving capacitive loads such as piezo devices used in inkjet printing applications. The amplifier provides flexibility in output drive; it can provide positive or negative pulses to a constantly changing number of piezo nozzles. MP206 is built on a thermally conductive, but electrically isolated substrate, delivering high power in a very compact module.

The amplifier gain is fixed at approximately 19.85V/V in non-inverting mode (or -15.7V/V for inverting mode). It is optimized to achieve a 0 to 40V (or -40 to 0V) output voltage swing. A combination of internal and external compensation allows MP206 to be tailor-fit to any of the print heads listed above, providing optimum slew rate and ensuring stability. Auxiliary voltages ( $+V_B$  and  $-V_B$ ) for the amplifier stage are used to reduce the power loss in the output drivers.

**Figure 1: Block Diagram**



**Figure 2: Typical Connection**



The above components and supply voltages are application-specific. Please see the following table for suggested values. Note that these values may be altered (within the Absolute Maximum Ratings of the MP206) for special applications.

**SUGGESTED CIRCUIT VALUES FOR VARIOUS PRINTHEADS**

Print Head	Positive Pulse Printheads	Negative Pulse Printheads (Samba G3L and GMA series)
Mode	Non-Inverting	Inverting
+VB	40 to 58V (5W capability)	18V (2W capability)
-VB	-18V (2W capability)	-40 to -58V (5W capability)
+VS	40V (100W capability)	0 (Ground)
-VS	0 (Ground)	-40V (100W capability)
CBP1, 8	1 $\mu$ F, X7R, 100V	1 $\mu$ F, X7R, 100V
CBP2, 6	1 $\mu$ F, X7R, 100V	DNP
CBP3, 7	220 $\mu$ F, ELEC, 100V	DNP
CBP4, 9	DNP	1 $\mu$ F, X7R, 100V
CBP5, 10	DNP	220 $\mu$ F, ELEC, 100V
D1, 6	MUR140	MUR140
D2, 3, 4, 5	MUR420	MUR420
CC_A, CC_B	150pF, COG, 100V	150pF, COG, 100V
RC_A, RC_B	750 $\Omega$ , 1/8 W	750 $\Omega$ , 1/8W
CN_A, CN_B	22nF, X7R, 100V	22nF, X7R, 100V
RN_A, RN_B	5 $\Omega$ , 1/8W	5 $\Omega$ , 1/8W
RISO_A, RISO_B	0.2 $\Omega$ , 2W	0.2 $\Omega$ , 5W

**Legend:**

X7R	Ceramic capacitor with temperature stability rating of X7R or better
DNP	Do not populate
ELEC	Electrolytic capacitor
COG	Ceramic capacitor with temperature stability rating of COG or better

Figure 3: Example Non-Inverting Schematic (One Channel)

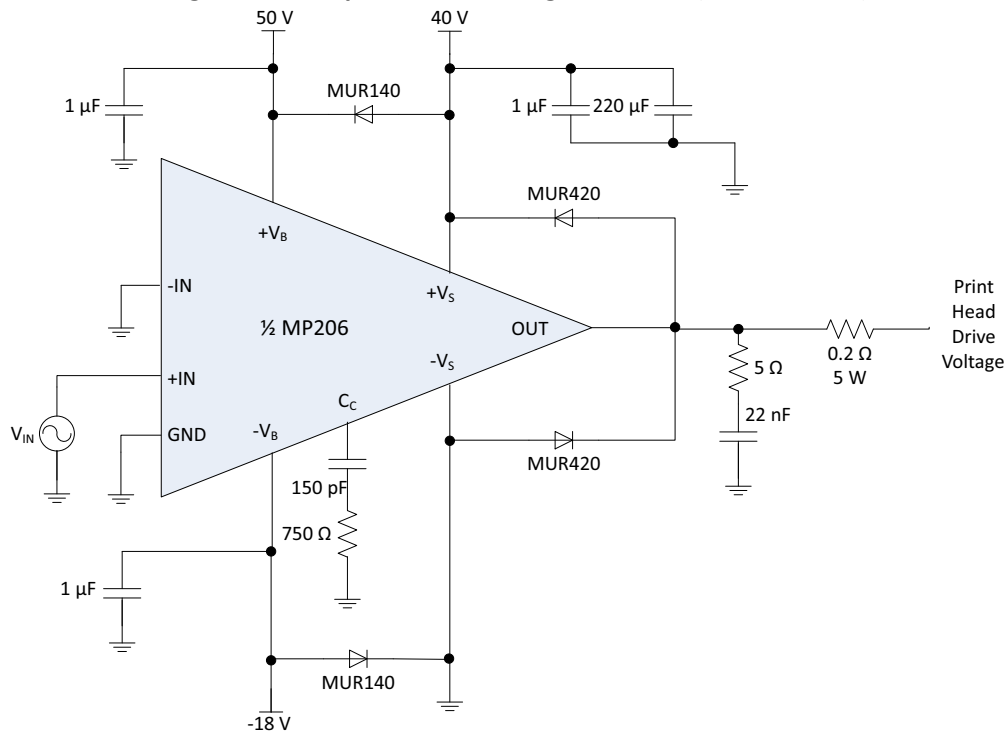
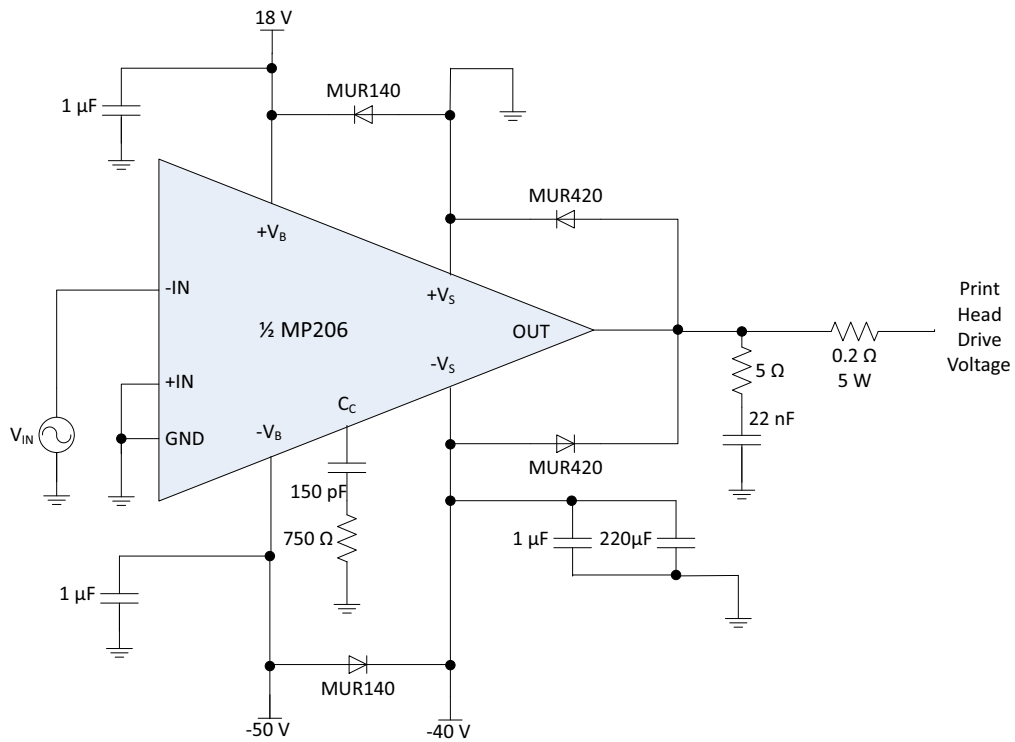


Figure 4: Example Inverting Schematic (One Channel)



**PINOUT AND DESCRIPTION TABLE**

**Figure 5: Pinout Diagram**



Pin	I/O	Description
1	TP	Apex test point. No connection.
2	BPLT	AC coupling to backplate. Connect to signal ground.
3, 9	-V <sub>B</sub>	The negative boost supply rail. Short to -V <sub>S</sub> if unused. See application section. Both -V <sub>B</sub> pins must be connected, even if only one channel is in use.
4	C <sub>C_B</sub>	Compensation capacitor connection for channel B. Select value based on specific Print Head. See applicable section.
5, 11	+V <sub>B</sub>	The positive boost supply rail. Short to +V <sub>S</sub> if unused. See applicable section. Both +V <sub>B</sub> pins must be connected, even if only one channel is in use.
6, 12	GND	Ground. Pins 6 and 12 are not connected on the unit. Connect both pins to system signal ground.
7	+IN <sub>B</sub>	The non-inverting input for channel B.
8	-IN <sub>B</sub>	The inverting input for channel B.
10	C <sub>C_A</sub>	Compensation capacitor connection for channel A. Select value based on specific Print Head. See applicable section.
13	+IN <sub>A</sub>	The non-inverting input for channel A.
14	-IN <sub>A</sub>	The inverting input for channel A.
15, 16	+V <sub>S_A</sub>	The positive supply rail for channel A.
17, 18, 19	OUT <sub>A</sub>	The output for channel A. Connect to the Print Head drive voltage pins.
20, 21	-V <sub>S_A</sub>	The negative supply rail for channel A.
22	TMP+	Case temperature sensor positive node. This node will output a voltage directly proportional to absolute temperature. See Temperature Sensing section below for transfer equation.
23	TMP-	Case temperature sensor negative node. Connect to ground.
24, 25	+V <sub>S_B</sub>	The positive supply rail for channel B.
26, 27, 28	OUT <sub>B</sub>	The output for channel B. Connect to the Print Head drive voltage pins.
29, 30	-V <sub>S_B</sub>	The negative supply rail for channel B.

## SPECIFICATIONS

Unless otherwise noted:  $T_C = 25^\circ\text{C}$ . DC input specifications are  $\pm$  value given. Power supply voltage is typical rating.  $\pm V_B = \pm V_S$ .  $C_C = 150\text{pF}$ ,  $R_C = 750\ \Omega$ ,  $C_N = 22\text{nF}$ ,  $R_N = 5\ \Omega$ ,  $R_{ISO} = 0.2\ \Omega$ .

### ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Min	Max	Unit
Total Supply Voltage	$+V_S$ to $-V_S$		60	V
Total Boost Supply Voltage	$+V_B$ to $-V_B$		90	V
Positive Boost Supply	$+V_B$	$+V_S-0.6$	$+V_S+20$	V
Negative Boost Supply	$-V_B$	$-V_S-20$	$-V_S+0.6$	V
Output Current, Peak, per Channel	$I_{OUT}$		21	A
Power Dissipation, per channel	$P_D$		70	W
Input Voltage	$V_{IN}$	-0.5	+5.0	V
Temperature, pin solder, 10s			225	$^\circ\text{C}$
Temperature, junction <sup>1</sup>	$T_J$		175	$^\circ\text{C}$
Temperature, storage		-40	105	$^\circ\text{C}$
Operating Temperature Range, case	$T_C$	-40	+85	$^\circ\text{C}$

1. Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.

## INPUT

Parameter	Test Conditions	Min	Typ	Max	Unit
Input Voltage, $V_{IN}$	Non-Inverting mode	0		3.0	V
Input Voltage, $V_{IN}$	Inverting Mode	0		4.0	V
Offset Voltage		0	6	10	mV
Offset Voltage vs. Temperature	Full temp range	7.2			$\mu\text{V}/^\circ\text{C}$
Offset Voltage vs. Supply		72			$\mu\text{V}/\text{V}$
Bias Current, initial			300	550	nA
Input Impedance, inverting			2		k $\Omega$
Input Impedance, non-inverting			160		M $\Omega$
Input Capacitance			3		pF
Noise, referred to input	$f = 10 \text{ kHz}$		13		nV/ $\sqrt{\text{Hz}}$

## GAIN

Parameter	Test Conditions	Min	Typ	Max	Unit
Inverting Gain, $-A_V$	Inverting mode	-15.85	-15.70	-15.55	V/V
Non-Inverting Gain, $+A_V$	Non-Inverting mode	19.70	19.85	20.0	V/V
Gain Bandwidth Product, 1 MHz			20		MHz
Power Bandwidth	$V_{OUT} = 40\text{V}_{\text{p-p}}$ sine, Load = 1 k $\Omega$	300			kHz

## OUTPUT

Parameter	Test Conditions	Min	Typ	Max	Unit
Output Voltage Swing, w/ Boost	$I_{OUT}=10\text{A}$ , $ V_B  =  V_S  + 10\text{V}$	$+V_S-1$			V
Output Voltage Swing, w/ Boost	$I_{OUT}=-10\text{A}$ , $ V_B  =  V_S  + 10\text{V}$			$-V_S+2$	V
Output Voltage Swing, w/o Boost	$I_{OUT}=10\text{A}$ , $ V_B  =  V_S $	$+V_S-5$			V
Output Voltage Swing, w/o Boost	$I_{OUT}=10\text{A}$ , $ V_B  =  V_S $			$-V_S+5$	V
Current, continuous, per channel		10		15	A
Current, peak, per channel	240 kHz, 40% Duty Cycle			21	A
Slew Rate	Non-Inverting, Load=180nF + 0.5 $\Omega$ , 40V pulse	90	97		V/ $\mu\text{s}$
Slew Rate	Inverting mode, Load = 270 nF + 0.5 $\Omega$ , 40V pulse	75	82		V/ $\mu\text{s}$



**POWER SUPPLY**

Parameter	Test Conditions	Min	Typ	Max	Unit
Supply Voltage, $+V_S$	$-V_S = 0V$	15	48	60	V
Supply Voltage, $-V_S$	$+V_S = 0V$	-60	-48	-15	V
Supply Voltage, $+V_B$ <sup>1</sup>		$+V_S$		$+V_S+20$	V
Supply Voltage, $-V_B$ <sup>1</sup>		$-V_S-20$		$-V_S$	V
Quiescent Current, $+V_S$ to $-V_S$ <sup>2</sup>			0		mA
Quiescent Current, $+V_B$ to $-V_B$			36	50	mA

1. For proper operation,  $\pm V_B$  must be at least  $\pm 18V$ , respectively. In addition, the voltages at  $\pm V_B$  must not be lower in magnitude than their respective  $\pm V_S$  voltage.
2. In addition to quiescent current,  $+V_S$  and  $-V_S$  will carry all load current. Be sure to select power supply and PCB trace widths accordingly.

**THERMAL**

Parameter	Test Conditions	Min	Typ	Max	Unit
Resistance, AC, Junction to Case	2 channels loaded		0.5		°C/W
Resistance, DC, Junction to Case	$f < 60$ Hz, 2 channels loaded			2.1	°C/W
Resistance, Junction to Air			13		°C/W
Temperature Range, Case		-40		85	°C

**TEMPERATURE SENSOR**

Parameter	Test Conditions	Min	Typ	Max	Unit
Temperature Accuracy	$T_C = -40^{\circ}C$ to $85^{\circ}C$			$\pm 1$	°C

TYPICAL PERFORMANCE GRAPHS

Figure 6: Closed Loop Gain vs. Frequency

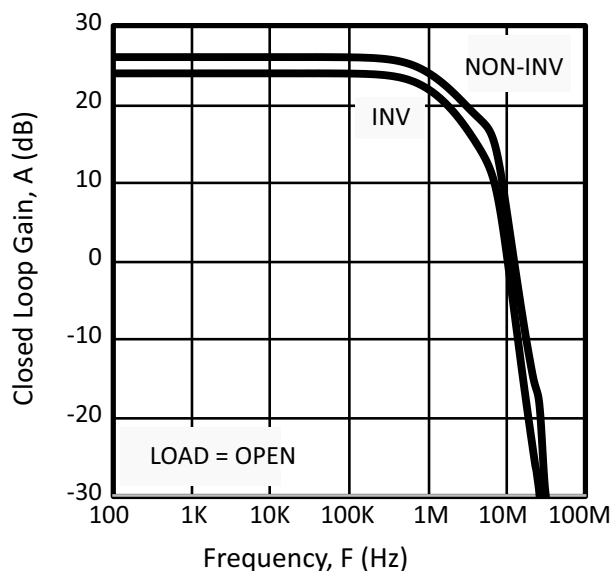


Figure 7: Closed Loop Phase vs. Frequency

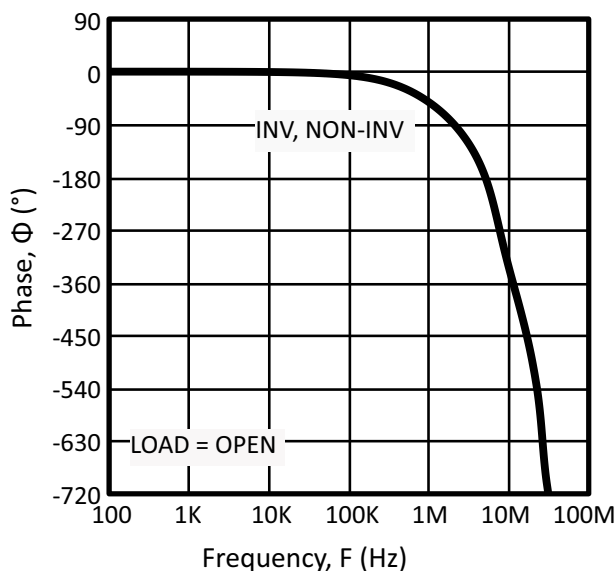


Figure 8: Power Derating

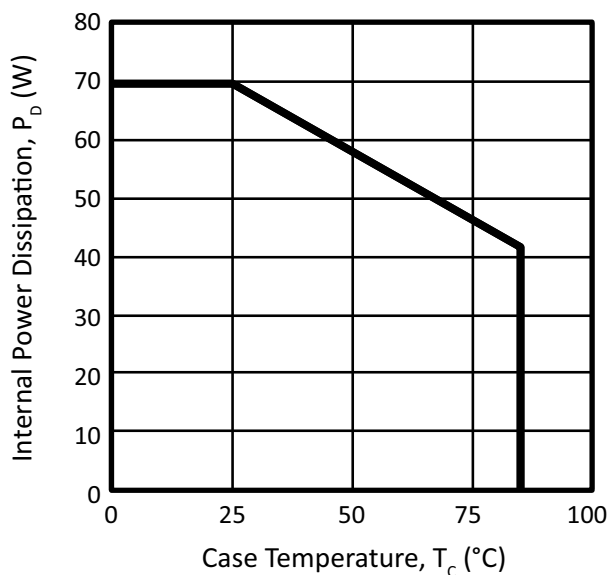
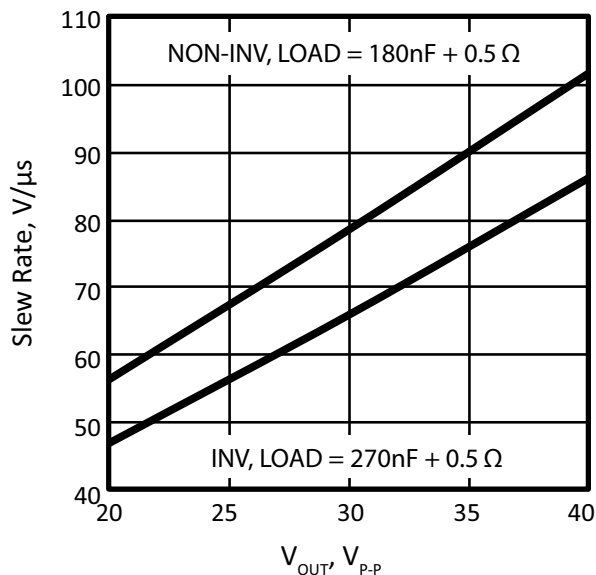
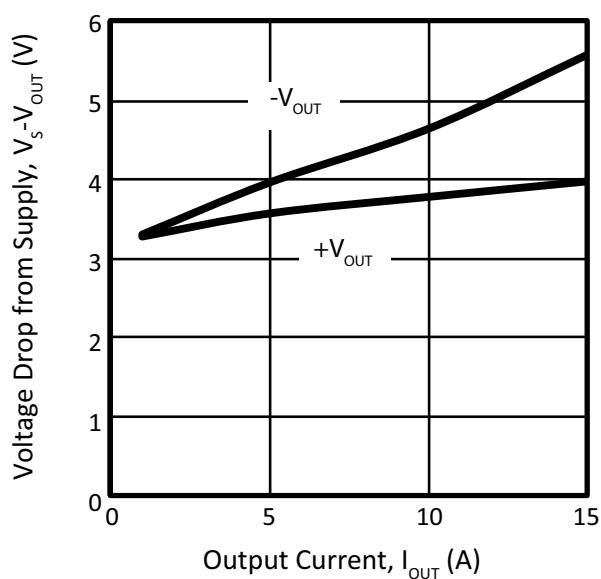


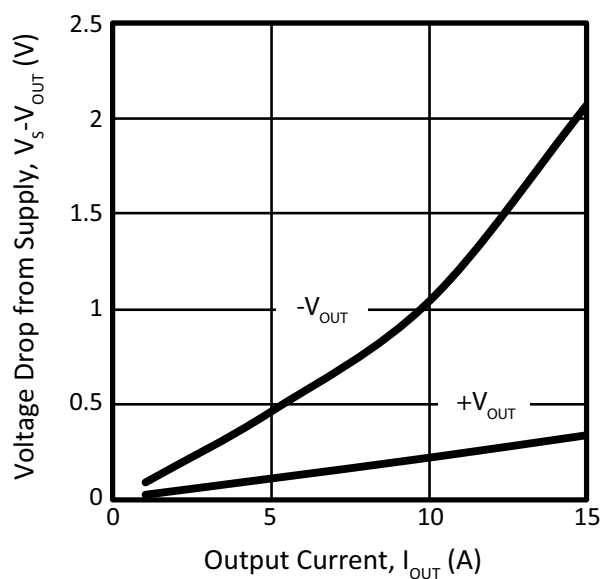
Figure 9: Slew Rate vs Output Voltage



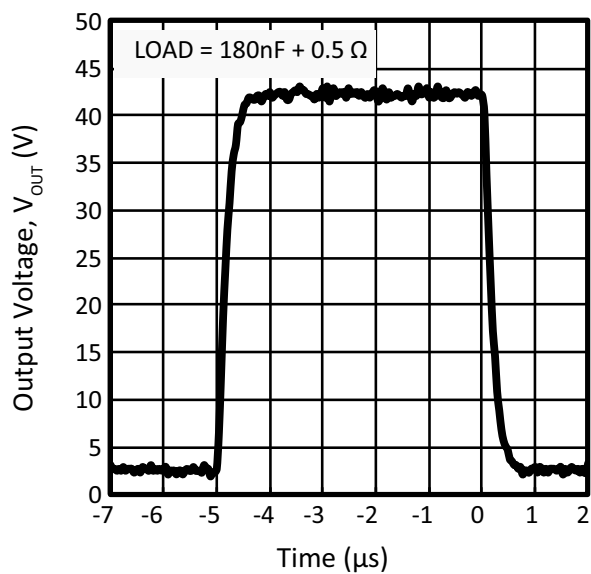
**Figure 10: Voltage Drop,  $V_B = V_S$**



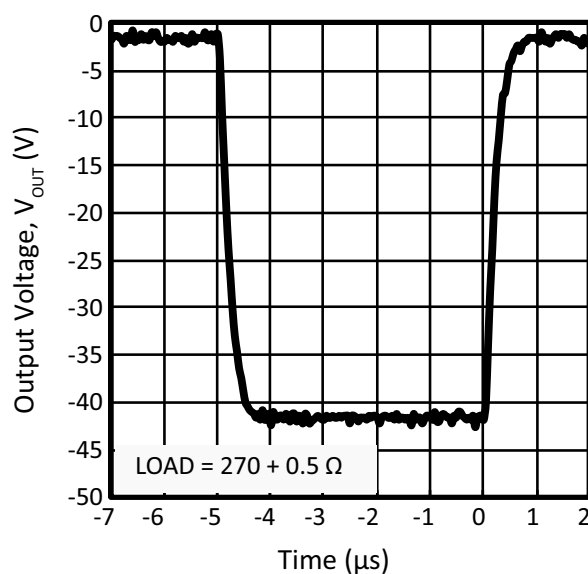
**Figure 11: Voltage Drop,  $\pm V_B = \pm V_S \pm 18V$**



**Figure 12: Pulse Response, Non-Inverting**



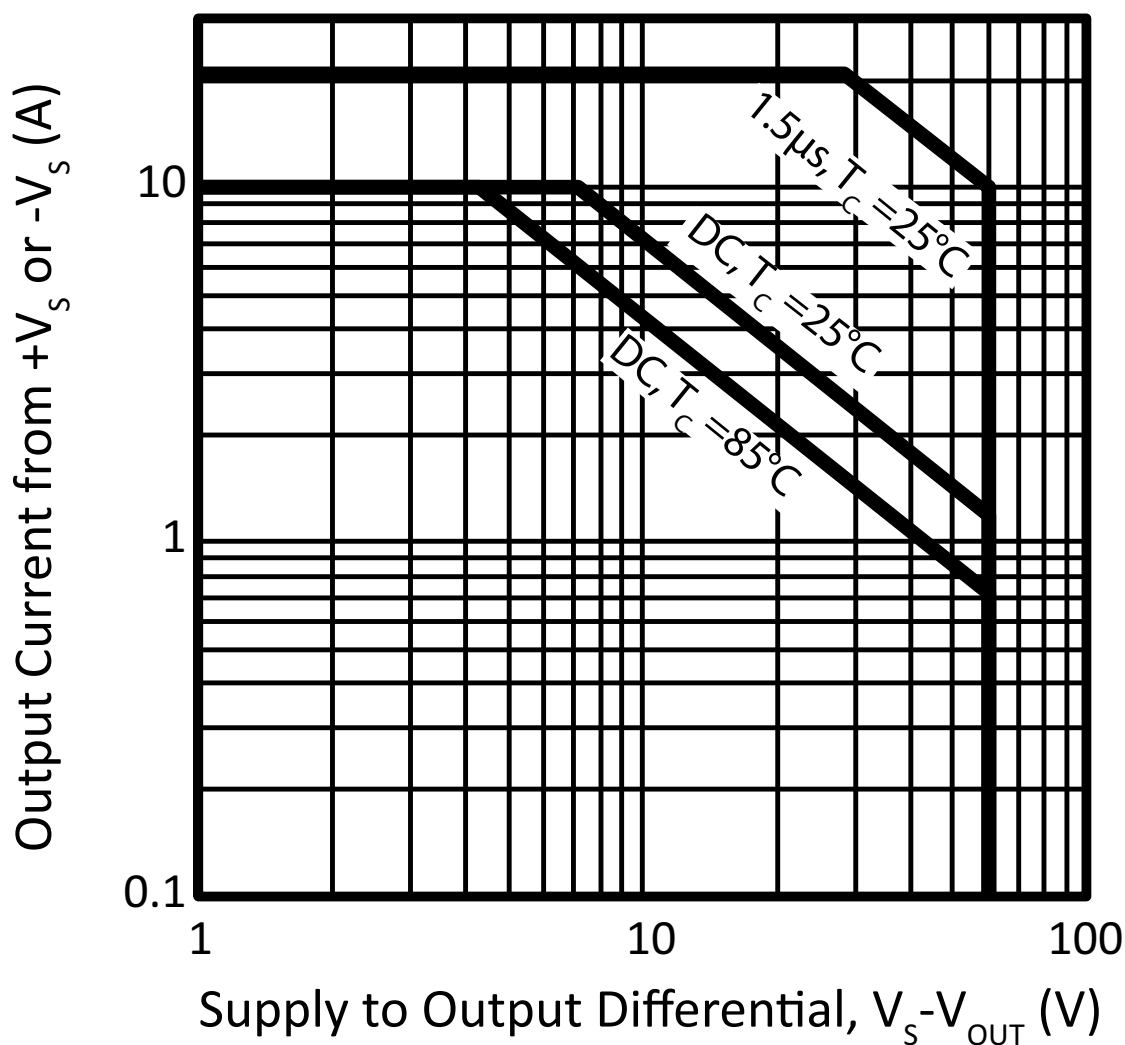
**Figure 13: Pulse Response, Inverting**



## SAFE OPERATING AREA

The MOSFET output stage of the MP206 is not limited by second breakdown considerations as in bipolar output stages. Only thermal considerations and current handling capabilities limit the SOA (see Safe Operating Area graph). The output stage is protected against transient fly back by the parasitic body diodes of the output stage MOSFET structure. However, for protection against sustained high energy fly back, external fast reverse-recovery diodes must be used.

Figure 14: Safe Operating Area (SOA)



## GENERAL

Please read Application Note 1 “General Operating Considerations” which covers stability, supplies, heat sinking, mounting, current limit, SOA interpretation, and specification interpretation. Visit [www.apexanalog.com](http://www.apexanalog.com) for Apex Microtechnology's complete Application Notes library, Technical Seminar Workbook, and Evaluation Kits.

## BOOST SUPPLIES

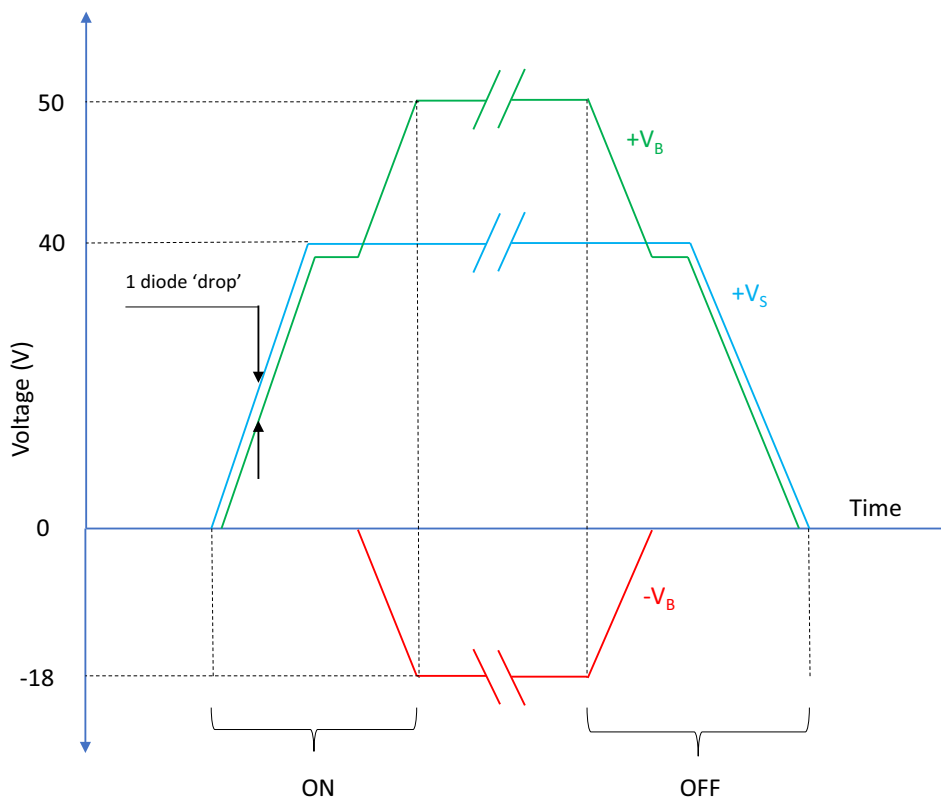
Boost supplies are an optional feature that allows the output stage to swing closer to  $\pm V_S$ . This works by powering the input stage of the amplifier with higher supply voltages (requiring much lower current), therefore driving the output MOSFETs deeper into the triode region. This allows MP206 to output close to 0V, even when one of the  $\pm V_S$  supplies is simply grounded. This also allows for more efficient operation in the amplifier, as a lower  $V_S$  voltage magnitude may be used when boost supplies are enabled.

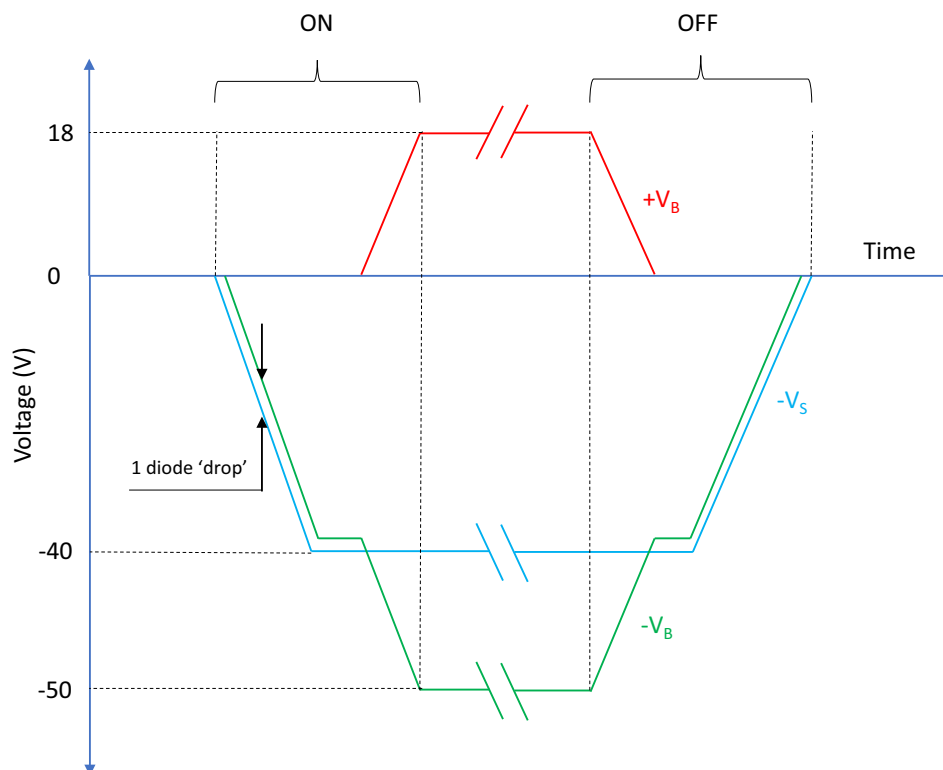
To use boost supplies, the designer has the choice to connect  $\pm V_B$  to:

1. Fixed, high-voltage low-current supplies referenced to ground, or
2. Floating, low-voltage low-current supplies referenced to  $\pm V_S$ .

In either case, the recommended power supply sequencing should follow a profile as shown below:

**Figure 15: Example Power Supply Sequence Profile for Boost Supplies (Non Inverting)**



**Figure 16: Example Power Supply Sequence Profile for Boost Supplies (Inverting)**


The 1 diode 'drop' is satisfied by D1 and D6 in the typical connection. If one of the  $\pm V_S$  supplies is ground, ramp the corresponding  $\pm V_B$  supply simultaneously with the opposite  $\pm V_B$  supply.

If boost supplies are not desired, connect  $+V_B$  to  $+V_S$  and  $-V_B$  to  $-V_S$ .

## POWER SUPPLY BYPASSING

Bypass capacitors to power supply terminals  $\pm V_S$  must be connected physically close to the pins to prevent local parasitic oscillation in the output stage of the MP206. Use electrolytic capacitors at least  $10\mu\text{F}$  per Ampere of output current required. Bypass the electrolytic capacitors with high quality ceramic capacitors (X7R)  $0.1\mu\text{F}$  or greater. Bypass capacitors are not required for a supply that is directly connected to ground. A bypass capacitor of  $0.1\mu\text{F}$  or greater is recommended for the  $+V_B$  and  $-V_B$  terminals. See Typical Connection.

## POWER SUPPLY PROTECTION

Unidirectional Transient Voltage Suppressor (TVS) diodes are recommended as protection on the supply pins. These diodes clamp transients to voltages within the power supply rating and clamp power supply reversals to ground. Whether the diodes are used or not, the system power supply should be evaluated for transient performance including power-on overshoot and power-off polarity reversal as well as line regulation. Conditions which can cause open circuits or polarity reversals on either power supply rail should be avoided or protected against. Reversals or opens on the negative supply rail are known to induce input stage failure. Unidirectional TVS diodes prevent this, and it is desirable that they be both electrically and physically as close to the amplifier as possible.

## COMPENSATION

When using MP206 with large capacitive loads (such as that presented by a Print Head when all nozzles are driven), compensation techniques are needed to keep the amplifier stable. This is accomplished by a combination of a compensation capacitor/resistor ( $C_C$  and  $R_C$ ), a snubber circuit ( $C_N$  and  $R_N$ ), and an isolation resistor ( $R_{ISO}$ ). Use the recommended values presented in the “Suggested Circuit Values for Various Print Heads” table for best performance.

## TEMPERATURE SENSING

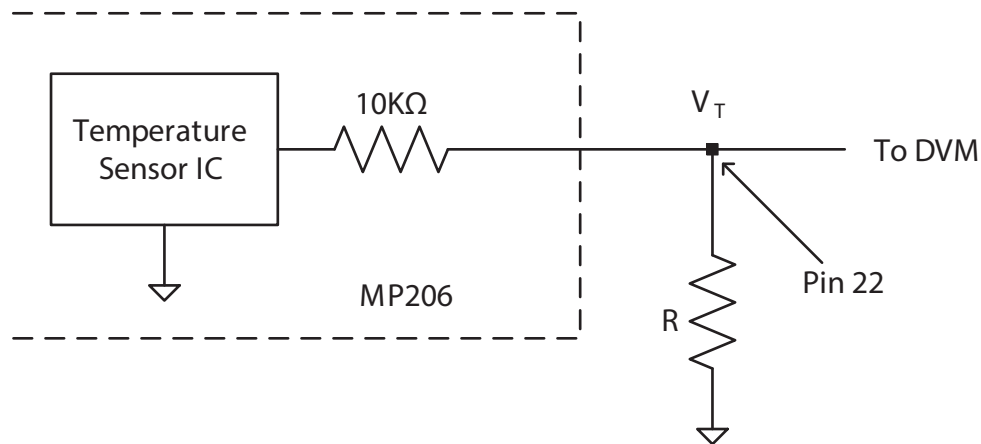
The MP206 contains an IC temperature sensor, located near the output MOSFETs. Temperature can be derived using the following equation:

$$T[^\circ C] = \frac{V_{TEMP}}{10 \frac{mV}{^\circ C}} - 273^\circ C$$

The scale factor of the sensor can be adjusted by connecting an optional resistor “R” (refer Fig 17) to TMP+ pin using the following equation:

$$T[^\circ C] = \frac{V_{TEMP}}{\frac{R}{R + 10k\Omega} 10 \frac{mV}{^\circ C}} - 273^\circ C$$

**Figure 17: Temperature Sensor**



## FULL LOADING

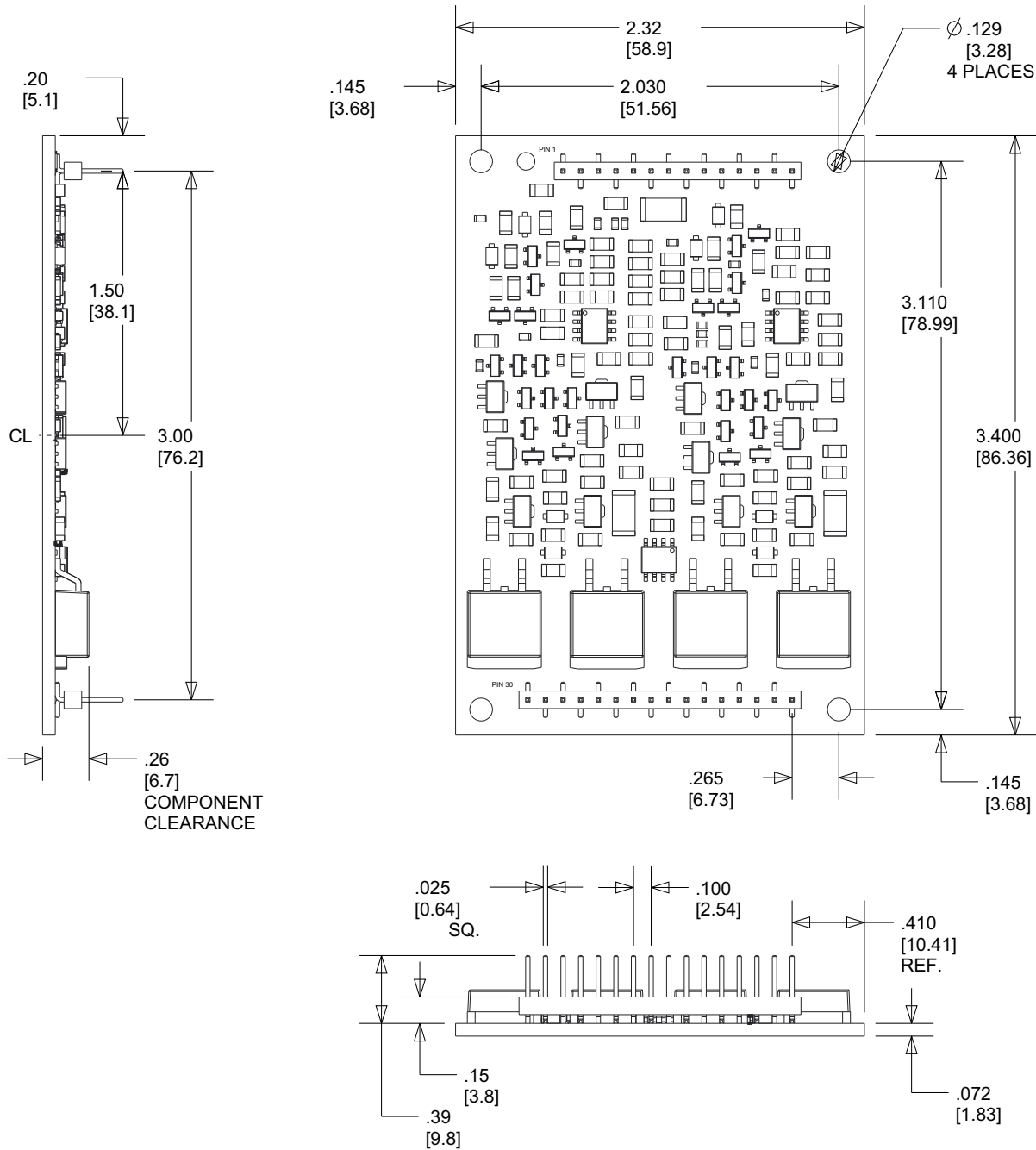
Consider the Safe Operating Area and Power Dissipation to ensure safe operation during all printing processes. Note that there is no current limit nor automatic temperature shutdown; the MP206 may permanently fail if the safe operating area is violated.

# MP206

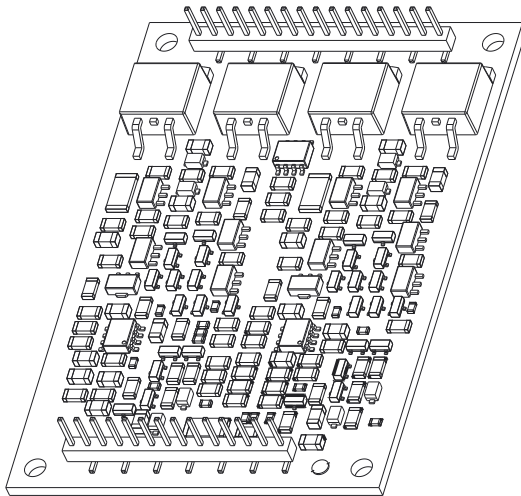
## PACKAGE OPTIONS

Part Number	Apex Package Style	Description
MP206	KP	30-pin Open Frame

## PACKAGE STYLE KP







**NOTES:**

1. Dimensions are in inches [mm].
2. Recommended PCB hole diameter for pins: 0.050 [1.27].
4. 2oz. copper over 600V dielectric over aluminum substrate.
5. Tin over nickel plated phosphor bronze pins.
6. It is not recommended that mounting of the package rely on the pins for mechanical support.
7. Use #4 or equivalent screws to mount to heat sink.
8. Package Weight: 35 grams.

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